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Numerical Analysis of Senggarang Embankment Constructed with Cement-CSP Stabilied Silty Clay

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Abstract One of the common problems faced at embankment is water seepage. In this study, seepage happened at the inland area which causing floods and disrupted agriculture in the surroundings area. The objectives of this research are to analyze the seepage characteristics of Senggarang embankment constructed with cement-CSP-stabilised silty clay and to evaluate the load-bearing capacity of the cement-CSP-stabilised silty clay embankment with the 'prescribed displacement approach' This study involved numerical simulation with the usage of the PLAXIS 8 software. Embankment was simulated using clay soil while the foundation of the embankment was treated and untreated silty clay. Data parameters were collected from previous study. Different water level was applied to see the changes of pore pressure distribution which lead to instability of the embankment. As water level increase, the total displacement increase. Therefore, mixture of cement-CSP are one solution to reduce seepage problem that faced at Senggarang embankment.

Keywords: Embankment, Seepage, Silty Clay, Cement-CSP

1. Introduction

Embankment are built for various applications such as embankment dams for reservoirs, as dikes for flood control along the river and the embankment roads, railways and airport runways in transportation [1]. One of the common problem faced at the dam sites is water seepage. Seepage takes place when a liquid leaks or drip through a porous soil. Seepage research and analysis is significant for designing and improving hydraulic problems in the environmental and civil engineering [2].

There are many ways of stabilizing soil which are compaction and use of admixtures. Chemical binders, industrial wastes, cement and fly ash are example of admixture. To change the different soil properties and improve soil performance, technique called soil stabilization is used [3]. Cockles is one of the aquaculture products. The scientific name of cockle is *Anadara granosa.* It is locally known as '*kerang*' and belongs to the family *Arcidae*. In Malaysia, total amount of collected cockle aquaculture

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is 12,482.34 tonnes. Based on the research from [4], the mineral mineralogical component in shell is calcium oxide (CaO). The cockle shell has 99.17 % concentration of CaO. Cockle shells was high and almost equal to limestone due to high content of calcium carbonate, $CaCO_3$ (95.00 -99.00 % by weight) [5].

The embankment was built along seaside at Senggarang, Batu Pahat. The real picture of the embankment at Senggarang, Batu Pahat, Johor based on Figure 1. Seepage at the Senggarang, Batu Pahat happened because of the aging embankment. This embankment has been built around for 40 years. Due to this, it shows signs of aging. One of the sign is seepage that happened at the inland area. Especially from the seashore to the inlands area which then causing floods and stagnant water that disrupted agriculture in the area. With this severe seepage problems, it can lead to potholes on services road on top. The seepage phenomenon has affected the stability and safety of the embankment and also increasing the risk of major floods in Senggarang area. The consequences during the high tide can affect livelihood and safety of approximate 12000 populations of Senggarang town. Close-up of the seepage happened at the inland area shown in Figure 2.

Figure 1: Embankment at Senggarang, Batu Pahat

Figure 2: Close-up of the seepage happened at the inland area

2. Materials and Methods

Methodology flow chart of this study are as shown in Figure 3. PLAXIS 8 software was used to simulate the embankment. The coordinate of the location from the google is 1°43'01.7"N 103°02'59.1"E. The embankment was built along seaside at Senggarang, Batu Pahat.

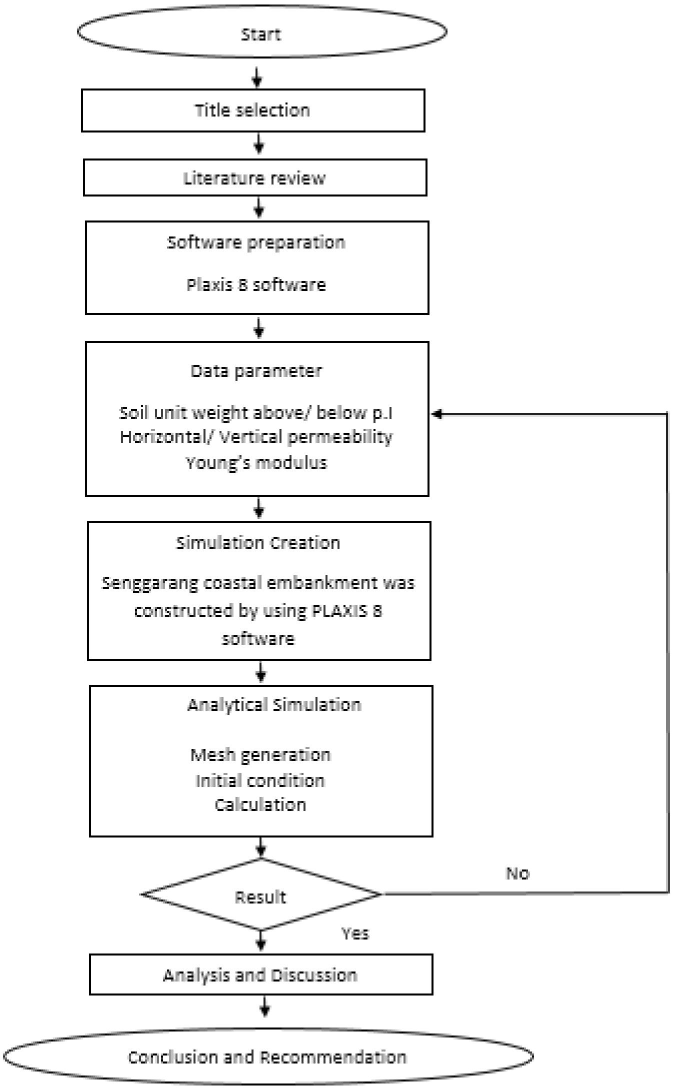

Figure 3: Methodology flow chart of the research

2.1 Silty Clay

Types of soil used in this study are treated and untreated silty clay. The embankment was modelled as silty clay for foundation soil with the height of 6 m and 21 m length. The foundation of embankment need to be treated to reduce the discharge of seepage. Hence, the silty clay need to be treated to improve the strength to become more stabilised and minimize seepage problem.

2.2 Material properties

Suitable set of data parameters has been assigned to conduct the simulation. Two material layers are adopted for the soil. Table 1 shows the material properties used for the PLAXIS simulation.

Table 1: Material properties of the embankment and subsoil

Parameter	Name	Unit	Clay	Clay	Silty Clay	Treated Silty Clay
Material model	Model	-	Mohr-Coulumb	Mohr-Coulumb	Mohr-Coulumb	Mohr-Coulumb
Type of behaviour	Type	-	Undrained	Undrained	Drained	Drained
Soil unit weight above p.I	γunsat	kN/m^3	16	16	16	17.2
Soil unit weight below p.I I	γsat	kN/m^3	18	18	17	19.5
Horizontal permeability	k_x	m/day	0.001	0.001	0.778	0.078
Vertical permeability	k_y	m/day	0.001	0.001	0.864	0.078
Young's Modulus	E_{ref}	kN/m^2	2000	5000	1300	187353
Poisson's ratio	υ	-	0.35	0.35	0.34	0.15
Cohesion	c_{ref}	kN/m^2	2.0	5	14	520
Friction angle	φ	°	24	25	34	38.7
Dilatancy angle	Ψ	°	0	0	0	0

2.3 Calculation

These calculations are generally used to define the different phases of embankment construction. In the modelling analysis, the calculation consists 5 phases. First the initial stress field has to be calculated since this has not been done during the input of the initial conditions. The third phase is to defined the loading. In this research, the load applied was 7.443 m.

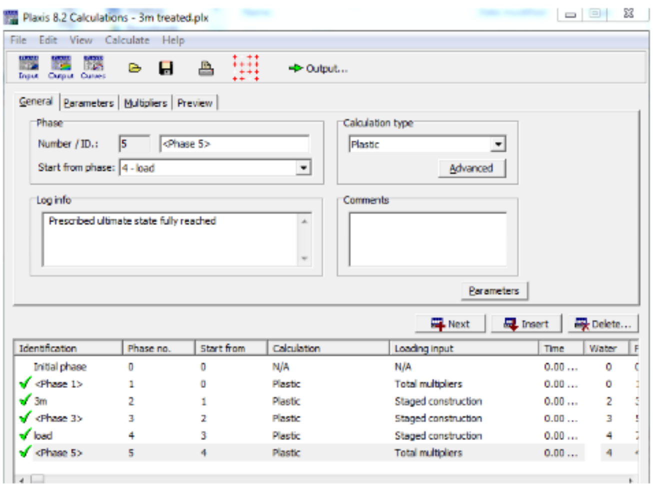

Figure 4: Calculation steps using FEM program

3. Results and Discussion

The results from the simulation are total displacement, effective stresses, excess pore pressure and discharge of seepage.

3.1 Total Displacement

The total displacements are the absolute accumulated displacements, combined from the horizontal and vertical displacement components at all nodes at the end of the current calculation step. Table 2 shows the total displacement of embankment in term of horizontal displacement (Ux) and vertical displacement and (U_y) with different water level applied. It shows that for 3 m water level, the value of total displacement of untreated silty clay was 10.40 m, while the value of total displacement of treated silty clay was smaller which was 8.48 m. Figure 5 show graph of water level vs total displacement. The settlement at the untreated silty clay embankment is higher than treated silty clay embankment. The influence of the cohesion value of the untreated and treated soil contribute to the changes of soil strength. The cohesion value for treated silty clay was 520 kN/m^2 and untreated silty clay was 14 kN/m^2 respectively. As the cohesion value of soil increase, the strength of soil increase which enable the embankment to withstand the 7.443 m load applied through prescribed displacement approach.

Table 2: Total displacement of embankment with different water level applied

Water level (m)	Soil Types	Horizontal and vertical displacement (m)	Total displacement (m)
1	Untreated silty clay	U_x : 7.67 U_y : 7.44	7.79
	Treated silty clay	U_x : 6.51 U_y : 7.44	7.44
2	Untreated silty clay	U_x : 9.05 U_y : 7.44	9.16
	Treated silty clay	U_x : 7.25 U_y : 7.45	7.51
3	Untreated silty clay	U_x : 10.33 U_y : 7.44	10.40
	Treated silty clay	U_x : 8.48 U_y : 7.44	8.48

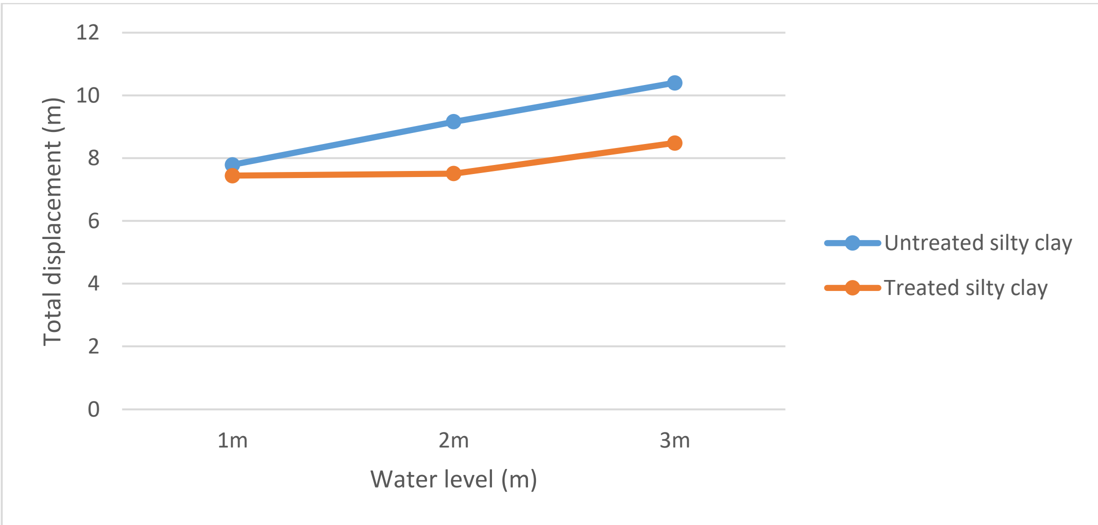

Figure 5: Graph of water level vs total displacement

3.2 Effectives Stresses

Effectives stresses displayed in a plot of the geometry at the end of calculation step in PLAXIS 8 software. The effective stresses output presented as crosses in the element stress points. Table 3.2 shows the results of effectives stresses from numerical simulation of embankment with untreated and treated (cement-CSP) silty clay. Pressure is considered negative according to PLAXIS manual. Figure 6 shows the graph of water level vs effective stresses for untreated and treated silty clay. The line graph was plotted using the results from Table 3. According to the knowledge of soil mechanics, with the decrease of groundwater level, the effective stress will increase.

Table 3: Effective stresses of embankment

Water level (m)	Soil Types	Effective stresses (kN/m^2)
1	Untreated silty clay	-73.48
	Treated silty clay	-91.46
2	Untreated silty clay	-73.67
	Treated silty clay	-91.52
3	Untreated silty clay	-74.47
	Treated silty clay	-91.90

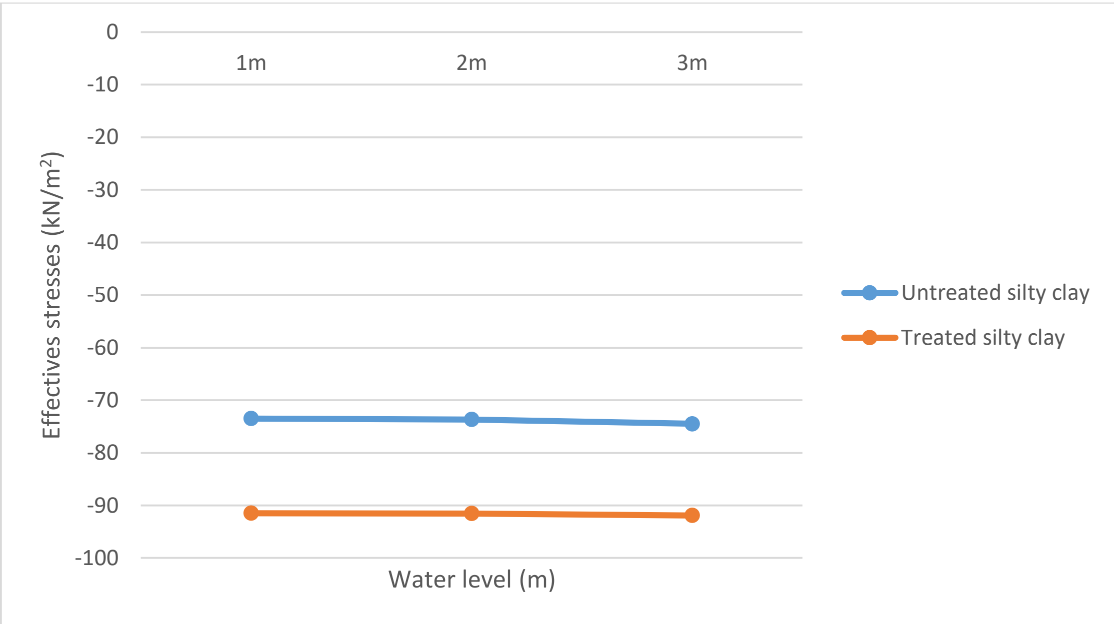

Figure 6: Graph of water level vs effective stresses

3.3 Excess Pore Pressure

Table 4 shows the excess pore pressure of embankment with untreated and treated (cement-CSP) silty clay. It can be seen from the Table 4 that the values of excess pore pressure are in negative value. Theoretically, when soil above the groundwater level is unsaturated, pore pressure is below atmospheric pressure and hence pore pressure is negative in value. According to M. Ghadrdan [6], excess pore pressure generated from compress saturated soil in undrained condition where it can reduce effective stresses. Saturated material will increase the excess pore pressure especially for 3 m water level because the embankment is saturated by the rising water. Figure 7 shows the line graph of water level vs excess pore pressure for untreated and treated silty clay. According to M. Ghadrdan [6], generation of pore water pressure influence the stability. From the value obtained from the simulation, it shows that the embankment with treated silty clay is more stable compared to embankment with untreated silty clay. This can relate with the decrease of permeability value of silty clay from 0.778 m/day to 0.078 m/day. The strength of soil can be increased with the decreasing value of permeability of soil.

Table 4: Excess pore pressure of embankment

Water level (m)	Soil Types	Excess pore pressure (kN/m^2)
1	Untreated silty clay	-32.54
	Treated silty clay	-37.48
2	Untreated silty clay	-18.21
	Treated silty clay	-49.85
3	Untreated silty clay	-31.44
	Treated silty clay	-33.06

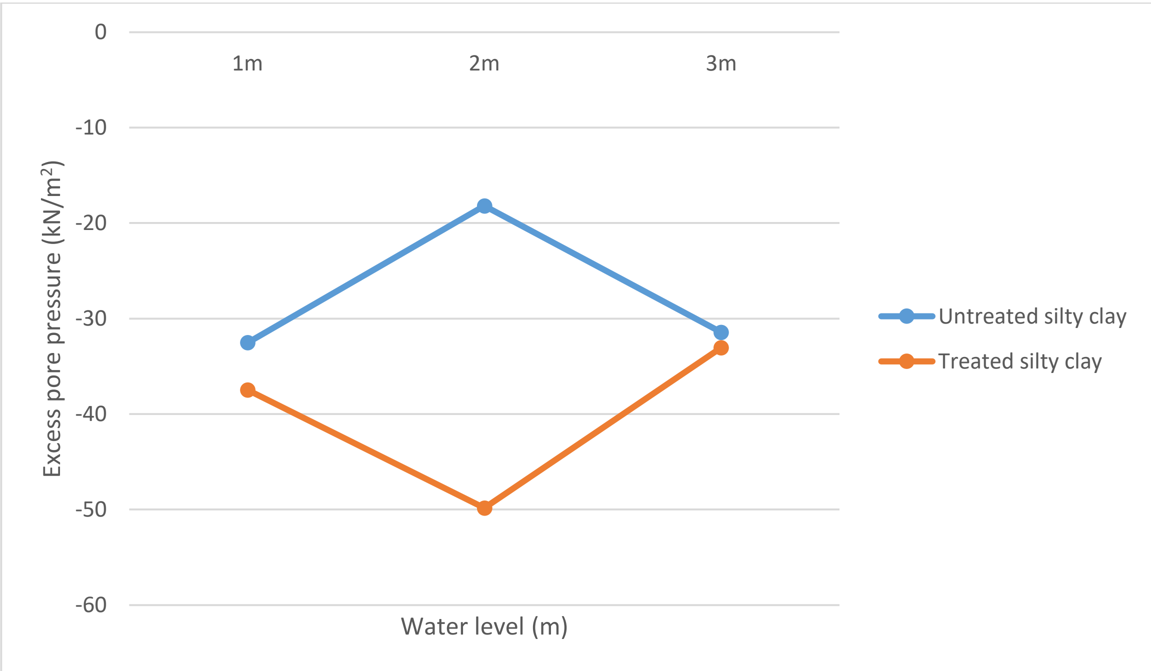

Figure 7: Graph of water level vs excess pore pressure

3.4 Seepage Analysis

This comparison between discharge of seepage from PLAXIS and manual calculation of seepage was to analyse the difference and accuracy for the value of seepage. Manual calculation was calculated by using flow net analysis. Table 3.4 shows comparison between discharge of seepage using PLAXIS and using flow net analysis. The discharge of seepage for treated silty clay of 1 m water level using PLAXIS was 42.58 x 10-3 m3/day while using flow net analysis was 77760 x 10^{-3} m^3/day. The difference was only 77717.42 x 10^{-3} m^3/day. As for 2 m water level, the difference between discharge of seepage was 91.07 x 10^{-3} m^3/day using PLAXIS and 345600 x 10^{-3} m^3/day using flow net analysis.

The difference was only 345508.93 x 10^{-3} m^3/day. Different of value between discharge of seepage using PLAXIS and using flow net analysis do not give big difference. The comparison between graph of water level vs discharge of seepage for untreated and treated silty clay can be seen in Figure 8 and Figure 9.

Table 5: Comparison between discharge of seepage using PLAXIS and using flow net analysis

Water level (m)	Soil Types	Discharge of seepage using PLAXIS (m^3/day)	Discharge of seepage using flow net analysis (m^3/day)
1	Untreated silty clay	436.44 x 10^{-3}	7776 x 10^{-3}
	Treated silty clay	42.58 x 10^{-3}	77760 x 10^{-3}
2	Untreated silty clay	910.12 x 10^{-3}	34560 x 10^{-3}
	Treated silty clay	91.07 x 10^{-3}	345600 x 10^{-3}
3	Untreated silty clay	1430 x 10^{-3}	99977 x 10^{-3}
	Treated silty clay	140.71 x 10^{-3}	999771 x 10^{-3}

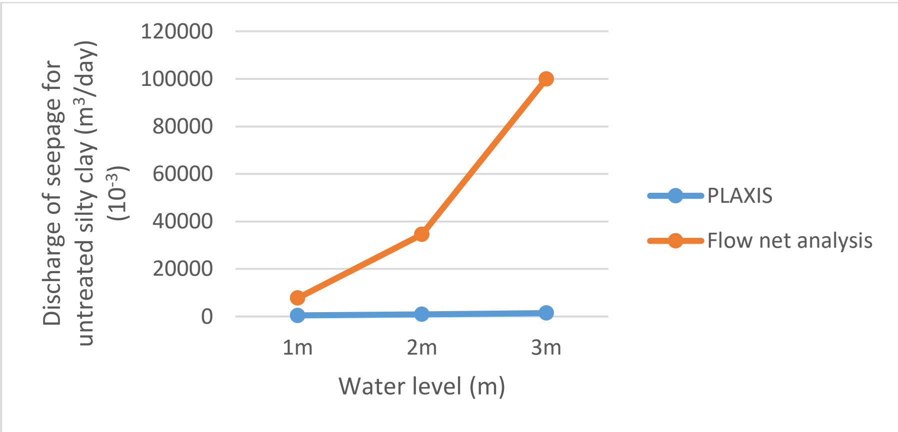

Figure 8: Graph of water level vs discharge of seepage for untreated silty clay

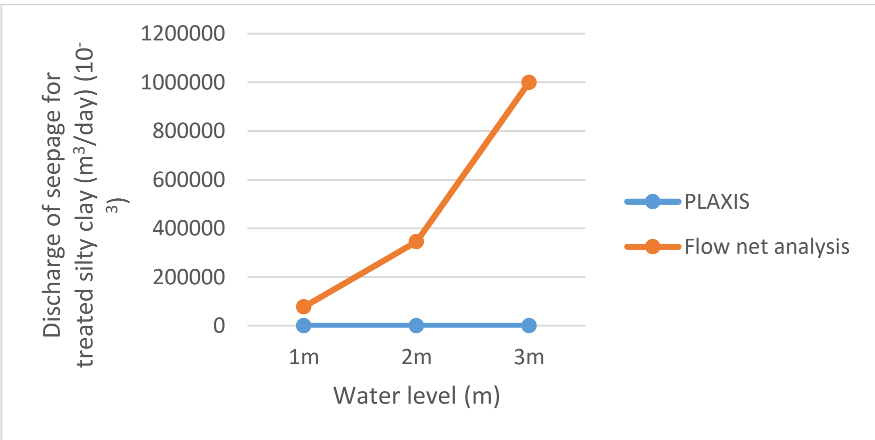

Figure 9: Graph of water level vs discharge of seepage for treated silty clay

4. Conclusion

This study has concluded that the value of discharge of seepage of treated silty clay is lower than the value of discharge of seepage of untreated silty clay. This conclude that the mixture of silty clay with cement-CSP reduce the seepage discharge of the embankment. The comparison that have been made between discharge of seepage using PLAXIS and using flow net analysis. As for that, the first objectives of this study is achieved which is to analyse the seepage characteristics of Senggarang embankment constructed with cement-CSP-stabilised silty clay.

The value of total displacement for untreated silty clay is bigger than treated silty clay (cement-CSP). In this simulation, 7.443 m load was applied by using prescribed displacement approach. Thus, value of the total displacement for treated is smaller than untreated as the strength of the embankment increase. Hence, the second objective to evaluate the load-bearing capacity of the cement-CSP-stabilised silty clay embankment with the 'prescribed displacement approach' was achieved.

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