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J-SUE

http://publisher.uthm.edu.my/ojs/index.php/j-sue

e-ISSN : 2821-2851

Journal of Sustainable Underground Exploration

Review on Soil Improvement by Using Various Chemical Additives for Foundation

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DOI: https://doi.org/10.30880/jsue.2021.01.01.006
Received 24 August 2021; Accepted 11 October 2021; Available online 16 December 2021

Abstract: This work aimed to study the most effective chemical additives to increase the strength of the clay soil. The problem statement is to improve the soil strength to avoid failure in the ground. The chemical additives that be used are lime, cement, and fly ash. These chemical additives were commonly used to stabilize the soil and make the shear strength of the soil increase. The data taken was from the previous research, where the data was compared to get the most effective chemical additives to improve the soil stability and soil strength. The percentage of the chemical additive used in the soil mixture was 8% to 10%. The data from previous research was chosen based on the rate used of the chemical additive and the research was taken from Science Directed website only. Data were collected through 30 previous studies using clay and chemical additives such as cement, lime, and fly ash. The data for Plastic Limit, Liquid Limit, Plasticity Index, Optimum Moisture Content, Maximum Dry Density, and Unconfined Compressive Strength was taken by referring to the previous study. Then the data was listed in Microsoft Excel to generate the graph for comparison. All the data obtained are then compared to get which chemicals can increase the strength of the soil. The result of this study shows that the cement was the most effective chemical additive to improve the soil strength and to stabilize the soil than the lime and fly ash.

Keywords: Improved soil strength, chemical additives, comparison

1. Introduction

Soft soil is included in organic soil and peak soil. In Malaysia, most of the soil was soft soil. Clay soil is one of the examples of problematic soil in Malaysia. The stabilization of the soil can be done using various types of substances. The mechanical and chemical substances can be used in the stabilization of soft soil. The clay soil was the most soil that can be found in Malaysia that can be found in the areas with the high moisture content. The type of soil in Johor mostly clay soil which contains high water content that consists of organic matter. There were many previous kinds of research that can be found to compare what is the best chemical additive for the improvement of the soil strength and stabilization. The stabilization of the clay soil can be improved by doing the compaction and mixing with additional chemicals to improve the soil condition. Soil stabilization is very important to increase the strength of the clay soil. Soil stabilization that using chemical additives involves the treatment of the structure of the soil

Usually for the construction of this type of soil should be avoided because it has a consolidation settlement. This is because usually, this type of soil can be found near the river or under the water table. The construction that is held in the clay soil area needs a high cost and takes a long period of time to be done. It also has a stability problem due to the high compressibility of the soil. This is because the soft soil contains high water content, so it has low shear strength to support the load from the building. But in this study, the use of chemical additives was chosen. So, how the chemical additives can improve the soil strength will be discussed in this paper. This research is done based on the case study of the critical review for clay soil stabilization using chemical additives.

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The scope of the study was focused on the effectiveness of the clay soil when using the different percentages and types of chemical additives. Based on the previous study, we can see the different strengths of the clay soil with the different types of chemical additives. If the compressibility of the clay soil after adding the chemical additives increases, so the strength of the clay soil also will be increased. The chemical was added to the soil and became a specimen. The data was taken from the result of the previous study. The data of the specimen was taken before adding the chemical and after adding the chemical substance. The data are taken compared to some previous studies to get the effective chemical additives for strengthening the soil.

2. Literature Review

This chapter will cover an analysis of the published research that will be outlined in order to ensure the design parameters and the use of chemicals as additives to stabilize the soft soil in the foundation. Generally, clay soils have poor drainage characteristics, which are largely dependent on the infiltration rate, which can be changed by adding larger particles of organic matter or pea gravel to the soil [1]. Clay soil has low shear strength when the soil in wet condition or other physical disturbance. Soft clay was the finest soil that obviously can be seen using the microscopic tool. The particle size for the soft clay was less than 0.075mm. The character of the clay component is divided into montmorillonite clays, kaolin clays, and illite clays [2].

Lime gives an inexpensive means of stabilizing the soil. An increase in strength brought by cation exchange capability rather than a cementing effect brought by the pozzolanic reaction is defined by Lime modification [3]. The reaction of cement does not rely on soil minerals, and its reaction to water that may be present in any soil plays a key role [3]. There were many types of cement in the market, such as ordinary Portland cement, blast furnace cement, sulphate resistant cement, and high alumina cement. The choices of cement are based on the type of soil treated and the final strength. Fly ashes are a by-product of electric power generating plants fired from coal that is relative to lime and cement; it has no cement characteristics. Most fly ashes belong to secondary binders that were the desired effect on their own may not be created by these binders [3]. By using a small amount of fly ash, it can react chemically to improve the strength of soft soil. Fly ashes were environmentally friendly, cheaper than the other additives, and readily available.

3. Equations

The methodology for this analysis is divided into four groups. This extends from the data entry to the archive. The database contains all information on the type of soil, exact location, liquid limit, plastic limit, atterberg limit, shear strength, and bearing capacity is displayed in the table. Once all the data is imported, the analysis was done using Microsoft Excel. Lastly, the result can be obtained in the graph to analyze the strength of the soil. The data taken for lime, cement, and fly ash stabilization was from ten results from a previous study for each chemical to compare the strength of clay soil that adding with chemical additives. The database was form 30 results on the previous study.

The data was collected from the experiment from previous research. Then the data were analyzed using Microsoft Excel to get the most effective chemical additive for stabilizing the soft soil in the foundation to prevent failure from obtaining. Fig.1 shows the flow process of the research. The specification for this research was based on the American Association of State Highway and Transportation Officials (AASHTO) and Unified Soil Classification System (USCS) for the soil size limit. The soil classification system, there were divided into groups and subgroups based on engineering properties. There is two major classification system that been used which is American Association of State Highway and Transportation Officials (AASHTO) soil classification system and Unified Soil Classification System (also ASTM) soil classification system based on the standard practice for classification of soil for engineering purpose.

The expectation for this study is to analyze the best chemical additive that can be used in the stabilization of the soil to avoid failure in the foundation. Based on the specification, the soil with the suitable shear strength can be chosen.

Fig.1 - The flow processes

4. Results and Discussion

This chapter is aiming to analyze the strength of clay by using lime, cement, and fly ash. This chapter will be discussing on results and analysis of all the comparison results from previous research related to clay soil properties. The previous research result including moisture content, liquid limit, plastic limit, plasticity index, optimum moisture content, maximum dry density, and shear strength result.4.1 Basic Data

The data for untreated soil from the previous research was taken to know the basic data of the clay soil before added with the lime, cement, and fly ash. The basic data taken was including moisture content, liquid limit, plastic limit, plasticity index, optimum moisture content, maximum dry density, and unconfined compressive strength result as shown in **Table 1**.

Table 1 - The summary result of data collection for the previous research for clay soil

Basic Properties for Untreated Soil

No.	**Soil Type** / **Researcher**	**Clay Soil** Plastic Limit %	Liquid Limit %	Plasticity Index %	Optimum Moisture Content %	Maximum Dry Density kN/m^3	Unconfined Compressive Strength, q_u kN/m^2
1	[4]	41	146	105	30	14.2	-
2	[5]	19	50	31	20	16.28	-
3	[6]	21.4	45.8	24.4	19	17.46	-
4	[7]	23	46	23	18	16.38	-
5	[8]	21	33	12	19	-	101.76
6	[9]	30	58.8	28.8	27	14.8	-
7	[10]	-	-	312	42	12.45	510
8	[11]	31.7	64	32.3	20	16.48	88.3
9	[12]	27.74	47.85	20.11	13.2	17.36	373.4
10	[13]	31.7	72.1	40.4	32.5	13.4	300
11	[14]	31	57	32	-	-	142.6
12	[15]	24.3	37.3	13	12.2	18.93	-
13	[16]	6	26	20	22	15.3	57.66
14	[17]	19.2	52.8	33.6	17.2	16.48	314.6
15	[18]	20	38	18	19.4	1.81	-
16	[19]	14.57	29.45	14.88	12.36	18.11	-
17	[20]	27	20.1	-	-	10	-
18	[21]	44.59	76.98	32.39	23.12	16.28	99.51
19	[22]	44	67	23	16.5	17.65	200
19	[22]	44	67	23	16.5	17.65	200
20	[23]	26	84	58	29.83	13.27	190
21	[24]	27	37	10	15.48	18.14	1930
22	[25]	29	43	14	20.3	16.5	-
23	[26]	20.13	24.37	4.24	11.69	18.73	564.87
24	[27]	27.36	40	12.64	-	-	-
25	[28]	27.28	36.74	9.46	25.43	14.49	22.47
26	[29]	8	8	1.19	-	-	168.8
27	[30]	39	108	69	-	-	92.6
28	[31]	29	73	44	22	15.6	89

The result that been analyzed from the previous study based on the type of soil used and the chemical additives used in the research. The result for liquid limit and plastic limit in the Table 2 showed that if the plastic limit result was higher than the liquid limit result, so the plastic content in the soil was higher than the water content in the soil and vice versa. The basic properties of untreated soil for the Liquid Limit data shows that 12 researchers got the soil in high silt compressibility and organic clay while the other researchers get low compressibility because the result was below 50%. So, the chemical additives were added to improve the soil classification and the Liquid Limit. Fig. 2 shows the graph for Researcher versus Plasticity Index (%).

Table 2 - The Plasticity Classification

No.	Researcher	Chemical	Plasticity Classification	
			Untreated Soil	Treated Soil
1	[8]	Cement	Medium Plastic	Medium Plastic
2	[9]		High Plastic	High Plastic
3	[12]		High Plastic	-
4	[16]		High Plastic	-
5	[17]		High Plastic	High Plastic
6	[23]		High Plastic	High Plastic
7	[24]		Medium Plastic	-
8	[26]		Slightly Plastic	-
9	[30]		High Plastic	High Plastic
10	[31]		High Plastic	-
11	[4]	Lime	High Plastic	-
12	[5]		High Plastic	High Plastic
13	[6]		High Plastic	High Plastic
14	[7]		High Plastic	Slightly Plastic
15	[9]		High Plastic	Slightly Plastic
16	[21]		High Plastic	Slightly Plastic
17	[22]		High Plastic	High Plastic
18	[23]		High Plastic	High Plastic
19	[27]		Medium Plastic	Medium Plastic
20	[28]		Medium Plastic	Medium Plastic
21	[4]	Fly Ash	High Plastic	High Plastic
22	[13]		High Plastic	Medium Plastic
23	[14]		High Plastic	High Plastic
24	[15]		Medium Plastic	Medium Plastic
25	[17]		High Plastic	High Plastic
26	[18]		High Plastic	Medium Plastic
27	[19]		Medium Plastic	Medium Plastic
28	[20]		High Plastic	Slightly Plastic
29	[22]		Medium Plastic	High Plastic
30	[29]		Slightly Plastic	Medium Plastic

For the overall result, for the lime, three studies from [7], [9], and [21] shows the plasticity classification for untreated soil change from high plastic to slightly plastic when the lime was added into the soil while for the other result remains unchanged. For result from [13] and [18] change from high plastic to medium plastic, for the result from [22] that change from medium plastic to slightly plastic, for the result from that change from medium plastic to high plastic and for the result from from [29] was changed from slightly plastic to medium plastic. For the medium plastic result, only the result when added the fly ash shows the increase of plastic classification, which is from medium to high plastic. For the slightly plastic result, when the fly ash was added into the soil, the plastic classification result change from slightly plastic to medium plastic, so it shows the increase of plastic classification. For cement, the result was remained unchanged for all the data obtain. This result shows that cement is an effective chemical additive to maintain the value of the plastic in the soil.

Table 3 shows the consistency classification, while Fig. 3 shows the the graph for Researcher versus Unconfined Compressive Strength (kN/m^2) Most of the soil-lime mixture and the soil-fly ash mixture consistency was very stiff where the q_u data was from 200 kN/m^2 to 400 kN/m^2 compared to the soil-cement mixture that has more than 400 kN/m^2 that the consistency was at hard. For the medium consistency, the result being improved to the hard consistency when the soil was added with the cement, which is the result get from [16], [30], and [31]. For the stiff consistency, the resulting increase when the soil was added with the fly ash and changed the consistency too hard where the result gets from. For the very stiff consistency, the resulting change to the hard when the soil added with the cement where the result from [12] and [17]. As a result, cement is the most effective chemical additive to improve soil consistency which is also can improve the strength of the soil. When the strength of the soil increase, the failure can be reduced.

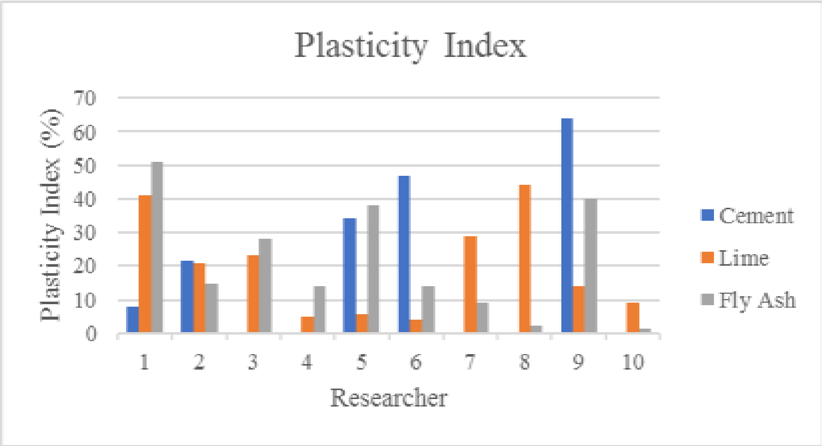

Fig. 2 - The graph for Researcher versus Plasticity Index (%)

Table 3 - The consistency classification

No.	Researcher	Chemical	Consistency Classification	
			Untreated Soil	**Treated Soil**
1	[8]		Stiff	Very Stiff
2	[9]		Medium	Medium
3	[12]		Very Stiff	Hard
4	[16]		Medium	Hard
5	[17]	Cement	Very Stiff	Hard
6	[23]		Stiff	Hard
7	[24]		Hard	Hard
8	[26]		Hard	Hard
9	[30]		Medium	Hard
10	[31]		Medium	Hard
11	[4]		-	-
12	[5]		-	-
13	[6]		-	-
14	[7]		-	-
15	[9]		-	-
16	[21]	Lime	Medium	Stiff
17	[22]		Stiff	Very Stiff
18	[23]		Stiff	Very Stiff
19	[27]		-	-
20	[28]		Very Soft	Stiff
21	[4]		-	-
22	[13]		Very Stiff	Very Stiff
23	[14]		Stiff	Hard
24	[15]		-	-
25	[17]		Very Stiff	Stiff
26	[18]	Fly Ash	-	-
27	[19]		-	-
28	[20]		Stiff	-
29	[22]		-	Stiff
30	[29]		Stiff	Very Stiff

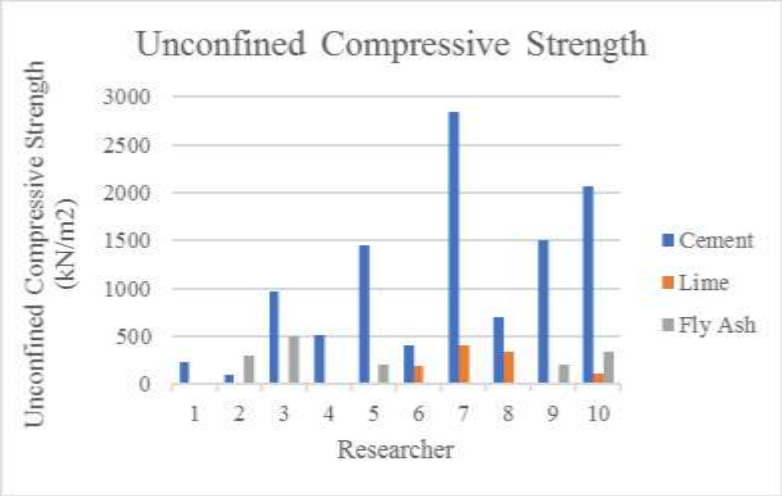

Fig. 3 - The graph for Researcher versus Unconfined Compressive Strength (kN/m^2)

5. Conclusions

This study was undertaken to determine the most effective chemical additives to improve the clay soil strength. This study was undertaken to research the most effective chemical used in the improvement of clay soil strength by using lime, cement, and fly ash. The parameter taken for the chemical additive was for the range of 8% to 10% used in the soil mixture. The comparison for lime, cement, and fly ash mixture was conducted to get the most effective chemical to improve soil strength. To reduce the compressibility, the use of lime chemical additive was very helpful than the cement and fly ash.

i. To maintain the value of the plasticity classification in the soil, cement was the most effective chemical additive.

ii. The result for the compaction test from the previous study shows that the result for optimum moisture content for most of the previous studies for treated soil with the chemical was lower than the untreated soil.

The most effective mixture of the chemical and soil was the soil-cement mixture because most of the result for cement was increasing the optimum moisture content and decreasing the maximum dry density. The result of the unconfined compressive strength shows that cement is the most effective chemical additive to improve soil consistency. For the overall conclusion, the cement was the most effective chemical additive to improve the soil strength and to stabilize the soil than the lime and fly ash. Even though fly ash was the cheapest chemical, it cannot help to improve the soil strength effectively like cement. Cement was the most used chemical to stabilize the soil and to increase the soil strength from the previous year of study.

Acknowledgement

The authors would like to acknowledge the Faculty of Civil Engineering and Built Environment, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johor, Malaysia.

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