Analysis of Physical Properties and Soil Uplift by Searching for Swelling Values in Barbate Quarry Soil for Earthquake Disaster Mitigation Efforts

Arissa Sabilla[1,*], Munirwansyah[1], and Halida Yunita[1]

[1]Civil Engineering, Syiah Kuala University, 23111 Darussalam, Indonesia

Abstract. Aceh Besar District is part of the Province which is located on the tip of the island of Sumatra and this area is on the Sumatra Fault fault as well as the local fault. Areas that are on active faults can result in the possibility of an earthquake being quite high, this is because the area is quite close to the epicenter. The purpose of this study was to determine the value of the physical properties and uplift of the quarry soil in the Barbate area of Kurma-Paya Kameng Gardens so that if the PI value of the soil is >17%, the soil needs to be stabilized with coffee husk ash as a mixed ingredient. The research research method was testing soil samples at the Soil Mechanics Laboratory at Syiah Kuala University. The results of the study show that this soil is of the clay type and has a PI value of 38.42% so stabilization is carried out, the soil uplift value also shows that the value is increasing and the highest point of the calculation results is at a 25% mixture of 22.37 kg.

1 Introduction

Aceh Besar District is an area that almost all of its parts are clay soil. Clay soil has two different types of properties, the first characteristic of this soil is being able to absorb water and the second is having impermeable properties to water. Soil which is a problem in the world of civil engineering is in the form of clay which absorbs water or commonly called expansive soil, this expansive soil phenomenon is a problem that must be addressed immediately. This soil has the ability to expand large enough to cause deformation which often cannot be supported by the rigidity of the building structure above it. This study aims to prove whether quarry soil is feasible or not if it is used in a construction project either as a building material or as a fill [1]. Many quarry land locations can be found in the Aceh Besar and Banda Aceh Regions, several locations identified as having quarries can be seen in figure 1.

* Corresponding author: author@email.org

Fig 1. Map of the distribution of research location plan points.

However, in this study the research location was in the Barbate area which is in the Aceh Besar District area.This location is also seen to have a fairly close distance to the Seulimum fault and the Aceh fault where these locations can have a greater potential for earthquake damage due to the location being quite close to earthquake sources as shown in figure 2 below.

Fig 2. Map of research locations that are close to the Seulimum fault area and the Aceh fault

Aceh Besar District is part of the Province which is located on the tip of the island of Sumatra and this area is located on the Sumatra Fault and local faults. Areas that are on active faults can result in the possibility of an earthquake being quite high, this is because the area is quite close to the epicenter. The epicenter of the earthquakein the mainland area can occur due to a shift in the Sumatran fault, which is indicated by the number of earthquakes along the fault and generally has a shallow depth.

Earthquake shocks will have an effect on the surrounding land, the effects can occur in various ways, such as shifting of the ground which impacts on the buildings above it, liquefaction, and other things. Earthquakes often occur even without any predictions, the waves generated by earthquakes in the ground are scattered in various directions so that the effects of earthquakes are quite extensive, the waves that occur in the ground provide great movement to the surface.

Areas that are in the epicenter area of the earthquake have a higher risk of the impact of the earthquake, so that inbuilding a construction it is necessary to calculate the load from the earthquake disaster to be able to mitigate the things that will have an impact on the area. To be able to mitigate this, a plan is needed when a construction will be carried out. The most basic planning is to ensure that the strength of the soil that will accommodate the load on it is of good quality, so that the construction can survive and the soil can accept the load that is distributed properly.

Soil is a material that is always used as a construction material, or used as a foundation for construction. However, the soil used must meet the carrying capacity strength requirements. We have observed many of the damages caused such as bumping and destruction of roads, cracking of building floors, all of this occurs as a result of using poor soil such as expansive clay. Soils that have poor physical properties or have a PI>17% have the potential for changes such as swelling and high elasticity, so soils like this need to be stabilized to improve the elements of the soil for the better. In this research, the physical properties test will be carried out on the original soil, so that if the soil has a PI>17% then this soil is stabilized with coffee husk ash, where coffee husk ash can be used as a soil stabilizing agent because it has properties that can increase the strength or carrying capacity of the soil [2].

This research focuses on the location of Paya Kameng Kurma Barbate Gardens in Aceh Besar District, this location is studied by calculating and obtaining the value of the physical properties of the soil and the uplift valuedue to the high swelling capacity that occurs due to changes in the soil layer so that it can cause damage to existing infrastructure. above the ground so that the uplift value will be obtained by using the equation.

2 Methodology

2.1 Data Collection

Data collection is the stage for finding the data needed in order to solve a problem scientifically and achieve research objectives. The data that will be collected include primary data and secondary data. Data collection was carried out by conducting laboratory tests to obtain atterberg limit values and soil uplift under study.

2.2 Data Analysis

Atterberg limit testing is done by looking for the value of Liquid limit (LL), Liquid limit (LL), Shrinkage Limit and Plasticity Index. The PI value can be searched by Equation (1) [3].

$$PI = LL - PL \quad (1)$$

Then, the test is continued by conducting swelling tests to obtain data on the development of the soil. States that more than 50% or even close to 65% of the soil in Indonesia is laterite soil. Soils of this type generally contain minerals that have high swelling potential, and can

be called expansive soils. This test is carried out by preparing a sample of the test object, the test object has been compacted with a hummer and placed in a mold as a sample container, the ready sample is soaked in water for 4 days and readings are taken at certain times to get the value from the dial used to measure ground elevation [4].

The rise and fall of the groundwater level can affect the construction that is above the land. So a review is needed to see whether the land is experiencing high increases and losses so that the construction on it is not able to accept it or vice versa. This also happens because the soil is problematic clay with a high swelling value and also a very high PI value. To get the Uplift value, the calculation is carried out using the following formula [5]:

$$\text{Uplift Force (Kg)} = \text{Dial reading x calibration} \qquad (2)$$

As for the lift force unit itself, the following equation is used:

$$\text{Lift Unit (kg/cm}^2\text{)} = \frac{\text{Dial reading x calibration}}{\text{mold area}} \qquad (3)$$

3 Result and Discussion

From the results of research at the location of quarry soil samples at the Barbate-Paya Kameng Dates Garden. This soil has a high PI value of 38.42% in the original soil sample, where this soil is classified as having a very high swelling value because it is greater than > 17% so this soil is stabilized with coffee husk ash as a mixture to improve soil composition. and lowering the PI value in the soil, this Barbate soil sample is described in the following table.

Table 1. Sample soil stabilization with coffee ash mixture

No	Quarry	Sample code	% coffee husk ash
1	Quarry Barbate	TS1	0%
2		TS2	5%
3		TS3	10%
4		TS4	15%
5		TS5	20%
6		TS6	25%

The soil type in the Barbate location is classified as clay, this type is obtained from the classification of the specific gravity values of the soil. In the calculation of soil mechanics analysis, specific gravity is needed to determine the type of soil being analyzed. The specific gravity of soil is a non-unit value [6]. The Gs value obtained, then it can determine the type of soil from the specific gravity of the soil with the values of the specific gravity of the soil, the calculation results are as shown in the following table.

Table 2. The results of testing the specific gravity of the soil as a result of coffee ash stabilization

Sample	Mixture	Specific Gravity (gr/cm^3)	Type of soil
TS1	0%	2,587	Clay
TS2	5%	2,623	Clay
TS3	10%	2,642	Silt

TS4	15%	2,674	Silt
TS5	20%	2,681	Silt
TS6	25%	2,690	Silt

From the test results it can be seen that the average specific gravity of the quarry soil samples originating from Aceh Besar District has silt or clay soil types. Where according to Munirwansyah (2018) soil that has cohesive properties such as clay soil has properties that are very sensitive to the influence of water content and has high shrink-swell properties, soil conditions like this can affect the carrying capacity of the soil [4].

This sample has also been subjected to Atterberg limit testing to obtain soil physical properties, where the results of testing on Barbate soil obtain sieving analysis values. Aggregate gradation is the distribution of grain size expressed in percent of the total weight. The main objective of the aggregate grain size analysis work is to control gradation in order to obtain a high quality mixed construction. The gradation is determined by filtering a sample of the material through a number of filters arranged in such a way from large to small sizes, the material remaining in each filter is then weighed [7].

This test is carried out to determine the diameter of the soil grains from the samples that have been tested.In this test, the value of the fine content (Fc) of the soil will also be obtained from the sieving analysis chart so that the point where the good fraction content is found in the soil,recapitulation of sieve analysis test results can be seen in the following table.

Table 3. Recapitulation of percent testing passed the sieve analysis testground coffee husk ash stabilization

Sample	**Mixture**	**Passes sieve #200**
TS1	0%	20,14
TS2	5%	22,13
TS3	10%	27,10
TS4	15%	31,42
TS5	20%	34,56
TS6	25%	36,29

From the results of research conducted, it has been found that the average soil has conditions that contain a lot of fine grains and the average soil is classified as clay and silt, soil conditions like this are not good for use in civil construction. The fc value has a fairly good content above 15%, which according to Hardiyatmo (1992) Fine Content below 15% (fine grain soil <0.005mm) can cause liquefaction [8].

Ssoil classification is the grouping of various types of soil into groups according to their characteristics. This classification system briefly describes the general properties of soil which vary widely, but none of them really provide a clear explanation of the possible users [9]. The purpose of soil classification is to determine suitability for certain uses, as well as to inform about the condition of the soil from one area to another in the form of basic data. such as compaction characteristics, soil strength, unit weight, and so on [6].

So if it is classified using the AASHTO and USCS methods, the Barbate soil belongs to the AASHTO A-7-5 and USCS CH classifications. Where Classification A-7-5 indicates that the soil has fine grains that pass sieve #200 as much as more than 35% of the total soil, the soil has a liquid limit value (LL) above 41% and a PI value above 11% where the PI value is more lower than the liquid limit value, this soil is classified as loamy soil.

Meanwhile, soil that is classified as CH is soil that has fine grains that pass the #200 sieve more than 50% of the total tested soil, this soil also has a liquid limit value of more than 50%,

this soil also has a high PI value so this soil is classified as a inorganic clays with high plasticity (fat clays). Soil classified as CH is soil that has fine grains that pass the #200 sieve more than 50% of the total tested soil, this soil also has a liquid limit value of more than 50% this soil also has a high PI value so this soil is classified as clay. inorganic with high plasticity (fat clay).

From the results of the calculation of the Atterberg limit, the results of the plasticity index and fine content values are obtained, so that the results of the calculations are described in the following table.

Table 4. PI and Fn values of Barbate soil

***Quarry* Barbate**	**PI (%)**	**Fn (%)**
TS1	38,42	20,14
TS2	35,72	22,13
TS3	35,59	27,10
TS4	35,26	31,42
TS5	35.08	34,56
TS6	34,83	36,29

Then the calculation is done to get the Uplift Force value. From each dial reading for each observation time, uplift force measurement data is obtained. This value is obtained from the relationship between the readings on the dial and the calibration value of the proving ring. From the results of these calculations are described in the table as follows.

Table 5. Test object dial reading value

Time (Hour)	**Dial reading**					
	0%	**5%**	**10%**	**15%**	**20%**	**25%**
1	6	0.2	6,5	0.7	32	48,6
2	12	5,1	9,2	7,3	56	73,8
4	18	18,2	18,3	18,9	80	96
8	19,8	27,2	29	32	93.8	116,3
12	21,3	36,8	37,2	41.6	106,4	138,2
24	22,2	54,3	56,7	71.4	122	158
36	28,6	63	65,1	72	122.5	159.5
48	36,8	72,4	78	90.4	122.9	161.3
72	49,2	87,1	88	97	123.8	163
96	54,9	94.3	95	99.7	124	164.5

Calculations are performed using the formula described in theory to obtain the soil Uplift Force value.

Uplift Force (Kg) = Dial reading x calibration
= 6 x 0.136
= 0.82 Kg (0% mixture, time 1 hour)

Table 6. Uplift Force value recapitulation

Time (Hour)	0%	5%	10%	15%	20%	25%
1	0.82	0.03	0.88	0.10	4.35	6,61
2	1.63	0.69	1.25	0.99	7,62	10.04
4	2.45	2.48	2.49	2.57	10.88	13.06
8	2.69	3.70	3.94	4.35	12.76	15,82
12	2.90	5.00	5.06	5,66	14,47	18.80
24	3.02	7,38	7,71	9,71	16.59	21.49
36	3.89	8.57	8.85	9.79	16,66	21.69
48	5.00	9.85	10.61	12,29	16,71	21.94
72	6,69	11.85	11.97	13,19	16.84	22,17
96	7,47	12.82	12.92	13.56	16,86	22,37

From the calculation results it was found that the Uplift Force value on the soil was read 10 times with different time ranges, from the reading results it was seen that the value continued to increase until the end of the test at 96 hours reading time and had the highest value at 25% mixture which was equal to 22,37. At the beginning of the test it was seen that the values from 0% to 25% had different variations, and the 25% mixture was the highest value, but among soils with other mixtures, the mixture with 5% had a decrease in value so that the lifting force that was read was small, namely 0.03. The calculation results are shown in the following figure.

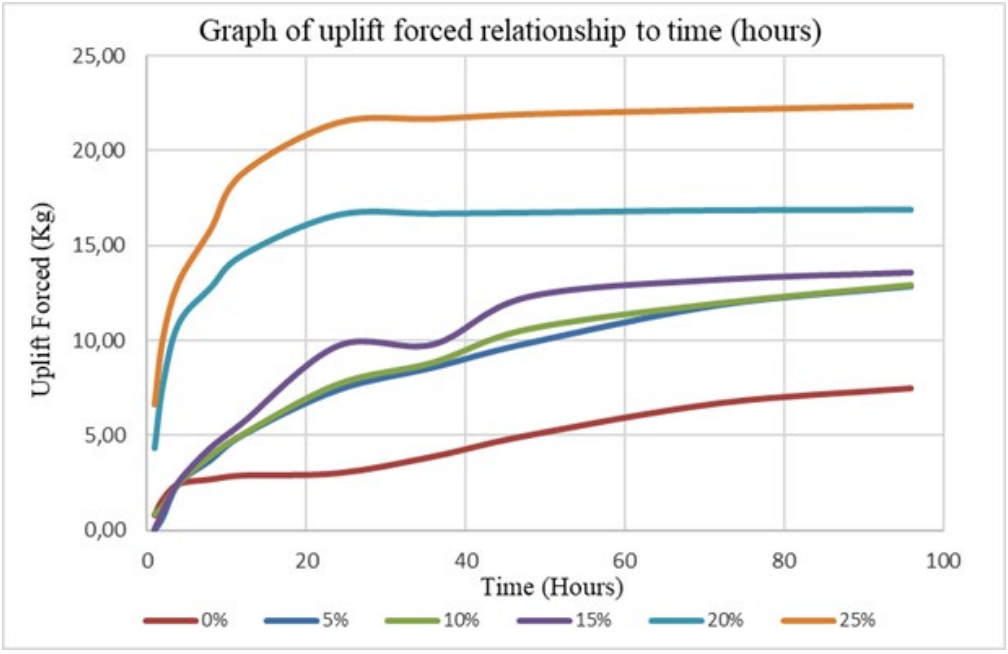

Fig 3. Graph of Uplift forced relationship to reading time

Then the calculation of the soil lift unit on the sample to find out the value of the soil lift per cm2, the calculation is carried out as follows.

$$\text{Lift Unit (kg/cm}^2\text{)} = \frac{\text{Dial reading x calibration}}{\text{mold area}}$$

$$\text{Lift Unit (kg/cm}^2\text{)} = \frac{6 \text{ x } 0{,}136}{379{,}94}$$

$$= 0{,}00215 \text{ kg/cm}^2$$

Table 7. Recapitulation of lift force unit values

Time (Hour)	0%	5%	10%	15%	20%	25%
1	0.002	0.000	0.002	0.000	0.011	0.017
2	0.004	0.002	0.003	0.003	0.020	0.026
4	0.006	0.007	0.007	0.007	0.029	0.034
8	0.007	0.010	0.010	0.011	0.034	0.042
12	0.008	0.013	0.013	0.015	0.038	0.049
24	0.008	0.019	0.020	0.026	0.044	0.057
36	0.010	0.023	0.023	0.026	0.044	0.057
48	0.013	0.026	0.028	0.032	0.044	0.058
72	0.018	0.031	0.031	0.035	0.044	0.058
96	0.020	0.034	0.034	0.036	0.044	0.059

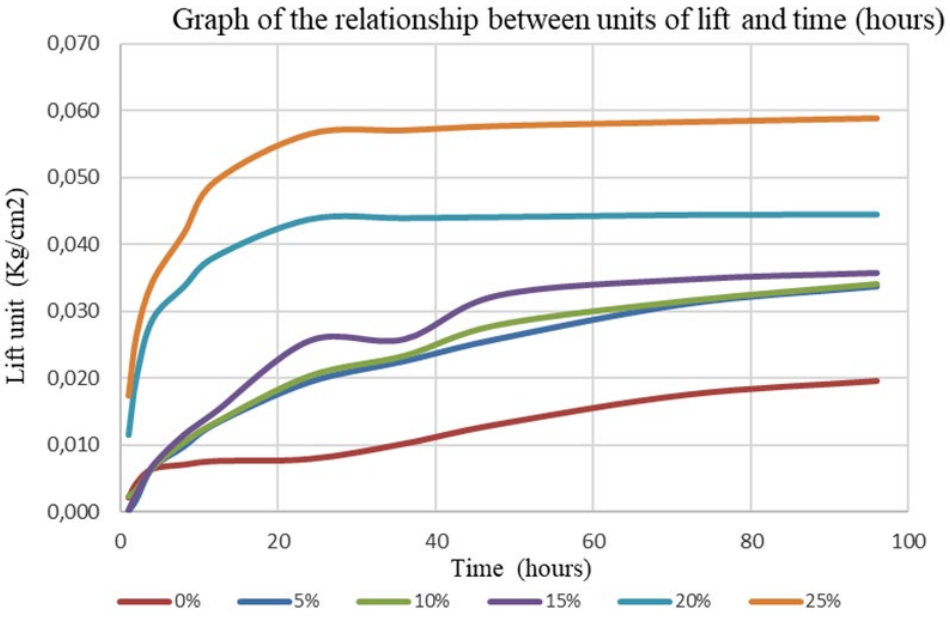

Fig 4. Graph of lift versus time units

From the results of tests carried out on stabilized barbate samples using coffee ashes as a mixture, it was found that the value of the lift force and the soil lift unit continued to increase. This can be seen in figure 3 and figure 4, where the graphs show the increase in the value of the lift force for each soil sample tested.

Earthquake mitigation is an effort to reduce the impact of damage and losses due to earthquakes. Earthquake mitigation efforts include designing earthquake-resistant buildings,

developing early warning systems, and educating the public about what to do when an earthquake occurs. In this study, there is no direct link between the atterberg and uplift limit values for earthquake mitigation. Although there is no direct relationship between testing the uplift value and earthquake mitigation, in the planning and construction of buildings, earthquake mitigation factors and soil characteristics must be considered together. This is because soil that easily swells or expands can increase the risk of damage to buildings due to earthquakes. especially if the building is not well designed to cope with volume changes in the soil. Therefore, in the planning and construction of buildings in areas prone to earthquakes, testing the value of soil swelling can be an important factor that must be considered to minimize the risk of damage to buildings due to volume changes in the soil.

4 Conslusion

The results of this study found that Barbate soil has a high PI value of 38.42%, judging from the PI value this soil has a very high swelling condition, this soil is of the clay type and is classified according to AASHTO namely A-7-5 and according to USCS namely CH. Then from the calculation results to get the soil uplift value it is found that the soil continues to expand, the highest swelling value occurs in the 25% mixture with a total uplift value of 22.37 kg. and the lowest value occurred in the 5% mixture of 0.03 kg.

5 Acknowledgments

Acknowledgments to the Ministry of Education, Culture, Research and Technology, Syiah Kuala University, Banda Aceh, which has assisted in some research activities. Professor Skim, Number. 141/UN11/SPK/PNBP/2022 dated 11 February 2022, to carry out this research

References

1. A. Sabilla, Munirwansyah and H. Yunita, Mapping of Problematic Clay Quarry Locations and Stabilization for Seismicity Mitigation Efforts, Final Project: Syiah Kuala University, 2021.
2. M. and H. Yunita, Study of Potential Liquefaction Due to Earthquake Based on SPT-NDI Data for Aceh Province, Aceh: Syiah Kuala University, 2017.
3. D. HI, Atterberg Limits Test ASTM D-4318-00, 2002.
4. M. R. P. Munirwan and H. Yunita, “Geotechnical Engineering Aspect Related to Pidie Jaya–Aceh Earthquake Disaster and Mitigation,” *International Journal Advanced Science Engineering Information Technology*, Vol.8 (2018) No. 3, 2018.
5. G. Paulie, Uplift Force Analysis on Reservoir, Final Project: University of North Sumatra. , 2016.
6. J. E. Bowles, Soil Physical and Geotechnical Properties, Jakarta: Erlangga, 1989.
7. R. Yonni, A Review of Marshall Values in Asphalt Mixture Laston AC-BC Using Crumb Rubber on Asphalt and Fly Ash Filler, Civil Engineering Thesis. Muhammadiyah University of North Sumatra., 2019.
8. H. C. Hardiyatmo, Soil Mechanics I, Jakarta: PT. Main Library Gramedia, 1992.
9. M. Das, Soil Mechanics (Principles of Geotechnical Engineering), Jakarta: Erlangga Publisher, 1995.