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INCREASING THE STABILITY OF EXPANSIVE SOIL USING LAPINDO SEDIMENTS MATERIALS

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ABSTRACT: Expansive soils contain water-absorbing clay minerals, including smectite and montmorillonite. So expansive soil undergoes a process of expanding and shrinking. Changes in expanding and contracting can weaken structures built on expansive soils. One effort to overcome the problem of expansive soils is a chemical stabilization process using lapindo deposits. The purpose of this study was to determine the effect of stabilizing expansive soils using lapindo sediment materials. Using physical and mechanical testing before and after the expansive soil stabilization process. Using a mixture of 0%, 5%, 10%, 15% & 20% between expansive soil and stabilizing agent. The results showed that the plasticity index decreased from 37.8% to 15.3%, and the compressive strength increased from 0.30 kg/cm^2 to 0.90 kg/cm^2 with the addition of 20% sediment material lapindo. The physical and mechanical properties of expansive soils can be increased by stabilizing them with lapindo sediments. These modifications can reduce the soil's expanding potential, increase its weight, and give it clay-like qualities.

*Keywords**:* *Expansive soil, Lapindo sediment material, Physical and mechanical properties, Stabilization*

1. INTRODUCTION

Seasonal changes in the amount of water in the soil can cause changes in the soil's volume and shape, which can damage the foundations and floors of buildings. Soils that are too loose have minerals like smectite and montmorillonite that can soak up water. The size of the soil will expand due to the minerals that absorb water. The amount of soil grows with the amount of water absorbed. These volume changes could weaken the stability of soil retention structures [1].

Buildings that have been damaged as a result of the expanding soil usually have cracks in them. When there is sufficient movement in the soil structure, damage can occur. The shrinkage occurs when the porous soil dries. The strength of the ground support can be reduced due to the shrinkage that can result in damage to the structure of the building. As a result of the cycle of swelling and shrinkage caused by the penetration of water through soil cracks, soil structures are subjected to repeated pressure. Generally speaking, expansive soil structures should be dealt with by limiting changes in water levels or by modifying the properties of the expansible slate so as not to be too expansionary. Appropriate repair actions should be carried out to repair the expansive soil or reduce its negative effects if found during the project's ongoing phase. It may be necessary to use different repair techniques during the planning and design process and after construction. To improve expansive soil, various stabilization techniques are applied, changing soil properties or removing and replacing problematic soil [2].

Expanding clay stability has been the subject of many studies. These methods can be used independently or in conjunction with certain design options. Other additives, such as fly ash, peppermint, calcium chloride, lime, and cement, are also used to change the soil's expansive properties. Design engineers should pay attention to three properties: permeability, compressibility, and durability. The main handling effort is to prevent damage to building structures due to the expansion of the soil. As a result, handling should be done using a variety of options to ensure the type of soil expanding that will be stopped or changed. The expanding soil has been strengthened and given a greater ability to expand and contract by using many stabilizing chemicals [3]. The field of improving soil quality through the use of additive materials such as fly ash, slag, rice seam, limestone, and other materials has been the subject of some research. In the construction industry, lime is a common stabilizing material [4]. By reducing the number of fine particles, the expansive soil stability achieved with gambling stones seeks to improve the quality of the expansionary soil. According to Tan et al., the strength parameters decrease most noticeably after the first half of the cycle, and the compression and internal friction angle decrease in a hyperbolic relationship with the number of dry and wet cycles [5]. A large-scale sliding test was carried out in the field on ground that expanded by Kumar et al. [6]. It was found that when the number of dry-moist cycles increased, massive cracks first appeared, then new small cranes emerged, breaking the surface of the soil and reducing the compression to half.

Clay that grows can respond to climate change in a very different way than traditional soils that don't grow, such as through rain or evaporation [7]. For example, this kind of behavior can be explained by the presence of highly active platinum minerals like montmorillonite in expansive soils. These minerals cause big changes in volume when they deposit and dry. Also, large cracks and holes that usually form on the surface layer have a big effect on the way water gets in. The retrogressive landslide on the expanding soil has a significant and complex mechanism [6]. To estimate how clay reactions spread with climate change, Firoozi et al. used computer simulations [8]. Their findings emphasize the importance of determining permeability characteristics and weather conditions.

She et al. used rain simulations to test how much soil expands and figure out the law of how water moves through soil after it rains [9].They found that the main things that make expansive soil unstable are the shrinking of the soil's stitching matrix and the way that wet expansion changes the shape of the soil.

Blayi et al. and Murali et al. conducted research on the soil's expansive resistance to rainwater resorption and conducted a comprehensive analysis of the relationship between the depth of rainfall resorption, decay, water levels, and the width of the resorptive line [10,11]. Table 1 shows some of the mixed materials and research results related to expansive soil stabilization.

Some studies also show that the stabilizing mixture is capable of improving the modules of soil elasticity and stiffness. When choosing the right stabilization method, it is necessary to consider the local resources available as well as local soil needs and conditions.

Based on the findings of the research that has been done, no one has spoken about the stabilization of expanded clay by using lapindo sediment. Lapindo sedimentary material, in comparison, contains 25.7% Si and 13.3% Al, used to toxicological data. However, SiO_2 makes up about 55% of this sedimentary composition. The chemical compound SiO_2 has more Si (silica powder) as a filler and less lime as a chemical bond with CaO than traditional cement [12,13]. In this study, we analyzed the impact of soil stabilization expansion using lapindo sedimentary material. Sediments or sediment-related materials from gas mining in the lapindo region are the new agent materials used here.

Table 1: Mixed materials and results of expansive soil stabilization research

Reff	Material	Results of research
[14]	Polyester fiber concentration	The addition of polyester fibers can reduce the number and size of cracks in the expansive soil that undergoes drying. The addition of 1.5% polyester fiber resulted in a 58.7% reduction in the number of cracks and a 49.2% decrease in total length.
[15]	Calcium concentration, drying time, and water content	The addition of limestone can increase the resistivity and stability of the expansive volume of soil. Drying the soil after adding limestone for 48 hours can increase the gliding strength by up to 114%. Reducing the water level by up to 6% can reduce the plasticity index by 64%.
[16]	Calcium and perlite concentration, drought rate, number of freezing-development cycles	The addition of limestone and perlite can raise the soil class from expansive soil to slightly expansionary soil. The sliding strength also increases with the addition of lime and perlite. The number of freezing-development cycles tolerated also increased, with the addition of 6% limestone and 20% perlite able to withstand up to 9 freeze-development cycles.
[17]	Types of stabilization additives (crumb rubber, quarry dust), stabilization material content, environmental conditions	The use of rubber crumbs and quarry dust as stabilization additives can improve soil quality and stability. The optimum content of stabilizing additives depends on the type of soil and environmental conditions at the project site. The use of environmentally friendly stabilization additives such as crumb rubber and quarry dust can also improve the sustainability of the use of stabilization additive materials on construction projects.
[18]	Number of wood ash, soil type, drying time, water content	The use of wood ash as a stabilizing additive can improve soil pressure strength and soil stability. The optimal amount of wood ash depends on the type of soil and the time of drying. The optimal water level for the use of wood ash should also be taken into account so that there is no degradation of the soil.
[19]	Plastic quantity, soil type, water rate, axile load	The use of plastic as a stabilization additive can improve the sliding strength, dimensional stability, and soil elasticity of modules. The optimal amount of plastic depends on the type of soil and water content. The axile load applied also affects the stabilization performance. Field trials show the effectiveness of the use of plastics in subgrade soil stabilization.

Based on toxicological tests, the sediment of lapindo has a very high SiO_2 content. This substance works amazingly well as a bonding agent for CaO compounds. In large soils, this combination of CaO can be found.

To increase the strength of the expansive soil slip, it is necessary to test the use of Lapindo's landfill materials. Quality, grain size, type weight, homogeneity, dry density, unlimited pressure strength, and ideal water content are all determined by a variety of tests. This research is important because it contributes to the development of technology, provides sustainable solutions, has potential economic benefits, contributes to scientific knowledge, and has social benefits. It addresses the problem of soil instability and reduces the environmental impact. It also opens up opportunities for further research on the use of waste materials in soil stabilization.

2. RESEARCH SIGNIFICANCE

This study suggested the stability of expansive soil using lapindo sediment materials. The existence of expansive soil around building construction becomes a serious problem because the expansive soil consists of platinum minerals that can absorb water and cause significant volume changes in the soil. These changes in volume can cause damage to the structures holding the soil, which can jeopardize the safety of the building. Therefore, expansive soil repair and control become crucial in building a building. Research results show that the addition of lapindo sediment to the expansive soil can increase the rectangular tension of the soil matrix, reduce development, and increase the sliding tension. The addition of lapindo sediment to the expansive soil can increase the tension of the soil matrix because the sediment contains minerals that have strong adhesive properties to soil particles.

When lapindo sediment is added, it makes the loose soil particles stick together more, which makes it harder for them to spread when the humidity changes. Also, the soil's particles that move around will be held together better, making the ground stronger and better able to handle loads and shifts. This will increase the soil's sliding tension.

3. PHYSICAL & MECHANICAL TESTS

Expanse soils were taken from Asri Park, Ampelgading, Malang District, and East Java in both uninterrupted and disturbed conditions. Uninterrupted soil samples are obtained by using a soil sample tube at a depth of 1 meter with a drill engine, whereas disturbed soils are taken from the remainder of the drilling process and placed in a plastic bag. In addition, sample sampling of lapindo sediment from Tanggul lapindo along National Road 1 No.168, West Siring, Jatirejo, Porong Prefecture, Sidoarjo District, East Java, in conditions interrupted by using bulges and scraps, The depth of sampling is 0.75 meters, and the collected sample is placed in a plastic bag with a speck, as shown in Figure 1. Lapindo sediment grains use finer sand that is rougher than ordinary fine sand. The expansive soil of Ampelgading looks like crumbling, fine-seeded soil. Physical properties, such as index and basic clay engineering properties, are given in Table 1. Both materials are mixed manually and dried until the dry surface is saturated. (SSD). All samples are prepared with different amounts of water.

(a) (b)

Fig.1 Material (a) Lapindo Sediment (b) Expansive soil of Ampelgading

Figure 1 shows the difference between the rougher lapindo sediment material and the expanding soil of Ampelgading. The blue color of the lapindo sediment shows that it has a higher concentration of metal elements than the expanding soil.

Table 1 Physical properties of expansive soil

No	Physical properties		Values
1	Water content (%)		57.5
2	Specific gravity		2.6
3	Weight volume	γw (gr/cm^3)	1.7
		γd (gr/cm^3)	1.2
4	Atterberg limits	Liquid limit (%)	79.3
		Plastic limit (%)	46.7
		Plasticity index (%)	32.6
5	Classification system	USCS	CH
		AASHTO	A-7-5 (318.7)

Based on Table 1, the soil can be categorized as slurred soil with high plasticity (Gs = 2.60). The USCS calls the soil CH, while the AASHTO calls it A-7-6 soil material. The ASTM classification system can be referred to as expansive soil with PI > 35%, which is categorized as soils with very high melting potential for samples from the Ampelgading area.

Here are the varieties of expansive soil mixtures and lapindo sediment material that will be used in this study, as shown in Table 2.

Table 2 Variations of a mixture of Lapindo sediment and expansive soil

Material	Percentage of mix-design				
Expansive soil	100	95	90	85	80
Lapindo Sediment	0	5	10	15	20

4. RESULTS AND DISCUSSIONS

The LL, PL, PI, and SL index values that are used to classify fine-seeded soils can be used to figure out the sliding strength, compressibility, and development of fine-seeded soil [20,21]. These parameters are also used to study soil mechanical behavior. One quality that can indicate the capacity of the soil to expand is the plasticity index (PI), which can have several different values. The development potential, slide fraction, and other variables can be attributed to the PI value. When it comes to estimating the pressure of swelling, the Atterberg limit contributes to as little statistical significance as possible [22].

Figure 2 shows water levels (w) for the original expansive soil and II, PL, and PI based on the content of Lapindo sediment material. Figure 3 shows the Atterberg Limit (LL, PL, and PI) versus the percentage of lapindo sediment material.

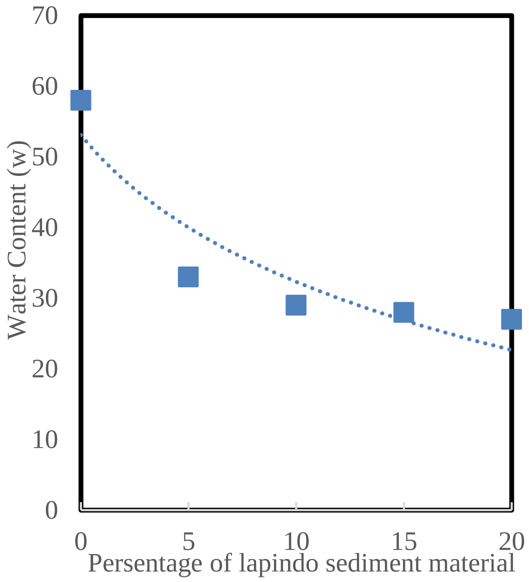

Fig.2 Water content (w) versus percentage of Lapindo sediment material

Figure 2 shows the water content (w) of the original expansive soil, as well as the values II, PL, and PI based on the percentage of lapindo sediment material shown on the results. The addition of lapindo sediment resulted in a decrease in the Atterberg boundary and an increase in crude grains, while groundwater levels decreased. This suggests that Lapindo sediment has the potential to reduce the potential for soil swelling. The addition of Lapindo sediment can cause a decrease in the Atterberg limit and an increase in coarse particles, while the groundwater level decreases. This indicates that Lapindo sediment has the potential to reduce the swelling potential of the soil.

The addition of Lapindo sediment can cause a decrease in the Atterberg limit because this sediment tends to have a higher content of coarse minerals and less clay compared to clay soil. The Atterberg limit is a measure of the ability of clay soil to change from a plastic state to a liquid state. The more coarse minerals present in Lapindo sediment, the lower the ability of clay soil to change into a liquid state, thus resulting in a lower Atterberg limit.

The addition of Lapindo sediment can also increase the content of coarse particles in the soil because this sediment tends to have more coarse particles than clay soil. Coarse particles can affect the physical and mechanical properties of soil, such as permeability and shear strength.

However, the addition of Lapindo sediment can also reduce the soil's swelling potential due to its lower clay content. Clay soil tends to have a high clay content, which can absorb water and expand (swell) when exposed to water. However, Lapindo sediment, which is coarser and less clayey, will reduce the soil's ability to absorb water and swell.

A decrease in the groundwater level can also occur due to the addition of Lapindo sediment, which reduces the soil's ability to retain water. This can be caused by a decrease in soil density and compactness due to sediment addition, causing the pore space in the soil to become larger and allowing water to easily penetrate the soil.

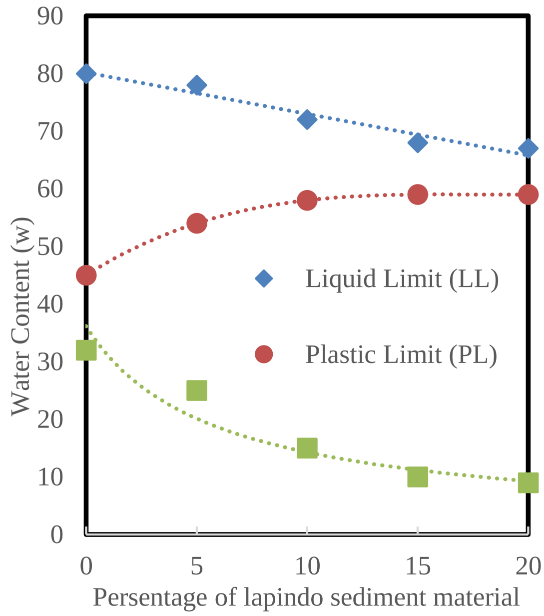

Fig.3 Atterberg Limits (LL, PL, PI) versus percentage of lapindo sediment material

Figure 3 shows changes in the physical properties of the soil after the treatment with lapindo material. The increase in Lapindo sedimentary material resulted in larger rough details and a decrease in the Atterberg boundary based on early groundwater levels. In addition, there was a decrease in PI values accompanied by increases in qu and Gs as well as decreases in natural water content, dry weight volume, and stretching (UCT), suggesting that the addition of lapindo sedimentary material to the expansive soil could increase the rectal tension of the soil matrix.

The addition of lapindo sediment to expansive soil can increase the soil matrix's shear stress because lapindo sediment has coarse particles that can act as shear keys to prevent interlayer sliding. Additionally, lapindo sediment is stiffer or less elastic than expansive soil, so it can restrain or limit the movement of expansive soil.

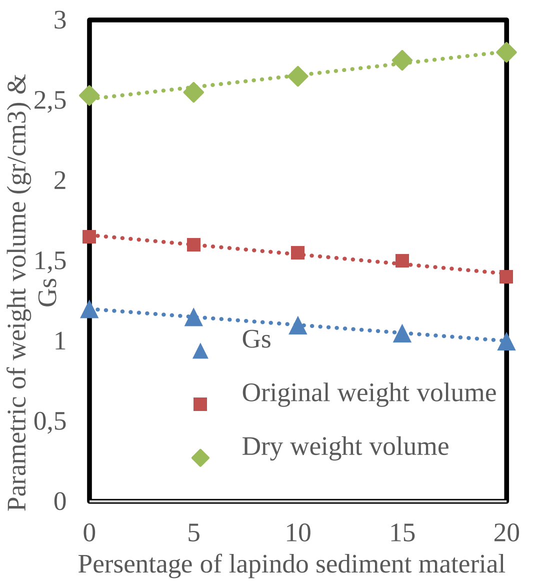

Fig.4 Weight of parametric units and Gs versus percentage of lapindo sediment material

When movement or deformation occurs in expansive soil, such as swelling or shrinkage, the soil matrix will experience shear stress caused by pressure or shear forces from surrounding materials. In the case of adding lapindo sediment to expansive soil, the sediment will act as shear keys and reduce the possibility of interlayer sliding in the soil layers. This will cause an increase in the soil matrix's shear stress because the soil matrix has to withstand greater pressure or shear forces due to the presence of lapindo sediment as shear keys.

Figure 4 shows the results of the unconfined compression test (UCT) with different percentages of lapindo sediment material. These results show how important it is to add lapindo sediment mixture to UCS for stabilizing expansive soil. The larger the percentage of lapindo sediment material, the higher the value of the soil voltage (qu). All soil mixtures show the same behavior; this is due to the process of adsorption of the emulsion of the lapindo sediment material that is more attached to the plate, as it is more likely to bind to the emulsifiers than sand or lawn particles. The molecules of the lapindo sedimentary material easily form electrostatic bonds with clay particles, which increase the UCT and the density of the particles of clay as they mix. This occurs through the absorption of lapindo sediment molecules on the surface of the internal and external pores and the small interlayer gaps.

Lapindo sediment has a higher content of rigid and stable minerals compared to expansive soil. Thus, when lapindo sediment is mixed with expansive soil, it can help increase the strength and stability of the soil.

As the percentage of lapindo sediment in the mixture increases, the soil's shear strength (qu) also increases. This is because lapindo sediment has a more rigid nature and larger particle size compared to expansive soil. Therefore, when lapindo sediment is mixed with expansive soil, the sediment particles act as shear keys and help increase the shear strength of the soil.

In addition, the molecules of lapindo sediment have the ability to form electrostatic bonds with clay particles in the expansive soil. This adsorption process occurs through the absorption of lapindo sediment molecules on the internal and external pore surfaces and in the small interlayer gaps. These electrostatic bonds increase the UCT (unconfined compression test) and density of clay particles when they are mixed with lapindo sediment. Thus, the lapindo sediment mixture can help increase the strength and stability of the expansive soil.

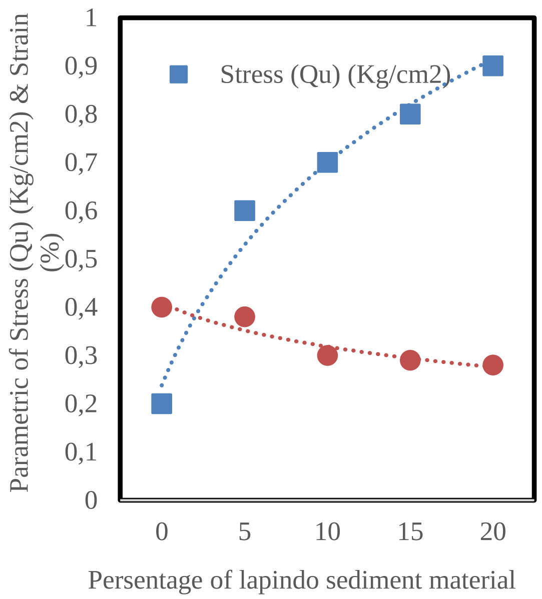

Fig.5 UCS stress (qu) and strain (%) parametric versus percentage of lapindo sediment material

Figure 5 shows how the soil plasticity index affects UCT for different concentrations of lapindo sediment material. Increased soil humidity results in a strong decrease in free pressure, while high plasticity leads to an unlimited decrease in the force of pressure. Lapindo sediments have an emulsifying tendency to merge with platinum minerals, and an increased concentration of bentonites reduces the availability of lapindo sediment stabilizing agents in the soil matrix. The results showed that the addition of lapindo sediment increases the strength of unsaturated plates. A higher plasticity index can lower the strong free pressure voltage in the expansive soil stabilization process. This is because the lapindo sediments have minerals that are harder and more stable compared to the expansive soil. In this process, lapindo sediments act as "shear keys" that help increase the shear strength of the expansive soil.

Moreover, the higher plasticity index of lapindo sediments can help reduce the free stress strength during the stabilization process of the expansive soil. This is because lapindo sediments have the ability to absorb water and bind soil particles, thereby helping to reduce soil moisture and prevent soil movement and swelling. In drier soil conditions, lapindo sediments can also help increase the stiffness and stability of the soil. However, the effects of adding lapindo sediments on the shear strength and plasticity index may vary depending on the characteristics and properties of the lapindo sediments and the expansive soil used. Therefore, further studies and analyses are recommended to understand the characteristics and properties of lapindo sediments and expansive soils before adding lapindo sediments for soil stabilization purposes.

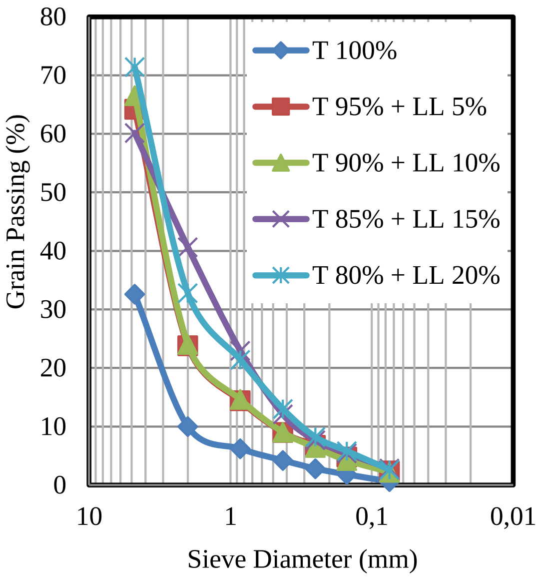

Fig.6 Relationships between grain sizes and sieve diameter

Figure 6 shows how the soil plasticity index affects the UCT when the concentration of lapindo sediment changes. Increased plasticity decreases the force of unlimited pressure and makes it harder for the stabilizer to be found in the lapindo sediment because it tends to stick to platinum minerals. However, the addition of lapindo sediment strengthens the unsaturated sludge. The higher plasticity index reduces the strong free pressure in the process of stabilizing the expansive soil.

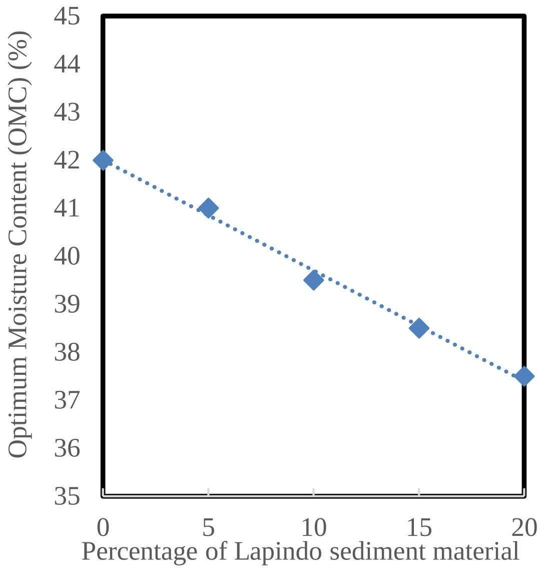

Fig.7 Parametric optimum moisture content (omc) standard proctor test versus percentage of lapindo sediment material

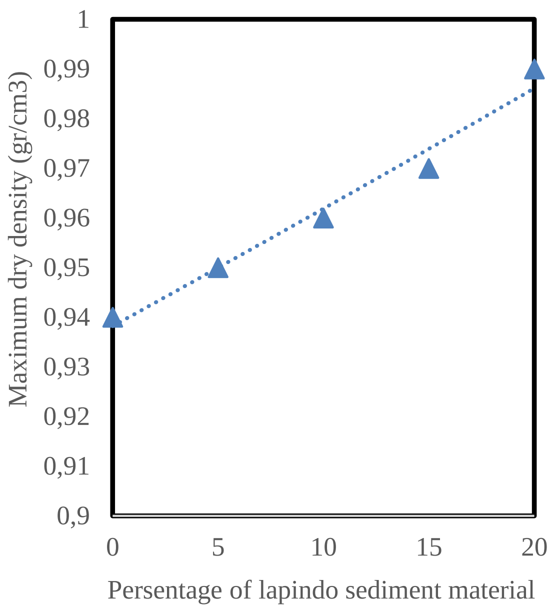

Fig.8 Parametric maximum dry density (dmax) of the standard proctor test versus percentage of lapindo sediment material

Figures 7 and 8 show that the use of lapindo sediment to mechanically stabilize the soil decreases the specific surface area and organic matter content but increases dmax. This approach is superior to chemical stabilization methods, which can cause environmental problems. However, mechanical stabilization is not usually considered an independent procedure and is often used in conjunction with chemical stabilization. This study used the independent swelling method to measure vertical expansion and free swelling potential, which is the easiest and safest method, although it takes the longest time to complete. The figures illustrate the relationship between strain and free swell potential in naturally expansive soils and those treated with lapindo sedimentary materials.

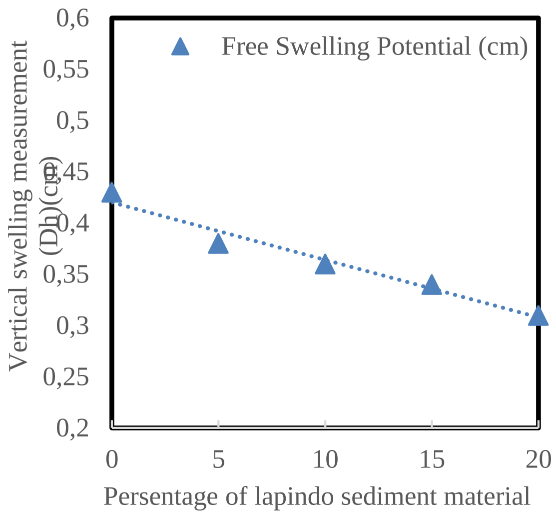

Fig.9 Parametric measurement of vertical swelling (vh) versus the percentage of lapindo sediment material

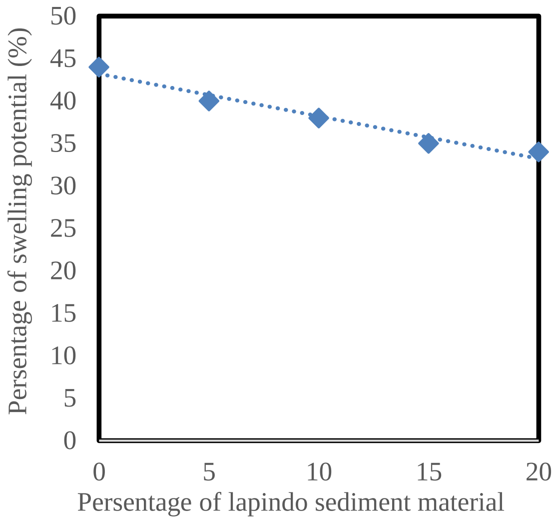

Fig.10 Parametric percentage of free swelling potential (FS) versus percentage of lapindo sediment material

Figures 9 and 10 show what happens to expansive soils when lapindo sediment deposits are added to them. Swelling of the soil can be reduced due to the chemicals contained in the lapindo mud, including gas, oil, and organic and inorganic materials. These substances can change the chemical properties of the soil and reduce the moisture content, resulting in reduced expansion. Sludge deposits also prevent the evaporation of water from the soil, which lowers the water content and reduces the chance of swelling. However, these silt deposits can put pressure on the subsoil beneath them, limiting the ability of expansive soils to expand. Vertical measurements and swelling percentage based on the percentage of lapindo sedimentary material resulted in a decrease in swelling value of up to 6.8%. These results can be categorized by some researchers from very high to high.

Figure 11 goes against the idea that the swelling pressure (SP) goes up in a straight line with the free swelling potential (FS). One possible reason is that the sedimentary material from lapindo lowered the expansion pressures of the soil when it was still wet. Below a certain moisture content, a typical compaction test may produce a lower dry density result than a test showing a typical swelling pressure, which is different from the behavior of the initial moisture content.

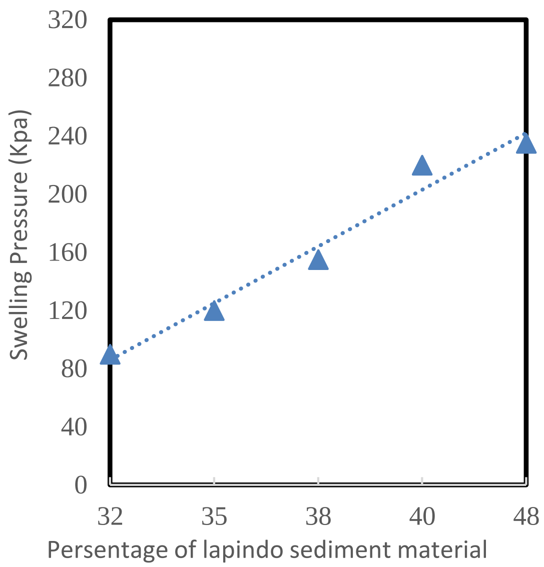

Fig.11 percent free swelling potential (FS) versus swelling potential (SP)

Figure 11 shows how the vertical axial strain decreased when the sample of expansive soil that was treated with more material from the lapindo deposit fell apart. The chemical makeup of the soil and its pH have a big effect on how well lapindo sediment materials are used to treat soil expansion. The characteristics of the lapindo mixture are influenced by the ingredients and curing conditions. The substance reacts with medium- and fine-grained soils, reducing swelling and increasing shear stress. Improvement of soil properties is achieved through three important chemical processes. The high SiO_2 content of lapindo silt makes it an excellent binder for CaO compounds, which can be found in a wide range of soils. Lapindo sediment material testing is very important to increase the shear strength of expansive soils, taking into account factors such as quality, grain size, specific gravity, homogeneity, dry specific gravity, unlimited compressive strength, and ideal moisture content determined through various test methods.

The scope of this study is limited to the use of samples from certain locations. Samples of expansive clay will be taken from the Ampelgading District in the Malang Regency in East Java, and samples of lapindo sediment will be taken from the overflow sediment in Porong in the Sidoarjo Regency in East Java. Furthermore, this study will examine disturbed and undisturbed soil samples.

5. CONCLUSION

The conclusion of the research results shows that:

1. The index values of LL, PL, PI, and SL of fine-grained soils can be used to calculate the shear strength, compressibility, and swelling of the soil. This parameter is also important in understanding soil mechanical behavior.
2. The addition of lapindo sediment to expansive soils can increase the adhesive stress of the soil matrix, reduce swelling, and increase shear stress. However, environmental issues related to the use of chemicals or the handling of the lapindo sediment need to be considered. Therefore, evaluation is needed to ensure that soil stabilization methods are sustainable and environmentally friendly.

6. ACKNOWLEDGEMENTS

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