

The paper discusses the comparison of fly ash with Lapindo mud as a land stabilizer for a landfill in Pasuruan, Indonesia. Land for landfills has a low level of stability due to the condition of garbage that has accumulated and undergoes a process of decay. This land condition is less favorable to support the construction of the building above it if one day the location is used for construction. Therefore, it is necessary to stabilize the soil first. The purpose of this study was to determine the effect of adding a mixture of TPA soil with fly ash and Lapindo mud. The method used by sieve testing and compaction of the specimens for each treatment consisted of a mixture of TPA soil with fly ash and TPA soil with Lapindo mud, while the percentages of fly ash and Lapindo mud to the dry weight of the original soil were respectively 0 %, 10 %, 15 %, and 20 %. The results showed that stabilization of the landfill with fly ash reduced the silt content while stabilization with Lapindo mud increased the levels of silt in the landfill so that fly ash was better than Lapindo mud for stabilization of the landfill. The specific gravity values for both stabilization mixtures increased equally. Based on the results of the standard compaction test for the addition of a mixture of fly ash, the OMC value decreases and the greater the value of  $d_{max}$  indicates that fly ash is good for landfill stabilization, while the addition of a mixture of Lapindo mud increases the OMC the smaller the value of  $d_{max}$ . For the direct shear test of the two mixed soils, the value of the internal friction angle ( $\varphi$ ) increased. The percentage value of the optimum mixture of mixed soil+fly ash is 14 % with an internal shear angle ( $\varphi$ ) of 38°, while the stabilization of landfill with Lapindo mud obtained the optimum mixture percentage value of 11 % with an internal shear angle ( $\varphi$ ) of 31°.

**Keywords:** landfill, soil stability, fly ash, Lapindo mud, sieve testing, compaction, silt, specific gravity, direct shear test, internal shear angle

# COMPARISON OF FLY ASH WITH LAPINDO MUD AS A LAND STABILIZER FOR LANDFILL IN PASURUAN-INDONESIA

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## 1. Introduction

Waste generated by human activities in the form of industrial waste or household waste is collected in a certain area called the final waste disposal site (TPA). Waste that has accumulated over the years with a large volume will undergo a decomposition process aerobically or anaerobically due to the activity of microorganisms [1, 2]. The decomposition process will produce leachate water containing chemical elements, which can reduce soil quality. The soil in the landfill site is a mixture of the original soil in that location with waste that has been decomposed by the activity of microorganisms. Because of this formation process, the soil in the landfill site is included in the classification of organic soil [3]. Such soil conditions are less favorable for the land as a support for the construction of the building on it if one day the location is used for construction. Therefore, it is necessary to improve or stabilize the soil first. Efforts to improve the bearing capacity of the soil have been carried out in various ways, including mechanical, chemical, and even special technology. Mechanical soil improvement is carried out by replacing the original soil with other soil that has better mechanical properties, while chemical soil

improvement is carried out by adding or mixing stabilizing agents into the original soil [4].

In any civil engineering work, the most important aspect is land. Some of the problems that are often encountered are because the soil's poor technical properties are characterized by excessive groundwater, large compatibility and low bearing capacity. Some soils have significant volume changes along with changes in water content. One of the types of soil that have poor physical and mechanical properties is landfill, which has been used as an urban waste landfill (TPA) [5].

The landfill is a former landfill that is more than 20 years old. As a result of the activity of microorganisms, the waste will undergo a decomposition process aerobically or anaerobically. The landfill is a mixture of the original soil of the area, decomposed waste, and soil that is used to cover each layer of waste [6]. Such soil conditions are less favourable for the land as a support for the construction of the building above it if one day the location is used for construction. Therefore, it is necessary to improve or stabilize the soil first.

Lapindo mud flow is an incident where hot mud spurts at the drilling location of PT. Lapindo Brantas Inc in Balongnongo Hamlet, Renokenogo Village, Porong District, Sidoarjo Regency. The chemical composition possessed by

Lapindo mud is SiO<sub>2</sub> 53.08 % and CaO 2.07 % where the silicate content functions as a filler material while the lime content plays a role in the binding process [7].

Efforts to improve the bearing capacity of the soil have been carried out in various ways, including mechanically, chemically, and even with special technology. Mechanical soil improvement is carried out by replacing the original soil with other soil that has good mechanical properties, while chemical soil improvement is carried out by adding or mixing stabilizing agents into the original soil. Several chemical soil improvement efforts can be carried out by utilizing the addition of a mixture of fly ash and Lapindo mud [8].

In Pasuruan City, there is only one TPA, which is located in Bugulkidul District, Blandongan Village with an area of 7.19 hectares and a capacity of 274 m<sup>3</sup>/day. The Pasuruan City Government plans to make Blandongan TPA Forum for Family Education so that many building facilities will be built in the landfill area. Currently, there are no buildings erected on the landfill because the landfill has excessive groundwater content, large compatibility and low carrying capacity.

Referring to the above statement, it can be seen that soil stability can be renewed by adding several elements that strengthen the soil. In this context, the study aims to evaluate the stability of the ex-landfill using the addition of fly ash and Lapindo mud.

## 2. Literature review and problem statement

The landfill is usually various types of ex-excavated soil. But in this case, what is meant by landfill is the land from former urban waste piles that is no longer used to accommodate waste. As a result of the activity of microorganisms, waste will undergo a decomposition process aerobically or anaerobically [9, 10].

The landfill is a mixture of the original soil in the area, decomposed waste, and soil that is used to cover each layer of garbage. The parameters of the land from the landfill of one location are different from other locations. This is influenced by several factors including different types of landfill, the method of compaction at the landfill location, different types of native soil, different water content, and different oxygen content. Because of the landfill formation process, landfill is a type of organic soil [11].

In previous studies, Lapindo mud was used because it contains silica, alumina and iron oxides, which make it possible to make roof tiles. And from the results obtained, it was found that the furnace dry Lapindo mud was then mashed to resemble cement powder. It has a tendency and can increase the compressive strength of the concrete. So there were several previous studies about the use of Lapindo mud [12], regarding “the use of Lapindo mud as a raw material for making roof tiles with variations in combustion temperature”. This study uses Lapindo mud because it contains silica, alumina and iron oxides, which make it possible to make roof tiles. From the research results, it was found that the higher the combustion temperature, the greater the compressive strength and the smaller the water absorption. [13, 14] conducted a study on the compressive strength of concrete using furnace dry Lapindo mud as a substitute for cement. From the results obtained, it was found that the dry Lapindo mud furnace, which was then mashed to resemble cement powder tended to increase the compressive strength of the concrete.

[15] conducted a study using Sidoarjo mud as a mixture for lightweight concrete using additional foam and natural fibers. The addition of foam and natural fibers to the mix can cause a chemical reaction by releasing a certain amount of gas, which can make the concrete expand and form a porous structure so that the concrete will be lighter with reduced concrete density. Using Lapindo mud as a building material was also researched in [16], which tested the potential of Lapindo mud as additional raw material for making bricks. The results showed class I bricks will be achieved by adding 15 % to 25 % of Lapindo mud to the clay.

[17] conducted a study using compressive strength and water absorption in a mortar using Lapindo mud and lime (CaCO<sub>3</sub>, CaO and CaOH<sub>2</sub>) as activators. In the implementation, Lapindo mud is dried by burning then mashed and mixed with several types of lime including CaCO<sub>3</sub>, CaO and CaOH<sub>2</sub>, where each component is added 0 %, 10 % and 20 % lime. The results obtained in this study show that several compositions of the mortar mix with the use of Lapindo mud are included in type K with a compressive strength above 5.25 kg/cm<sup>2</sup> based on ASTM C 270. The compositions include the composition of 0.5PC: 8PS: 0.5 LL with the addition of 10 % CaCO<sub>3</sub>, 10 %CaO, 10 % and 20 % CaOH<sub>2</sub> and the composition of 0PC: 8PS: 2LL with the addition of 10 % and 20 % CaOH<sub>2</sub>.

Some studies above are the things that underlie the differences between this study and previous research, namely in the mixture of light brick making, where this study uses CaOH<sub>2</sub> as an activator in Lapindo mud, which will be made into cement.

This hot mud began gushing to the surface of the earth in Porong, Sidoarjo, East Java on May 29, 2006 and became a tragedy when this hot mud flood began to inundate rice fields, residential areas and industrial areas. Several studies on the practical use of Lapindo mud have been carried out. However, so far this has only been limited to supporting purposes as building materials, for example, bricks, cement, concrete blocks, paving blocks, and roof tiles. Meanwhile, in medical terms, Lapindo mud was examined for the content of substances, which are harmful to humans or not. In this study, it was found that Lapindo mud was not harmful to humans because the test results were below the quality standards set by the government.

As for the chemical composition of Lapindo mud [18], which is then compared with the chemical composition of cement, the results are shown in Table 1.

Table 1

Comparison of Lapindo mud and cement composition

Material	Chemical Element (%)				
	SiO <sub>2</sub>	CaO	Fe <sub>2</sub> O <sub>3</sub>	Al <sub>2</sub> O <sub>3</sub>	TiO <sub>2</sub>
Lapindo mud	53.1	2.07	5.6	18.27	0.57
Cement	20.8	65.3	3	6.9	0
Material	MgO	Na <sub>2</sub> O	K <sub>2</sub> O	SO <sub>2</sub>	SO <sub>3</sub>
Lapindo mud	2.89	2.97	1.44	2.96	0
Cement	2	0	0	0	1.6

Lapindo mud has higher silica (SiO<sub>2</sub>) content than cement but its lime (CaO) content is lower than in cement. The content of silica serves as a filler material, so it is very supportive as a material in the manufacture of bricks, ceramic tiles, paving blocks and other building materials.

Fly ash and bottom ash are solid waste generated from burning coal in power plants. Fly ash is a material that has a fine grain size, is grayish in color and is obtained from the combustion of coal. In essence, fly ash contains chemical elements, including silica ( $\text{SiO}_2$ ), alumina ( $\text{Al}_2\text{O}_3$ ) [19].

Soil stabilization is a method used to improve the properties of the subgrade so that the carrying capacity of the soil is better, the soil becomes stable and can bear the burden that works on above-ground construction [20].

The known stabilization methods are mechanical stabilization, chemical stabilization, mineral stabilization, hydraulic stabilization. Mechanical stabilization is the addition of strength and bearing capacity of the soil by adjusting the gradient of the intended soil. This business usually uses a compaction system. Compaction can be done with various types of mechanical equipment such as rollers, heavy objects that are dropped, static ground pressure explosions and so on [14]. Based on previous research, there has been no discussion about the comparison of the stabilization of ex-landfill using fly ash and mud. Therefore, the authors examined the comparison of the stabilization of the ex-landfill using a mixture of fly ash and Lapindo mud.

### 3. The aim and objectives of the study

This research was conducted to stabilize the carrying capacity and low landfill shear stress by mixing Lapindo mud and fly ash.

To achieve this aim, the following objectives are accomplished:

- to determine the effect of adding fly ash and Lapindo mud on the physical properties of landfills;
- to determine the effect of adding fly ash and Lapindo mud on the mechanical properties of landfills;
- to determine the effect of adding fly ash and Lapindo mud on the chemical composition of landfills;
- to find the optimum value of the two landfill stabilization agents in improving the shear stress of landfill soil.

### 4. Material and methods

Landfill soil samples were taken from the Pasuruan City Final Disposal Site, which is addressed in Bugulkidul District, Blandongan Village. Fly ash samples were taken from PT. CJI and Lapindo mud samples were taken from a hot mud flow in Balongnongo Hamlet, Renokenogo Village, Porong District, Sidoarjo Regency. Testing of the objects was carried out at the Mectane and Geology Laboratory of Brawijaya University. The preparation of test objects for each treatment consists of a mixture of landfill soil with fly ash and landfill soil with Lapindo mud, while the percentage of fly ash and Lapindo mud against the dry weight of the original soil in each test is 0 %, 10 %, 15 %, and 20 %. The independent variable in this study is the composition of a mixture of fly ash and Lapindo mud in each treatment.

The stages of the research from beginning to end can be concluded as shown in Fig. 1 research flow chart.

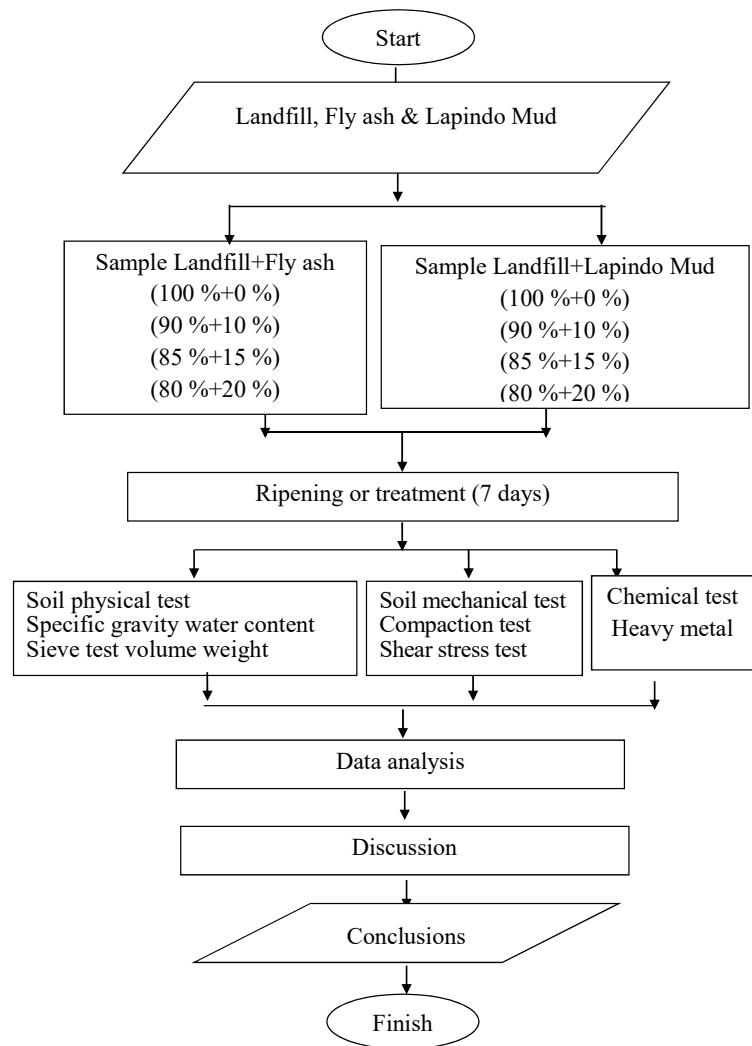


Fig. 1. Research flow chart

To find out how the effect of mixing fly ash and Lapindo mud on the original landfill soil, laboratory tests of the test object that has been made according to the percentage of the mixture in Fig. 1 in the form of mixed soil were carried out. The laboratory test has 3 parts, namely: physical properties test, mechanical properties test and mineral test. Physical properties test consists of sieve test and specific gravity test. Mechanical properties test consists of compaction test and direct shear test. In this direct shear test, the parameters of the shear stress will be known, namely the internal friction angle ( $\phi$ ).

### 5. Results of the research of stabilizing the carrying capacity and low landfill shear stress

#### 5.1. Results of physical properties of landfill soil and mixed soil

A test standard based on ASTM 698-70 was used. This test aims to determine the relationship of water content to soil density when it is compacted with a certain compactor. From testing the landfill of the Pasuruan City TPA with the addition of fly ash and Lapindo mud, the physical properties data consist of the test results of grain grading and specific gravity of the original landfill and mixed soil. The results of the grain grading test are shown in Fig. 2.

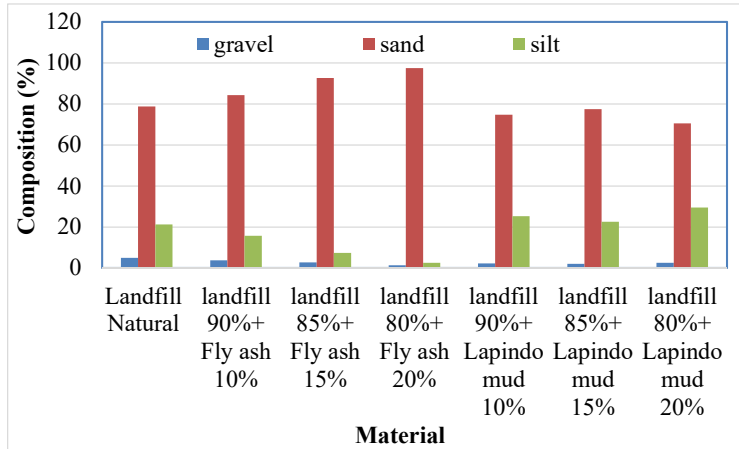


Fig. 2. Comparison of the composition of the test results from the landfill+fly ash filter with the landfill+Lapindo mud

The results of the grain grading test (Fig. 1) of the original landfill and mixed soil consisted of 3 types of soil, namely: gravel, sand and silt. Comparison of each type of soil after stabilization with fly ash and Lapindo mud for gravel soil types is shown in Fig. 3, sandy soil in Fig. 4 and silty soil in Fig. 5.

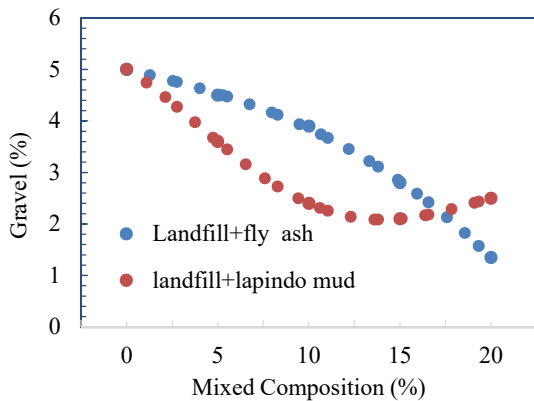


Fig. 3. Comparison of gravel grain size with the percentage of landfill mixture with fly ash and Lapindo mud

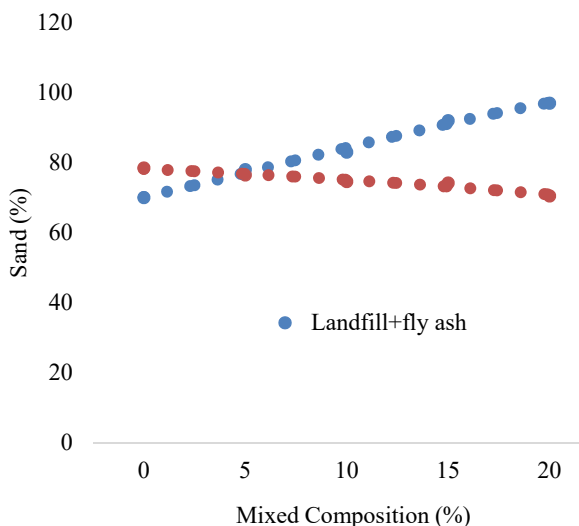


Fig. 4. Comparison of the grain size of sand with the percentage of landfill mixture with fly ash and Lapindo mud

The second test result of the physical properties of the sterilized landfill is the specific gravity of the soil. Density test results are shown in Tables 1, 2.

Table 1

Specific test results for Gravity landfill+fly ash

Material	Specific Gravity
Landfill Natural	2.658122629
Landfill 90 % + Fly Ash 10 %	2.686296242
Landfill 85 % + Fly Ash 15 %	2.695371434
Landfill 80 % + Fly Ash 20 %	2.727950529

Table 2

Specific test results for Gravity landfill+Lapindo mud

Material	Specific Gravity
Landfill Natural	2.658122629
Landfill 90 % + Lapindo mud 10 %	2.674126751
Landfill 85 % + Lapindo mud 15 %	2.697083229
Landfill 80 % + Lapindo mud 20 %	2.700449134

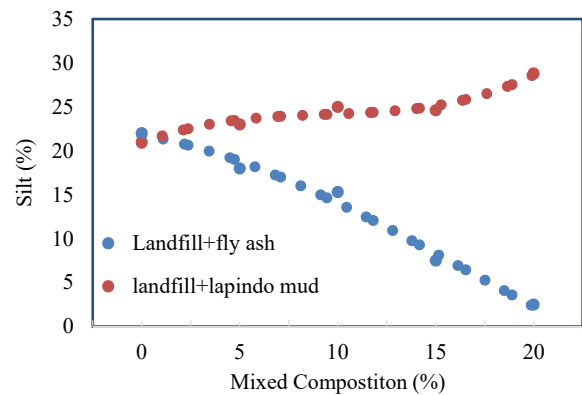


Fig. 5. Comparison of the grain size of silt with the percentage of mixtures of landfill with fly ash and Lapindo mud

Table 1 is the result of the specific gravity ( $G_s$ ) test for the original mixed Landfill+Fly Ash, while Table 2 is the result of the specific gravity ( $G_s$ ) test for the original mixed Landfill+Lapindo Mud.

### 5. 2. Result of tests for mechanical properties of landfill and mixed soil

The mechanical properties test was carried out by testing the compaction of natural soil and mixed soils to determine the shear stress and bearing capacity of the soil by compaction test and direct shear test. The standard compaction test is carried out to obtain the maximum dry weight ( $\gamma_d$ max) and optimum moisture content (OMC), the results of the standard compaction test for landfill+fly ash can be seen in Fig. 6.

Fig. 2 shows that the mixture of landfill and fly ash has a higher dry density than natural landfill, the greater the mix of fly ash, the better the dry density. This is due to the ability of fly ash to absorb high landfill moisture content so that the dry weight value is high with the optimum moisture content. This can be seen in the landfill material of 80 % + 20 % fly ash, obtained OMC values of 24.8 % and  $\gamma_d$ max 1.348 gr/cm<sup>3</sup>. As for the material with a mixture of landfill+Lapindo mud, a low dry weight value with a high moisture content can be seen.

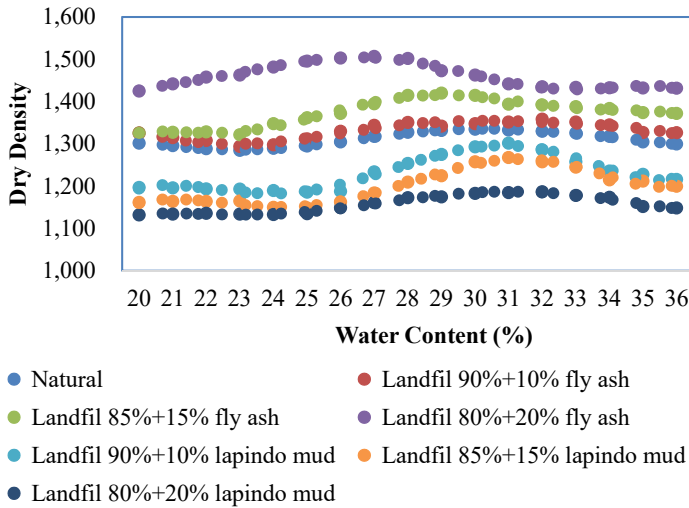


Fig. 6. Comparison of the results of the landfill compaction test of a mixture of fly ash and Lapindo mud

This can be seen in the landfill material of 80%+20% Lapindo mud, the obtained OMC values of 32 % and  $\gamma_{dmax}$  1.185 gr/cm<sup>3</sup>. This value is lower than the natural landfill material where the OMC value is 30 % and  $\gamma_{dmax}$  1.334 gr/cm<sup>3</sup>. This shows that the material with a mixture of landfill – fly ash is better for compaction than a mixture of landfill – Lapindo mud.

The results of the direct shear test for natural and mixed soils are shown in Table 3.

Table 3

Direct Shear test results Landfill mixed with Fly Ash

Material	Cohesion	$\theta$
Landfill Natural	0.304	2.665
Landfill 90 %+Fly Ash 10 %	0.01	36.104
Landfill 85 %+Fly Ash 15 %	0.03	34.793
Landfill 80 %+Fly Ash 20 %	0.01	30.158

Table 4

Direct Shear test results Landfill mixed with Lapindo Mud

Material	Cohesion	$\theta$
Landfill Natural	0.304	2.665
Landfill 90 %+Lapindo Mud 10 %	0.05	29.638
Landfill 85 %+Lapindo Mud 15 %	0.06	28.887
Landfill 80 %+Lapindo Mud 20 %	0.23	12.539

Table 3 is the result of a direct shear test for a mixture of landfill and fly ash, while Table 4 is the result of a direct shear test for a mixture of landfill soil and Lapindo mud.

### 5. 3. Test results of landfill and mixed soil minerals

The data of the mineral content test for natural landfill and mixed soil yields are shown in Tables 5, 6.

The mineral content test results show that the content of iron (Fe), potassium (K), sodium (Na) and magnesium (Mg) decreases while the content of lime (Ca) increases with the addition of more fly ash mixture in landfills. The addition of the Lapindo mud mixture shows that the content of iron (Fe), potassium (K), sodium (Na), magnesium (Mg) and lime (Ca) decreases with the addition of the Lapindo mud mixture in the landfill.

Table 5

Test Results for Landfill Minerals+fly ash

Material	Mineral content				
	Fe	Ca	K	Mg	Na
Landfill Natural	1.0918	0.1214	2.894	0.1747	1.576
Landfill 90 %+Fly ash 10 %	0.7965	0.9039	2.8744	0.2695	1.5007
Landfill 85 %+Fly Ash 15 %	0.7211	1.357	2.7961	0.2371	1.4831
Landfill 80 %+Fly Ash 20 %	0.6725	1.4132	2.6971	0.2829	1.3528

The landfill mineral content test+Lapindo mud is obtained as shown in Table 5.

Table 6

Test Results for Landfill Minerals+Lapindo Mud

Material	Mineral content				
	Fe	Ca	K	Mg	Na
Landfill Natural	1.0918	0.1214	2.894	0.1747	1.576
Landfill 90 %+Lapindo Mud 10 %	0.9751	0.178	2.7813	0.1899	0.2976
Landfill 85 %+Lapindo Mud 15 %	0.9285	0.1989	2.9164	0.2371	0.2712
Landfill 80 %+Lapindo Mud 20 %	1.1975	0.2371	3.3042	0.2536	0.4263

### 5. 4. Optimum mix percentage determination

The results of the direct shear test on landfills with the addition of fly ash and Lapindo mud in Table 3 are graphed for the relationship between the percentage of the mixture with the value of the inner friction angle ( $\theta$ ) for mixed landfill+Fly Ash as shown in Fig. 7 while the mixed soil of Landfill+Lapindo Mud is as shown in Fig. 8. While the comparison of the two stabilizers to the inner friction angle ( $\theta$ ) is shown in Fig. 9.

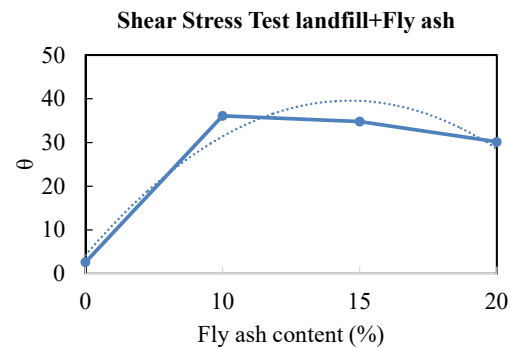


Fig. 7. Relationship between the inner shear angle and the fly ash mixture percentage

Fig. 7, 9 show that for the stabilization of landfill+Fly ash and landfill+Lapindo mud with a mixture of 0 %, 10 %, 15 % and 20 %, the value of the internal shear angle ( $\theta$ ) of mixed soil with fly ash is better than for mixed landfill soil with Lapindo mud.



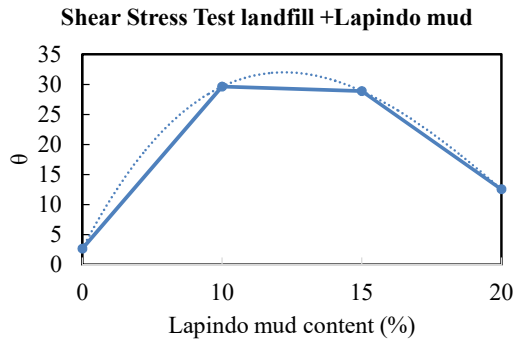


Fig. 8. Relationship between the inner shear angle and the Lapindo mud mixture percentage

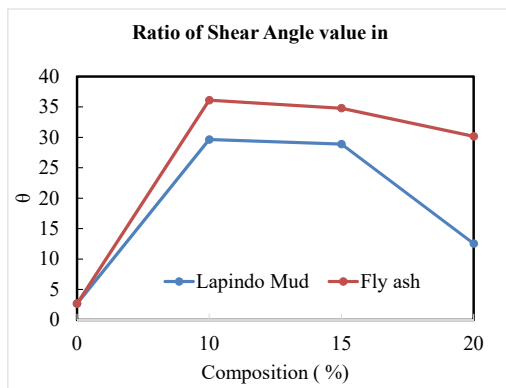


Fig. 9. Comparison of the results of the shear angle of landfills

Fig. 7, 9 show that for the stabilization of landfill+Fly ash and landfill+Lapindo mud with a mixture of 0 %, 10 %, 15 % and 20 %, the value of the internal shear angle ( $\phi$ ) of mixed soil with fly ash is better than for mixed landfill soil with Lapindo mud.

## 6. Discussion of experimental results

Soil classification based on soil grain size in a mixture of landfill+fly ash and landfill+Lapindo mud in Fig. 2 shows that landfill soil is located between sand and silt, natural landfill soil initially had high silt content so that the addition of the fly ash mixture resulted in less silt and increased sand content. It is shown that fly ash PT. CJI is good for the material mixture for landfill stabilization in Pasuruan City, whereas landfill mixed with Lapindo mud has increased silt content. This shows that the increasing addition of the Lapindo mud mixture to the landfill has increased its silt content so that Lapindo mud is not good for landfill stabilization material in Pasuruan City.

The model of the relationship between gravel and the percentage of landfill mix with fly ash is shown in Fig. 3. It is shown that the higher the percentage of fly ash mixture, the lower the gravel content in the landfill. Likewise, for the Lapindo mud mixture. This shows that the physical properties of the landfill are getting better. The model of the relationship between sand and the percentage of landfill mixture with fly ash is as in Fig. 4. It is shown that the

higher the percentage of the fly ash mixture, the higher the sand content in the landfill. This shows better physical properties of the landfill. However, for the mixture of landfills and Lapindo mud, it is shown that the higher the percentage of the Lapindo mud mixture, the lower the sand content in the landfill. This indicates that the physical properties of the landfill are getting worse. The model of the relationship between silt and the percentage of landfill mixture with fly ash is shown in Fig. 5. Fig. 5 shows that the higher the percentage of fly ash mixture, the lower the silt content in the landfill. This shows that the physical properties of the landfill are getting better. However, this phenomenon is inversely proportional to the landfill mixture with Lapindo mud showing that the higher the percentage of the fly ash mixture, the higher the silt content in the landfill. This indicates that the physical properties of the landfill are getting worse.

The specific gravity with the percentage of the mixture of landfill and fly ash as in Table 1 shows that the higher the percentage of the fly ash mixture, the higher the landfill  $G_s$ . This shows that the physical properties of the landfill are getting better. The specific gravity with the percentage of landfill mixture with Lapindo mud as in Table 2 shows that the higher the percentage of the Lapindo mud mixture, the higher the landfill  $G_s$ . This shows that the physical properties of the landfill are getting better.

The standard compaction test with the addition of fly ash mixture found that the OMC value decreased and  $d_{max}$  increased. This shows that fly ash is good for stabilizing landfill soils in Pasuruan City, as shown in Fig. 6. This is in contrast to the results of the compaction test (Fig. 6) for clay soil mixed with Lapindo mud, the OMC value increases with the increase in the percentage of the Lapindo mud mixture, while  $d_{max}$  decreases with an increasing percentage of the Lapindo mud mixture. This shows that Lapindo mud is not good enough for the landfill stabilization process.

Direct shear test to determine the parameters of shear stress, namely the value of soil cohesion ( $c$ ) and the inner friction angle ( $\phi$ ) is shown in Table 3. The value of natural landfill cohesion before stabilization with fly ash is 0.304, after the addition of 10 % fly ash, the cohesion value is 0.01, after the addition of 15 % fly ash the cohesion value is 0.03, after the addition of 20 % fly ash the cohesion value is 0.01. This shows that with the addition of fly ash mixture to stabilize landfill soils, the cohesion value decreases with an increasing percentage so that the fly ash cannot increase the cohesion value because the sand content in the soil increases. The landfill cohesion value after being stabilized with 10 % Lapindo mud was 0.05, after the addition of 15 % Lapindo mud, the cohesion value is 0.06 %, after the addition of 20 % Lapindo mud, the cohesion value is 0.23. This shows that the cohesion value decreases with the increasing percentage of the Lapindo mud mixture in the landfill.

Determination of the optimum mixture of the two stabilizing materials to increase the shear stress with the internal friction angle parameter ( $\phi$ ) is shown in Fig. 7, 8. With the addition of 10 %, 15 % and 20 % fly ash mixture, the optimum percentage value of the fly ash mixture is 14 % with an inner shear angle of 38° (Fig. 7). With the addition of 10 %+15 % and 20 % Lapindo mud mixture,

the optimum percentage value of the Lapindo mud mixture is 11 % with a shear angle of 31° as in Fig. 8.

This research is a laboratory study only, to find out 2 landfill stabilization materials in Pasuruan City, which have low shear stress with fly ash and Lapindo mud, including the comparison of the stabilization qualities of the two stabilization materials.

This research needs to be further developed by applying the results of laboratory tests to the existing land in Pasuruan City, Indonesia, which has low shear stress and high compressibility. So that when landfill land is to be erected, civil engineering buildings already have high shear stresses so that the bearing capacity of the foundation to support the building becomes stronger and safer.

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## 7. Conclusions

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1. The physical properties of stabilized landfill soils are better, for the gradation of Landfill+Fly ash, the sand increases by 7.12 % and the specific gravity increases by 2.63 %, for the gradation of Landfill+Lapindo mud, the silt grains increases 19.04 % and its specific gravity also increased by 1.50 %.

2. The mechanical properties of stabilized landfill soil increase in compaction of Landfill+Fly ash, the maximum

dry weight ( $\gamma_{dmax}$ ) increases by 11.22 %, but for the compaction test of Landfill+Lapindo Mud, the maximum dry weight ( $\gamma_{dmax}$ ) decreased by 11.16 %. For the direct shear test of the two mixed soils, the value of the internal friction angle ( $\phi$ ) increased, the original landfill soil was 2.665° after being mixed with fly ash to 36.104° and mixed with Lapindo mud to 29.638°.

3. The mineral content of lime (Ca) in the soil is used to determine the shear stress of the soil, the more Ca minerals, the higher the shear stress of the soil. The Ca content of the mixed Landfill+Fly Ash soil increased by 106.41 % from the original landfill and mixed soil+Lapindo Mud rose by 95.38 % from the original landfill.

4. The optimum mixture percentage value is 14 % with an optimum internal shear angle of 38° for landfill stabilization with fly ash, while for landfill stabilization with Lapindo mud, the optimum mixture percentage value is 11 % with an optimum internal shear angle of 31°.

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## Acknowledgments

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