BEHAVIOUR OF NATURAL AND TREATED SOIL WITH MICROORGANISMS UPON CERTAIN WATER CONTENT DUE TO DYNAMIC LOAD

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Abstract: *The use of microorganisms such as fungus or bacteria as stabilizers in soil stabilization was not so often being practised or experimented with in the field. Also, there was so little information about this type of stabilization being carried out even in a minor scale experiment such as a laboratory experiment. A previous study using a fungus with the type of Rhizopus oligosporus resulted in a significant increase in soil consistency under certain water content conditions in the soil with a high percentage of the sand component. Therefore, this experiment is intended for analyzing loose sandy soil in Kulonprogo where the New Yogyakarta International Airport was built and the soil itself was highly saturated and vulnerable to experiencing liquefaction phenomenon. Liquefaction is a condition in highly saturated loose sandy soil where highly excess pore water pressure causes the loss of effective stress between soil particles simultaneously due to dynamic load and it will have an impact on building damage or failure laid on that type of soil. Therefore, an experimental model was carried out to analyze the behaviour of loose sandy soil when stabilized with Aspergillus fungus as the microorganisms. The soil stabilized by Aspergillus will be tested for liquefaction due to dynamic load and it will analyze the changes in soil parameters after the soil stabilization. The experiment shows that the appropriate percentage of soil mixture consists of ordinary sand with a percentage of 62% plus silt and clay with a percentage of 38%. Aspergillus fungus isolates at a concentration of 10^{-2} showed good tissue growth without the presence of foreign substances. Based on the results of the shear strength test in the form of Triaxial UU (Unconsolidated Undrained) experiment on remoulded soil that was given a stabilizer in the form of Aspergillus, it increased the cohesion parameter (c) when the remoulded soil was given Aspergillus with a percentage of 6% at a water content of 48,5%. From the soil parameters, liquefaction analysis is performed and resulted that there was still a high probability of liquefaction occurring because, from the analysis, the safety factor (SF) was lower than the minimum safety factor (SF) required.*

Keywords: *Earthquake, soil stabilization, fungus, water content*

INTRODUCTION

An earthquake is a phenomenon where there is a vibration on the earth's surface due to the sudden release of energy from the epicentre. The released energy propagates through the soil in the form of vibration waves, resulting in structural failure and loss of soil stability. The most earthquake-prone areas are generally at the meeting point of the plates and the meeting of two tectonic plates will cause a relative shift in the plate boundaries (Figure 1) [11].
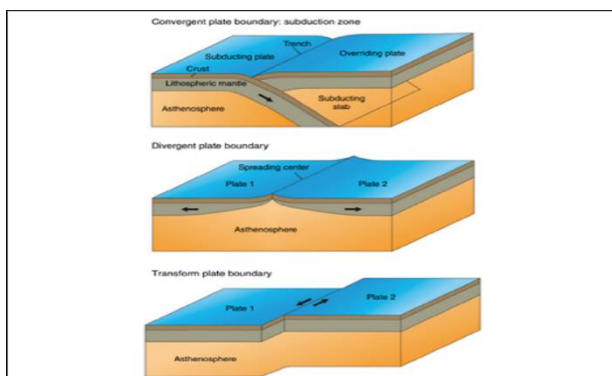

Figure 1 Illustration of an earthquake due to plate movement (tectonic earthquake)

The consequences of the earthquake were liquefaction and tsunami which resulted in the loss of life, loss of property, and enormous material losses. One of the consequences of an earthquake is liquefaction and liquefaction itself is an event or phenomenon of loss of mechanical resistance of the soil due to cyclic loads (earthquakes) or monotonous loads [7]. The loss of soil resistance is indicated by the loss of effective stress between soil particles ($\sigma' = 0$) as a result of the increase in pore water pressure (u) until it reaches the overburden pressure point ($u = \sigma$) in a relatively saturated soil ($S_r = 95\%$ - 100%). The increase in the value of the pore water stress occurs in undrained or short-term conditions as a result of sudden and repeated cyclic loads from an earthquake which causes the behaviour of the soil to change to become fluid-viscous [2].
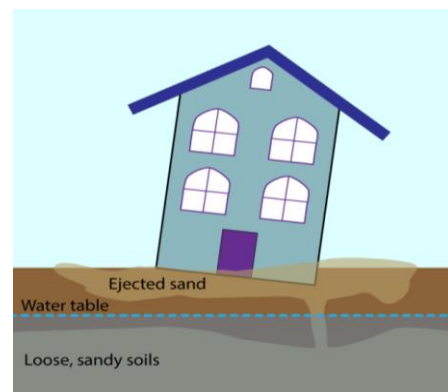

Figure 2 Liquefaction illustration

Soil with a dominant component of sand has a very low level of resistance to dynamic loads such as earthquakes so, in areas that have a dominant component of sand, the resistance of the soil to receive earthquake loads is very decisive and affects the potential for liquefaction (Figure 2) [6]. Other impacts or consequences caused by liquefaction events are settlement, the release of water to the ground

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Table 1a Laboratory test result of soil investigation in Kulonprogo, Yogyakarta (a) [9]

No.	Sample ID	Depth (m)	Specific Gravity, G_s	γ_n (kN/m^3)	γ_d (kN/m^3)	S_r (%)	W_n (%)
1	BH-10A	1.00 – 1.55	2.575	18.302	12.434	100	48.50
2	BH-11A	1.00 – 1.55	2.541	18.609	12.545	100	50.11
3	BH-12A	1.00 – 1.55	2.543	17.804	12.101	100	41.20

Table 1b Laboratory test result of soil investigation in Kulonprogo, Yogyakarta (b) [9]

No.	Sample ID	Depth (m)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	% Finer by weight passing Sieve No. 200
1	BH-10A	1.00 – 1.55	0.00	58.61	21.09	20.30	41.39
2	BH-11A	1.00 – 1.55	0.00	40.16	35.14	24.70	59.84
3	BH-12A	1.00 – 1.55	0.00	33.58	38.22	28.20	66.42

surface, and even damage to the destruction of buildings, bridges, roads, railways, as well as earthen dams. To overcome these problems, a soil improvement experiment was carried out with stabilizers in the form of microorganisms in this case fungus and carried out on a small scale through laboratory testing through conditioning soil samples according to conditions in the field.

This time the test used a soil mixture with a composition that adjusted as much as possible to the dominant conditions in the soil from the previous investigation (field conditions) in Kulonprogo, Yogyakarta, which are listed in Table 1a and Table 1b above.
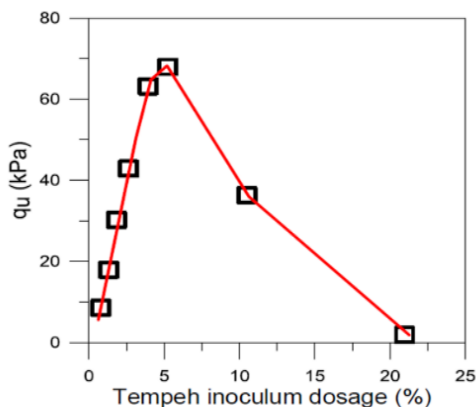

Figure 3 The impact of variations in the dose of the fungus *Rhizopus oligosporus* on the value of q_u
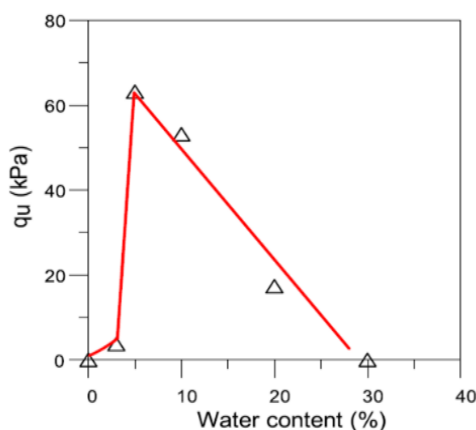

Figure 4 The impact of giving water content varies on the value of q_u

The use of the above data as a reference for modelling is due to the construction of a new international airport in Kulonprogo, Yogyakarta standing on soil with high sand content, thus requiring an analysis of the liquefaction potential. Previously, there had been researched with the fungus *Rhizopus oligosporus*, and the results at a certain percentage level (Figure 3) and conditioned with a certain percentage of water content (Figure 4) with sandy soil media gave an increase in the value of q_u which was parallel to the value of q_u for medium clay soil [7].

The above experiment used a sand dominant soil sample in Padang and showed the results that by giving a fungi dose of 5.24% and a percentage of 5% water content, it could increase the q_u value up to 68 kPa or equivalent to the consistency of medium clay soil. Based on the graph in Figure 3, information is also obtained that when the fungi content exceeds 5.24%, there is a decrease in the value of q_u which indicates that the application of excess fungi to the soil also does not help improve the consistency of the soil [7]. Likewise, the excess water content (Figure 4) also reduces the value of the consistency of the soil.Based on the results of this experiment using *Rhizopus oligosporus*, it can be seen the right percentage of fungi and the right percentage of water content for the fungus to grow and function optimally to increase the soil consistency or the value of soil resistance.

RESEARCH SIGNIFICANCE

This experiment was conducted to determine changes in natural soil behaviour and changes that occur in other aspects of soil parameters when stabilized in the form of microorganisms, in this case, a fungus, and their impact when receiving dynamic loads. The type of fungus used in this experiment is *Aspergillus*. The use of *Aspergillus* was based on previous experiments which showed that a percentage of 5% gave an optimum impact when applied to the soil [4]. The percentage of fungi and the percentage of water content that is proper for the fungus to grow can also be known through this experiment.

METHODOLOGY

In this experiment, laboratory testing is carried out which is divided into several stages and each stage has a different final result. However, each stage of testing has a link or relationship starting from the first stage to the last stage.

The first stage of testing aims to obtain the right type of sand and the grain size distribution results that are closest to field conditions with a predetermined percentage interval of soil mixture. In the second stage of testing, tests were carried out to obtain the composition of the soil mixture that had the highest similarity to the conditions in the field (Table 1a – Table 1b).

Furthermore, the third stage of testing aims to obtain or determine the impact of adding stabilizers to the soil mixture at several variations in the levels of stabilizing agents through changes that occur in the cohesion parameter (c) and the shear angle parameter (Φ). In the fourth stage of testing or lastly, physical parameter testing is carried out on soil that has been through triaxial testing to determine the impact of adding stabilizers to changes that occur in the physical parameters of the soil.

The additional dose of *Aspergillus* fungus varies in numbers from 3%, 6%, and 9% and seen at which dose the fungus functioned optimally [7]. Meanwhile, the percentage of water content that will be applied to the soil mixture refers to the water content (wc) from the results of field tests in Kulonprogo (Yogyakarta) in perfectly saturated soil conditions ($S_r = 100\%$). Finally, liquefaction potential analysis from the soil parameters was conducted to give us information about the potentiality of liquefaction to occur [6].

ANALYSIS AND DISCUSSIONS

A. SECONDARY DATA ANALYSIS

Preliminary analysis of secondary data is carried out to determine soil conditions with parameters such as what will be used for modelling in laboratory tests. The initial stage is the analysis of the liquefaction potential based on particle size distribution data using the Lee-Fitton, Kishida, and Seed-Idriss methods and the analysis of the liquefaction potential based on the data of other soil parameters using the Wang, Seed et. al., Chinese Criteria, and Bray-Sancio. The following is a graph and table of the results of the liquefaction potential analysis based on particle size distribution data.
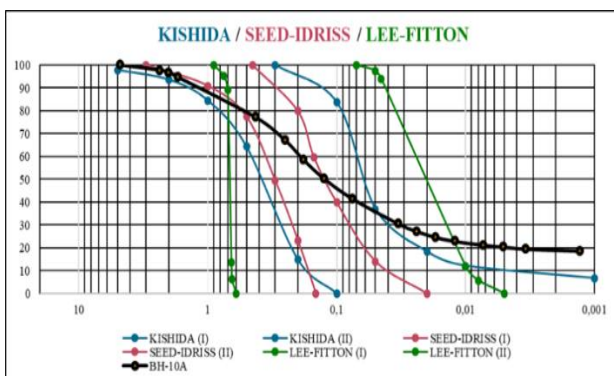

Figure 5 Particle size distribution of BH-10A sample [9]

The analysis of the BH-11A soil data (Table 1a – Table 1b) as well as the BH-12A soil data (Table 1a – Table 1b) was carried out in the same way as the BH-10A soil data (Figure 5). The following is the result of the analysis of the potential for liquefaction based on particle size distribution data where the graphic method itself is said to have a high potential for liquefaction to occur if through the grain

gradation it is known that the percentage of grains that are within the limit in each method is more than or equal to 50% ($\geq 50\%$) and it is said to have a low potential for liquefaction if through the grain gradation it is known that the percentage of grains within the limit in each method is less than 50% ($<50\%$).

Table 2 Result of liquefaction potential analysis based on the particle size distribution [9]

Sample	Lee-Fitton Method	Kishida Method	Seed-Idriss Method
BH-10A	High Potential (61%)	High Potential (63%)	Low Potential (30%)
BH-11A	High Potential (63%)	Low Potential (42%)	Low Potential (24%)
BH-12A	High Potential (63%)	Low Potential (34%)	Low Potential (16%)

Based on the table above (Table 2), it can be seen that there is no distribution graph of the soil sample showing the high potential for liquefaction for the overall graph method. However, the BH-10A sample was classified as high potential based on two methods (Lee-Fitton and Kishida) of the total three graphic methods.

Next, analyze the potential for liquefaction based on other soil parameter data using several methods (Wang, Seed et. al., Chinese Criteria, and Bray-Sancio). The criteria for soil parameters that have the potential to experience liquefaction are based on the Seed et. al. are as follows :

- If the Liquid Limit (LL) < 37% and the Plasticity Index (PI) < 12%, there is a high potential for liquefaction.
- If 37% < Liquid Limit (LL) < 47% and 12% < Plasticity Index (PI) < 20%, it has the potential to experience liquefaction.
- If the Liquid Limit (LL) > 47% and the Plasticity Index (PI) > 20%, there is no potential for liquefaction.

The following are the results of the liquefaction potential analysis using the Seed et al.

Table 3 The results of the liquefaction potential analysis based on the method of Seed et. al. [9]

Sample	LL (%) (*Liquid Limit*)	PI (%) (*Plasticity Index*)
BH-10A	NP (Non-Plastic)	NP (Non-Plastic)
BH-11A	High Potential (36.85%)	High Potential (7.39%)
BH-12A	Medium Potential (37.20%)	High Potential (7.88%)

Furthermore, secondary data analysis was also carried out in the same way as the Seed et. al. (Table 3) using other methods (Wang, Chinese Criteria, Bray-Sancio) under the conditions specified in each of these methods.

After conducting a preliminary analysis of the secondary data with several methods, it is continued by calculating the results of the liquefaction potential analysis to determine which parameters in the sample data will be the modelling reference for laboratory testing. From analyzing all the methods, it is the soil conditions and parameters on the BH-10A sample that are used as the modelling reference for testing in the laboratory.

B. PREPARATION OF ASPERGILLUS

For the preparation of *Aspergillus* fungus, it was carried out in The Microbiology Laboratory of The Department of Biology (Sepuluh Nopember Institute of Technology) using fungi that were still in a dormant phase to be further awakened and purified before being multiplied (replication). At this stage of preparation, foreign substances were found which caused the fungus to not grow optimally, so it was quite difficult to obtain isolates of the fungus.

Figure 6 The condition of *Aspergillus* fungus isolates in the absence of foreign substances

After going through several purification processes that took ± 7 days for each purification process and an additional ± 3 days for each process of multiplying (replication) finally obtained fungal isolates that had been separated from foreign substances and the condition of the isolates on the 7th day after this purification phase which shows the fungal isolates are free from foreign substances are as follows shown in Figure 6 [3]. In the next stage, isolates that were free from foreign substances were developed with several variations in concentration and the results were as follows shown in Figure 7.

The results of purification and multiplication (replication) with various concentrations of *Aspergillus* fungus (Figure 7) showed three types of fungal growth with the best conditions at different concentrations (10^{-2}, 10^{-4}, and 10^{-5}). From those variations of different concentrations of the *Aspergillus* fungus, isolates were selected at a concentration of 10^{-2} because the hyphae growth produced was evenly distributed and in each part of the spreading hyphae the tissue grew thick enough and there was no visible gap between each spreading hyphae [3]. In addition, it can be seen from the uniform colour produced without any different colour gradations in the *Aspergillus* fungal isolates with a concentration of 10^{-2} (Figure 7). After obtaining the right concentration of fungi to be purified and propagated for further application to soil samples, a purification process is carried out and multiplied again with a predetermined concentration (10^{-2}) to ensure that the growth of fungi at that concentration has the same growth pattern and at the same time. The process is carried out with a period for the multiplying phase (replication) which is longer than the minimum time (> 3 days) and the growth of fungi has been going well. However, when the replication process was running, all activities in the laboratory, including testing, had to be stopped due to the lockdown decision so that the control over the growth of fungi did not work at all and stopped. When activities in the laboratory have started to recover and activities in the laboratory have been able to function, the fungi that had been abandoned

and not controlled for their development are damaged and it is difficult to see whether the hyphal tissue that has grown is appropriate and equal to the growth of fungi at a concentration of 10^{-2} or not. The form of fungal growth with a concentration of 10^{-2} which was damaged was as follows shown in Figure 8.
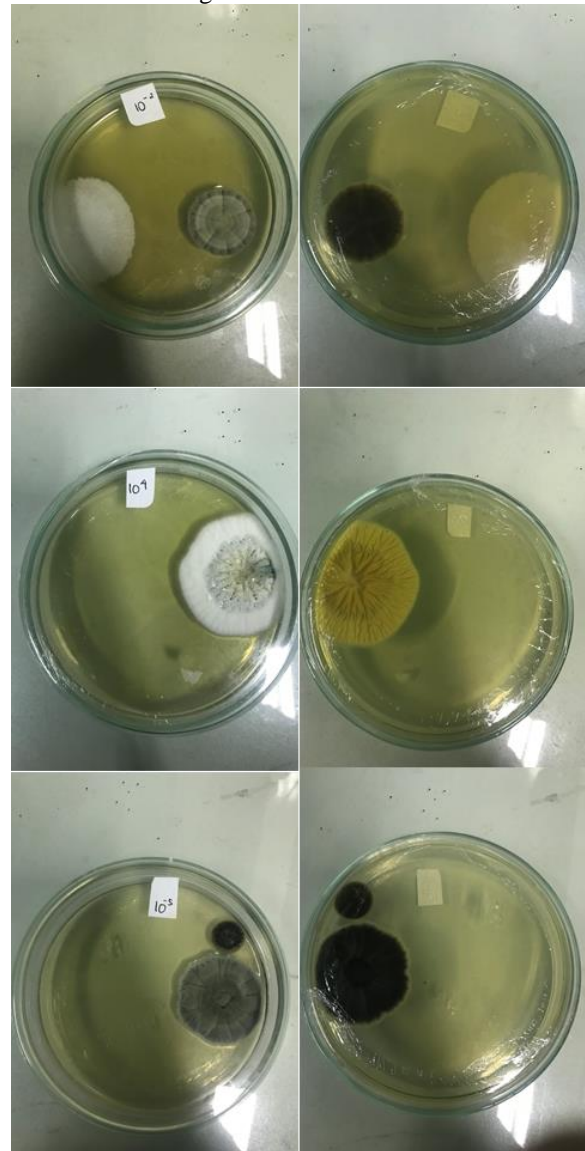

Figure 7 Condition of isolates with developed concentrations of 10^{-2}, 10^{-4}, and 10^{-5} (sequentially from top to bottom)

Figure 8 The condition of the *Aspergillus* fungus that was damaged (failed)

Table 4 Specific gravity test result (phase one)

Test Type	Lumajang Sand 55% : Silt + Clay 45%	Lumajang Sand 60% : Silt + Clay 40%	Lumajang Sand 65% : Silt + Clay 35%	Lumajang Sand 70% : Silt + Clay 30%
G_s	2,648	2,606	2,672	2,626
Test Type	Ordinary Sand 55% : Silt + Clay 45%	Ordinary Sand 60% : Silt + Clay 40%	Ordinary Sand 65% : Silt + Clay 35%	Ordinary Sand 70% : Silt + Clay 30%
G_s	2,544	2,513	2,505	2,529

Table 5 Sieve analysis and hydrometer test result (phase one)

Sample	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
Lumajang Sand 55% : Silt + Clay 45%	5	64	17	14
Lumajang Sand 60% : Silt + Clay 40%	4	66	13	17
Lumajang Sand 65% : Silt + Clay 35%	5	67	11	17
Lumajang Sand 70% : Silt + Clay 30%	6	67	7	20
Sample	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
Ordinary Sand 55% : Silt + Clay 45%	10	40	35	15
Ordinary Sand 60% : Silt + Clay 40%	5	58	20	17
Ordinary Sand 65% : Silt + Clay 35%	10	55	20	15
Ordinary Sand 70% : Silt + Clay 30%	10	57	18	15

From the picture above (Figure 8) it can be seen that more than 90% of the surface has been covered with hyphal fibres which makes it difficult to know the location of the main spore where the hyphae grow. This is most likely caused when the fungus grows without supervision, contamination by foreign substances that damage the tissues for the fungus to grow and result in disruption of the spore growth pattern and also the disruption of the hyphae that grow from the fungal spores. However, from the picture above, it can be seen that the fungi have grown even though not as expected and as a solution, isolates were taken from the sample spores in Figure 8. The fungal tissue was cultured and then it went through the incubation phase before being purified and grown for further reproduction. The results of the process are as follows shown in Figure 9.

Figure 9 Fungus conditions that have the correct growth

From Figure 9 it can be seen the results of the process which show the location of the *Aspergillus* fungal spores centred in one point and the growth of hyphal fibres that surround the spores evenly and the hyphae that grow around the spores do not show any gaps or cavities. In other words, the growth of the hyphal fibres was very tight and this indicated that the growth of the fungus was going well and successfully [1]. When the same process and stages are carried out with a slant agar growth medium as shown in Figure 10, it shows a homogeneous tissue growth result

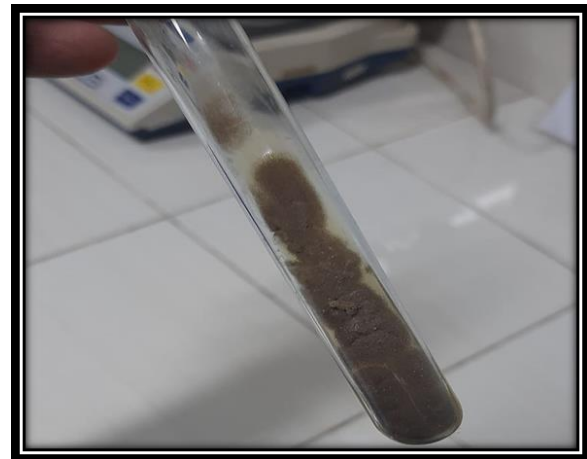which indicates that the tissue growth is stable and evenly distributed and is growing well.

Figure 10 Fungi grown in slant agar

C. LABORATORY TEST (PHASE ONE)

The first stage of laboratory testing includes testing of specific gravity (G_s) and testing of sieve and hydrometer analysis using two types of sand material (ordinary sand and lumajang sand) mixed with silt and clay. In this test, four variations of the percentage of the mixture of sand with silt and clay were used, respectively, as follows: (55% : 45%), (60% : 40%), (65% : 35%), and (70% : 30%). Test results for phase one shown in Table 4 and Table 5. Based on the results of laboratory tests, it can be seen that the use of ordinary sand as a mixed material gives the results of specific gravity values and also the percentage value of particle grains that are close to field conditions in the secondary data (Table 1a and Table 1b) [9].

D. LABORATORY TEST (PHASE TWO)

In the second stage of laboratory testing, specific gravity (G_s) testing was carried out, sieve and hydrometer analysis, proctor test, and density (γ) testing using only ordinary sand as a material mixed into silt and clay. At this stage of testing, a variation of the percentage of the mixture is used with the intervals between variations being narrowed or denser than the intervals in the first stage of the test. The

Table 6 Specific gravity test result (phase two)

Test Type	Ordinary Sand 58% : Silt + Clay 42%	Ordinary Sand 60% : Silt + Clay 40%	Ordinary Sand 62% : Silt + Clay 38%
G_s	2.435	2.434	2.539

Table 7 Sieve analysis and hydrometer test result (phase two)

Sample	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
Ordinary Sand 58% : Silt + Clay 42%	5	56	20	19
Ordinary Sand 60% : Silt + Clay 40%	6	54	21	19
Ordinary Sand 62% : Silt + Clay 38%	6	56	20	18

mixture of sand with silt and clay were used, respectively, as follows: (58% : 42%), (60% : 40%), and (62% : 38%). The result for stage two shown in Table 6 and Table 7. Through analysis of the data from the specific gravity test and also the test results from the analysis of the sieve and hydrometer, it was found that the variation of the mixture with the percentage of ordinary sand of 62% and the percentage of silt and clay of 38% gave results that were close to the field condition data listed in Table 1a and Table 1b.

E. LABORATORY TEST (PHASE THREE)

At this stage, the soil was remoulded with a mixture of 62% sand plus 38% silt and clay for the Triaxial Test. This test aims to determine the value of the parameters of the mechanical properties of the soil (cohesion (c) and shear angle (Φ)) with the composition of a mixture of sand (62%) with clay (38%) and also on the remoulded triaxial test sample, the addition of microorganisms will be added to see changes in the behaviour of the soil mixture with the composition of the modelled mixture. Before that, the soil mixture was added with water as much as the percentage of water content listed in the secondary data in Table 1. a and then the soil was cured for ± 3 – 4 days so that the soil mixture reached or approached a perfect saturation condition which refers to secondary data on soil conditions in Kulonprogo, Yogyakarta. (Table 1.a) which has a degree of saturation (Sr) = 100% (fully saturated).

Table 8 The results of the triaxial test with *Aspergillus*

Aspergillus Percentage (%)	Cohesion (*c*) (kg/cm²)	Shear Angle (*Φ*) (⁰)
0	2.356	4.169
3	0.987	16.096
6	2.412	6.812
9	0.617	28.231

The addition of a stabilizer material, in this case, the *Aspergillus* fungus, also has various impacts on the soil, where when given an additional 3% of fungi, the soil is expected to increase the value of soil resistance and experiences a drastic decrease in the cohesion value. Then, when the percentage of fungi was increased to 6% the cohesion value experienced a very drastic increase compared to when given the fungi at a level of 3% and when the fungi content was increased again to 9%, the cohesion value which had touched the figure of 2,412 kg/cm² decreased even more drastically compared to when the cohesion value decreased from the original condition without the addition of fungi to the condition with the addition of 3% fungi. This can be influenced by the

percentage of fungi that have given a maximum impact at 6% with remoulded soil conditions and can also be influenced by the condition of the soil itself which before being remoulded and also before being given the fungi were in a disturbed condition and this is not what the soil conditions in the field should be.

F. LABORATORY TEST (PHASE FOUR)

At this stage, physical parameters are tested for the soil mixture that has been added with stabilizers (*Aspergillus* fungi) that have passed the Triaxial UU testing phase. From the test, the results of the soil physical parameters are as follows.

Table 9 The results of testing the physical parameters of the soil mixture with the addition of *Aspergillus* fungi fungal stabilizer

Sample	G_s	γ g/cm³	γ_d g/cm³	e	n	S_r %	W_c %
Secondary Data	2.6	1.8	1.2	1.3	0.4	100	49
Initial	2.5	1.7	1.4	1.0	0.5	64	22
+ 3%	2.6	1.5	0.9	1.8	0.6	83	55
+ 6%	2.9	2.1	1.9	0.5	0.4	51	10
+ 9%	2.8	2.0	1.7	0.7	0.4	72	17

Based on the physical soil parameters listed in Table 9 for the soil added with *Aspergillus* fungi, it can be said that the addition of *Aspergillus* fungi as much as 6% gave good results which can be seen from the decrease in water content as well as a decrease in the degree of saturation which indirectly causes an increase the value of other soil physical parameters such as specific gravity and density. This shows an increase in soil strength or consistency which has also been shown through the results of the previous Triaxial UU testing phase.

G. LIQUEFACTION POTENTIAL ANALYSIS

After all of the soil testing is carried out, the next stage is to analyze liquefaction potentiality using the soil parameters from previous soil testing. From the calculation and the analysis process, the results are as follows.

Table 10 The results of liquefaction potential analysis

Sample	CSR	CRR	MSF	SF	Liquefaction Potentiality
Initial	0.28	0.05	1.56	0.28	YES
Aspergillus (6%)	0.28	0.06	1.56	0.31	YES

Based on the results above (Table 10), it can be concluded that there is an improvement in the soil

parameters which is shown by the increase in safety factor (SF) although not drastically or significantly. In a matter of liquefaction, liquefaction can occur even if there is an increase in the number of safety factors (SF) but still below the minimum safety factor (SF) required. In addition to the factor of soil conditions that are used in disturbed conditions, the use of microorganisms such as *Aspergillus* is still limited to increasing the soil consistency or the value of resistance of soils with high sand content and has not been reviewed to what extent it has an effect on the potential for liquefaction in soil that is given *Aspergillus* as stabilizers in the previous experiments.

CONCLUSIONS

Based on the results of the tests that have been carried out, it can be concluded that:

1) The effect given by the fungus on the variation of percentage as above on disturbed remoulded soil such as this experiment has not given the results or effects as expected.

2) Changes in the value of the soil shear parameters (e. g. cohesion) are not linear with the addition of the percentage of stabilizers applied to the remoulded soil mixture. The application of fungi to the remoulded soil mixture with a composition of 62% ordinary sand: 38% silt + clay at the various percentage of 3%, 6%, and 9% showed a change in the cohesion value and the shear angle value compared to the initial conditions. There was a 58% decrease in the cohesion value from the initial condition to the condition with the addition of *Aspergillus* (3%) and from the condition of the addition of *Aspergillus* (3%) to the condition of the addition of *Aspergillus* (6%), there was an increase in the cohesion value by 144% or almost 1,5-times the cohesion value with the addition of *Aspergillus* (3%). This can be due to intervals or multiples of the percentage value of the stabilizers applied to the soil with these conditions not yet appropriate to significantly affect the soil mixture.

3) The percentage that gives an increase in the cohesion value (c) after being given additional stabilizers compared to the cohesion value (c) in the original condition (initial) at a percentage level of *Aspergillus* (6%) with the result of the cohesion value (c) is 2,412 kg/cm^2 and the shear angle value (Φ) of 6,812⁰.

4) The water content applied when entering the remoulded stage was 48,5% which was the result of testing on samples in the field, the effect of giving the fungi tested was the effect of fungi on the soil at the appropriate water content conditions in the field.

5) The right concentration for *Aspergillus* fungi can grow and show the best hyphae and tissue development and produce a uniform colour at a concentration of 10^{-2}. The concentration of fungi indicates the conditions in which the fungi can live and develop with the most stable conditions possible so that the effect given to the soil with a high sand content in this experiment can work optimally.

ACKNOWLEDGMENTS

REFERENCES

[1] T. Harianto, S. H. Nur, and R. A. Arfandy, "Stabilisasi tanah ekspansive dengan metode bioremediasi," B.S. Thesis, Fakultas Teknik, Universitas Hasanuddin, Makassar, 2017

[2] O. Chandra, A. I. Putra, and M. Yusa, "Potensi likuifaksi pada tanah timbunan pasir diatas tanah gambut dengan variasi berat beban melalui uji model laboratorium," *Jurnal Online Mahasiswa Fakultas Teknik,* vol. 5, pp. 1-16, 2017.

[3] K. Diba, P. Kordbacheh, S. H. Mirhendi, S. Rezaie, and M. Mahmoudi, "Identification of aspergillus species using morphological characters". *Pakistan Journal of Medical Sciences*, vol. 23, no. 6, pp. 867 – 872, 2007.

[4] Y. K. Firmansyah, *Dilation and Inoculation Bacillus Safensis*. Japan: National Institute of Technology, Wakayama College, 2020.

[5] A. Hakam and H. Darjanto, "Penelusuran potensi likuifaksi Pantai Padang berdasarkan gradasi butiran dan tahanan penetrasi standar". *Jurnal Teknik Sipil*, vol. 20, no. 1, pp. 33-38, 2013.

[6] K. Ishihara. *Soil behaviour in earthquake geotechnics*. Eastbourne, Great Britain: Antony Rowe Ltd., 2003.

[7] A. Lim, P. C. Atmaja, and S. Rustiani, "Bio-mediated soil improvement of loose sand with fungus," *Journal of Rock Mechanics and Geotechnical Engineering*, vol. 12, no. 1, pp. 180-187, 2020.

[8] E. Mina, R. I. Kusuma, and Sudirman, "Analisa potensi likuifaksi berdasarkan data spt (studi kasus : proyek pembangunan Gedung Baru Untirta Sindang Sari)," *Jurnal Fondasi*, vol. 7, no. 1, pp. 11-21, 2018.

[9] P. P. KSO. *Penyelidikan tanah*, *Lokasi: Land Side (Proyek Pembangunan Bandara Internasional Yogyakarta)*, 2018.

[10] H. B. Seed, "Soil liquefaction and cyclic mobility evaluation for level ground during earthquakes," *Journal of the Geotechnical Engineering Division*, vol. 105, No. GT2, pp. 201-255, 1979.

[11] K. C. Tijow, O. B. A. Sompie, and J. H. Ticoh. "Analisis potensi likuifaksi tanah berdasarkan data standart penetration test (SPT) (studi kasus : Dermaga Bitung, Sulawesi Utara)" *Jurnal Sipil Statik*, vol 6, no. 7, pp. 491-500, 2018.

[12] H. Warman and D. Y. Jumas, "Kajian potensi likuifaksi pasca gempa dalam rangka mitigasi bencana di Padang," *Jurnal Rekayasa Sipil*, vol. 9, no. 2, pp. 1-19, 2013.

[13] A. G. D. Warouw, F. J. Manoppo, and S. G. Rondonuwu, "Analisis potensi likuifaksi dengan menggunakan nilai SPT (studi kasus : Jembatan Ir. Soekarno, Manado)," *Jurnal Sipil Statik*, vol. 7, no. 11, pp. 1453-1464, 2019.