MATEC Web of Conferences **400**, 02002 (2024) https://doi.org/10.1051/matecconf/202440002002
SPICE 2024

Comparison of Mechanical Properties of Compacted Waste Soil from Open Dumping Area and Clay Soil for Future Development

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Abstract. Estimating the mechanical properties of soil samples involves analysing properties such as shear strength, density, and moisture content. It is important to use consistent and standardized testing methods, as well as to normalize the data to the same volume or weight, when comparing soil mechanical properties. Evaluating multiple properties will provide a more complete understanding of the differences between soils. Additionally, it is crucial to consider factors such as soil composition, history, and location when comparing soil properties. The main purpose of this paper is to compare the two types of soil which are waste soil and clay soil. Waste soil tends to have weak structure due to the multiple content of waste while clay soil is weak because of water absorption of in the clay structure. These two properties will have implications in terms of its mechanical properties. The experimental works that was conducted in this research are direct shear stress, density, water content and compressive strength. Clay soils tend to be less dense due to their fine-grained nature and the small size of their particles. Waste soil, on the other hand, can vary in density and can often be less dense than natural soils due to the presence of large void spaces. The water content in clay soils can significantly affect its shear strength, as excessive water can weaken the cohesive forces between the clay particles. In waste soil, the moisture content can affect the density and compaction of the soil, which can impact its stability. The expected outcome from this research is the conclusion of the mechanical properties for both types of soil.

1 Introduction

The studies are to compare the mechanical properties of the compacted clay soil with the waste soil. The compacted clay soil is a type of soil that contains a high proportion of clay

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particles which has been compacted at the laboratory. Clay is a type of soil mineral that has a very small particle size, typically less than 2 microns. The small size of the clay particles gives the soil its unique properties, including high plasticity, low permeability, and high compressibility. On the other hand, waste soil is a type of soil that is formed because of human activity that produces waste every day. It can be composed of a variety of materials, including construction waste, industrial waste, and municipal waste. The properties of waste soil depend on the type and composition of the waste material. Both of the soil have different properties where clay materials is highly compressible, high absorption of water and low permeability while waste soil is moderately compressible, moderately absorbed water and the water can moderately permeable in the waste soil.

These different types of solid waste are disposed in open dumping. More than 1.4 billion tons of municipal solid waste is disposed annually, which is 70% of the total waste. This waste forms leachate, which is the major reason for the odor, methane etc. [3],[8]. Due to this formation, physical, chemical, and biological process take place which alters the hydrological cycle (change in infiltration, compaction of solid waste etc. [2]. Waste soil from dumping area which is heterogenous content which consist of many materials such as rubber, metal, wood, steel, construction waste, concrete and others [1]. These different forms of properties including the compressive strength, direct shear strength of soils should be studied in detail to check the material composition. This research is performed for estimation and comparison of the mechanical properties of the waste soil from dumping areas.

2 Mechanical characteristics of waste soil

Soto et al. [4] researched on the mechanical recycling of plastics waste with the intention of promoting the recycling of polyethylene plastic contained in waste that has not been accumulated and to lessen the volume of this material in landfills. This study supplies information on the principal structure of the raw fabric, the collections of the reprocessed plastic and the wastewater all through its recycling technique, which included the steps of washing (without chemical substances), drying and extrusion. A figure showing the composition of municipal solid waste is shown in Fig. 1. From Fig. 1 the highest compositions of the waste materials is the organic waste which is 34.4% followed by other materials which is 31.2%. Then an evaluation of the primary waste materials of the machine recycling technique become completed. Subsequently, the ash content material, relative density, thermal houses, mechanical properties, rheological houses, and others were decided for the recycled fabric and compare with the original material.

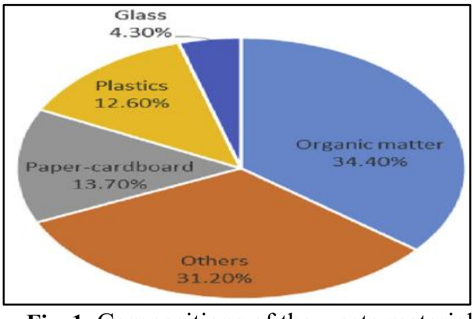

Fig. 1. Compositions of the waste materials

Tran et. al, [5] conducted an investigating on the properties of corn silk fibers on the mechanical possessions of paved soil by performing compaction, firmness and splitting assessments, effect of fiber contented (0%, 0.25%, 0.5% and 1% dry soil weight), cement contented (4%, 8% and 12% dry soil weight) and curing time (7, 14 and 28 days). From the investigation on these properties, numerous nonlinear regression pattern had been obtained considering parameters consisting of setting time, fiber content, and cement content material, expected compressive energy and tensile strength. The effective degree of each parameter for compressive and tensile energy become also evaluated. Experimental results showed that the addition of corn silk fibers to the cemented soil stepped forward the compressive energy and tensile splitting. A fiber content of 0.25%-0.5% is recommended to be used in cemented soil strengthened with corn silk fibers. Splitting the tensile electricity is identical to 0.148 instances the compressive electricity for each cemented and fiber cement-stabilized soil. Compressive and tensile electricity may be predicted using regression models with high accuracy. primarily based at the proposed version and sensitivity analysis, cement content material is the simplest parameter affecting compressive energy and splitting tensile electricity followed by means of setting time and fiber content.

Wei et. al. [10] illustrated soil increases in strength with each lime and fibers added to the soil including the mechanical properties of the soil. Wheat straw, rice straw, jute and polypropylene fiber have been added to the soil with a purpose to increase the strength. The fiber content and the ultimate fiber duration, a strain of the fibrous soil without restrictions changed when the fiber is added completely. A fibre-lime-soil triaxial compression test is conducted to analyse the shear energy, deviatoric strain-strain residences and failure pattern of the specimen. The outcomes are as follows: The most reliable fiber content material became 0.2% or 0.25% and the best fiber period was 30% or 40% of the sample diameter. The reinforcement significantly expanded concord and barely improved the perspective of inner friction. The cohesion increments of polypropylene fibers – lime, jute – lime, rice straw – lime and wheat straw – lime step by step reduced. All 4 styles of fibers can enhance the strength and deviatoric strain-pressure properties of soil and calcareous soil, in which polypropylene fiber is the quality for reinforcement.

Research by Nur Irfah et. al. [6] on the waste soil at open dumping area in Malaysia shows that the friction angle between 14^{o} to 27^{o-} and cohesion value between 2-4 kPa. The waste soil at the study area consists of waste with construction waste materials. Moreover, research by [7] also suggests on the improvement of waste soil using the eggshell powder plus lime. It was found that the addition of 7.5% eggshell powder with 7.5% lime with the waste soil shows the increase in compressive strength to 337.13 kN/m^2 after the samples has been cured for 28 days. This will become the benchmark for this research in terms of waste soil strength. The advantages of using waste soil as compared to clay was that waste soil consist of many materials which contribute to increase the strength of the soil and eventually increase the bearing capacity of the soil. The limitations of waste soil is due to the different types of waste, there are some void or gap in between the layers that can cause the soil to collapse. To overcome these challenges, we need to make sure to compact the waste soil layers by layers to decrease the void ratio. The void in between the layers could also filled with water during the raining season. This will cause settlement at the area as compared to clay soils.

3 Methodology of Research

The methodology of the research starts from the problem statement and objectives of the research. The objectives of this research are to determine the mechanical strength properties of waste soil and clay soil. For both soils, the comparison in terms of the strength is to be analyzed to characterize the behavior of the waste soil and clayey soil. The flow chart in Fig. 2 shows the methodology of research.

The study area selected for this research is the construction area near UNITEN. The waste soil consists of waste combined with soil. The waste in the soil is around 20 percent to 50 percent of the weight. Furthermore, the clayey soil sample is the soil with 100% clay soil which is obtained from the supplier.

The sample preparation process starts from the mixing of the construction waste with the soil. The mixing should be done with a mixer so that the samples will completely blend with the soils. Then the soil will be left to be dried for 24 hours before it can be tested. For clayey soil, the clay soil is added with water to make it into a cylinder shape using a mold.

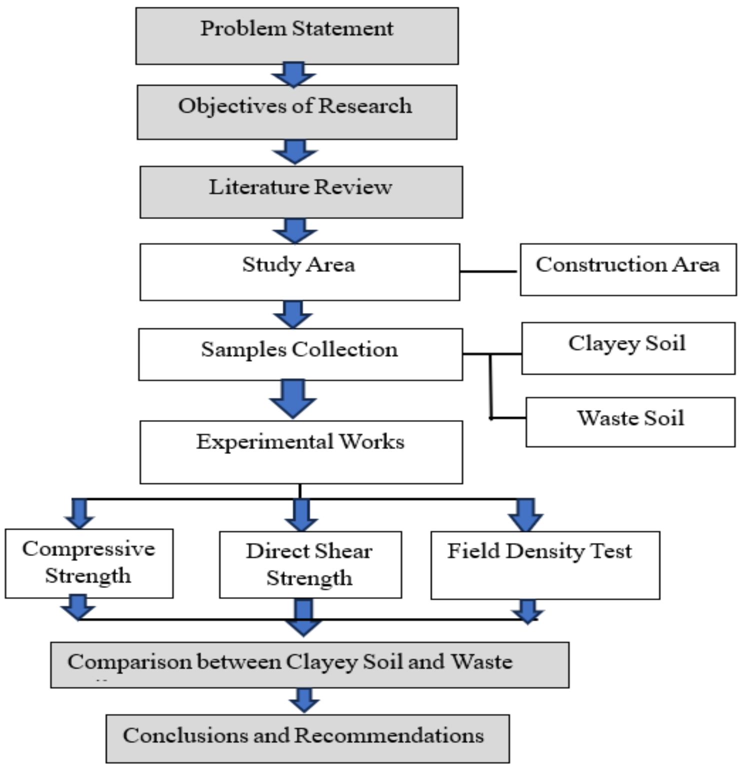

Fig. 2. Methodology of Research

4 Experimental Works

There are three tests that are conducted in this research such as compressive strength, direct shear test and field density test. Field density test is an important laboratory technique for determining the density of a soil that is tested. It is a simple, reliable, and precise method, but

it also has some limitations. For this experiment, the samples with different density are tested for the strength test. The field density test for soil is conducted to at the construction site to determine the in-place density and moisture content of a soil sample. This test is essential in geotechnical engineering and construction projects to assess the compaction of soil, which is crucial for the stability and performance of structures built on or with soil.
The Unconfined Compressive Strength (UCS) are based on the standards for UCS Test (2022) test. It is used to determine the compressive strength of a cohesive soil. This test is particularly applicable to cohesive soils such as clays and silts. It provides valuable information about the soil's strength and load-bearing capacity under compressive forces. The steps in conducting the unconfined compressive strength are as follows,

(a) The sample is prepared into a cylindrical shape and the sample is usually collected from the field. The samples must be trimmed and shaped following the shape of a cylindrical specimen.
(b) The samples then being applied for loading and testing. The cylindrical soil specimen is placed in a testing apparatus. Unlike other soil strength tests, there is no confining pressure for this test. The sample is only subjected to axial load. The testing is done until failure occurs.
(c) The maximum compressive stress at failure for this sample is recorded as the unconfined compressive strength. This will represent the soil's ability to resist compression.

Fig. 3 shows the step in the compressive strength testing for clayey soil and waste soil.

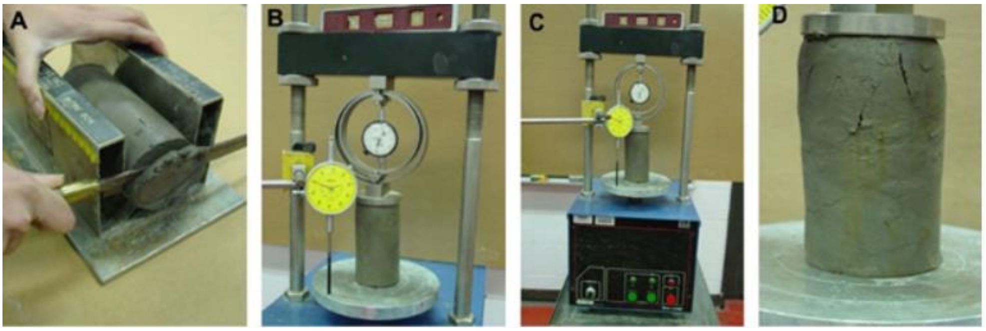

Fig. 3. Compressive strength testing apparatus

Direct shear test is another test conducted in this research. The direct shear test is a laboratory method used to determine the shear strength parameters of soil, particularly cohesion (c) and the angle of internal friction (φ). This test is commonly employed for granular soils (such as sands and gravels) and cohesive soils (such as clays). It simulates a horizontal shearing motion along a predefined failure plane within a soil sample. The test starts from the sample preparation. Fig. 4 shows the apparatus of direct shear test.

A soil sample is compacted into a shear box apparatus. The sample is typically confined within a square or circular box and a horizontal plane is designated as the potential failure plane. The box will be sheared into halves using the applied shear stress. The soil is subjected to the confining pressure which stimulated the overburden pressure the soil would experience in the field. The pressure is applied at the normal stress and shear stress direction. The upper and lower halves of the shear box are then displaced horizontally. The test concludes when the soil reaches failure, usually defined by a constant reading of shear displacement or a significant drop in shear stress on the observe displacement along the failure plane. The shear stress at failure is used to calculate the shear strength parameters. The test measures the applied shear force and the corresponding displacement as the soil undergoes shearing. The resulting stress-displacement data are used to determine the shear strength parameters, including cohesion (c) and the angle of internal friction (φ).

Fig. 4. Direct shear testing apparatus

5 Results and Discussions

5.1 Density Test Result

The density of 3 samples of clayey soil gives an average value of density of 1.16 while 3 samples of waste soil give an average value of 1.62 as shown in Table 1. The samples which were collected from the field were tested using the density test to determine its field density. The density of soil can vary significantly depending on the type of soil and the composition of its constituent particles. Cohesionless soils, such as sands and gravels, tend to have higher densities than cohesive soils, such as silts and clays. The density of cohesive soils is also highly dependent on moisture content, as the particles are held together by water molecules. Additionally, organic materials in the soil can further reduce the density of the soil. Generally, sandy soils have a higher density than clay soils, as the larger particles of sand take up more space than the smaller particles of clay. The density shows that the waste soil has higher density than the clayey soil.

Table 1. Density of the sample

Soil	Clayey Soil			Waste Soil		
Sample No.	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
Density (g/cm^3)	1.17	1.15	1.15	1.56	1.66	1.65
Average (g/cm^3)	1.16			1.62		

5.2 *Unconfined Compression Test Result*

Compressive strength is a type of stress that results from an applied load that tends to compress or shorten the material. It is typically measured as the force per unit area of the material, and its magnitude depends on the size and direction of the applied force, as well as the properties of the material. Another important characteristic of both clay soil and waste soil is their compressibility behavior.

Clay soil is known for its high compressibility, which can result in significant settlement and deformation under loading. Waste soil, on the other hand, can also exhibit high compressibility depending on its composition and history. Based on the analysis shown in Fig. 5 and Fig. 6, the highest shear force for clayey soil is 11.99 kPa with the 3 kg applied normal load, while the highest shear force for waste soil is 15.05 kPa.

The mechanical characteristics of clay soil and waste soil can vary widely depending on their composition and history. While clay soil is known for its low strength and high compressibility, waste soil can have a wide range of strength, permeability, and compressibility characteristics. Understanding these differences is important for engineering and environmental applications and can help ensure the safe and effective use of these materials in construction and other activities.

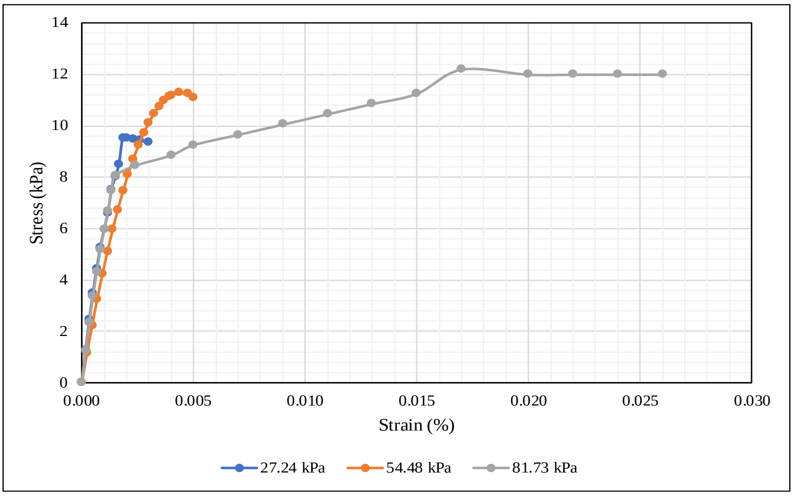

Fig. 5. Stress versus strain for clayey soil

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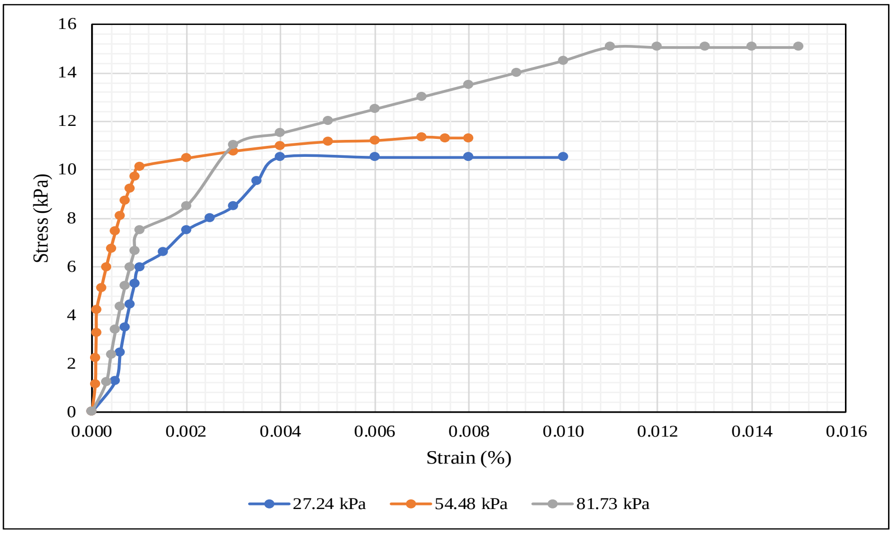

Fig. 6. Stress versus strain for waste soil

5.3 Direct *Shear Test Result*

Direct shear stress is a type of stress that results from an applied load that tends to cause adjacent parts of the material to slide past each other along a plane parallel to the direction of the force. It is typically measured as the force per unit area of the material, and its magnitude depends on the size and direction of the applied force, as well as the properties of the material. Based on the direct shear tests of clayey soil and waste soil, both soils have the same friction angle which is 15.52 degree. The cohesion for clayey soil is 8.31 KPa and waste soil is 7.78 kPa. Details of the data as shown in Table 2 and Table 3. Fig. 7 shows the shear stress versus normal stress for clayey soil and waste soil.

Table 2. Direct shear test data for clayey soil.

Normal Load (kPa)	Shear Force (N)	Displacement (mm)	Shear Stress (kPa)	Cohesion (kPa)	Friction Angle (^{0})
27.24	34.3	0.002	9.53	8.31	15.52
54.48	40.3	0.004	11.19		
81.73	43.9	0.017	12.19		

Table 3. Direct shear test data for waste soil

Normal Load (kPa)	Shear Force (N)	Displacement (mm)	Shear Stress (kPa)	Cohesion (kPa)	Friction Angle (^{0})
27.24	37.9	0.004	10.53	7.78	15.52
54.48	40.8	0.007	11.33		
81.73	54.2	0.011	15.06		

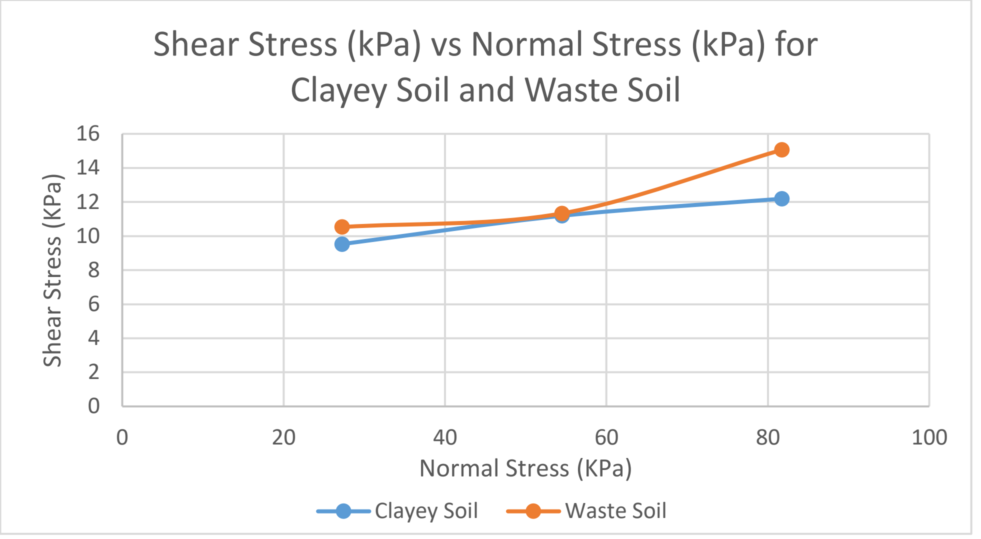

Fig. 7. Shear stress versus normal stress for clayey soil and waste soil

5.4 Advantages and limitations of Waste Soil compared to Clay

There are advantages and limitations of using the waste soils as compared to clay soil, The advantages are in terms of cost effectiveness, the waste soil is easily obtained and often available at lower costs especially if it is a byproduct of construction or industrial processes, reducing the need for expensive disposal methods. Another advantage is the utilizing waste soil promotes recycling and sustainable construction practices by reducing the need for raw materials. Furthermore, the reuse of waste soil reduces the amount of waste at the landfill and addressing waste management challenges. Waste soil is higher in strength as compared to clay because waste soil does not absorbed water and retained the water.

However, there are limitations of waste soil such as inconsistent properties of waste because waste have many layers of different types of materials. Waste soil can have highly variable properties due to its diverse origins, making it unpredictable in terms of strength, compressibility, and permeability. Waste soil is prone to contamination risk. There is a potential risk of contamination from hazardous substances, which can pose environmental and health risks. There may be stringent regulatory requirements and testing needed to ensure that waste soil is safe and suitable for use in construction, which can be time-consuming and costly.

For clay soils, the advantages are that clay soil engineering properties are predictable with low permeability, high plasticity and cohesion. Thus, it a reliable choice for specific applications while waste soils variability can be a limitation unless thoroughly tested and characterized. In terms of regulations and safety, waste soil often faces more stringent regulatory scrutiny due to potential contamination, whereas clay soil is typically easier to certify for use in construction projects.

6. Conclusions

In conclusions, based on the comparison between the clay soil and waste soil, it can be summarized as follows: -

1. Clay soils tend to be less dense due to their fine-grained nature and the small size of their particles. Waste soil, on the other hand, can vary in density and can often be less dense than natural soils due to the presence of large void spaces. Moisture content also plays an important role in the mechanical characteristics of soil. The water content in clay soils can significantly affect its shear strength, as excessive water can weaken the cohesive forces between the clay particles.
2. In waste soil, the moisture content can affect the density and compaction of the soil, which can impact its stability. Clay soils tend to have less shear strength and density as compared to waste soils. But if the waste soil consists of weak materials, it can have lower shear strength and can be less dense, depending on their composition.
3. The mechanical properties for clay soil are that clay soil has the maximum shear stress of 11.99 kPa while waste soil has the maximum shear stress of 15.05 kPa. Friction angle for clay soil is less than the waste soil. Waste soil with the construction waste have higher friction angle.
4. Between these two soils, clay soil is not suitable for construction if the soil is not treated but for waste soil which in dry conditions, the waste soil could be reused for the new development. The pre-consolidation process should be applied to clayey types of soil before the soil can be used for new development. The method of perforated vertical drain can also be applied to the site to drain out the water before the construction can proceed.
5. In term of cost, the usage of waste soil is generally more cost-effective than clay soil, especially if sourced locally from construction or industrial sites. Waste soil is using the unused waste and mixed it with soil so that it can be reused back for the construction purposes. On the other factor such as environmental impact, using waste soil can be more sustainable by promoting recycling and reducing landfill usage. However, it requires careful handling to avoid environmental contamination.

It is recommended that to do some soil improvement to the waste soil or clay soil by applying method of stabilizations such as stone column, dynamic compactions, vertical drain method or pre-consolidation methods. For further exploration on this research, it was suggested that to find the stabilization method to treat the clay soil such as using lime and fly ash, the application of dynamic compactions to improve the strength of waste soil and the modelling of long-term settlement of waste soil using software simulations such as PLAXIS 3D or SLOPE W.

The author would like to acknowledge DTLK grant with grant number (20238001DTLK) for funding this research. This research supports the 17 Sustainable Development Goals under category Goal No 13 Climate Action and Goal No 11 Sustainable Cities and Communities.

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