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Modification Compression Strength of Test Machine by Using Control System on Compaction Energy

Modification Compression Strength of Test Machine by Using Control System on Compaction Energy

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Abstract. Soil compaction for specific construction is determined soil density tests. Several methods have been developed by previous researches and the prominent method is soil density. Several types of soil compaction method in the field, namely compaction method using vibration machine, impact, and pressure. In laboratories, soil compaction test was performed by using a hammer which uses human strength to solidify soil. An experimental investigation was conducted to explore a new modification related to compression strength test machine with energy compaction control system control system the energy of compaction. Researchers tried to design and make a soil compactor with a different mould measures from the standard Proctor method to modified method. The special of this new tool is that it can measure the compaction energy from each layer and dry density values. This research used different pressures as much as 1.67 N/mm^2 - 20 N/mm^2, every load conducted for sandy clay and silt samples. The values of dry density obtained from this research were between 1.59 kN/m3 - 1.68 kN/m3 and the value is higher compared with the value obtained from experiments using the Standard Proctor system. Meanwhile, the soil compaction results in the laboratory by using a new modification compression strength test machine with energy compaction control system can be an option of heavy equipment which can be used in the field.

1. **Introduction**

Since the construction cost of soil management works is quite high therefore soil play a very crucial role in supporting infrastructures such as road, dams and embankment. Moreover, the development of science in the field of civil engineering construction must follow the progress of field needs so that the infrastructures which are going to be built could have decent quality, economical value in terms of the planning and implementation of the work and all of which must meet the required

qualifications. Soil compaction work becomes the second which require high costs, great deal of time and also selection for decent materials after cut and fill works.

Soil compaction is a process of soil density by reducing the distance between particles; consequently, there will be reduction in air volume and compressed soil grains. The soil would have reduction in air volume [1-2]. By applying compaction method, it is expected to obtain stable soil and not easy to get penetrated by water so that building constructions would last longer.

Research studies on soil compaction held in a laboratory with the proctor test tool which include the uses of proctor standard and proctor modified. Consequently, the results of this kind of experiment will eventually get a maximum soil density and optimum moisture content. The maximum soil density can also be achieved depending on the soil grains and soil water content. The importance of compacted soil is that it will have an impact on some soil characteristics such as the shear strength and permeability value [1-3].

Theoretically, it is much convenient to run the experiment of maximum soil compaction in a laboratory although the practicality of running the experiment in the field could be very challenging. In order to get a decent compaction, one must meet the standards of Bina Marga. The construction works would be suitable for a building in a flat area and has good hard soil; hence the implementation would not be going to be too difficult. However, when the construction works are undergoes at a non-flat area, therefore excavation and embankment works are needed.

The aim of this research is to develop a compaction tool which could be used often in soil compaction experiments in laboratories. This tool was made by modifying the proctor in the laboratory. The purpose of making this tool is not to replace the existing tools and become the standard tool in all soil mechanics laboratories. This soil compactor tool could obtain the right solution in order to observe the value of compaction energy and it could be distinguished by the amount of energy that could be used to compact soil on the field. Meanwhile as contractors or even the government, in this case the decision maker, should be able to quickly determine the use of compactor at various kinds of soil. Whereas the advantage is that it can shorten the compaction work time in the laboratory, and the energy used to condense a type of soil measured. During soil compaction tests, the energy used can be measured. For example, a soil compaction experiment is given a pressure of 5 N/mm^2 in each layer, after the end of the research it will produce its dry density value. It means that the value of dry density is obtained by using 5 N/mm^2 of pressure energy. The energy of soil compaction using the Standard Proctor method is using formula I. However, by using this new modification equipment, the amount of direct compaction energy can be obtained. Other advantages of using the modification tool is it can shorten the implementation time and energy as well as the accuracy of the results.

The process of soil compaction will increase the soil density by knowing the density between the soil particles so that it will reduce the volume of air and remove some of the groundwater. The effect of groundwater will act as a lubricant and can increase the compaction quickly when the load is placed by on the ground. It is essential because the results of experiments in the laboratory become a reference for implementation in the field.

At the beginning of the compaction process, with the fixed compaction energy, the value of soil density (γd) will increase by increasing the water content. But if the optimal water level reaches a maximum value and the water continue to flow then the dry density will gradually decrease [4]. This kind of soil conditions will approach saturated and weak soil conditions, thus, in the implementation of compaction energy or the burden given to compact the soil tends to exceed the strength of the soil

and it is carrying capacity. This condition will produce excessive wheel slippage, and the curve of the wheel will damage the ground. This event often experienced by expansive soil conditions [5]. Therefore, it is essential to know the density of soil energy before engineers implement it in the field.

2. Experimental

Standard Proctor and Modified Proctor tests are performed to obtain optimal moisture content and optimal dry density. The relationship of parameters between the optimum moisture content and the maximum dry volume weight (γd_{max}) for various types of soil has been observed by several scientists and researchers in the field of soil mechanics such as Proctor [6],[7]. Until now the Proctor's tool was created by Proctor for soil compaction testing which produces both parameters.

Relationship between dry density (γd) with the weight of volume (γb) and moisture content (w), is expressed in the equation (1) [8]:

$$\gamma d = \frac{\gamma b}{1 + \omega} \tag{1}$$

Based on the Proctor test experiment, the researcher tries to complete the research by making other compaction test equipment, namely making soil compaction testing with pressure. The idea and purpose of creating a soil compactor with pressure is to convert human energy into a machine of power and make it easier to use. When the soil is compacted, the energy is used according to the research plan and has the same functions as a Proctor system. The hydraulic system uses a manometer to measure the pressure applied when the soil is under pressure and the same functions as a Proctor system. In addition, it uses a manometer to measure the pressure applied when the ground is under pressure (the pressure energy can be measured). This tool is called modelling the soil compression test by the pressure method, which is shown by Figure 1 and 2.

For this reason, a test will be conducted between the soil compression modelling test with the pressure method and comparing the standard and proctor modified test equipment to the compaction amount of the compaction energy meter.

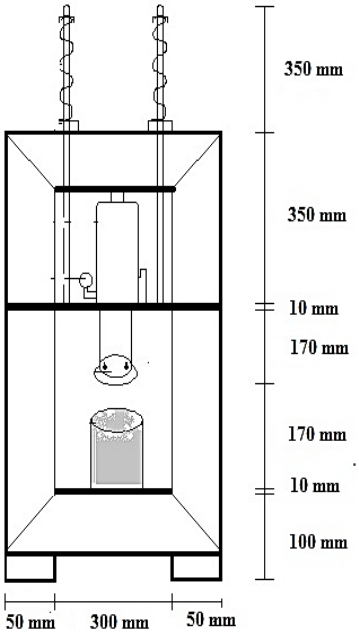

Figure 1. Prototype of modification compression test for soil compactor

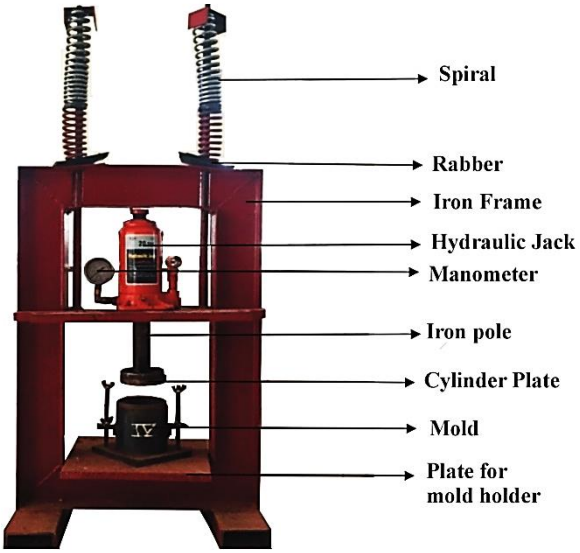

Figure 2. Modification compression testing machine .

The height of this tool is 110 cm, with a length of 40 cm, and a width of 30 cm. The size is not too big, and it can be used only for research material by using fine-grained soil samples until sandy clay soil samples.

The first test is to find the optimal moisture content and dry density using the Modified Proctor test and standard Proctor test. Optimal water content (w_{opt}) as well as maximum dry density (γd_{max}) that are found from the compacting curve, [7],[8]. After γd_{max} and w_{opt} are obtained, the optimal air content becomes the reference used in each subsequent soil test sample.

After the soil sample containing water content optimal is ready, the soil sample is then put into a mould with 10.20 cm in diameter and a height of 11.60 cm. Compaction system is divided into three layers or five layers. Each layer must be compacted by having the same energy and each layer is pressed with a present pressure. The pressure applied to each specimen is 1,67 N/mm^2 – 20 N/mm^2.

The energy required for compaction at standard compaction is formulated as in equation (2) [4],[8]:

$$E = \frac{N_b N_i W H}{V} \tag{2}$$

Notes:
E= Compaction energy (ft-lb/ft^3)
N b=Amount of pounding each layer
N i=Amount of layers
W=Weight of hammer (lb)
H=Falling height of hammer (ft)
V=Volume of mould (ft^3)

The working system of the ground press tool is to pump the hydraulic jack manually, at the end of the jack, there is an iron plate as thick as 5 mm thick. At the end of the jack is placed a 5 mm thick iron plate. When the hydraulic jack pushes the plate down, the iron plate will press the ground in the mould; then the soil becomes solid. When the plate has touched the soil and has begun to be compacted, the manometer will move, so that it can know the amount of pressure received by the ground when reading the value on the manometer. The initial test is applied testing the physical properties of the soil, for density, right before the soil is going to be tested. The data was taken from secondary data, [9].

3. Results and Discussion

The primary function of the soil layer is to support the building foundation in hence the required soil layers must be in a stable state. Thus, before building a construction, the base soil must be compacted first, adding soil to the ground from another place and then compacted is the solution for problems that often occur when the location of the building has a distant elevation difference. Soil compaction system usually has thickness of 30 cm for each layer. Additionally, soil compaction is needed so that the soil particles become solid and stable towards the load of the building structure.

Based on the background of the problem, this discussion will discuss about the physical properties of soil, density, and energy required when the soil is compacted. Sampled soils are from two different locations, the first sample was from Sukabumi Bandar Lampung and the second sample was from

Gedung Agung, South Lampung. These areas were chosen as an area of the study because the soil often used as a dam and other infrastructure works.

Soil compaction is a mechanical method for obtaining stable soil layers in support of building structural loads. It is necessary to study the amount of compaction energy since the result of soil compaction depends on the compaction energy. The amount of energy is measured by the making of a compactor model designed to conduct experiments of soil compaction. Compaction system uses a hydraulic jack as pressure or as a soil loading that will be compacted. This pressure has a function as compaction energy, while the instrument is called the soil density modification test with the control system on compaction energy.

The limitation problems in this study are sandy soil samples and clay samples. This study is limited to testing the physical characteristics of the soil which are tested by using standard proctor and modified proctor methods as well as design the testing tools for soil compaction with pressure conditions. This new pressure tool is expected to have the similar energy which is used in compaction experiment in the laboratory with compaction energy in the field.

Soil samples used in this study were from Sukabumi deposit and Gedung Agung deposit in South Lampung, Indonesia and these locations are less than 5 km apart. The reason these places were chosen was because these areas are often used for landfill of road bodies. The first research conducted was to find the value of physical properties and the value of w_{opt} and γd_{max}. [9],[10].

Based on the value of soil samples from Gedung Agung which was taken from the results of the test of the physical properties of the soil indicated that no more than 35% of material is larger than 200. It means, it is less than 35%. While for the liquid limit value (LL) was 39.42%, it means it did not exceed 40%. While, the plastic index value (PI) was 9.5%, it also did not exceed 10 %. The sieve graphic analysis can be seen in Figure 3. The results of soil analysis and plasticity index according to the AASHTO Classification System and USCS, (Standard procedures carried out in line to ASTM D698 and AASHTO T90) [7]. Meanwhile, samples from Sukabumi are categorized as sandy soil and samples from Gedung Agung soil are categorized in soil group A-2-4 sandy clay. In previous studies, both of this soil samples were used with different parameters [11],[12].

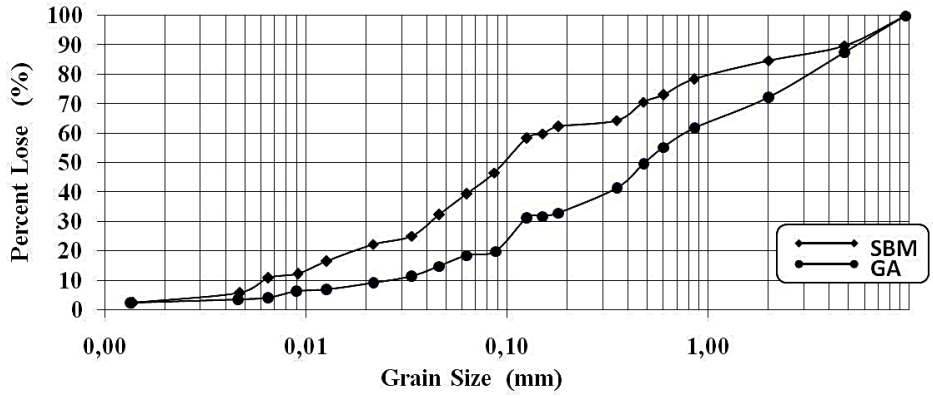

Figure 3. Graph of soil analysis [10]

The results of the study using a modified proctor for Gedung Agung soil were maximum dry volume weight of 1.70 gr/cm^3 and an optimum moisture content of 19.3%. While the energy needed

for compaction according to equation (1) is equal to E = 56,250 (ft.lb/ft^3) = 2,6933,106 J/m^3 or equivalent to 2.7 N/mm^2. The amount of effort stress will be converted into pressure on the machine compactor. The compacting energy approach is for heavy equipment such as grid rollers at 6.2 MPa - 10 MPa, [12],[13]. The optimal moisture content obtained from the Proctor Modified testis used as a mixture of all samples in subsequent trials. The pressure used in this experiment using a new modification tool is 1.67 N/mm^2; 5.0 N/mm^2; 6.2 N/mm^2; 7.0 N/mm^2; 8.0 N/mm^2: 10.0 N/mm^2; 15.0 N/mm^2 and 20.0 N/mm^2. This research was also examined again by other researchers with different parameters by using the same amount of pressure and sample. From the results of the study as many as three parameters that were using a pressure test (research results using a machine compression tool modification compression testing machine) and modified proctor, the effect is observe as in Figure 4.

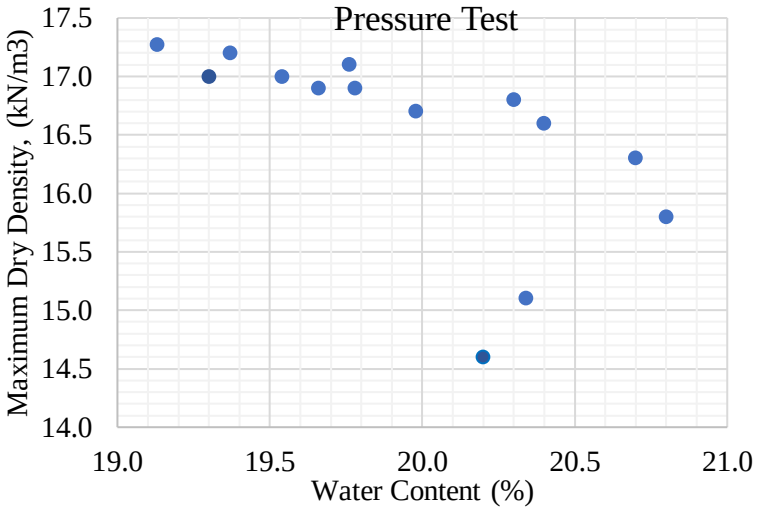

Figure 4. Water content against optimal dry density

The results of the study as seen in Figure 4 and henceforth are the optimal dry density and water content values of each experiment. Figure 4 shows that the greater the pressure for all samples, the higher the γd_{max} and the higher the water content will decrease the γd_{max} value. The higher the pressure to compact of soil, the denser the soil will be, and the water will quickly come out, even the soil becomes challenging to compact, as shown in Figure 5 and Figure 6.

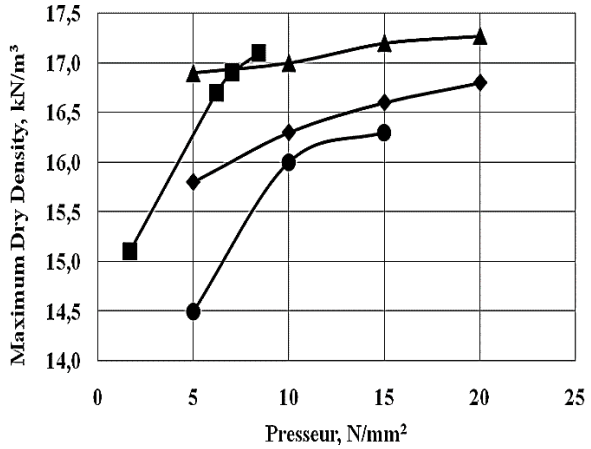

Figure 5. The value of maximum dry density against pressure

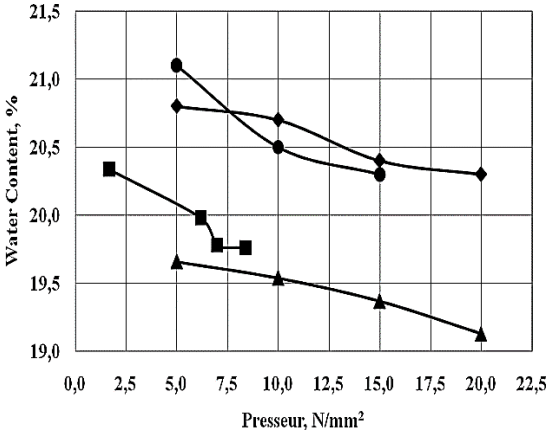

Figure 6. The value of water content against pressure

From graph in Figure 5 and Figure 6, it can be concluded that the compaction with a pressure of 1.6 N/mm^2 - 15 N/mm^2 is enough. It means that the soil density approaches the Zero Air Void (ZAV) value. In addition, the amount of water content used in this study is higher than the value of the optimal water content of the test results with modified proctor, it is still within the tolerance range of 4% - 8% of optimal water content.

Meanwhile, at a pressure of 20 N/mm^2, the soil density approaches the ZAV value, which means that the soil has no space for water and air. By converting from the optimal dry volume weight value obtained from the pressure experiment and the proctor modification (Figure 5 and Figure 6), the using of compaction energy pressure results in almost the same dry volume weight from the two tools. Therefore, the modified compactor can be used as a substitute for the modified proctor testing tool in compaction energy testing. Other researchers, such as Hilman and Rubianty [11],[12] get the same result. Testing with a pressure compaction tool using a hydraulic jack to reach a pressure of 1.67 N/mm^2 - 20 N/mm^2 then the dry density results obtained was between 14.5 kN/m^3 - 1.73 kN/m^3. This value is higher than the value obtained from experiments using the Standard Proctor system. Whereas, the values obtained for the pressure of 5 N/m^2 - 20 N/m^2 the dry density value was between 1.59 kN/m^3 - 1.68 kN/m^3. Since the soil samples were divided into several layers at the time of the research. Moreover, each layer is compacted until the mould full filled. Figure 6 shows the results of experiments were using three layers and five layers. The result is an experiment with five layers of denser compared to the experiment with three layers. It means that dry density is more considerable for five segments of denser soil.

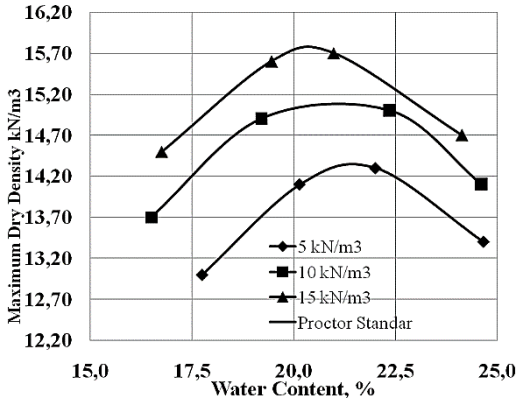

Figure 7. The results of experiments with 3 layers with a pressure between 5 N/mm^2 - 20 N/mm^2

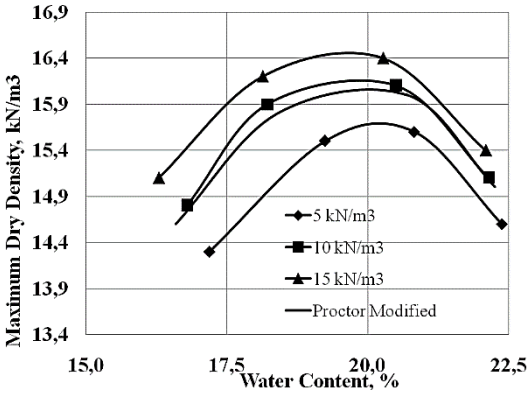

Figure 8. The results of experiments with 5 layers with a pressure between 5 N/mm^2 - 20 N/mm^2

Soil compaction work will obtain the results in which the state that compaction will reduce the void ratio and soil pores so that water is more difficult to flow into the soil. This condition is essential when the oil is used to collect water as needed for dams, dikes, and pavement structures so that it will reduce water loss. Compaction can also prevent the occurrence of high-water pressures and cause the soil to soften, shown in Figure 7 and Figure 8. It means that the importance of soil compaction is not only for compaction of road piles but also for the body of the dam.

Soil compaction is a process of pressure that is applied to the soil surface and causes the density toward the soil. Soil density occurs due to the presence of water and air coming out of the soil pores. If the area is small, it is enough to use a compacting or vibro tamper in the field. But if the area is large, the compaction machine is used. The choice of a compacting machine tool is depending on soil type and humidity conditions. The most used compactor is the sheep leg roller or vibro tamper. The speed and number of sheep leg roller trails depend on the type of soil and on the project requirements. Field compactors typically use a vibro machine for compacting small areas and this machine is suitable for compaction of all types of soil [14].

Contact pressures from sheep leg rollers are between 1400 and 7000 kPa or 6.9 N/mm^2, [11]. This study proves that the pressure value on the roller is a compacting machine almost close to the pressure on a modified compression test of 8 N/mm^2. It means that the new test equipment is a recommendation for the selection of heavy equipment in the field; this can be seen in Figure 9.

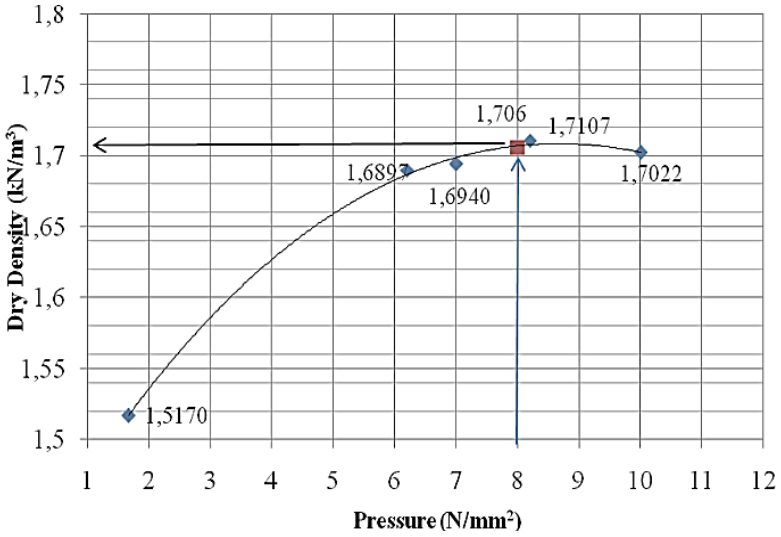

Figure 9. Relation of dry volume weight with pressure on modified compression test equipment and modified proctor test press, [10].

In the picture 7, it shows clearly the effect of compaction results with a new device and with the results using a modified proctor. That $\gamma d_{max}$of proctor modified by 17.01 kN/m^3 also can be seen from the picture showing the value of γd of 17.01 kN/m^3 could be able to be pressed with a machine pressure of 9 N/mm^2.

Compaction energy is influenced by the amount of clay content in the soil. If the compaction energy is low, the effect of the clay content has a significant impact. But when energy levels are high, the result of clay content is more striking, as found in many practical projects, this effect is less significant. When the clay content of the mixture in the soil increases, the optimum moisture content also increases [11]

In Figure 4, the higher the compaction energy it will reduce the value of soil water content. There is a supporting proof by Blotez [13]. Whereas, a research on nine types of soil had been carried out. In addition to study in the laboratory also showed using the equation (3), related the effect of compaction energy on maximum dry unit weight and optimum water content versus the logarithm of compaction energy. So, there is a linear relationship between the optimal dry unit weight and the general logarithm of compaction energy (log E) from equation (2). This verification is the result of the tests based on the observed behaviours of well-graded micaceous silty sand.

$$\gamma d_{max} = [3 - 1.23 \log(\%clay)] \log E + 5.27 \log(\%clay) + 10.59 \quad (3)$$

Other researchers stated that compaction can increase shear strength, reduce voids ratio thereby reducing permeability and porosity, reducing volume changes and swelling-shrinkage. The results of

the study found a change in the influence of the void ratio for the modified modifier test as high as 1.69. This is smaller than the void ratio of the Standard Proctor test, 1.85 at the same moisture content. This experiment was using compaction energy for the Standard Proctor is 594.8 KJ/m^3. While the energy compaction for Modified Proctor is 2698 kJ/m^3 [14].

Vinoid and others [16] researched the effect of compaction energy of soil with the bearing capacity of the soil (California Bearing Ratio, CBR Value). The results of the study state that when compaction energy can increase from 237 kJ/m^3 to 1197 kJ/m^3, CBR increase from 1% to 10.2%. The reason for the rise in CBR is like UCS of soil. Higher compaction energy reduces OMC, which results in flocculated soil structure with stronger inter-particle bonding so that it obtains a higher value of CBR. That compacting soils at the dry side of optimum reduce the permeability of the soil, resulting in a decrease in the swell potential of soil. It means that soil compaction energy very much needed in the process of building

Conclusions

This paper summarizes the result of laboratory analyses on all tests conducted. The first test was modelling of Modification Compression Strength Test Machine with Control System on Energy of Compactor. The result modelling the compaction method was using hydraulic jack as pressure and converted it into a very successful working tool. The models that best explain variability include compaction energy, moisture content, Atterberg limits, material passing not more than 200 sieve, and maximum dry density. The results showed that compaction energy was the main factor in determining the strength and stiffness parameters of the soil. Therefore, compaction work becomes an essential consideration during the planning stages of earthwork construction operation.

Acknowledgments

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CERTIFICATE

NO : 1537.10.414.08.19

This is to certify that :

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