Analysis of Soil Compaction using Proctor Standards in Highway Construction Design

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Abstract. Soil is an essential structural material since it must be able to support the load applied, which is why soil must have sufficient bearing ability. The dry density affects the strength and deformation parameters. To achieve stable soil and meet the technological specifications for building a foundation, good embankment conditions necessitate compaction. In this analysis, the updated proctor method was compared to the soil compaction energy proctor test method. Compaction energy is a crucial factor in assessing the soil's intensity, and it must be taken into account during the planning stage. The laboratory's Standard Proctor density was 1.63 gr/cm3, and the modified proctor density was 2.18 gr/cm3, according to the findings of this report. The outcome of the soil density sand cone test indicates that the degree of soil density is 97.31 percent for the standard proctor test process, indicating that the soil density has been achieved and the soil embankment should be used, but as applied to the soil density in the laboratory by standard proctor test, the degree of soil density is 73.54 percent lower.

1. Introduction

Soil is a very important material for the construction of buildings, roads, as well as dams as support and distribution of the foundation load from the construction of buildings that are above ground level. Whereat the time a job will be carried out In construction, the soil must have sufficient soil bearing capacity and exceed the overall capacity load of the building construction which is transmitted to the foundation [1].

Soil compaction is one of the mechanical efforts to bring the soil grains together, the soil volume will decrease along with the decrease in pore volume. However, the grain volume did not change [2]. Compaction can be done by grinding or grinding in soil compaction is often considered by many engineers in designing construction work. Dry soil density and moisture content in the soil can be controlled within certain limits, to reveal soil properties there are important points (density, CBR, consolidation, permeability, shear strength, etc.). Soil compaction plays an important role in the construction of structures, roads, airports, and other constructions. For different soil compaction is one of several other important factors affecting soil compaction. Proctor (1933), stated the relationship between soil density and water content in the soil in a graph [3]-[5].
Figure 1. The relations between density (Yd) and water content (Yw)

Experiments in the laboratory that are often carried out to get the maximum dry volume weight and optimum moisture content are the Proctor Compaction Test [6],[7]. Compaction test methods in the proctor compaction test are the standard proctor test and modified proctor test. This research was conducted [8]-[10]. To compare the results of compaction testing in the laboratory with the standard proctor test and modified proctor test methods, which are then compared with the results of compaction in the field using the sand cone test [11],[12]. In soil compaction with a certain compaction force will produce a certain density as well. The best moisture content to produce high density is called Optimum Moisture Content = OMC = Wopt. The greatest density is also called Maximum Dry Density = MDD.

Table 1. Shows the size limitations for soil types that have been developed by several organizations that are experts in their fields

| Name of organization | Gravel (mm) | Sand (mm) | Silt (mm) | Clay (mm) |
|-----------------------|------------|-----------|-----------|-----------|
| Massachusetts Institute of Technology (MIT) | >2 | 2 to 0.06 | 0.06 to 0.002 | <0.002 |
| U.S. Department of Agriculture (USDA) | >2 | 2 to 0.05 | 0.05 to 0.002 | <0.002 |
| American Association of State Highway and Transportation Officials (AASHTO) | 76.2 to 2 | 2 to 0.075 | 0.075 to 0.002 | <0.002 |

Unified Soil Classification System (U.S. Army Corps of Engineers, U.S. Bureau of Reclamation)

Figure 2. Land Class Size Limits
2. Method and Material

Soil compaction was carried out to find the optimum moisture content and maximum dry weight. This study used soil samples that passed sieve no. 4 and have been oven dry. To get the optimum moisture content (OMC) curve and maximum dry weight (MDD), from the results of soil properties testing, data can be seen in the table.

![Compaction in the laboratory](image)

**Figure 3.** Compaction in the laboratory

**Sand Cone Testing**

From the results of soil density testing in the field using a sand cone, it aims to directly check the soil density in the field. From the soil weight and soil volume, the density/weight volume of the soil will be obtained (γt), then the soil is ovenized and the moisture content (w) is obtained, and the density/volume weight of the dry soil (γd). From field d and soil d, the laboratory test results obtained the degree of density.

![Field testing of sand cones](image)

**Figure 4.** Field testing of sand cones

3. Result and Discussion

From the results of the tests carried out on the standard test proctor test on the soil in Sijantung Village, the maximum dry soil weight value (Maximum Dry Density = γd_max) was obtained at 1.64 gram / cm³, which means it is smaller than the test results; γd_max modified proctor test of 2.18 gr / cm³, or an increase of 32.92% from the density value with the standard proctor test. The maximum moisture content (Wopt) or Optimum Moisture Content (OMC) modified by 13.8% is smaller than the Wopt standard proctor with a moisture content value of 15%, or a decrease of 8%. This is in accordance with the theory which says that the same soil when compacted by standard and modified methods is obtained (Das, 1995):

a) (MDD) γd_max modified > γd_max standard

b) (OMC) W opt modified < W opt Standard
Figure 5. Modified Proctor Compaction Graph Proctor Standard

From the results of soil density testing in the field using a sand cone, the density value of the degree of density is 97.31% in compaction with the standard proctor test, so that the required density has been achieved. It is reached and the soil can be used in stockpiling work, but when compared to the density of the modified proctor test, the density value of 73.54% is 23.77% smaller than the density in the laboratory with a standard proctor.

Table 2. Comparison of compaction results of Standard proctor test with Modified proctor test

| Value compaction               | Standard proctor test | Modified proctor test |
|-------------------------------|-----------------------|-----------------------|
| MDD (gr/cm³)                 | 1.64                  | 2.18                  |
| OMC (%)                       | 15                    | 13.8                  |
| Degree of field density (%)   | 97.31                 | 73.54                 |

Consolidation

This consolidation test aims to determine the speed of settlement or settlement. From the consolidation test in the laboratory, the consolidation coefficient (Cv) is obtained as follows:

Table 3. Calculation results of laboratory consolidation coefficient (Cv)

| Pressure (kg/cm²) | Consolidation coefficient (cm² / minute) |
|-------------------|-----------------------------------------|
| 0.5               | 0.013                                   |
| 1                 | 0.016                                   |
| 2                 | 0.029                                   |
| 4                 | 0.039                                   |

Figure 6. The graph of e log p

Analysis of pressure graph data (P) to pore number (e): From the results of graph 43, the line extension crosses e0 to the right position of point A, so that the land is considered Overconsolidated (OC). On OC soil, according to Hardiyatmo (2012), the soil has experienced pre-consolidation pressure, then in the past the land above it was dismantled and the load was reduced until it reached overburden pressure (Po').
4. Conclusion

From the results of the analysis, the conclusions are obtained from the analysis of the compaction result data with a vibrating plate compacting device with the addition of sand from Klatak as follows:

a) Soil originating from the test with the addition of sand, after the Standard Proctor compacting test is carried out, the maximum density at the addition of 30% Jebrod sand is 1.14 gr / cm3.

b) From the results of the vibrating plate compaction test with the addition of 30% sand, obtained. The highest density / CBR value was in the 8 mills, namely 17.99%.

The results of the property index test showed that the soil moisture content was 17.38%. Soil Density of 2.57%. From the results of the Atterberg limit test for Sijantung Sei Gong - Batam, the Liquid Limit is 41.67%. Plastic limit of 28.25%. and the plasticity index of 13.42%. The results of the Atterberg test. Soil limits in the village of Sijantung, Sei Gong - Batam have a moderate shrinkage rate of 41.18%. The results of the sieve analysis test showed that 69.92% of the soil passed the 200 sieves. Soil samples used in this study based on the AASHTO classification system were classified in groups A-7-5 (clay soil). Clay soils are more plastic in nature and have quite large change properties and the USCS classification of these soils is classified into the CL group (Inorganic clays). If the two soil classifications are compared using the comparison of the unified soil classification with AASHTO, the land has similarities in its classification.

The soil density of the standard proctor test and modified proctor test in the laboratory is 1.64 gram / cm3 and 2.28 gram / cm3, with OMC values of 15% and 13.8%. The degree of density obtained from the results of testing in the field using the Sand Cone tool obtained the value of the standard density degree of the proctor, namely 97.31% (the degree of density eligible because the value is> 95%) and the value of the modified proctor degree of density is 73.54% (does not meet the standard because it is <95%). If from the results of compaction testing in the field, the landfill has met the requirements for subgrade planning and road foundations, but if the landfill is a landfill for basic dam planning which usually uses a modified proctor test, then the compaction results still do not meet the standard. The greater compaction energy results in a higher density value. For further research, the following suggestions can be given:

a) Can be searched by adding compacting load.

b) With the addition of a sand mixture above 30%.

c) Compaction testing can be done with different tools such as stamper, stoom wall, etc.

d) You can find a comparison test method with sandcone and rubber ballon.

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