Influence of Coconut Shell Ash and Lime Towards CBR Value and Subgrade Bearing Capacity

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Abstract. In North Toraja district, there are many roads built on soft soil which have low carrying capacity. To get a high bearing capacity of soil, it can be done by adding chemicals (chemical stability). One of them is the addition of coconut shell ash and lime which are often found in North Toraja. The purpose of this study was to determine the CBR value and the value bearing capacity of soil with the addition of coconut shell ash and lime which is used as a soft soil stabilizer. The method used in this research is the experimental method in laboratory. Soft soil samples were taken from Bori Village, Sesean District, North Toraja Regency, South Sulawesi. With the addition of a mixture of coconut shell ash 0%, 3%, 6%, and 9%, while for the lime mixture content of 2%. Based on the results of the study, it shows that soft soil stabilized with coconut shell ash and lime can increase the CBR value and soil bearing capacity. In soil without stabilized (native soil mixture), the CBR value was 6.47% and soil bearing capacity was 39.62%. For a mixture of 3% shell ash and 2% lime, the CBR value was 13.13% and the soil bearing capacity value was 49.21%. For a mixture of 6% shell ash and 2% lime, the CBR value was 31.32% and the soil bearing capacity value was 60%. For a mixture of 9% shell ash and 2% lime, the maximum value is 35.50% and the soil bearing capacity value is 61.45%.

INTRODUCTION

Land is an inseparable part of the planning of civil engineering buildings. Land has an important role because all civil buildings are above the ground. Soil has different specifications of each type, so it requires different handling both mechanically and chemically. This treatment cannot be separated because it is closely related to one another. If the handling is not done properly, there will be structural damage to civil buildings caused by soil reactions both mechanically and chemically (Febriani, 2013). Soil improvement can be done by stabilizing the soil.

Soil stabilization or soil improvement known in geotechnical engineering is generally divided into three categories, namely mechanical means, chemical methods, and physical methods. The mechanical method is based on mechanical measures, such as compacting and consolidation. Through the most commonly used method, soil density will increase, soil compressibility decreases, which is then followed by an increase in bearing capacity and soil stability. In a chemical method, an additive in the form of binders (water hyacinth fiber and water glass) is mixed in the soil which then changes the properties and strength of the soil. Whereas in the physical way, a reinforcing material such as geotextile is inserted or arranged in the soil layer to strengthen the soil.

Various alternatives can be made in an effort to increase the carrying capacity of the soil. One of them is by using coconut shells as ash, lime and water glass.

Shell, which has a percentage of 12% by weight of coconut fruit, is a by-product of coconut processing (Grimwood, 1975) which has been widely used as a raw material for activated charcoal and fuel in food companies.

According to Djafar (1996) in Lay and Novarianto (2006) the composition of coconut shell consists of 10.43%, 8.94% ash, 27.39% lignin, 51.55% cellulose and 0.85% protein. The method that can be done to get coconut shell charcoal is by burning the shell charcoal which can be used as organic fertilizer because it contains P, K and other elements (Menon and Pandalai, 1958).

According to Zulfa Hadiiyah (2014), the use of coconut has not been optimal, it is only limited to coconut shells, it is burned and even thrown away. Given its availability, easy access and low selling value, it encourages to optimize the value of the coconut shell. In addition, the content of lignin, cellulose and organic compounds contained in coconut shells provides a fairly good heating calorific value. Thus, coconut shell ash is very suitable for clay stabilization. The variation of the mixture used is 0%, 3%, and 6%, on the weight of the soil contents.

Previous research conducted by Karaseran (2015) using shell charcoal as a stabilizing agent for expansive clay, shell charcoal can improve water and air circulation, as a medium that can bind carbon, and can reduce swelling in the soil because it reduces the soil plastic index. This is the background of the use of shell charcoal as a stabilizing agent with a percentage of 0%, 5% and 10% of the weight of the soil.

According to Ingles and Metcalf, 1972, in soft soil stabilization work using lime, the time between mixing and compaction is 24 hours, this is due to the cementation process that occurs between lime and water, this results in the need for a long time. In lime clay stabilization work in the field, sometimes there are work delays resulting in the time between mixing and compaction of more than 24 hours. The previous research related to this research is as follows:

According to Putra Andrean A. (2016) who examines: "The Effect of Curing Time Variation on Free Compressive Strength Value in Clay and Silt Stabilized Using Lime in Soaking Conditions" following the results of the study

1. From the results of the modified proctor compaction test, the addition of a mixture of lime to clay and silt soil is proven to increase the maximum volume weight (γd) value continuously from 5%, 10%, to 15% lime content and curing duration of 7 days, 14 days. , up to 28 days.
2. The free compressive strength test was carried out on clay and silt soils which were added with lime, 5%, 10%, and 15% respectively, then ripened with variations of curing time of 7 days, 14 days, and 28 days respectively. After curing, the soil samples were soaked for 4 days (soaked) before being tested.
3. From the results of the free compressive strength test carried out in the laboratory, it can be seen that the free compressive strength value increases and decreases with each addition of the lime mixture, but the tendency is to increase. In clay soils, the value of free compressive strength (qu) tends to increase from 5%, 10%, to 15% lime content. In the 5% lime clay sample, the 14-day curing obtained the greatest qu value compared to 7 and 28 days of curing. Then on clay soil with lime 10% and 15%, the longer the curing time variation, the better the compressive strength results. Clay samples + 15% lime with curing time of 28 days obtained the greatest (qu) free compressive strength (qu) of other clay samples, namely 0.3636 kg/cm^2.
4. From the results of the silt free compressive strength test, samples with 5% lime do not show a significant increase in the value of free compressive strength (qu) in each variation of the curing time. However, in samples with 10% and 15% lime, a significant increase in value (qu) was obtained. Samples mixed with 10% lime have shown a good qu value starting from 7 days of curing and continued to increase at 14 days and 28 days of curing. In samples with 15% lime, the increase was seen after 14 and 28 days of curing. Silt soil samples with 15% lime with 28 days of ripening obtained the greatest value of free compressive strength (qu).
5. From the test for the free compressive strength of clay and silt, it can be concluded that the curing time has an effect on the free compressive strength of the lime-capable soil, the longer the curing time, the more the value of free compressive strength (qu) increases. This is because the cementation process that occurs between lime and soil takes quite a long time. Lime shows a better effect on loam soils than silt soils, although the difference is not very significant.

According to Muhamad Fadhilah Derajat (2019) who researched on "The Effect of Curing Against Stabilization of Clay Soil with Tohor Lime as the Soil Layer of the Mariat Pantai Road" stated the results of his research, namely;

1. For testing the physical properties of the original Mariat Pantai soil obtained the water content value of 19%, specific gravity of 2.49 g/cm^3, Passing the 200 filter is 78.04%, the liquid limit is 54.99%, the plastic limit is 28.09%, and the plasticity index of 26.90%. In addition, the soil in this area is also included in the A-7-6 clay type, namely moderate to poor clay according to the AASHTO and according to the USCS is included in the CH category, namely inorganic clay soils with high plasticity.
2. The physical properties of the soil in the Mariat Pantai area have changed after soil stabilization with quicklime is seen from the liquid limit of 6% = 49.24%, 8% = 48.11%, 10% = 47.39%, 12 % = 44.29%, 15% = 44.68% with an average reduction effect of 2.68%, plastic limit 6% = 23.67, 8% = 23.45%, 10% = 22.98% , 12% = 21.58%, 15% = 20.34% with an average reduction effect of 1.55%, plasticity index 6% = 25.57%, 8% = 24.66%, 10% = 24 , 41%, 12% = 22.71%, 15% = 24.34% with an average decrease effect of 1.05%. While the density that has increased from the original soil is 6% = 2.62 g/cm^3 8% = 2.67 g/cm^3, 10% = 2.73 g/cm^3, 12% = 2.64 g/cm^3, 15 % = 2.61 g/cm^3 with an average effect of an increase of 0.08 g/cm^3.

3. From the CBR test results, the original soil CBR value was 53.72%. After mixing quicklime using curing time, CBR has increased with the highest CBR value at the percentage of lime content of 8%, namely 63.39%.
4. In contrast to the results of previous researchers who obtained CBR values with the method without ripening with the highest CBR value increase at 6% lime content with a value of 48.41% from the original soil CBR value of 46.48%.

In this research of the use of lime as a stabilizer with a percentage of 0%, 4% and 7% of the weight of the soil.

MATERIALS AND METHOD

Soil

Soil samples used in this study were land taken in the vicinity of Bori 'sub-district, Sesean sub-district, North Toraja Regency. Then the research was carried out in the civil engineering laboratory of the Indonesian Christian University Toraja which is on campus II UKI Toraja. Table 1 shows the physical characteristics of soil.

TABLE 1. Physical characteristics of soil

No.	Characteristics	Result of inspection
1	Spesific gravity	2.49 gr/cm^3
2	Water content	23.5%
3	Liquid limit	35.58 %
4	Plastic limit	27.68%
5	Plasticy index	7.43%
6	Sieve analysis	A-2-4
7	Dry content weight	1.38 gr/cm^3
8	California bearing ratio	6.47%

The sieve analysis test is intended to determine the grain size distribution and grain composition (gradation) of the soil, which aims to classify it based on the uniformity coefficient (Cu) value and grain size distribution curve. Figure 1 shows the sieve analysis of soil. Based on the results of the sieve analysis test, it can be seen that D10, D30 and D60 are 0.079 mm, 0.20 mm and 0.54 mm, respectively. The resulting uniformity coefficient (Cu) was 6.835 and the gradient coefficient (Cc) was 0.9376.

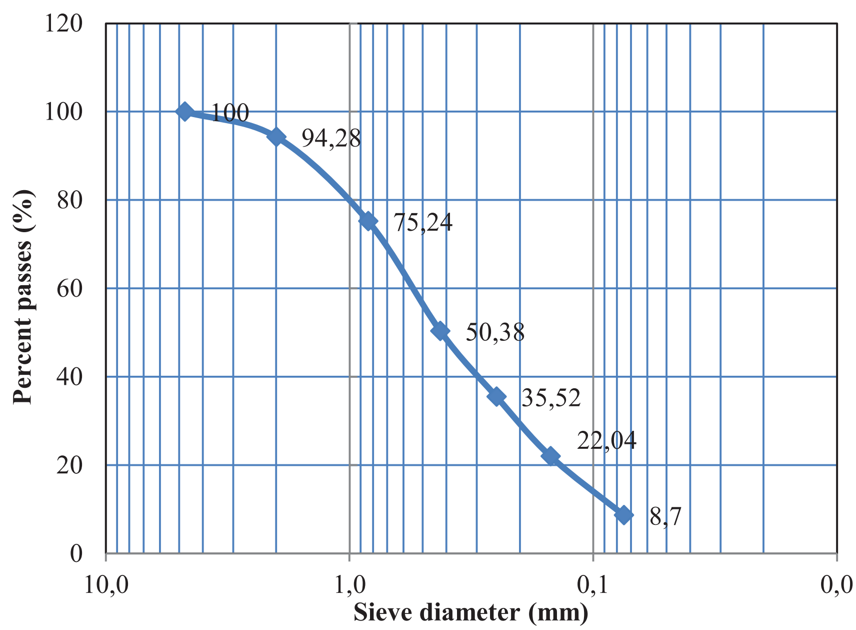

FIGURE 1. Sieve analysis of soil

Soil compaction testing is carried out to find the soil water content after it is compacted; this test is intended to determine the relationship between water content and soil density. In this compaction test, it is used for the manufacture of soil mixture specimens according to SNI 1743: 2008 weight density test for soil, by entering the soil into a compaction mold, with a diameter of 152.40 and a mold height of 116.43, then pounding it with a pounder that has a crushing load 4.5 kg (10lbs) with a fall height of 457 mm. Figure 2 shows the compaction test of soil.

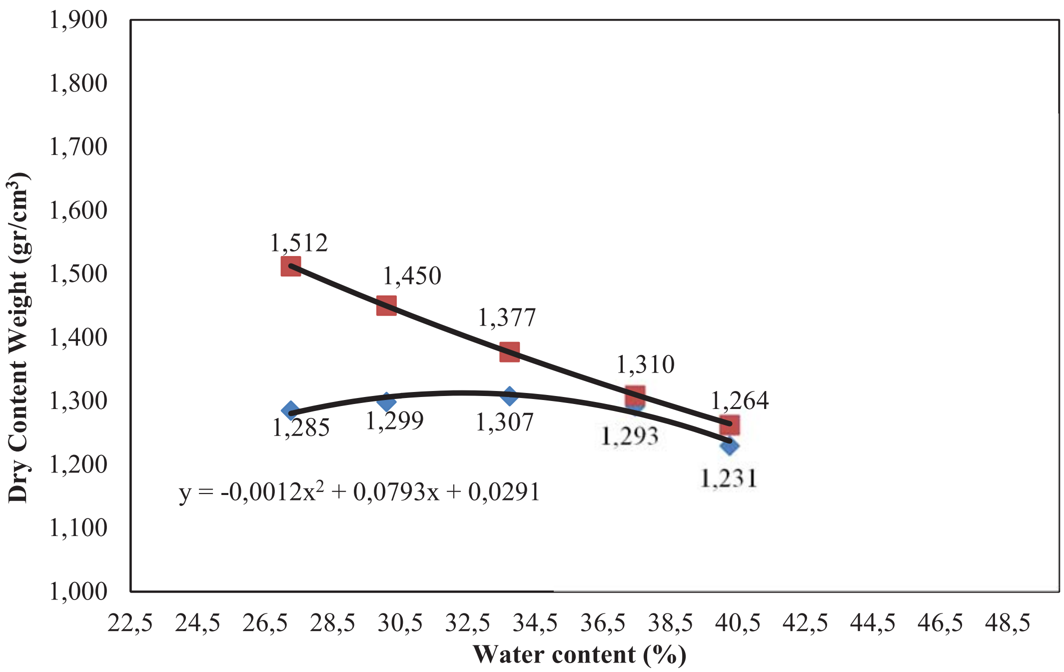

FIGURE 2. Compaction of soil

Based on Figure 2, it is found that the optimum water content is 23.60% with a maximum dry weight of 1.3902 gr/cm^3 where the optimum moisture content and maximum dry weight are used to prepare samples for compressive strength, CBR and other test samples that must be compacted at the optimum moisture content. The laboratory CBR (California Bearing Ratio) test referred to in this modification proctor is the determination of the CBR value of soil material samples, aggregates or a mixture of soil and aggregates compacted in the laboratory at the specified water content. Figure 3 shows the CBR test value of soil.

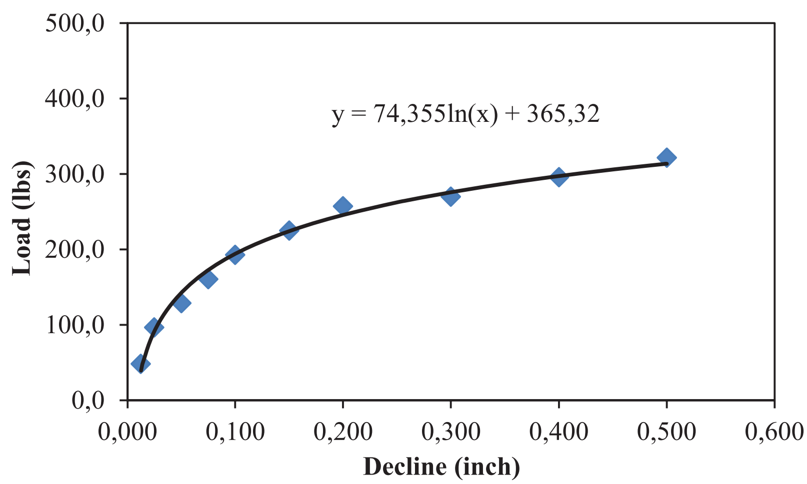

FIGURE 3. CBR test of soil

Coconut Shell Ash

Coconut Shell ash which has a percentage of 12% by weight of coconut fruit, is a by-product of coconut fruit processing (Grimwood, 1975) which has been widely used as raw material for activated charcoal and fuel in food companies. According to Djafar (1996) in Lay and Novarianto (2006) the composition of coconut shell consists of 10.43%, 8.94% ash, 27.39% lignin, 51.55% cellulose and 0.85% protein.

Lime

Table 2 shows the physical characteristics of calcium oxide (CaO).

TABLE 5. Physical characteristics of calcium oxide (CaO)

No.	Kind of testing	Testing result
1	Spesific gravity	2.70
2	Sieve analysis	> 30% pass sieve No. 200

Making Specimen

The making of the test object is carried out for tests in accordance with the research carried out in the laboratory. The amount and variety depends on the type of research. For a mixture of coconut shell ash that passed sieve No. 50 with the percentages: 0%, 3%, 6%, and 9% for the percentage of lime 2% of the dry weight of the soil.

RESULTS AND DISCUSSION

Compaction Testing and CBR With The Addition of 3% Coconut Shell Ash and 2% Lime

Figure 4 shows the result of compaction testing of soil with the addition of 3% coconut shell ash and 2% lime.

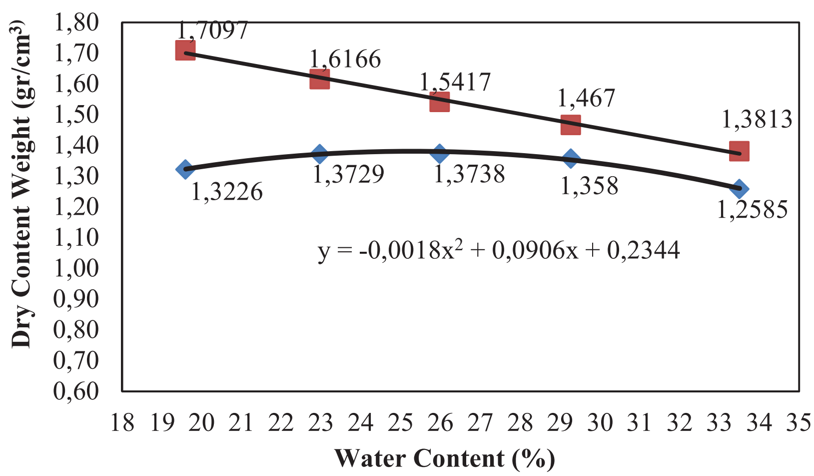

FIGURE 4. Compaction test result of soil with the addition of 3% coconut shell ash and 2% lime

It can be seen in Figure 4 that the compaction test value decreases with increasing water content. According to Rollings and Rollings (1996) this is because lime provides abundant calcium ions (Ca^{2+} and Mg^{2+} ions). These ionic ions tend to replace cations in general and result in a flocculation process where small particles of soil will gather and coagulate to form larger particles so that they will increase their strength and stress-deformation properties. Pozzolanic reactions also take part in forming a variety of cementation-forming materials where this reaction depends on time and temperature. The ultimate strength of the mixture takes place gradually where the process will occur faster at high temperature conditions. Figure 5 shows the CBR test result of soil with the addition of 3% coconut shell ash and 2% lime.

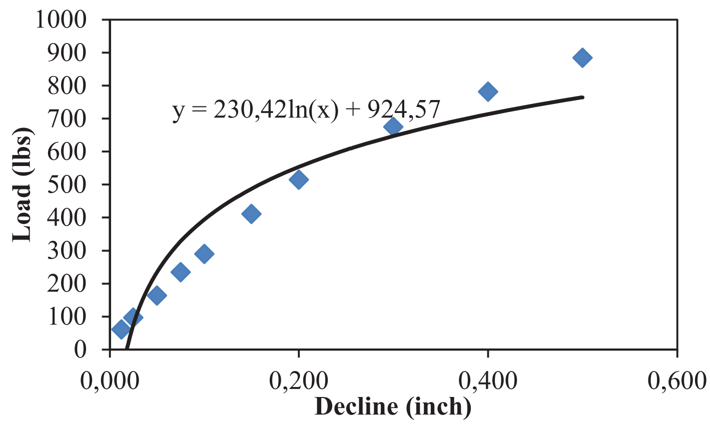

FIGURE 5. CBR test result of soil with the addition of 3% coconut shell ash and 2% lime

It can be seen in Figure 5 that the load gets bigger along with the increasing decrease given. According to book 1 Road Foundation Work (General) of the Directorate General of Highways of 2006, article 6.6.3, that because oxides react quickly with water to form hydroxides, the main reactions of all types of lime with stabilized materials are the same. The increase in strength in the long term (pozolanic reaction) takes place in a high alkaline environment (pH> 12.3) resulting in the breakdown of clay, especially at the ends of the clay plates (particles) and allows the formation of calcium silicate and aluminate in the area. This process is relatively slow, because the existing lime has to spread through the matrix of materials and cementitious materials that were originally formed. The stabilization reaction cannot take place continue, because there is clay or some pozolanic material in the pavement material which will react with the lime. The cementation material has the same composition as that of the cement paste. Article 6.6.4.3 states that in the stabilization of lime, the addition of lime will increase the optimum moisture content, due to the fine grained nature of quenched lime. This effect was exacerbated by the delay in compaction after the addition of lime content.

Compaction Testing and CBR With The Addition of 6% Coconut Shell Ash and 2% Lime

Figure 6 shows the result of compaction testing of soil with the addition of 3% coconut shell ash and 2% lime.

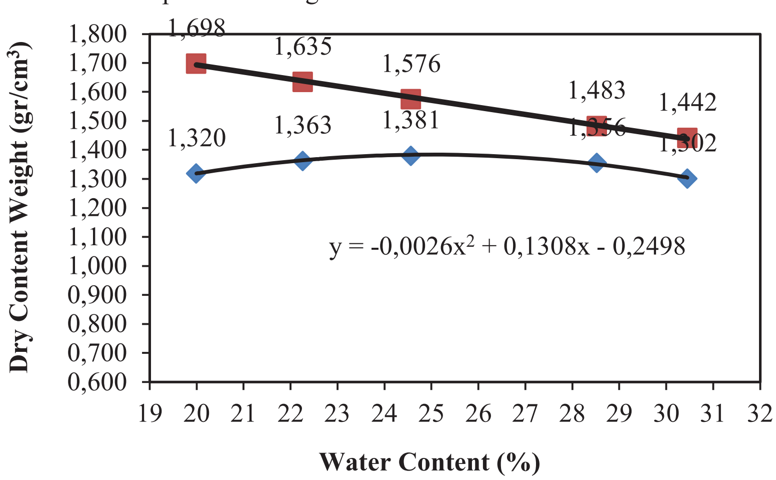

FIGURE 6. Compaction test result of soil with the addition of 6% coconut shell ash and 2% lime

Based on the maximum compressive strength value of the laterite soil mixture against grain gradations, the best mixture was obtained with the largest maximum compressive strength value but with the least lime content, namely the mixture of laterite soil and limestone which passed the # 40 filter as much as 5%. This means that the maximum value of the maximum compressive strength can be achieved if the size of the $CaCO_3$ grains is not too large (coarse) and not too small (fine). This is due to the mutual support or complementarity between the finer laterite soil particles and $CaCO_3$ particles. The criteria for the strength of soil stabilization with lime must be in accordance with the compressive strength value for the top foundation layer based on the book 7 Road Foundation Work (Lime Soil Foundation) Dirjen Bina Marga 2006 is 2.2 MPa so that for all gradations of limestone grains ($CaCO_3$) does not meet the specifications required by book 7 of the Director General of Highways. Therefore, limestone ($CaCO_3$) does not have a good binding ability so quenched lime ($CaOH_2$) is used to compare the compressive strength values. Figure 7 shows the CBR test result of soil with the addition of 6% coconut shell ash and 2% lime.

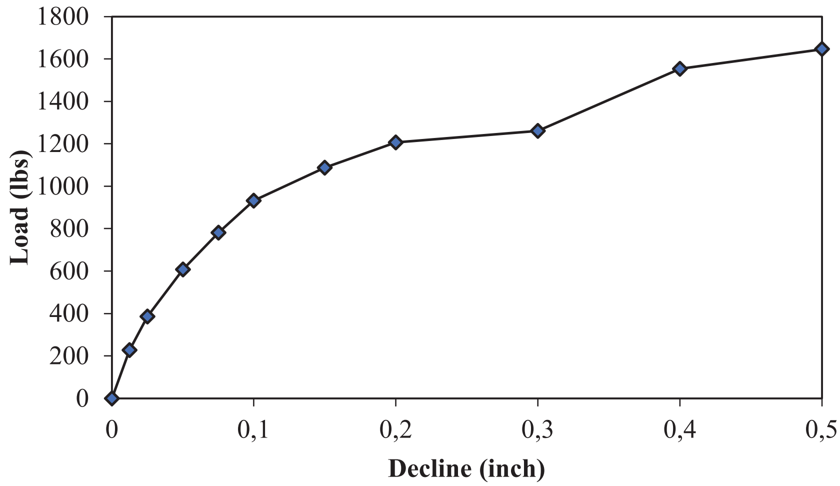

FIGURE 7. CBR test result of soil with the addition of 6% coconut shell ash and 2% lime

The criteria for soil stabilization strength with lime must be in accordance with the compressive strength value for the top foundation layer based on the book 7 Road Foundation Work (Lime Soil Foundation) Dirjen Bina Marga 2006 is 2.2 MPa so that all the variations of the above mixture do not meet the required specifications. So that it is necessary to add other materials to increase the compressive strength as required. From the results of the comparison of mixing soil with 2 types of lime material, it is found that in terms of reducing the liquid limit and plasticity index, mixing laterites soil material with $CaCO_3$ and $Ca(OH)_2$ can be used but better results are shown by mixing the soil material with $CaCO_3$, but for the compressive strength test, $Ca(OH)_2$ gives better results. Based on the above considerations and also considering the mineral content of Ca in lime, a mixture of lateritic + $Ca(OH)_2$ soil was chosen as a mixture which would be further investigated by adding another stabilizing material, namely Portland cement.

CONCLUSIONS

Based on the results of research conducted at the Laboratory of the Christian University of Indonesia Toraja, it can be concluded based on the problem formulation that the effect of using coconut shell ash and lime on the CBR (California Bearing Ratio) value of the modified proctor and soil bearing capacity has increased. The CBR value of soil without mixture (native soil) has a maximum value of 6.47% and a soil bearing capacity of 5.3%. For the CBR value with a mixture of 3% shell ash and 2% lime, the maximum value is 13.13% and the soil bearing capacity value is 6.5%. For CBR values with a mixture of 6% shell ash and 2% lime, the maximum value is 31.32% and the carrying capacity value soil is 8.1%. For CBR values with a mixture of 9% shell ash and 2% lime, the maximum value is 35.50% and the soil bearing capacity value is 8.3% so a mixture of coconut shell ash and lime can increase the CBR value and can increase the value of the soil bearing capacity.

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