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Utilization of Sengon Wood Ash for Soil Stabilization and Its Impact on Unsoaked CBR Value

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ABSTRACT
Soil is one of the critical factors influencing construction robustness. The land situated in Cibingbin Village, Cibaliung District, Pandeglang Regency, falls under the category of soil with low bearing capacity. Therefore, the soil in this area requires stabilization to enhance its load-bearing capacity. The field's CBR value, determined through DCP testing, was found to be 2.67%. The target CBR value for subgrade suitability is 6%, indicating the necessity for soil stabilization at this location. This study aims to assess the physical characteristics of the native soil and its CBR value after stabilization using sengon wood ash. Various percentages of sengon wood ash, namely 4%, 6%, 8%, 10%, and 12%, were utilized with curing periods of 0 and 3 days. Soil classification was performed using the USCS method, and the CBR test conducted was the unsoaked CBR test. The results revealed that the addition of 4% sengon wood ash, with a 3-day curing period, yielded an optimum CBR value of 7%. Sengon wood waste ash proved effective in increasing the CBR value. Furthermore, the use of sengon wood ash did not significantly reduce the plasticity index (PI) value. After stabilization with sengon wood ash, the PI value remained at 35.685%, categorizing it as highly plastic. Additional research is recommended to address the limitations of sengon wood ash and achieve a significant reduction in the PI value to meet the subgrade criteria

Keywords: Sengon wood ash, CBR, stabilization, subgrade, soil.

Introduction

Expansive clay is soil that has high shrinkage, this soil often causes damage to infrastructure such as bumpy roads, wall cracks, and other types of damage. Soil from Cibingbin Village, Cibaliung District, Pandeglang Regency is an example of expansive clay because the CBR value at this location is 2.67%. Based on the 2017 Binamarga Ministry of PU & PR regulations, land with a CBR designated for subgrade below 6% needs to be stabilized. Stabilization with additives has been carried out with organic additives such as ash left over from burning bamboo leaves and palm ash. Research on stabilization with organic added materials has been carried out by previous research, namely research on stabilization of clay soil using ash left over from burning bamboo leaves on unsoaked compressive strength values [1]and unsoaked CBR values [2]. Soil stabilization using wood ash has been carried out in previous research, either using wood ash alone or with a combination of wood ash and other materials [3]–[10].

The availability of wood saw waste in Pandeglang district is quite large, especially in the Cibaliung area, because in the Cibaliung area there are many wood industries, this is the background for the author to use waste from

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wood saws as an additional material for soil stabilization. Research on the effect of sengon wood ash has been carried out by Herman and Sarumha, the variations of sengon wood ash used were 0%, 3% and 6% of the dry weight of the soil [11]. The research results show that sengon wood ash can improve the physical and mechanical properties of clay soil. This is proven by the liquid limit value, plastic index decreasing, while the plastic limit value, shrinkage limit, soil density and CBR value increase. Optimum conditions are achieved when curing for 1 day with a mixture of 6% sengon wood ash. Replacing cement with 5% wood ash produces excellent performance [12]. Previous research also showed that the addition of wood ash could significantly increase soil strength [13].

In this research, expansive clay soil from Cibingbin Village, Cibaliung District, Pandeglang Regency was stabilized by adding 4%, 6%, 8%, 10% and 12% of the dry weight of the soil with curing times of 0 days and 3 days. The percentage of added substances was taken based on several previous research references, the optimum CBR was obtained at a wood ash variation of 6%. The percentage of wood saw waste ash is the basis for determining variations in added materials in this research. The location of soil sampling is shown in Figure 1.

Figure 1. Location of soil samples

Wood dust waste is quite widely available and easy to find, especially in the Pandeglang district. Wood ash, which is formed as residue from burning biomass, can be applied as a construction material [14].
Efforts to chemically improve soil can be done by adding materials containing silica such as sengon wood ash. In the process of burning sawmill waste, inorganic substances are left behind. The remaining inorganic material is weighed and expressed as ash content. Sengon wood ash contains two main ingredients. If these two chemical elements are mixed and hydrated, a pozzolan reaction called lime-silica cement will be formed, where the pozzolan will later be useful as a substitute for cement in the soil.

Methods

The research consists of several stages shown in Figure 2. The tools and materials used in this research include:
Tools:
1. DCP (Dynamic Cone Penetrometer) Testing
2. Testing of soil physical properties consists of: specific gravity, grain size analysis, Atterberg limits.
3. Proctor standard compaction testing
4. Unsoaked CBR testing
5. Chemical analysis testing, namely XRF testing
Material’s:
1. Disturbed soil samples
2. Sengon wood ash

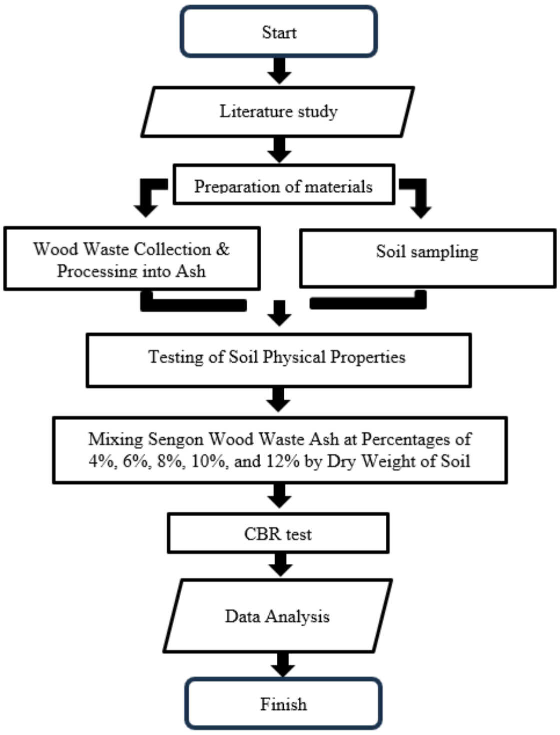

Figure 2. Research Flowchart

The research stages consisted of literature study, material preparation (disturb soil samples and sengon wood ash) and testing in the laboratory. Laboratory testing consists of chemical analysis tests, physical properties tests and mechanical properties tests.

Physical properties testing consists of analysis of grain size, soil specific gravity, water content, plastic limit, liquid limit and compaction (to determine the maximum water content and maximum dry unit weight). The chemical analysis test carried out was an XRF (X-ray fluorescence) test to determine the elemental composition of sengon wood ash. Determination of soil classification uses the USCS method and the CBR test carried out is unsoaked CBR. The test standards in this study are shown in Table 1.

Table 1. Testing standard

No	Testing	Standard
1	Moisture content	SNI 1965:2008
2	Liquid limit	SNI 1967:2008
3	Plastic limit	SNI 1966:2008
4	Sieve analysis	SNI 3423:2008
5	Specific gravity	SNI 1964:2008
6	Compaction	SNI 1742:2008
7	CBR unsoaked	SNI 03-1744-2012

Results and Discussions

Physical Properties of Original Soil

The soil used is disturbed soil, when taking the soil the surface must first be cleaned by digging around 10 cm. Soil from this location was then taken to the laboratory for testing. The soil from the location must be in the oven first for a minimum duration of 24 hours before testing. Oven-dried soil is shown in Figure 1.

Figure 1. Oven Dry Soil

The added material in this research is artificial pozzolan in the form of ash from sengon wood industrial waste. The ash in this study was produced from a regular combustion process without a furnace. The additive materials used in this research are shown in Figure 2.

Figure 2. Sengon wood waste ash

The use of sengon wood waste ash as a volume filler in soil samples. A mixture of soil with sengon wood ash is shown in Figure 3.

Figure 3. Soil mixed with sengon wood ash

Testing of physical and mechanical properties was carried out at the Civil Engineering Laboratory at Sultan Ageng Tirtayasa University. Testing of the physical properties of the original soil consists of water content, specific gravity, bulk density, Atterberg limits and grain size analysis. The results of testing the physical properties of the original soil in this study are shown in Table 2.

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Table 2. Test Results for Physical Properties of Original Soil

No	Properties	Value
1	Moisture content	27,86%
2	Gravity specific	2,701
3	Density	1,418 gr/cm^3
4	Liquid limit	75%
5	Plastic limit	42,57%
6	Plasticity Index	32,43%
7	Particle size analysis (passes through sieve no. 200)	52%

Compaction

Compaction testing refers to SNI (SNI-1742, 2008) [15]. The information obtained from compaction testing in the laboratory is the optimum water content and maximum dry unit weight, these two parameters are used to determine the requirements that must be achieved in soil compaction work in the field. The data obtained from the results of the compaction test in the laboratory are then plotted in a compaction graph with the x-axis being water content and the y-axis being the dry bulk weight, then identifying the maximum dry bulk point and optimum water content. The results of the original soil compaction test are shown in Figure 4.

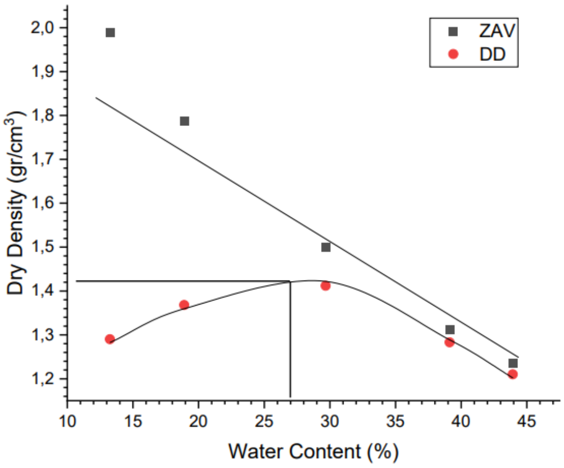

Figure 4. Graph of the relationship between water content and dry unit weight

Based on the graph in Figure 2, the maximum dry unit weight value is 1.425 grams/cm3 and the optimum water content (ω optimum) is 26%.

Dynamic Cone Penetrometer

This test method is a test to evaluate the strength of the subgrade using a Dynamic Cone Penetrometer (DCP). This test method is an alternative for obtaining information on field CBR values. This test provides the strength of the material layer at a depth of 90 cm below the existing surface to the desired reading depth. From the results of DCP testing in Cibingbin village, a CBR value of 3% was obtained.

Soil Classification System

Soil classification in this research uses the USCS (Unified Soil Classification System) method with grain size analysis testing referring to SNI (SNI-3423, 2008)[16] . In this research, the results of the grain size analysis test were obtained, namely the amount of soil that passed sieve no. 200 more than 50% (including fine-grained soil), the liquid limit (LL) value of the soil is more than 50% and the plastic limit (PL) value of the soil is 32.6%.

Table 3. Classification of fine-grained soil according to USCS

UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART		
COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)		
	Clean Gravels (Less than 5% fines)	
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
	GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
	Gravels with fines (More than 12% fines)	
	GM	Silty gravels, gravel-sand-silt mixtures
	GC	Clayey gravels, gravel-sand-clay mixtures
	Clean Sands (Less than 5% fines)	
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	SW	Well-graded sands, gravelly sands, little or no fines
	SP	Poorly graded sands, gravelly sands, little or no fines
	Sands with fines (More than 12% fines)	
	SM	Silty sands, sand-silt mixtures
	SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (50% or more of material is smaller than No. 200 sieve size.)		
SILTS AND CLAYS Liquid limit less than 50%	ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts with slight plasticity
	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
	OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
	CH	Inorganic clays of high plasticity, fat clays
	OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS	PT	Peat and other highly organic soils

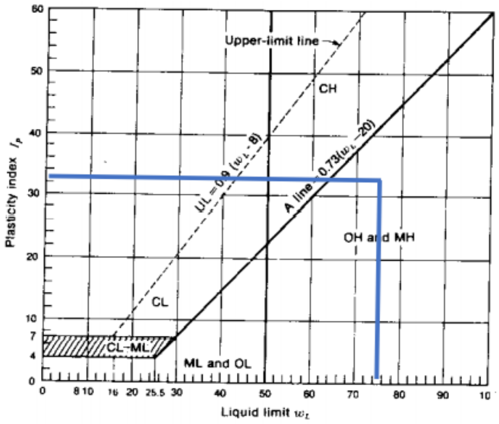

Figure 5. Graph of the relationship between Liquid Limit and Plasticity Index

Based on Table 3 and Figure 5, the results show that the soil on Jalan Kampung Cibingbin, Cibaliung-Pandeglang falls into the OH soil category (organic clay soil with high plasticity).

Characteristics of Wood Powder Ash

The chemical analysis test for wood ash carried out in this research was the XRF (X-Ray Fluorescence) test. This test was carried out in the Physics Department laboratory, FMIPA UNPAD. The XRF test results are shown in Table 4.

Table 4. Characteristics of wood dust ash

Component	Result 1	Result 2	Result 3	Unit	Average
Mg	3.2	3.14	3.16	mass%	3.17
K	16.7	15.2	17.1	mass%	16.3
Ca	71.4	73.6	71.1	mass%	72
Ti	ND	0.0221	0.0232	mass%	0.0226
V	0.0194	ND	ND	mass%	0.0194
Mn	0.494	0.314	0.504	mass%	0.438
Fe	1.17	0.811	1.16	mass%	1.047
Co	0.0099	0.0077	0.0118	mass%	0.0098
Cu	0.018	0.0124	0.0182	mass%	0.0162
Zn	0.0518	0.0366	0.0508	mass%	0.0464
Al	1.16	1.18	1.14	mass%	1.16
Si	2.74	2.82	2.71	mass%	2.76
P	0.943	0.959	0.939	mass%	0.947
S	0.796	0.779	0.783	mass%	0.786
Cl	0.692	0.684	0.685	mass%	0.687
Br	0.0054	0.0035	0.0055	mass%	0.0048
Pb	0.0048	0.0025	0.0049	mass%	0.0041
Zr	0.102	0.0742	0.103	mass%	0.093
Au	0.0029	ND	0.0029	mass%	0.0029
Sn	0.0107	0.0109	0.0109	mass%	0.0108
Ba	0.0518	0.0543	0.0573	mass%	0.0544
Rb	0.031	0.0225	0.0313	mass%	0.0283
Sr	0.373	0.252	0.375	mass%	0.334
Y	ND	0.0062	ND	mass%	0.0062

Table 4 shows that wood ash from burning without a furnace is dominated by Ca (Calcium) at 72 mass %. The Si (Silica) content is 2.76 mass %. Wood ash that is burned without a kiln can produce silica but the value is very small.

Specific gravity

Specific gravity testing refers to SNI (SNI-1964, 2008) [17]. The results of specific gravity testing with a mixture of sengon sengon wood ash are shown in Figure 6.

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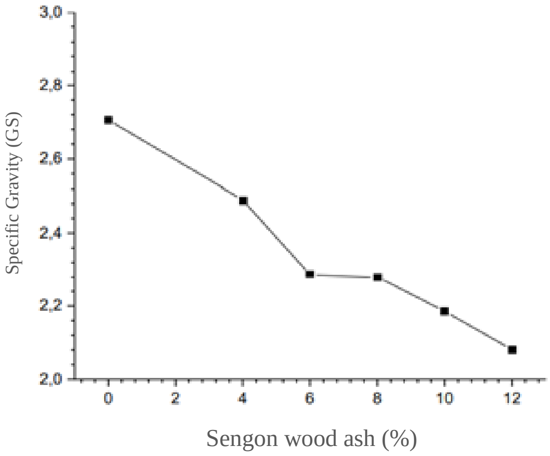

Figure 6. Graph of the relationship between specific gravity and Sengon wood ash

From Figure 6 it can be seen that the specific gravity value continues to decrease as the percentage of sengon wood ash increases.

Liquid Limits

Liquid limit testing refers to SNI (SNI-1967, 2008) [18]. The results of liquid limit testing with a mixture of sengon sengon wood ash are shown in Figure 7.

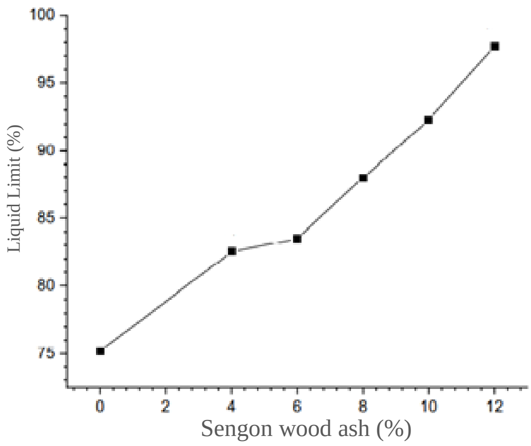

Figure 7. Graph of the relationship between liquid limits and Sengon wood ash

From Figure 7 it can be seen that the liquid limit value continues to increase along with increasing ash content of sengon wood.

Plastic Limit

Plastic bat testing refers to SNI (SNI03-1966, 2008) [19]. The results of the plastic limit test with a mixture of sengon sengon wood ash are shown in Figure 8.

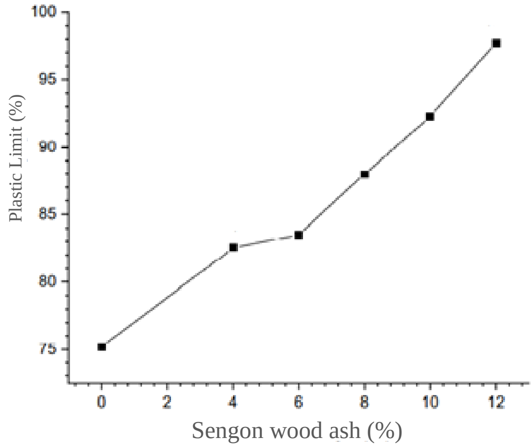

Figure 8. Graph of the relationship between plastic limits and Sengon wood ash

From Figure 8 it can be seen that the plastic limit value continues to increase along with increasing ash content of sengon wood.

Plastic Index

From the liquid limit and plastic limit tests with a mixture of sengon wood ash that have been carried out, we can find out the plasticity index from this research, the results are shown in Figure 9.

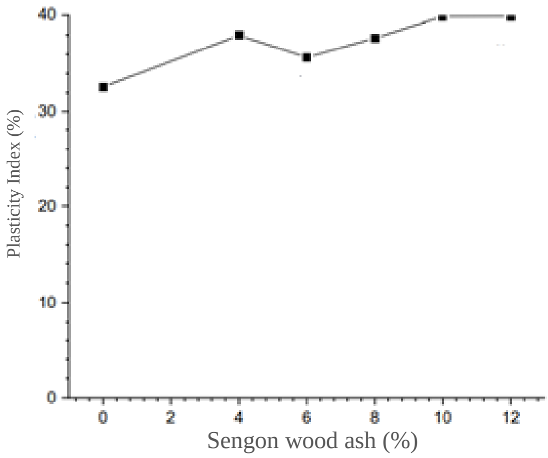

Figure 9. Graph of the Relationship between Plasticity Index and Sengon wood ash

From Figure 9 it can be seen that the plasticity index value fluctuates but tends to increase. This shows that the use of sengon wood ash resulting from burning without a kiln cannot reduce the plasticity index value. The increasing plasticity index value and decreasing specific gravity value due to the low SiO_2 content in the added material make

the pozzolan reaction unable to change the soil texture. Weak bonds are unable to form new, larger and more stable grains which can reduce soil plasticity. Increasing the SiO_2 content or SiO_2 + Al_2O_3 will increase the pozzolan reaction (Lea, 1970).
The plasticity index value falls into the high plasticity category [20] where the plasticity index value required for subgrade is less than 15%. In this study, the addition of sengon wood ash did not reduce the plasticity index value significantly, it could be influenced by the very small SiO_2 content of wood ash in this study, namely 2.71 mass %.

California Bearing Ratio

CBR testing refers to SNI (SNI-1744, 2012) [21]. Each test object with a variety of ingredients added with sengon wood ash was subjected to curing, namely 0 days and 3 days. The variations in additives used were 0%, 4%, 6%, 8%, 10% & 12% with a total sample of 54 because each variation of the mixture was tested three times. In the 0% wood ash variation with 0 days of curing, sample 1 showed a planned CBR value of 4.600%, sample 2 obtained a planned CBR of 4.6% and sample 3 obtained a planned CBR value of 4.3%, so the average planned CBR value with the addition of 0% sengon wood ash, namely 4.50%. The relationship between variations in sawdust ash and CBR values is shown in Figure 10.

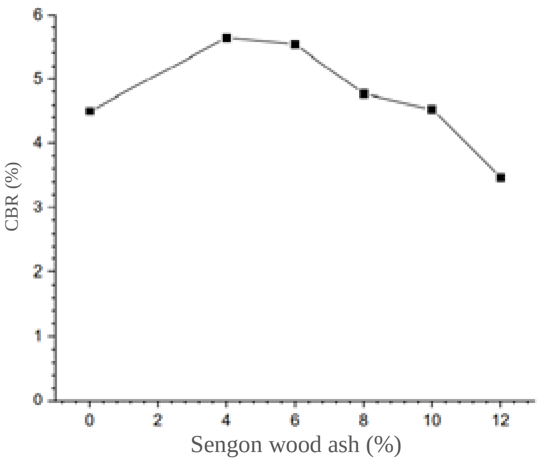

Figure 10. Graph of the relationship between CBR and Sengon wood ash

Based on the graph in Figure 10, it shows the optimum CBR value at 4% variation with a CBR value of 5.633%.
Variations in added materials with 3 days of curing were 0%, 4%, 6%, 8%, 10% & 12%, resulting in soil CBR values of 4.6%, 7%, 6%, 4.8%, 4 respectively. .6% and 3.9%.

From the research results, it can be seen that the CBR test object that was cured had a greater value than the CBR value that was not cured, because when the test object was cured only then did bonding between particles occur and chemical reactions from the added materials into the test object mixture [22]. This did not occur in test objects that were not given curing treatment.

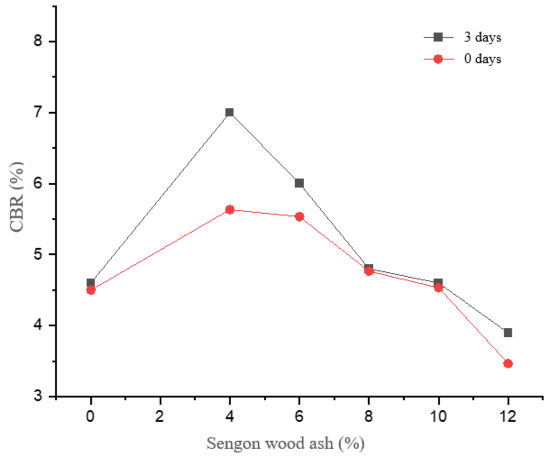

Figure 11. Comparison graph of CBR testing for 0 day curing and 3 day curing

Based on the graph in Figure 11, sengon wood ash influenced the CBR value based on the percentage of addition. The addition of saw waste ash has an effect on increasing the CBR value in the soil. At 0% variation in 0 day and 3 day curing, the CBR values were 4.5% and 4.6% respectively. At 0 days of curing there was an increase in the 4% variation amounting to 5.633%. The addition of sengon wood ash in the following percentages decreased with the addition of 6%, 8%, 10% and 12% of sengon wood ash to obtain CBR values of 5.533%, 4.767%, 4.533% and 3.467% respectively. In 3 days of curing, the percentage increased by 4% and 6% with CBR values of 6% and 7.8% respectively. The addition of sengon wood ash in the following variations decreased with the addition of 8%, 10% and 12% of sengon wood

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ash to obtain soil CBR values of 4.8%, 4.6% and 3.9% respectively.

The increase in the CBR value is due to the pozzolan process that occurs between calcium hydroxide in the soil which reacts with additional silicate (SiO_2) and aluminate (Al_2O_3) materials to form a soil binding material consisting of calcium silicate and aluminate silicate [23]. The reaction of Ca^{2+} ions with silicates and aluminates on the surface of soil particles forms cement paste (hydrated gel) thereby binding the soil particles.

Increasing the SiO_2 content or SiO_2 + Al_2O_3 will increase the pozzolan reaction [24]. The low SiO_2 content in the ash used means that the pozzolanic reaction in the soil cannot provide a strong bond to the granules so that new granules that are larger, stronger and more stable do not form. The decrease occurred due to this variation, the ratio of the amount of sengon wood ash to soil was almost the same because the weight of sengon wood ash was light so that the sengon wood ash grains were more dominant when mixed with soil which caused the bonds between soil grains to decrease and reduce the CBR value.

Conclusions

Based on the results of the research that has been carried out, it can be concluded that the soil classification according to the USCS (Unified Soil Classification System) soil classification system, the soil on the Cibingbin village road, Cibaliung subdistrict, Pandeglang district is categorized as organic clay soil with high plasticity which has the symbol OH with a plasticity index value amounting to 32.595%. With the addition of sengon wood ash at a percentage of 4% and a curing time of 3 days, the CBR value reached an optimum value of 7%, but with variations of 6%, 8%, 10% and 12%, the CBR value decreased. The addition of sengon wood ash can increase the CBR value by 7%, but cannot reduce the plasticity index value significantly. So further research needs to be carried out so that the plasticity index value can be reduced significantly and meet the general criteria for subgrade requirements.

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Author Contributions

All author contributed to the intellectual input and assisted in the preparation of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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