# The Effect of The Addition Steel Slag and Bamboo Leaf Ash on The CBR Unsoaked Value in Subgrade Stabilization

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**ABSTRACT**

This research was conducted to determine the physical and mechanical properties of origin and mixed soil with added steel slag (SS) and bamboo leaf ash (BLA) and to determine soil classification based on the Unified Soil Classification System (USCS) guidelines. This study used a mixture of steel slag and bamboo leaf ash with variations (0% SS ; 0% BLA), (20% SS; 10% BLA), (40% SS; 10% BLA), (60% SS, 10 % BLA), (100% SS; 10% BLA) with a curing time of 0 and 7 days. The mechanical properties test in this study was the unsoaked CBR test. In the USCS soil type classification system at the road location, it is included in the OH group (organic clay with high plasticity) with a plasticity index value of 22.8%, a liquid limit above 50%, which is equal to 64.5% and a DCP (Dynamic Cone Penetrometer) was obtained by 3.0%. The results showed that mixing native soil with added materials increased the CBR value. The optimum soil CBR value is found in the percentage of added material, 100% steel slag, and 10% bamboo leaf ash during seven days of curing with an unsoaked CBR value of 24.9%.



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## 1. INTRODUCTION

Soil is a very important material as the basis for the main needs of the structure, so the soil must have a good carrying capacity value [1]. Based on the survey results, the land in the research location is Jalan Kampung Juhut, Tanjung District, Pandeglang Regency, Banten. It is right in the coral mountain area, and there is a tourist spot called Wisata Kampung Domba Pandeglang, which has potholes, causing vehicle access to be obstructed. The Dynamic Cone Penetrometer (DCP) test shows a soil carrying capacity value of 3.0%; according to the Revision of the Pavement Design Manual (2017) that the effective CBR (California Bearing Ratio) value of subgrade should not be less than 6%, then the soil needs to be stabilized [2]. There are several ways to improve the soil, one of which is the soil stabilization method using additives that aim to get better soil conditions. The location in this study is shown in Figure 1.

**Figure 1. Research location**

In this study, soil stabilization was carried out with the addition of steel slag and bamboo leaf ash. Steel slag is a non-hazardous waste with the largest chemical content CaO of 40-52% [3] , and bamboo leaf ash is charcoal from burning bamboo leaf waste with the second largest calcium carbonate content after rice husk ash. However, the composition of bamboo leaf ash is very high. Depending on the type of bamboo and burning method. The silica content of bamboo leaf ash is 75.90 – 82.86%. The second largest silica content in bamboo leaf ash after rice husk ash is 93.2%. From the extraction of silica from bamboo leaves, 84.53% silica was obtained [4]. Bamboo leaf ash from furnace combustion can produce high silica and increase the unsoaked CBR value [5], [6]. Adding bamboo leaf ash to clay soil can increase the free compressive strength value of the soil at a percentage of 2% bamboo leaf ash but has not been able to reduce the plasticity index value significantly [7]. Bamboo leaf ash affects marshall characteristics in road pavements as a filler [8].

Rahmadya R. R (2014) used a combination of added materials to stabilize the soil, such as steel slag and fly ash. The percentage variation value of the mixture of 5% consists of (3.75% steel slag; 1.25% fly ash), 10% consists of (7.5% steel slag; 2.5% fly ash), and 15% consists of ( 11.25% steel slag; 3.75% fly ash) with a curing time of 1 day, the optimum CBR value of the soil is obtained at a percentage of 10% by adding a mixture of added ingredients of 8.316% [9]. Furthermore, Kusuma et al. (2018), with two added ingredients at a percentage of 0, 5, 10, and 15% waste carbide and a mixture of 20% fly ash with curing time of 0, 4, and 7 days, the optimum soil CBR value is obtained at a percentage of 15% waste carbide and 20% fly ash, with a curing time of 7 days, the soil CBR value of 53.45% is included in the excellent category [10]. Kabdiyono E. A's research (2019) added materials from bamboo leaf ash and lime. The variations used were 5% lime and bamboo leaf ash with variations of 10%, 15%, and 20% by weight of dry soil with a curing time of 4 days, the optimum immersion CBR value increased to 65.18%, and the optimum value produced at the time of addition 20% bamboo leaf ash and 5% lime with four days curing time [11]. Research by Abdalqadir et al. (2020) showed that using a combination of steel slag and limestone could increase geotechnical parameters on expansive soils [12]. From the explanation of the four studies, the authors concluded that the research used a mixture of steel slag and bamboo leaf ash with variations of (0% SS ; 0% BLA), (20% SS; 10% BLA), (40% SS; 10% BLA), (60% SS; 10% BLA), (100% SS; 10% BLA) to the CBR unsoaked value with a curing time of 0 and 7 days.

## 2. METHODS

Based on the sampling method, the soil sample is disturbed soil. The sampling process is by digging the soil surface to a depth of ± 20 cm. Before digging, the soil's surface is cleaned of waste such as roots, humus, and dry and wet waste so that the soil does not mix with the waste. After digging, the soil is put into sacks. There are several conditions for air-dry soil, including soil in natural conditions, air dry, and oven dry. In addition, some soil samples are in the form of large enough chunks that need to be pounded with a rubber mallet.

The added material in the form of steel slag is stored in a special plastic bag. The bamboo leaves are taken from gardens in Pandeglang Regency, Banten. Then, bamboo leaves are burned manually. Steel slag and bamboo leaf ash were filtered using sieve no. 200 before being used as a mixed ingredient. The process of filtering added ingredients is shown in Figure 2.

**Figure 2. Screening of Additives**

Data calculations are adjusted to the applicable SNI provisions for each test as follows:
a. Water content testing(SNI 1965-2008) [13]
b. Liquid imit testing (SNI 1967-2008) [14]
c. Plastic limit testing (SNI 1966-2008) [15]
d. Sieving analysis testing (SNI 3423-2008) [16]
e. Specific gravity testing (SNI 1964-2008) [17]
f. Standar proctor compaction testing (SNI 1742-2008) [18]
g. CBR testing (SNI 1744-2012) [19]

The research flowchart is shown in Figure 3.

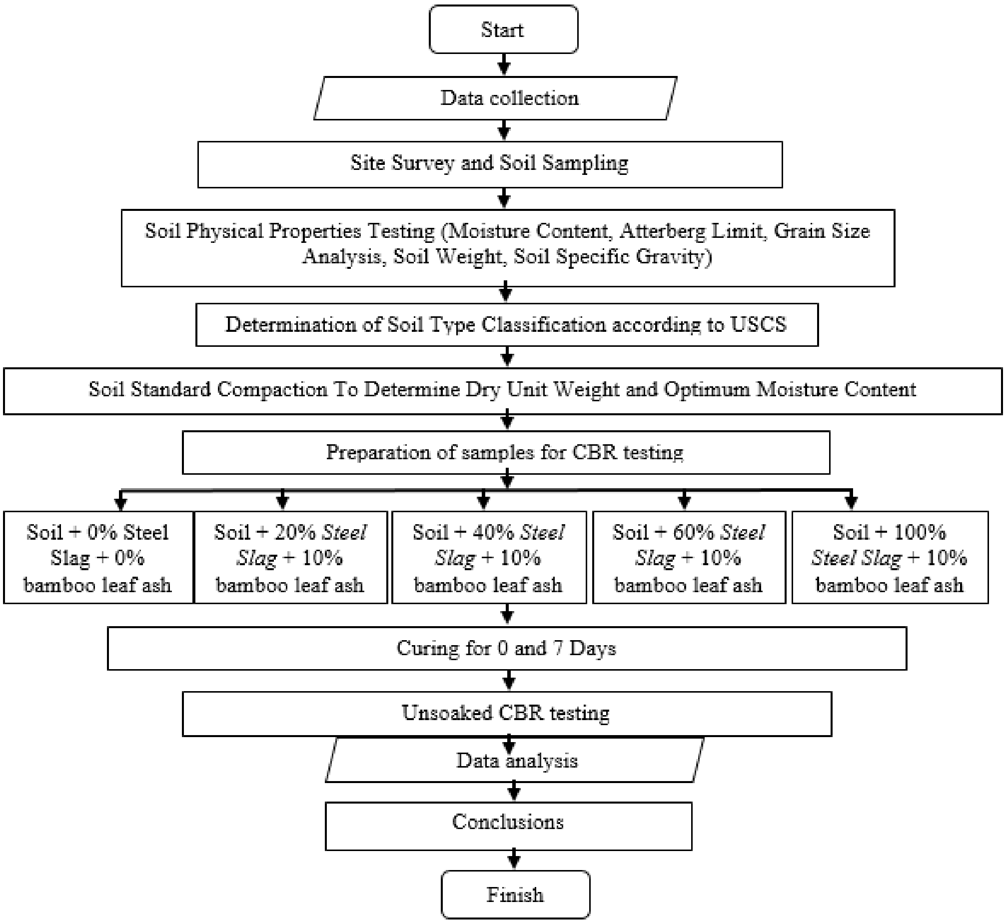


**Figure 3. Research Flowchart**

## 3. RESULTS AND DISCUSSION

### Results of testing the physical properties of the original soil

From the results of testing the physical properties of the original soil, the property data obtained from the physical properties of the original soil are shown in Table 1.

**Table 1. Original Soil Properties Test Results**

| No | Test | Unit | Result |
|---|---|---|---|
| 1 | Grain size analysis | gr | 51.6 |
| 2 | Gravity specific | gr/cm$^3$ | 2.6 |
| 3 | Liquid limit | % | 64.5 |
| 4 | Plastic limit | % | 41.6 |
| 5 | Plasticity index | % | 22.9 |
| 6 | Maximum dry density | gr/cm$^3$ | 1.1 |
| 7 | Optimum water content | % | 34.9 |

Soil classification according to USCS with a native soil plasticity index value of 22.86% indicates that native soil is included in the OH category (organic soil with moderate to high plasticity). Based on the proctor standard compaction test results, the maximum dry unit weight value was 1.1 gr/cm$^3$, and the optimum moisture content was 34.9%.

**CBR unsoaked test results**

Soil CBR test results are the strength value of soil obtained from laboratory tests and directly in the field. The CBR value is used for pavement planning for a road. CBR testing is also carried out on the needs that have been calculated.

The initial step is to the soil that has been dried and then pounded to the size of small grains and then sifted with sieve no. 4. After that, the soil, water, and added materials are prepared according to the needs that have been calculated. Then put the soil on the tray. After that, add the mixture of steel slag and bamboo leaf ash and the calculated distilled water until evenly distributed. Then prepare plastic to put the soil mixture in, bind it, and then ripen for a curing time of 0 and 7 days. When the curing time is over, the soil is removed from the plastic and put into the CBR mold. After it is evenly mixed, put the soil into the mold 1/3 part, then pound it with a pounder on each test object for 10, 30, and 65 collisions (3 test objects) and repeat the process until the mold is full 3/3 parts. Then do penetration testing.

Furthermore, the soil in the mold is removed with a jack. After removing the soil, take the top, middle, and bottom soil samples, then put them in the oven to dry for ± 24 hours. After from the oven then, cool and weigh to determine the moisture content. The results of CBR testing of native and mixed unsoaked soils are shown in Figure 4 and Figure 5.

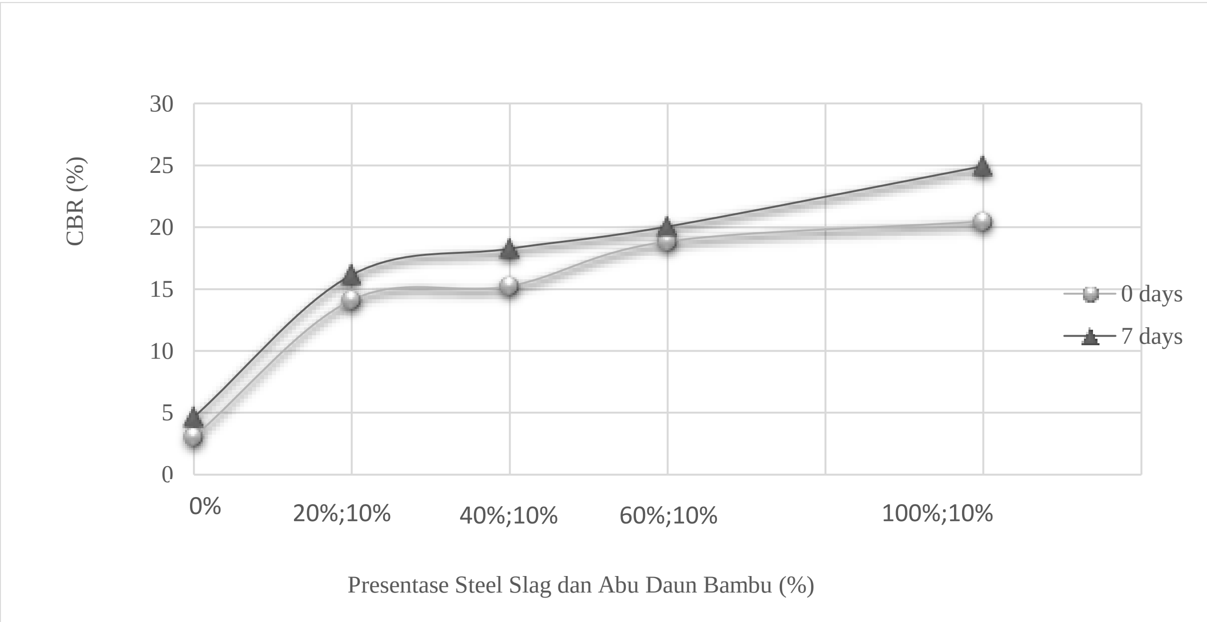


**Figure 4. Graph of the Relationship of CBR Value to the Percentage Variation of Steel Slag Additive and Bamboo Leaf Ash**

Figure 4 shows the addition of steel slag and bamboo leaf ash to produce the optimum CBR value obtained in a variation of 100% steel slag and 10% bamboo leaf ash. Adding steel slag and bamboo leaf ash, which is getting bigger, can significantly increase the soil CBR value because the added steel slag and bamboo leaf ash will fill up the cavities in the soil particles more and more, thus making the soil more solid. The resulting soil makes the added material granules more dominant when mixed with the soil, which causes an increase in the CBR value.

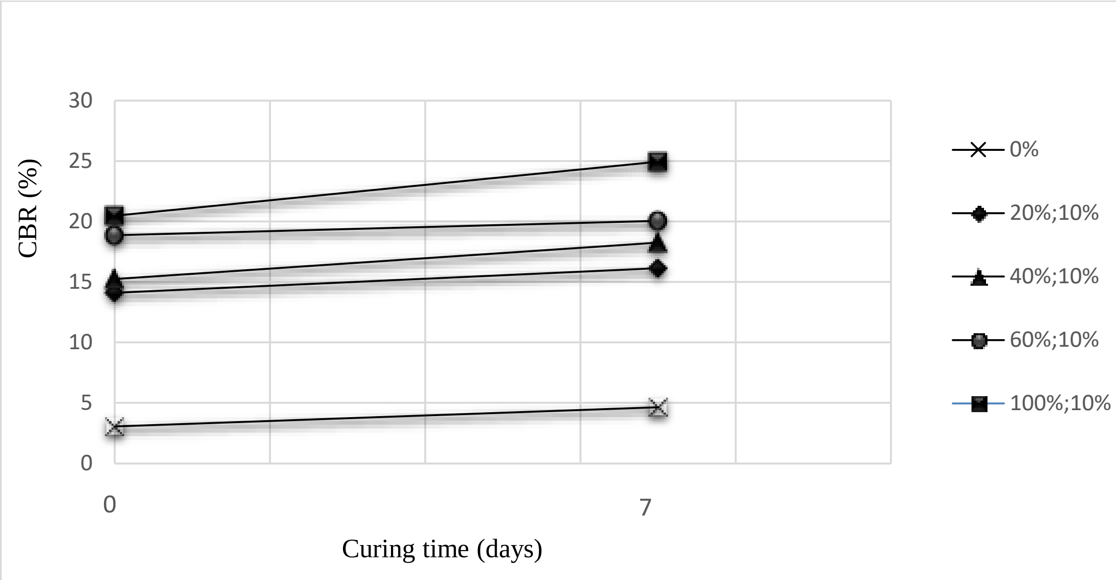


**Figure 5. Graph of the Relationship between CBR Value and Curing Time**

Based on Figure 5 shows a significant increase in the CBR value, where the steel slag, bamboo leaf ash, and soil have different grain diameters so that the longer the curing time can cause the bond between the steel slag and bamboo leaf ash with the soil to be increasingly filled with soil pore cavities by materials. added so that it causes interlocking properties between soil grains due to the nature of the pozzolanic reaction in bamboo leaf ash so that it can increase the CBR value.

**Mixed soil compaction test results**

Mixed soil compaction test with various additions of Steel Slag (SS) and Bamboo Leaf Ash (BLA) (0% SS ; 0% BLA), (20% SS; 10% BLA), (40% SS; 10% BLA) ), (60% SS; 10% BLA), (100% SS; 10% BLA) are shown in Figure 6 and Figure 7.

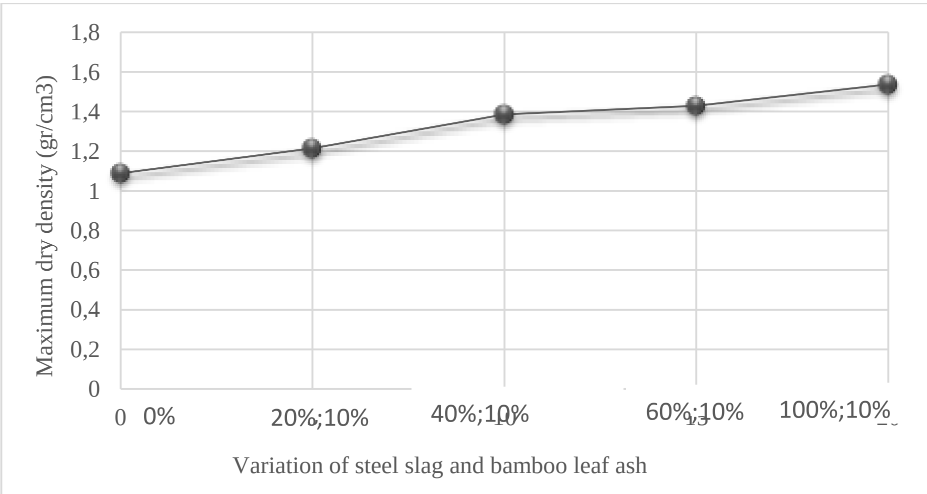


**Figure 6. Graph of Maximum Dry Content Weight with Mix Additive Percentage**

The test results in Figure 6 shows that the percentage of steel slag and bamboo leaf ash in the soil mixture increases. This addition results in the soil shrinking a pore cavity resulting in increased soil density.

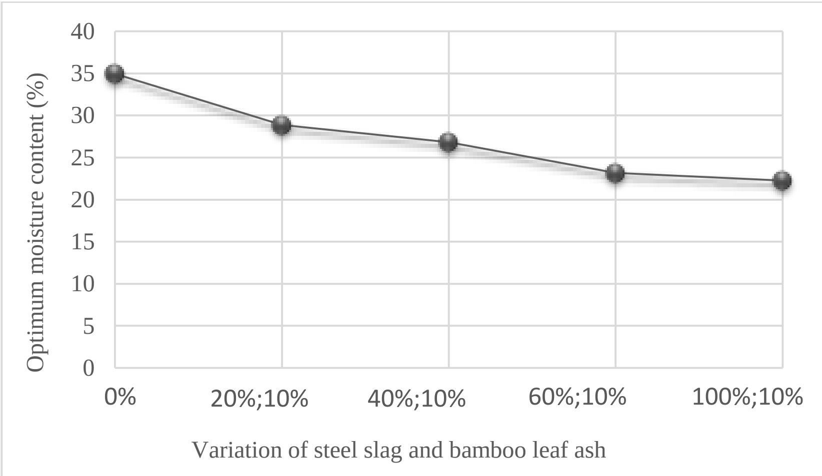


**Figure 7. Graph of Optimum Moisture Relationship in Additive Variations**

The test results in Figure 7 shows that the optimum water content value decreases with the increasing percentage of steel slag. Bamboo leaf ash increases water absorption and pore number in steel slag and bamboo leaf ash because the solid grains make the soil volume less or less.

## The results of the liquid limit test and the plastic limit of mixed soils

This test was conducted to determine the effect of steel slag and bamboo leaf ash additives on the liquid limit, plastic limit, and plasticity index values. The results of the Atterberg limit test, namely the liquid limit and plastic limit of the mixed soil, are shown in Table 2. Then the results are plotted in the graph shown in Figure 8 and Figure 9.

**Table 2. Test results for the Atterberg limits of mixed soils**

| Variation of additive (Steel slag + Bamboo leaf ash) | Test result | | |
|---|---|---|---|
| | Liquid limit (%) | Plastic limit (%) | Plasticity index (%) |
| 0%;0% | 64.5 | 41.6 | 22.8 |
| 20%;10% | 59.2 | 43.1 | 16.0 |
| 40%;10% | 56.1 | 43.8 | 12.3 |
| 60%;10% | 52.8 | 44.7 | 8.0 |
| 100%;10% | 50.3 | 45.0 | 5.3 |

Table 2 shows the results of the liquid limit and plastic limit tests in this study, and then the plasticity index value is a reduction from the liquid limit value to the plastic limit. The mixed soil plastic index values are plotted on the graph shown in Figure 8.

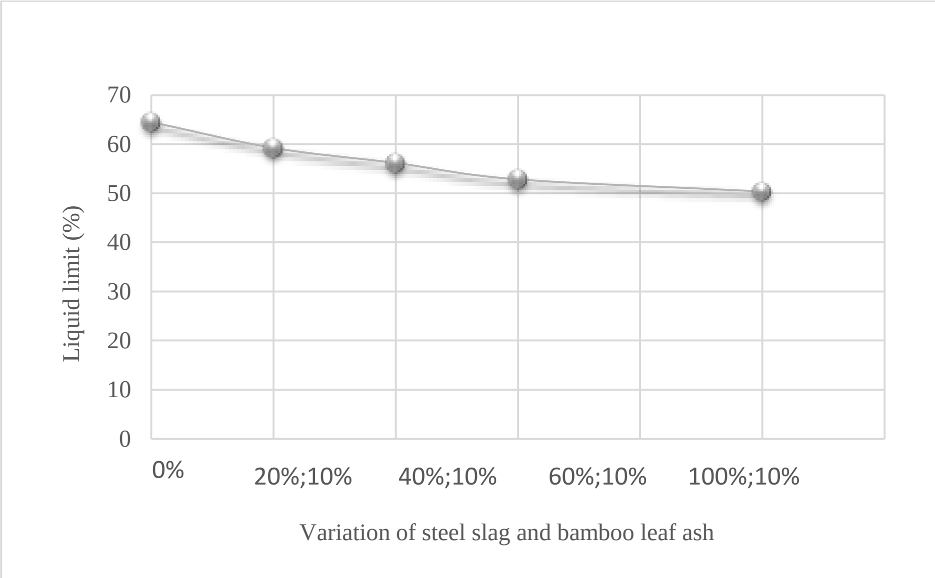


**Figure 8. Graph of Liquid Limit Relationship in Additive Variations**

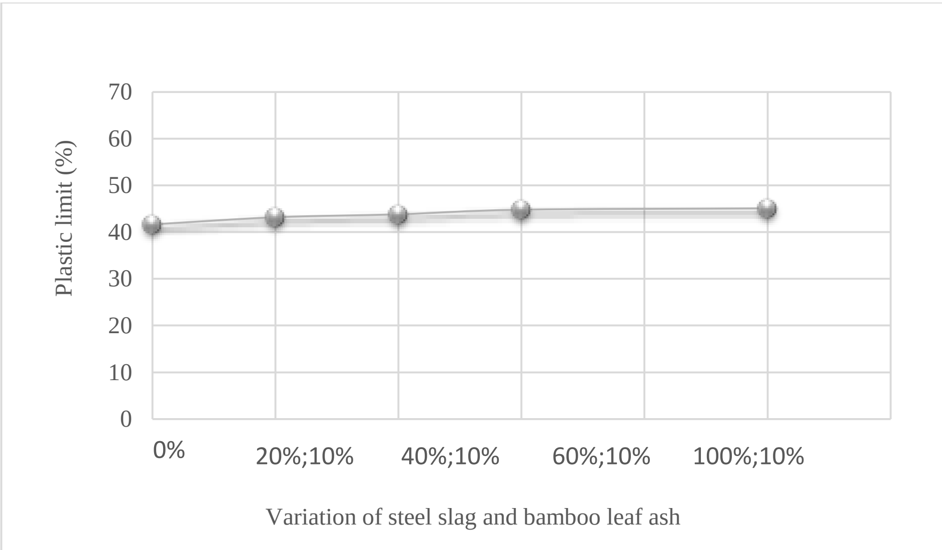


**Figure 9. Graph of Plastic Limit Relationship in Additive Variations**

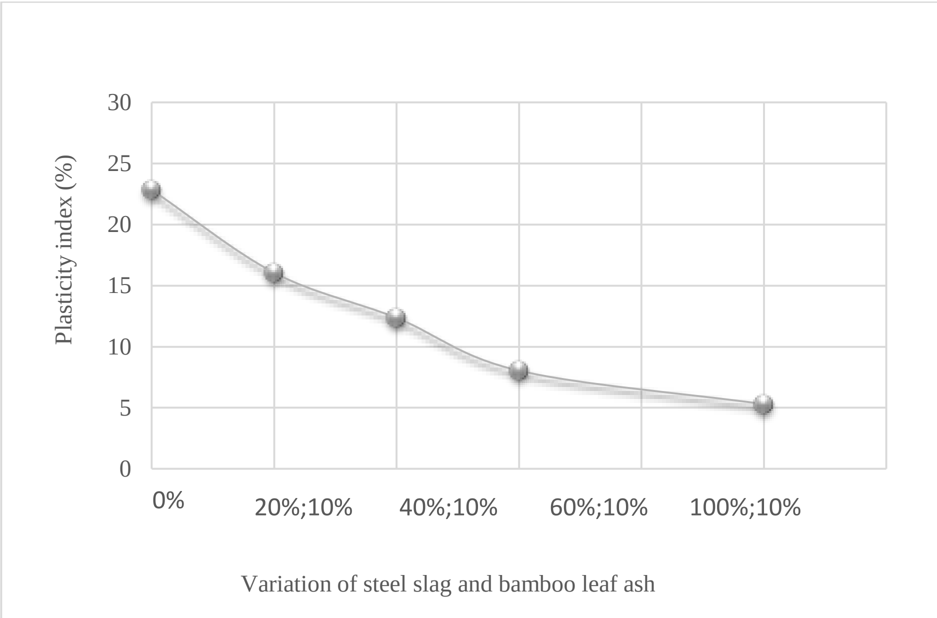


**Figure 10. Graph of Plasticity Index Relationship in Additive Variations**

Figure 8 shows a decrease in the liquid limit value with an increasing mixture of steel slag and bamboo leaf ash. Figure 9 shows an increase in the plastic limit value with an increasing mixture of steel slag and bamboo leaf ash. Figure 10 shows a decrease in the plasticity index with a significantly increasing mixture of steel slag and bamboo leaf ash. The index value of soil plasticity in variations of 100% steel slag and 10% bamboo leaf ash of 5.3% is included in the category of low plasticity index.

Based on the CBR value obtained on the land of Jalan Kampung Juhut, Tanjung District, Pandeglang Regency, Banten. Before stabilization with the addition of steel slag and bamboo leaf ash, it was included in people with low incomes to the appropriate category with a CBR value of 3.01%. In comparison, the CBR value that had been stabilized used a mixture of Steel Slag (SS) and Bamboo Leaf Ash (BLA) added with percentage variations as much as (0% SS ; 0% BLA), (20% SS; 10% BLA), (40% SS; 10% BLA), (60% SS; 10% BLA), (100% SS; 10% BLA) with a curing time of 0 and 7 days is included in the good category [20]–[22] in the variation of the added material mixture of 100% Steel Slag and 10% bamboo leaf ash with a curing time of 7 days, the soil CBR value is 24.9%, and the plasticity index is 5.3%, so it can be concluded that this combination of additives can be used as a subgrade stabilizing agent because the CBR value and plasticity index meet the minimum criteria for subgrade.

## 4. CONCLUSION

Based on the research that has been done, it can be concluded as follows:

a. Soil classification using the USCS method, native soil belongs to the OH group, namely organic clay soil with high plasticity, because it has a plasticity index value of 22.3% liquid limit above 50%, which is 64.5%.
b. The use of added materials such as steel slag and bamboo leaf ash affects decreasing the value of the soil plasticity index as the percentage of steel slag and bamboo leaf ash increases, from 0% percentage which is 22.3% to 5.3% at 100%steel slag and 10% ash percentage. Bamboo leaves without curing.
c. Adding steel slag and bamboo leaf ash increases the unsoaked CBR value. The optimum soil CBR value is produced at the percentage of added material 100% steel slag and 10% bamboo leaf ash at seven days of curing time of 24.9% and is included in the good category.
d. Curing time affects increasing the unsoaked CBR value. At the time of curing for 0 days, the CBR value was 20.4% for the variation of 100% steel slag and 10% bamboo leaf ash, and at the

time of curing for seven days, the CBR value was obtained for 24.9% for the variation of 100% steel slag and 10%.

e. The combination of steel slag and bamboo leaf ash can be used as a subgrade stabilizing agent because the resulting CBR value and plasticity index meet the minimum criteria for subgrade.

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