

# Soil Stabilization Using Slag Cement for Improved CBR Performance: A Study in Lebak Regency, Banten

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## ABSTRACT

The site of Kukulu Village, Parungsari Village, Sajira District, Lebak Regency, Banten was examined in this study. The Dynamic Cone Penetrometer test indicated that the soil carrying capacity value in this location was rather low, at 3.8%. It is crucial to remember that excellent subgrade soil (basic soil) has to have a CBR value of at least 6%. The use of slag cement is good for stabilizing soil because it contains silica and is cementitious. Slag cement is an environmentally friendly material, therefore in this study slag cement was used. The Unified Soil Classification System (USCS) will be used in this study to define the soil type and classification. The soil's grain size, Atterberg limits, compaction, and laboratory CBR tests will all be examined in order to achieve this. The CBR value will be calculated for a period of time and at different percentages of 0%, 8%, 10%, and 12% before and after stabilization using slag cement. In previous research, it was carried out and obtained an optimum CBR value when adding 10% slag cement and experienced a decrease when adding 15% slag cement, so in this study we wanted to find out whether there was still an increase in the CBR value in the range of 10% to 15%. The results of the CBR test obtained the highest CBR value of 23% from the addition of 12% cement slag and 7 days of curing.



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## 1. INTRODUCTION

Clay soil is a type of soft soil that has the characteristics of fine-grained soil and has a larger specific surface area, larger void ratio, and lower permeability than coarse-grained soil. Clay formed due to weathering chemical reactions forms groups of colloidal particles with a particle diameter of less than 0.002 mm [1]. Clay soils are very hard when dry and plastic with moderate moisture content. When the water conditions are higher, the clay is sticky (cohesive) and very soft. This factor can interfere with the strength of a construction building so that the construction can experience physical damage.

Slag cement is an environmentally friendly and easy material to make because slag cement does not go through a high burning process. The slag cement used in this research came from PT. Krakatau Semen Indonesia can be categorized as environmentally friendly because the materials used in making slag

cement come from granulated furnace waste produced by blast furnaces which can damage the environment. Therefore, the use of slag cement for soil stabilization can reduce environmental pollution caused by granulated furnace waste.

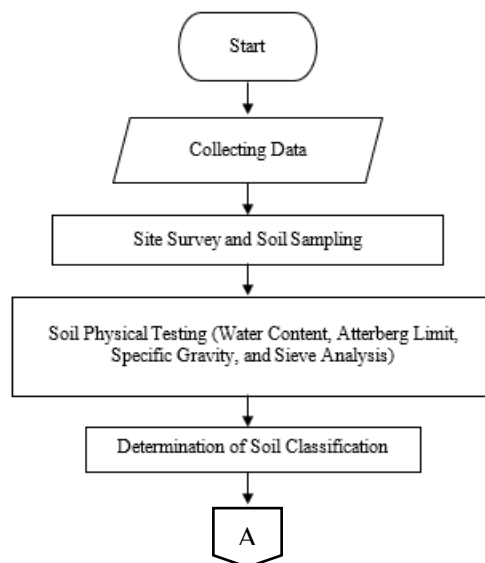
The results of the soil survey at the location of Kukul Village, Parungsari Village, Sajira District, Lebak Regency, Banten produced by field CBR testing using the Dynamic Cone Penetrometer (DCP) tool obtained a CBR value of 3.8% according to the Revision of the Road Pavement Design Manual (2017) Number 02/M/BM/2017 that the effective CBR of subgrade should not be less than 6%, if it is less then the soil needs to be stabilized [2].

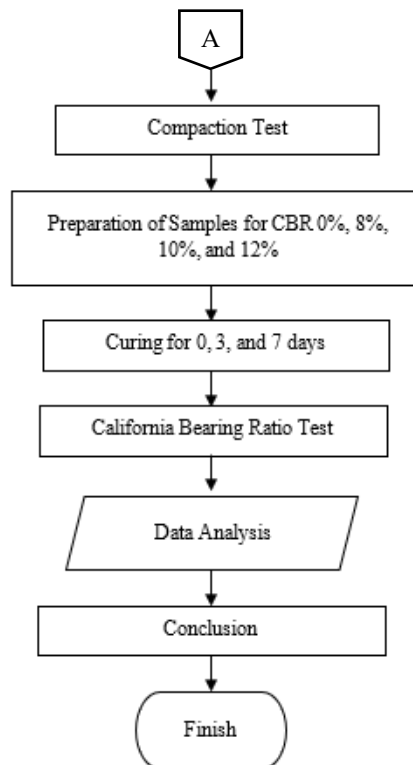
Soil stabilization using cement slag was previously studied by Fathonah, W (2020) with variations in percentages of 0%, 10%, 20%, and 30% with curing durations of 0 days, 3 days, and 7 days [3]. Furthermore, Mina, E (2021) with cement slag added, the percentage variation values are 0%, 10%, 20%, and 30% with a curing time of 0 days, 3 days, and 7 days [4]. Furthermore, Kusuma, R.I (2020) with the addition of slag cement, the percentage value for the mixture variation is 0%, 5%, 10%, and 15% without curing based on the optimum moisture content [5]. Furthermore, Pathak, A.K. (2014) with the addition of cement slag, the percentage values for the mixture variations were 0%, 5%, 10%, 15%, 20%, and 25% [6]. Furthermore, Saravanan, R (2017) with the added ingredients of lime and Ground Granulated Blast Furnace Slag, the percentage values for variations in lime and GGBS mixtures for the California Bearing Ratio test were 1% and 0%, 2%, 4%, and 6%, respectively [7].

## 2. METHODS

### 2.1 Stages of Research

While conducting the study, the research design steps to be taken have been completed, the research begins with data collection by searching library sources such as books, and research journals used as research materials. references in the study. Then a field survey was carried out to collect soil samples for the study. The soil sampling location is in Kukul Village, Parungsari Village, Sajira District, Lebak Regency, Banten. Slag cement samples were taken at PT. Krakatau Semen Indoneisa. The soil sample used is mixed with cement slag to bond and fill the volumetric space in the soil sample.





**Figure 1. Research flowchart**

Stabilization Measurements in the Field based on SNI 03:3437:1994 [8]:

1. Prepare the soil to be stabilized by mixing clay soil stabilization with added materials on site.
2. Loosen the soil to be stabilized.
3. Spread the added ingredients to be mixed evenly manually or with a mechanical spreader.
4. Mix the two soils and cement slag until evenly distributed. During the mixing, water can be added if necessary and the water should be applied gradually until it meets the applicable regulations.
5. Adjust to the plan and the capabilities of the mixing equipment for the thickness of the mixture in the field before compacting, namely 30 cm loose.
6. Compact the soil to the grain using a rubber wheel compactor or something similar.
7. Carry out initial compaction.
8. Carry out final compaction.
9. Check the density and measure the thickness of the solid layer after a minimum of 4 passes.
10. Ensure that the mixed layer construction does not dry out, during implementation and during the maintenance period.
11. Carry out quality control during work, humidity observations are carried out to determine the effectiveness of the treatment methods used.

California Bearing Ratio Measurements based on SNI 1744:2012 [9] :

The California Bearing Ratio test procedure (SNI 1744:2012) [9] is install a load plate on top of the sample with the same mass as the load plate used during immersion. Installation of load pieces is done per piece. To prevent soft material from rising through the hole in the load plate, after installing one load plate, set the penetration piston until it touches the sample surface and apply an initial load of 44 N. Then the penetration measuring watch is set to the zero position.

Apply a load to the penetration piston such that the penetration speed is uniform at 1,27 mm/min. Record the load if the needle penetration shows 0,32 mm, 0,64 mm, 1,27 mm, 1,91 mm, 2,54 mm, 3,81 mm, 5,08 mm, and 7,62 mm. Load readings at 10,16 mm and 12,70 mm penetration can be determined if necessary.

The standards that apply to each test will be utilized to examine the data that has been collected, and the references used include:

1. Water content (SNI 1965:2008) [10]
2. Specific Gravity (SNI 1964:2008) [11]
3. Liquid Limit (SNI 1967:2008) [12]
4. Plastic Limit (SNI 1966:2008) [13]
5. Sieve Analysis (SNI 3423:2008) [14]
6. Compaction (SNI 1742:2008) [15]
7. California Bearing Ratio (SNI 1744:2012) [9]

## 2.2 Number of Samples

The samples used in this study were 36 pieces for CBR (California Ratio) testing. The blend variations used are 0%, 8%, 10%, and 12%. The water content test and sieve analysis do not use a mixture of slag and cement. Tests for density, Atterberg limit, unit weight, compression, and CBR use each variant.

## 2.3 Additive Requirements

The soil requirement for the CBR test is calculated based on the calculation of the mold volume multiplied by the maximum dry unit weight from the compression test. The demand for cement slag admixture is calculated based on the volume of soil multiplied by the percentage of cement slag mixture used. The required water content to be used is based on the calculation of the soil mass multiplied by the optimum moisture content obtained from the compaction test.

Slag cement is cement produced from Grinding Blast Furnace metal processing mixed with gypsum limestone. Slag cement is Soil stabilization material that is quite good because it contains silica ( $\text{SiO}_2$ ) and has cementitious binding properties (capable of hardening and increasing strength if used as an additive) is very useful in obtaining a soil mass that is strong and resistant to deformation [4]. Slag cement is an environmentally friendly and easy material to make because slag cement does not go through a high burning process.



Figure 2. Slag Cement

## 3. RESULTS

### 3.1 Results the Physical Properties of Clay Soil

Tests for the physical properties of the soil are performed to determine the type of soil. Tests were conducted regarding water content, density, unit weight, particle size analysis and Atterberg limit. The initial soil water content test result was 29,52% with a soil specific gravity of 2,617 gr/cm<sup>3</sup>.

The initial liquid limit value of the soil is 52%. The plastic limit is 35,356%. The plasticity index is obtained from the result of reducing the yield strength by the plastic limit, the value of the plasticity index is 16,644%. Based on the table of plasticity index of soil with plasticity index value from 7 to 17, it is classified as medium plasticity clay. Experimental results of particle size analysis obtained soil that passed sieve No. 1. 200 out of 52%, the soil belongs to the type of fine-grained soil.

Based on the results of the compaction test, the maximum dry unit mass and optimal water content were obtained for use in the CBR test. The optimum dry unit weight value is obtained at 1.2 gr/cm<sup>3</sup> and will be used to determine soil requirements. The optimum water content value obtained is 34% and will be used to determine the water mixing needs. The results of testing the physical properties of the original soil are shown in Table 1.

**Table 1. Physical properties of origin soil**

No	Test	Unit	Result
1	Water Content	%	29,52
2	Specific Gravity	gr/cm <sup>3</sup>	2,617
3	Liquid Limit	%	52
4	Plastic Limit	%	16,644
5	Plasticity Index	%	35,356
6	Dry Density	gr/cm <sup>3</sup>	0,836
7	Sieve Analysis	-	Fine grained soil
8	Maximum Dry Density	gr/cm <sup>3</sup>	1,2
9	Optimum Water Content	%	34
10	CBR	%	4,15

### 3.2 Classification System with USCS

The USCS (Unified Soil Classification) method was used in this study. To determine the soil classification, several tests must be performed, such as yield strength, plastic limit and particle size analysis. Based on the results of these tests, the soil is classified as OH class with a moderate plasticity organic clay.

### 3.3 The Results of Mix Soil

This study was performed using a cement slag added to several tests including specific gravity, Atterberg limit, unit weight, compressibility and CBR. Four variations of the addition of cement to slag were performed for research purposes, namely 0% cement to slag, 8% cement to slag, 10% cement to slag and 12% cement to slag. . Through the addition of additives in the form of cement slag, differences in soil properties can be determined.

#### 3.3.1 Specific Gravity Test

Based on the results of the specific gravity test carried out on the soil of Kukul village, Parungsari village, Sajira district, Lebak district, Banten, it was found that the specific gravity value gives 0% change of cement slag (original soil) yields a value of 2,617 gr/cm<sup>3</sup>. and increased after the addition of cement slag in 12% with the value 2,756 gr/cm<sup>3</sup>. It can be concluded that the addition of the admixture in the form of cement slag will increase its density value. Specific gravity test results are shown in Table 2.

**Table 2. Specific Gravity of soil with addition of slag cement**

Variation	Gravity Specific (gr/cm <sup>3</sup> )
Variation A (0% slag cement)	2,617
Variation B (8% slag cement)	2,699
Variation C (10% slag cement)	2,724
Variation D (12% slag cement)	2,756

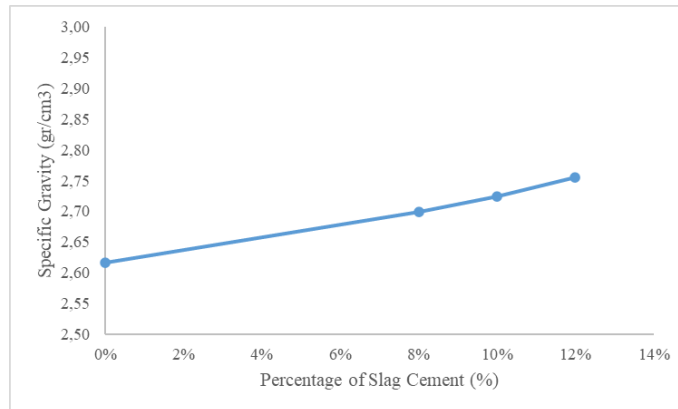


Figure 3. The Specific Gravity of Clay Soil with Addition of Slag Cement



Figure 4. Specific Gravity Test

Specific gravity test is very important to carry out in this research because the specific gravity value is used to calculate zero air voids in compaction test. The zero air void line is the line between dry bulk density and optimum water content if the soil pores do not contain air. This graph is always above the compaction graph which is concave downwards.

### 3.3.2 Liquid Limit Test

Based on the liquid limit test performed, it can be concluded that the addition of cement slag admixture can reduce the liquid limit value. The results of the tests performed can be seen in Figure 5. The curing time can affect the liquid limit value, the liquid limit value decreases gradually after each curing. Indeed, slag cement with binding properties can harden and increase in strength if used as an additive [4]. The optimal liquid limit value was obtained from initial soil and 0 day maturation time with a liquid limit value of 52%. The lowest value was obtained when adding slag cement at the rate of 12% with a liquid limit value of 46%. The liquid limit test results are shown in Table 3.

**Table 3. Liquid limit test of clay soil with addition of slag cement**

Curing (days)	Liquid Limit (%)			
	Variation A (0% Slag Cement)	Variation B (8% Slag Cement)	Variation C (10% Slag Cement)	Variation D (12% Slag Cement)
0	52	48	47	46
3	50	46	45,5	44
7	48,12	44	42	40

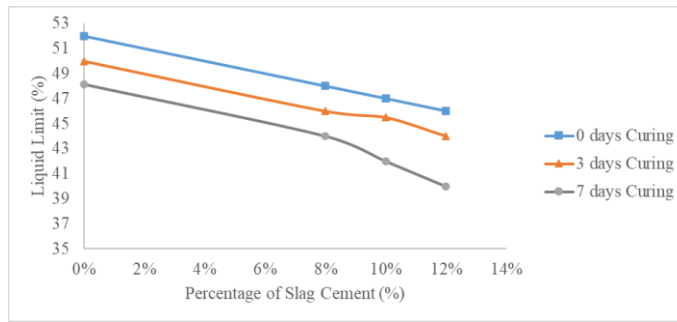


Figure 5. Liquid limit of clay soil with addition of slag cement

### 3.3.3 Plastic Limit Test

The results of the tests performed can be seen in Figure 6, whereby the plastic limit value tends to continue to decrease with the addition of each percent of the cement slag. This is possible because the addition of cement slag can increase the cohesion value of the soil, thereby binding the soil particles together. This reduction is also due to the separation of the dispersed bilayer and leads to flocculation. This can reduce the plasticity of the soil, manifested by a decrease in the plasticity index [16]. The plastic limit test results are shown in Table 4.

Table 4. Plastic limit test with addition of slag cement

Curing (days)	Plastic Limit (%)			
	Variation A (0% Slag Cement)	Variation B (8% Slag Cement)	Variation C (10% Slag Cement)	Variation D (12% Slag Cement)
0	35,356	34,925	34,110	33,778
3	33,889	33,24	32,932	31,931
7	32,62	32,005	30,753	29,651

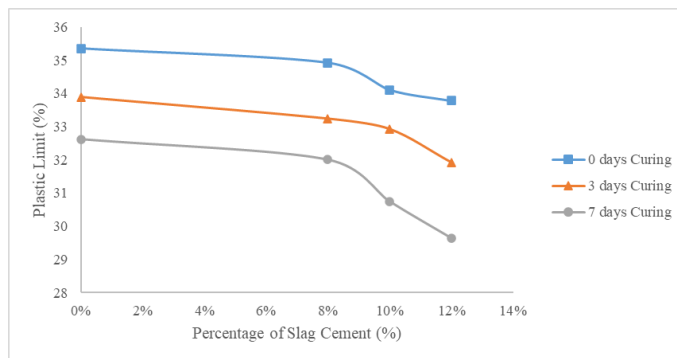


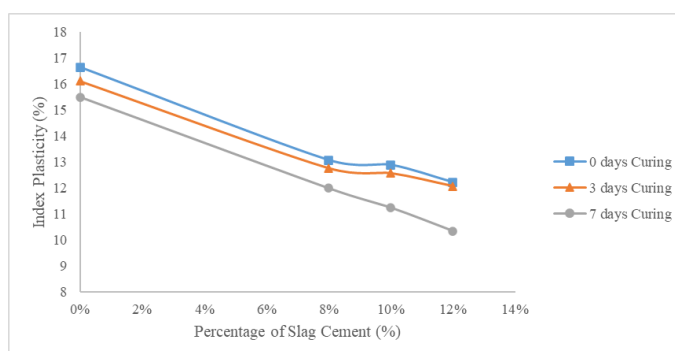
Figure 6. Plastic limit of clay soil with addition of slag cement

### 3.3.4 Plasticity Index

Based on the results of data analysis of liquid and plastic limit tests, it is known that the addition of admixtures in the form of slag cement can affect the reduction of plasticity index values. The reduced values of yield strength, plastic limit, and plasticity index can be influenced by the diffusion decomposition of the bilayer surrounding the clay particles leading to a decrease in ductility [16]. A decrease in the Plasticity Index value can occur because the slag cement containing SiO<sub>2</sub> can absorb moisture if the soil sample absorbs too much water, minimizing swelling and shrinkage of the soil and making the soil stable [5]. Mixed soil plasticity index is shown in Table 5 and the results of the tests performed can be seen in Figure 7.

**Table 5. Plasticity index with addition of slag cement**

Curing (days)	Plasticity Index (%)			
	Variation A (0% Slag Cement)	Variation B (8% Slag Cement)	Variation C (10% Slag Cement)	Variation D (12% Slag Cement)
0	16,644	13,075	12,890	12,222
3	16,111	12,760	12,568	12,069
7	15,500	11,995	11,247	10,349

**Figure 7. Index plasticity of clay soil with addition of slag cement****Figure 8. Atterberg limit test**

Soil plasticity can be demonstrated by the plasticity index value. If the soil has a high plasticity index value, it shows that the soil contains a lot of clay grains [17]. If the soil has a plasticity index value of more than 17%, the strength of the soil can decrease and the properties of the soil can be disturbed, soil shrinkage will easily occur because the soil easily absorbs water [18]. An increase in soil quality can be shown by a decrease in the plasticity index value, which increases with the addition of cement and lime levels mixed in [1].

### 3.3.5 Compaction Test

Based on Figure 9, with the addition of admixture in the form of cement slag, the maximum dry unit weight value continues to increase until the percentage of added cement slag reaches 10% because the cement slag contains silicon and calcium, which can cause water retention. . bonded with clay, so clay particles are bound together by cement paste. Silica in cement slag has a higher density than clay, so silica will increase the density of the original soil. The soil will become hard and harden rapidly due to hydraulic bonding caused by cement [19]. The maximum dry unit weight has been reduced since the addition of the slag cement ratio from 10% to 12% due to the addition of too much slag cement and the lack of raw material, which makes it difficult to achieve good compaction [20].

From Figure 9, the addition of admixture in the form of cement slag will reduce the optimal water content, this is because the effect of cement addition can reduce voids in the secondary soil [21]. In



addition, the optimal water content can be reduced because the cement slag contains silica and the water in the porous soil will be bound by the clay and lime, resulting in a reduced optimum water content. By optimally reducing the water content, it can accelerate the transition from soft soil to fast drying soil [19]. The results of the compaction test are shown in Table 6.

**Table 6. Optimum water content and maximum dry density of clay soil with addition of slag cement**

Variation	Optimum Water Content (%)	Maximum Dry Density (%)
Variation A (0% Slag Cement)	34,00	1,20
Variation B (8% Slag Cement)	31,33	1,23
Variation C (10% Slag Cement)	29,67	1,26
Variation D (12% Slag Cement)	30,25	1,25

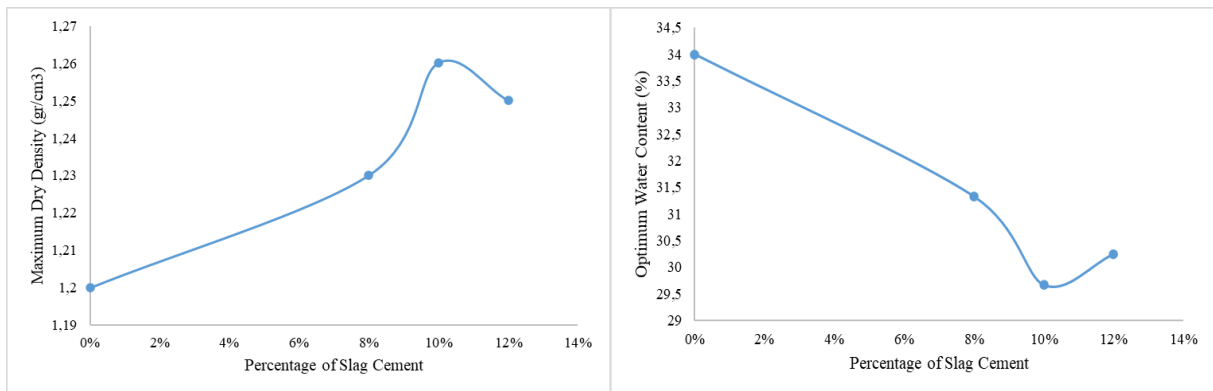


Figure 9. Optimum water content of clay soil with addition of slag cement



Figure 10. Compaction test

Compaction test is used to find out the maximum dry unit weight and optimum water content. The maximum dry unit weight is useful for determining the amount of soil to be used in the California Bearing Ratio test. Meanwhile, the optimum water content is used to determine the water requirements that will be used in testing the California Bearing Ratio.

From the results of the compaction test, the water content value was obtained. This water content value will be used in determining the water content requirements in the California Bearing Ratio test. The higher the water content, the less optimal the compaction will be, causing a low California Bearing Ratio value. Otherwise, if the soil contains less water, the compaction carried out will be optimal so that the California Bearing Ratio value will be high.

### 3.3.6 CBR Test

The results of the tests performed can be seen in Figure 11, CBR test results keep getting better as cement slag is added. The addition of 12% cement slag produced the highest result, which had a CBR value of 23% after 7 days of curing. Due to the cementitious character of stabilization using cement slag can raise the CBR value, cement slag has a relatively high silica concentration. Cement has a hardening property

and can increase value by acting as an additive [4]. Additionally, cement slag contains lime, which helps accelerate the cementation process. This cementation causes clumping, which strengthens the link between grains. As the relationship between grains grows, so will the grains' capacity to interlock. The grains won't be easily harmed or deformed by the effects of water since a robust cementation agent will cover the partially filled pore space [22].

The length of curing can also have an impact on CBR value. According to the preceding table, a 7-day curing period can enhance the CBR value compared to no curing. Because the chemicals in the additives must first be present before they can react, the chemical processes that determine soil quality take time [22]. Comparatively to compacted curing in the mold followed by plastic curing, compacted curing in the mold can raise the CBR value. This is due to the soil particles' tendency to cluster together. Larger soil grains will result from compaction, which weakens the cohesiveness of the soil. The lime-impregnated soil mixture, on the other hand, has hardened before caking occurs if the sample is compacted first and then cured in a CBR mold [18]. Additionally, the gap between the soil particles also becomes tight, enhancing strength. While the CBR value with the highest 7-day curing is 23% with the addition of 12% cement slag, the CBR value with the smallest 7-day curing is 4.6% without additives.

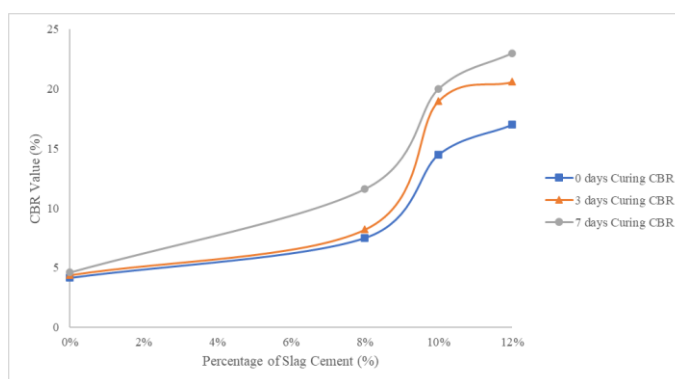


Figure 11. CBR value of clay soil with addition of slag cement and curing



Figure 12. CBR test

#### 4. CONCLUSION

According to the outcomes of the tests, it can be concluded that clay soil in Kampung Kukulu, Parungsari Village, Sajira District, Lebak Regency, Banten, was stabilized using cement slag with percentages of 0%, 8%, 10%, and 12% for lengths of 0, 3, and 7 days, it can be concluded that the soil is classified as the OH classification having a plasticity index of 16,644%. The addition of cement slag can affect the physical properties of the soil where the plasticity index of the soil has decreased from

16,644% to 12,222%. The addition of cement slag can increase the CBR value where the CBR value increases from 4,6% to 23%.

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