The utilization of lime and plastic sack fiber for the stabilization of clay and their effect on CBR value

Enden Mina [a,1], *Woelandari Fathonah* [a,2], *Rama Indera Kusuma* [a,3], *Ina Asha Nurjanah* [a,4]

[a]*Department of Civil Engineering, Faculty of Engineering, Universitas Sultan Ageng Tirtayasa, Jl. Jenderal Sudirman Km.3, Cilegon 42435, Indonesia*

E-mail: [1]*enden@untirta.ac.id,* [2]*woelandari@untirta.ac.id,* [3]*rama@untirta.ac.id,* [4]*inaashan@gmail.com*

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ABSTRACT

The soil of Kubang Laban Road at Terate Village, Kramatwatu-Serang district, can be classified as a clay soil type with a low bearing capacity with a field California Bearing Ratio (CBR) value of 2.16%. Therefore it is necessary to improve the soil, which is stabilization using added lime and plastic sack fiber. This study used variations of Plastic sacks fiber content 0%; 0.2%; 0.4%; 0.6% and 0.8% with the addition of 10% lime for each variation of the total dry weight of the soil. This study determines how adding plastic sack fiber and lime in the subgrade soil affects the CBR value and physical properties. The soil classification system used is based on the unified soil classification system (USCS). The results showed that the original soil was classified as OH type, organic clay with high plasticity. Thus, soil stabilization with plastic sack fiber and lime may reduce the IP and enhance the CBR. With 0.2 percent plastic sack fiber and 10% lime, the greatest CBR value was 41.78 percent. The optimum CBR value obtained meets the requirements for a road construction subgrade.

ABSTRAK

Tanah di Jalan Kubang Laban Desa Terate Kecamatan Kramatwatu-Serang dapat tergolong jenis tanah lempung yang memiliki daya dukung rendah dengan nilai california bearing ratio (CBR) lapangan rendah yaitu 2.16%, sehingga perlu dilakukan perbaikan tanah. Salah satu cara perbaikan tanah adalah dengan penambahan kapur dan serat karung plastik. Penelitian ini bertujuan untuk mengetahui pengaruh penambahan serat karung plastik dan kapur pada tanah dasar terhadap nilai CBR dan sifat fisiknya. Penelitian menggunakan variasi kadar serat karung plastik 0%; 0,2%; 0,4%; 0,6% dan 0,8% dengan penambahan kapur 10% untuk setiap variasi berat kering total tanah. Sistem klasifikasi tanah yang digunakan didasarkan pada sistem klasifikasi Unified Soil Classification System (USCS). Hasil penelitian menunjukkan bahwa tanah asli tergolong jenis OH, lempung organik dengan plastisitas tinggi. Stabilisasi tanah dengan menggunakan karung plastik fiber dan kapur dapat menurunkan nilai indeks plastisitas (IP) dan meningkatkan nilai CBR. Berdasarkan hasil pengujian CBR, nilai CBR tertinggi diperoleh pada variasi serat karung plastik 0,2% dengan kapur 10% sebesar 41,78%. Nilai CBR optimum yang diperoleh memenuhi persyaratan untuk tanah dasar konstruksi jalan.

1. Introduction

Good road construction is inseparable relation with the field conditions. Some of them have a vital role in the feasibility of construction, in this case, the soil. The soil can be categorized as good soil if it has a high bearing capacity, but not all soil types have high bearing capacity. Kubang Laban road in Serang District was damaged in the surface layer structure. Based on the field CBR test result, the soil base has a low bearing capacity with a CBR value of 2.16% and unfavorable properties. Therefore it needs improvement or stabilization. One of the methods to improve the soil is by adding admixtures such as plastic sack fibers and lime. This study was conducted to determine the effect of adding plastic sack fiber and lime to the value of the California Bearing Ratio (CBR) and the physical properties of the soil before and after being mixed. Variations in the content of the mixture used were 0%, 0.2%, 0.4%, 0.6%, and 0.8% and mixed with 10% lime for each variation. Case studies are undertaken at Kubang Laban Road, where the soil condition has deteriorated due to daily traffic. Figure 1 depicts the road condition.

The addition of materials such as plastic sack fiber and lime is expected to have a good influence on soil properties to increase the soil's bearing capacity. Lime that hardens quickly is expected to become a binding strength. In contrast, sack fiber material as a good plastic material (non-brittle material) is expected to increase the value of the soil's shear strength, compressive strength, and tensile strength. Some studies have been conducted on soil improvement methods utilizing lime and plastic shack fiber [1-5]. Lime and plastic sack fiber give a significant effect in increasing CBR value. Other additives are also used with the same characteristics properties as lime, such as gypsum, fly ash, and cement slag [6-8]. Adding lime to soil improvement efforts has improved the geotechnical properties of the soil, such as soil plasticity, but soil stabilized with lime only tends to behave brittle and have low tensile strength [9]. Utilization of plastic waste such as plastic sack fibers having a polypropylene (PP) base material can also provide good results good for improving soil mechanical properties, such as soil shear strength [4].

Figure 1. Soil condition at Kubang Laban Road, Serang.

Several previous studies on plastic sack fibers have become the basis for developing these research methods and hypotheses. In this section, several methods and results from the previous studies are described, such as [3] conducted a study on the effect of adding plastic sack fiber and lime to changes in CBR value in soft clay soil with a percentage of 0.2% plastic sack fiber; 0.4%; 0.8% and lime 0%, 5%, and 10%. The results showed that the addition of plastic sack fiber and lime could increase the CBR value of the soil up to 447.78% of the original soil CBR value. The optimum CBR obtained at 0.4% sack fiber variations and 5% lime is 12.76% [3]. [4] conducted a study using polypropylene fibers to see their effect on soil physical properties with variations in fiber content in the range of 0.075% to 3%. The results showed that the soil experienced an increase in the soaked CBR value until it reached an optimum value of 7.06% from the original CBR value of 4.8%, with a curing time of 4 days [4].

[5] examined the effect of adding plastic sack fiber as a mixture to strengthen the clay heap with a variation of 1% plastic sack fiber content; 1.5%; 2%; 2.5%; 3%. The test results with the highest value for the stockpile material get the percentage content of the mixture of pieces of plastic sack fiber. Triaxial UU Testing result with soil cohesion (c) of $0.390kg/cm^2$ at a level of 1%, with a shear angle (ϕ) of 6,277° at a mixed content of 3%. The research by [6] utilizes gypsum waste and its effect on CBR values by using gypsum mixture variations of 0%, 3%, 6%, and 10%. The results showed the highest increase in 10% gypsum mixing with curing in three days of 57.876%. The percentage increase in CBR value is 35.46% from the original land [6-7]. Based on the findings of earlier investigations, The variance in the plastic sack fiber and lime combination used in this investigation was determined by the findings of prior experiments. The method that varies in this study includes variation at 0.6 percent. The fixed variable is the content of 10% lime to determine its influence on the CBR value and the physical parameters of the soil. Thus, the variation of the plastic sack fiber mixture was taken as 0%, 0.2%, 0.4%, 0.6% and 0.8% mixed with 10% lime.

2. Research Methodology

The test sample consisted of five versions of a combination of plastic sack fiber and lime. Each plastic sack fiber and lime concentration variant was compacted to produce the optimal dry density and moisture content for mixed soil samples. For the CBR test, at least need 15 samples which are each variation requires three samples for each CBR test. The soil tests include the soil's physical properties, such as water content, liquid limit, plastic limit, specific gravity, and sieve analysis based on SNI (Standard National Indonesia) [10-16]. Classification of soil types is determined based on the USCS method from the results of the physical properties tests of the soil.

The compaction test (proctor) was carried out to obtain the optimum moisture content and maximum dry density, which became the basis for making samples. Soil mixing was carried out using plastic sack fibers with a variation of 0 %; 0.2%; 0.4%; 0.6%, and 0.8% mixed with 10% lime for California Bearing Ratio (CBR) tests without soaking. According to the variation, the plastic sack fiber is cut into sufficient pieces with 1-2 cm mixed with soil. The determination of the variation of the mixture is based on the results of previous studies where variations of 0.2% [1] and 0.4% [5] of plastic sack fiber can increase the CBR value, which is quite high. This study added 0.6% and 0.8% variations to compare the result.

2.1. Research Procedure steps

Some theory basis is used such as soil classification system to determine the type of soil, the atternberg limit test to obtain plasticity index, compaction test to obtain the dry soil density and optimum water content to use as a parameter in the making of sample test. The California Bearing Ratio Test is conducted to obtain the CBR value for each variation. The description for each testing process of the soil sample is shown in the next section, and also the description about material additives Plastic sack fiber and lime. Based on the objective of this research, the output of some testing procedures is analyzed to determine the effect of those material additives on the CBR value and soil physical properties.

2.1.1. Soil Classification System
Soil classification is very helpful for designers in providing empirical references based on past experiences. The most frequently used soil classification system is according to the USCS (Unified Soil Classification System) system proposed by Prof. Arthur Casagrande. Based on the USCS classification, soils are categorized into two major groups: coarse-grained soils and fine-grained soils [17].

2.1.2. Plasticity Index

The plasticity index is the water content interval at which the soil is still plastic [10].

$$PI = LL - PL \tag{1}$$

Description :

PI   = Plasticity Index (%)
LL   = Liquid Limit (%)
PL   = Plastic Limit (%)

The value of the plasticity index with its correlation with soil type and soil cohesive properties is shown in Table 1.

Table 1. Plasticity index value and soil type.

PI	Characteristic	Soil types	Cohesiveness
0	Non plastic	Sand	Non cohesive
< 7	Low plasticity	Silt	Partly cohesive
7 –17	Medium plasticity	Silty clay	cohesive
> 17	High plasticity	Clay	cohesive

Sieve analysis is an attempt to get the size of the soil distribution by using a sieve. The size of the grain becomes the basis for presenting or classifying the names of certain soil types. Soil properties are highly dependent on grain size [17].

2.1.3. Compaction

The purpose of soil compaction is to increase the shear strength of the soil, reduce compressibility, reduce permeability, and reduce volume changes as a result of changes in water content [9]. The level of soil density is measured from the value of dry volume weight (γd), density, or dry volume weight is expressed by the formula:

$$\gamma d = \frac{Ws}{V} \tag{2}$$

Description :

γd = Dry volume weight (gram/cm^3)
Ws   = Weight of granules (grams)
V   = Volume of soil (m^3)

2.1.4. California Bearing Ratio (CBR)

The CBR value is obtained from comparing the load required to achieve a certain penetration to the standard requirement load to achieve a standardized penetration in the soil sample with water content conditions and certain volume weight [11].

$$CBR == \frac{\text{corrected load}}{\text{standard load}} \times 100\% \tag{2}$$

Description :

CBR   = California Bearing Ratio (%)
Corrected load   = Corrected load at penetration of 2.54 mm (0.10 inch) and penetration of 5.08 mm (0.20 inch)
Standard load   = Standard load at 2.54 mm (0.10 inch) penetration of 13kN (3000 lbs) and at 5.08 mm (0.20 inch) penetration of 20 kN (4500 lbs)

Table 2. Soil classification based on CBR Value.

CBR value (%)	Level	Function
0 - 3	Very poor	Subgrade
3 - 7	Poor to fair	Subgrade
7 - 20	Fair	Subbase
20 - 50	Good	Base or subbase
>50	Excellent	Base

2.1.5. Plastic Sack Fiber (Polypropylene Fiber)

Plastic sack fiber is a form of description of plastic sacks. Plastic sacks are usually considered unused and thrown away by their owners. Plastic sack fibers are processed using thermoplastic polypropylene polymer (PP). This arrangement makes the fiber strong in tension and pressure. The raw material for polypropylene is obtained by decomposing petroleum (naphthene) [5]. Plastic sack fiber can be used as an alternative material for soil improvement. Previous studies have shown that the addition of variations in the fiber of plastic sacks affects changes in the soil CBR value and shear strength [1-4].

2.1.6. Lime

Lime is one of the minerals that are quite effective for soil stabilization. Lime commonly used in soil stabilization is live lime CaO and Ca(OH)$_2$. Lime is good for soil improvement because lime can react with groundwater to change the soil properties, reducing the stickiness and softness of the soil.

Expansive properties that shrink and expand due to water conditions will decrease drastically due to lime grains [9]. Expansive properties that shrink and expand due to water conditions will be drastically reduced due to lime grains. There are several types of lime as follows:
1. Type I lime is lime which contains high hydrated calcium; with the highest level of Magnesium Oxide (MgO) is 4% by weight;
2. Type II lime is magnesium or dolomite lime which contains Magnesium Oxide of more than 4% and up to 36% by weight;
3. Quicklime (CaO) is the result of burning limestone at a temperature of ± 90°C, with a composition of mostly calcium carbonate ($CaCO_3$);
Lime Padam is the result of extinguishing quicklime with water to form the hydrate [$Ca(OH)_2$].

2.1.7. Soil Stabilization

Soil stabilization is an effort to increase the stability and carrying capacity of the soil. If the soil found in the field is loose or easily compressed, or if it has an inappropriate consistency index, permeability is too high, or other undesirable properties that are not suitable for a development project, then soil stabilization must be carried out [18]. Improved soil stabilization can be done chemically and mechanically. Mixing the soil with other components may improve chemical soil stability. Additives for chemical repair can be additives such as lime, rice husk ash, and others, while repairs chemically can also be in the form of synthetic materials such as plastic sack fibers that contain polymer polypropylene (PP).

3. Results and Discussion

3.1. Soil Properties

Based on the results of laboratory tests for physical properties of the original soil, it showed that the water content of the soil was 5.54%, the specific gravity was 2.58, where 81.2% of the fine grains passed the sieve no. 200, the liquid limit was 51%, the plastic limit was 13%, and the index plasticity was 37.36%. Based on the parameters of the physical properties of the soil and the USCS classification system, original soils can be categorized as organic clays with high plasticity (OH).

3.2. Compaction Results

Figure 1 shows the results of soil compaction testing. It showed that the maximum dry weight of soil is 1.398 gr/cm^3, and the optimum water content is 27%. The compaction testing of dry soil using a rubber mallet for pounding the soil and then filtering it using a siever no. 4. After being filtered, a sample of 2500 grams of the specimen is prepared, add plastic sack fiber as much as 0%; 0.2%; 0.4%; 0.6%; 0.8%, and 10% of lime of the dry weight of the soil then distilled water. Mix the soil, plastic sack fiber, lime, and water until evenly distributed (homogeneous). Clean the mold and weigh it and then measure the volume. Then fill the prepared mold with soil and then mash it using a hammer 25 times. Proctor test results for samples of each variation are presented in Table 3.
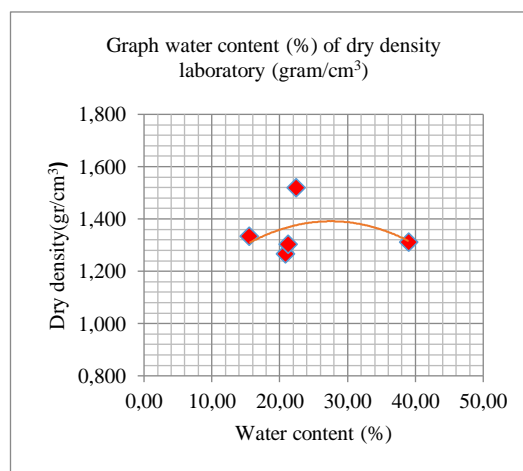

Figure 1. Graph of relationship between moisture content and dry density.

Table 3. Proctor test results for each variation of plastic sack fiber and 10% lime.

Percentage of variation plastic sack fiber	W opt (%)	Dry max (gram/cm^3)
0%	34.00	1.370
0.2 %	32.00	1.500
0.4%	34.00	1.400
0.6%	38.00	1.370
0.8%	44.50	1.345

3.3. Califronia Bearing Ratio (CBR) Unsoaked Test Results

Table 4 shows the results of the CBR test of soil samples for each variation in the percentage of a mixture of plastic coral fiber and 10% lime. The CBR value that worked best was produced from 0.2% plastic sack fiber and 10% lime. The largest CBR value is 41.8 percent, and the lowest CBR value is 11.98 percent. Testing the CBR value with various percentages of plastic sack fibers is shown in Table 4.

Table 4. The results of CBR test each variation of percentage plastic sack fiber.

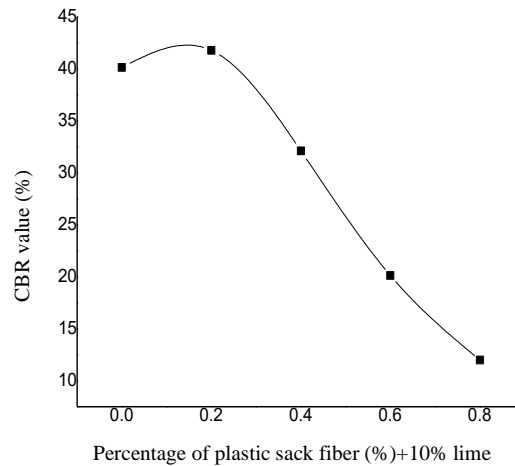| Variation of percentage of plastic sack fiber	Designed CBR value (%)
0%	40.13
0.2%	41.78
0.4%	32.11
0.6%	20.11
0.8%	11.98

Figure 2. **Graph of the relationship between CBR value and percentage of additives.**

Based on Figure 2, the decrease occurred in the variation of 0.4% of plastic sack fiber and 10% lime, and it decreased with increasing plastic sack fiber content. The lowest CBR value obtained was 11.98% at a 0.8% plastic sack fiber mixed percentage. If the CBR value is still greater than 5%, it can be considered qualified as a road subgrade. The decrease of CBR value can be caused by the increasing ratio of the number of plastic sack fibers to the soil volume, which causes the plastic sack fibers to be more dominant when mixed with the soil and reduce the axial strength of the soil.

3.4. Soil Physical Properties After Stabilization

The physical properties of the soil tested were the value of the plasticity index (PI) of the soil after the soil was mixed with variations of percentage plastic sack fiber adding with lime in order to see its effect on soil plasticity. Table 3 shows the Plasticity Index (PI) test results for each variation.

Table 3. Plasticity index data for each percentage of plastic sack fibers and 10% lime.

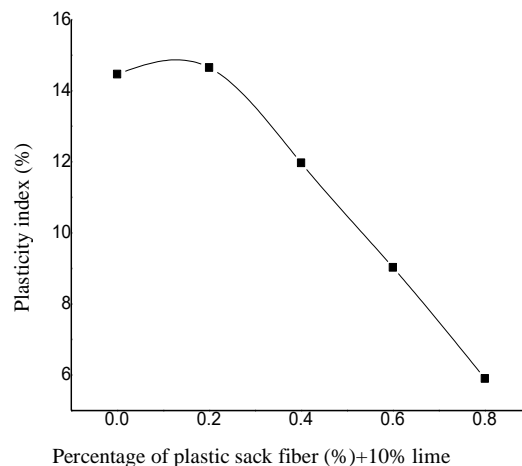| Percentage of plactic sack fiber (%)	Lime (%)	Plasticity index (%)
0	10	14.47
0.2	10	14.65
0.4	10	11.97
0.6	10	9.03
0.8	10	5.90

Figure 3. **Graph of relationship between plasticity index and mixed percentage.**

Based on Figure 3, the plasticity index (PI) value decreases with the increase in the mixture of plastic sack fibers. The plastic sack fiber content of 0.8% and 10% lime resulted in the lowest plasticity index value of 5.9%, categorized as low plasticity. At the percentage of 0.2% sack fiber and 10% lime, the PI value is 14.65% in the medium plasticity category. Based on the requirements of the PI and CBR values that meet the requirements for the subgrade, in the field implementation, the most effective percentage is 0.8% of plastic sack fiber and 10% of lime because it meets the requirements of the

PI value for the subgrade which is less than 7%. Therefore, it can be concluded that the addition of fiber content of plastic sacks and lime can improve the quality of the soil in terms of strength.

4. Conclusion

Based on tests conducted on the soil before and after soil improvement, the following percentages of plastic sack fibers were used: 0%; 0.20%; 0.40%; 0.60%; 0.80%; and 10% lime for each percentage of plastic sack fiber in the total dry weight of the soil without curing time. The original soil may be categorized as high plasticity organic clay (OH) due to its plasticity index of 37.36 percent and CBR value of 2.16 percent. The ideal CBR value of 41.78 percent was determined using 0.2 percent plastic sack fiber and 10% lime. The lowest CBR value of 11.98% was attained using 0.8 percent plastic sack fiber and 10% lime. Based on these findings, adding plastic sack fiber to soil may raise CBR while decreasing PI, reducing soil plasticity. Plastic sack fiber may also lower the soil's plasticity index (PI) from 37.36 to 5.9% when combined with 10% lime. When applying this combination in the field, the most effective amount of plastic sack fiber content is 0.8 percent plastic sack fiber and 10% lime, since this fits the standards for CBR and PI values for road subgrades, which cannot be less than 6% and less than 7%, respectively.

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