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Effect of Gypsum Waste Stabilization in Clay Soil on California Bearing Ratio Value

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A B S T R A C T

The problem that occurs in road construction is the low CBR value of the subgrade. Advances in stabilization technology for soil improvement by mixing clay with a mixture of gypsum powder which has elements of the compound Calcium Oxide (Cao), Potassium (Ca), Water (H_2O), Hydrogen (H), and Sulfur (S), so it is necessary to conduct further research and testing in the laboratory with the aim of obtaining the California bearing ratio value on variations in gypsum powder mixing. The research method used is an experimental method in the laboratory with reference to the 2018 Bina Marga General Specifications. With mixing variations of 5%, 10%, 15% and 20% gypsum waste. The soil used in this research was taken from Jalan Badak area, Sail, Tenayan Raya sub-district, Pekanbaru City, Riau which was then tested in the laboratory by testing the specific gravity, soil density and california bearing ratio. The results of laboratory testing, it can be concluded that the addition of 5%, 10%, 15% and 20% gypsum has increased the CBR value, namely with a CBR value of 1.70% to 12.50%. The CBR value has met the Binamarga specification, 2018 which is 6%. So from the results of the equation obtained, it shows a positive relationship, namely the optimum moisture content (OMC) value increases with the increase in the California Bearing Ratio (CBR) value.

1. Introduction

The subgrade is a layer of soil that functions as a pavement foundation and can support the construction of the pavement above it [1]. Because the subgrade is very influential for construction work, the subgrade is a component that must be considered in planning construction work [2]. Clay soils are problematic for construction because they have high plasticity, low bearing capacity, high shrinkage properties, and low permeability [3]

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As the population continues to grow, space is limited in urban areas and civil infrastructure is expanding into areas with poor soil conditions. For this reason, it is necessary to carry out soil improvement, which depends on the soil conditions and the project to be carried out [4]. Soil improvement is relevant to chemical stabilization and physical stabilization. It aims to improve soil bearing capacity values, and soil shear strength, and control soil volume stabilization [5]. Soil stabilization is a technique for modifying soil properties by mixing and incorporating new materials [6]. Soil improvement by chemical methods which can be further differentiated in several angles of view of the type of additive [5]. Soil improvement with chemical methods can be divided into soil improvement with powder (powder stabilization), soil improvement with solutions (solvent stabilization) [7].

California Bearing Ratio (CBR) value of subgrade prepared for flexible pavement > 6% after soaking for 4 days. The problem that occurs in the field is the low California Bearing Ratio (CBR) value of the subgrade that does not reach the minimum California Bearing Ratio (CBR) value based on the 2018 Bina Marga Specification, which is 6% for the subgrade [8]. The low bearing capacity value results in the construction above it being damaged due to an unstable foundation. To overcome this, one way that can be done is to carry out soil improvement, one of which is by chemical stabilization [9]. Therefore, it is necessary to carry out special treatment for subgrade soils with bearing capacity that does not reach these specifications, namely by stabilization [10].

Rising world population and the need to live continue to increase the price of raw materials and reduce natural resources. Waste materials, when properly processed, prove effective as construction materials and readily meet design specifications [11]. Currently, the trend of using waste materials in soil stabilization or soil reinforcement is growing worldwide [6]. One of them is gypsum waste, where gypsum can be obtained in a natural state, recycled products and waste that has the potential to be used as an adhesive material to replace cement and can be used to increase the bearing capacity of soil [4]. Gypsum is an effective way of stabilizing materials that are easily obtained with a high calcium content that serves to bind the soil with organic matter in clay soils and absorb more water which is useful for strengthening the soil [12]. Gypsum mixed in clay soil can reduce cracking because the sodium in the soil is replaced by calcium in the gypsum to reduce the occurrence of development [13].

This research reviews gypsum waste as a stabilizing material in clay soil on the value of California Bearing Ratio (CBR) to determine the effect of gypsum powder mixture can increase the value of California Bearing Ratio (CBR) on clay soil according to the specified standard. Because the mineral content is very high in gypsum, it can reduce cracks in the soil and replace it with calcium so that the development is small [14]. The chemical elements in gypsum are calcium oxide (Cao), calcium (Ca), water (H_2O), hydrogen (H) and sulfur (S) [15] [16].

Previous research related to the stabilization of clay soil with gypsum waste is [17] to improve the physical and mechanical properties of soil with gypsum mixture. Research [18] stabilization of clay with gypsum with variations of 3%, 6%, 9%, and 12% to increase the CBR value of soil in Sohar city. Research [19] stabilization of clay with gypsum waste with variations of 5%, 10%, 15%, and 25% on CBR value. Research [20] stabilization of clay soil with gypsum variations of 10%, 15%, 20%, and 25% on the value of free compressive strength of soil. Research [21] improvement of clay stability with gypsum waste and tin tailings. The difference between the research and the previous research is the variation of gypsum waste used and the location of the clay soil sampling.

2. Research Method

This research takes clay soil as the object of research to be stabilized using gypsum waste powder as a soil stabilization material against CBR value. Subgrade soil samples from

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Jalan Badak, Sail, Tenayan Raya District, Pekanbaru City, Riau. Samples taken are disturbed and undisturbed soil. For disturbed sample collection use a hoe to dig clay soil, while for undisturbed soil collection use handbore tools. Before testing the samples that have been prepared in the sun or in the oven to dry. The soil is then dried and then dried in the sun until dry. Then the soil is sieved using a no.4.75 sieve. While undisturbed soil is taken by using a handbook, to get the value of specific gravity and Zetterberg limit of native soil.

The gypsum waste carried out in the test is gypsum, the ceiling comes from the remnants of the installation of residential plafonds, Pekanbaru. The parameters used to increase the bearing capacity of the soil are the California bearing ratio (CBR) value, the California bearing ratio (CBR) value of the soil can be determined by testing the Proctor Test and CBR Test, to determine the dry weight value and CBR value of the soil.

Sorce: Google Map 2023

Figure 1. Research Location

3. Description and Technical

1. Population and Samples.

   This study used soil samples from Jalan Badak, Sail, Kec. Tenayan Raya, Pekanbaru City, Riau. The samples taken were disturbed and undisturbed soil. For disturbed sample collection use a hoe to dig clay soil, while for undisturbed soil collection use a handbore tool. Before testing the samples that have been prepared in the sun or dried in the oven until completely dry. The number of samples required in the original soil test is based on [22] :

   Table 1. Native Soil Testing Needs

No	Testing	Sample Quantity
1	Moisture Content Test	3
2	Specific gravity test	3
3	Sieve Analysis	3
4	Atterberg Test	3
5	Compaction Test	3
6	California Bearing Ratio (CBR) Test	3

2. Sampling Techniques.

   Once all the test specimens were prepared, they were put into one large plastic bag. The plastic bag is then sealed and placed in a shady place for exactly seven days [8]. After 7

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days of curing, the specimens were removed from the plastic bags, and laboratory CBR testing of clay stabilization with variations of 5%, 10%, 15%, and 20% gypsum waste. Gypsum waste left over from the installation of ceilings in housing is used as a clay stabilization material.

3. Definition of Variable Operations.
   The original soil tests carried out were testing water content, specific gravity, sieve analysis, Atterberg limits, compaction, and CBR. For testing the stabilization of clay with gypsum waste is CBR.

4. Instrument Analysis Tool.
   The tests carried out are laboratory tests, namely:
   a. Specific gravity testing equipment that refers to SNI 1964-2008 [23]
      The goal is to obtain the specific gravity of the soil.
   b. Soil moisture content testing tool that refers to SNI 1965-2008 [24]
      The aim is to obtain soil moisture content values.
   c. Sieve analysis testing tool refers to SNI 3423-2008 [25]
      The aim is to get the gradation of the soil sample.
   d. Atterberg limits testing apparatus refers to 1967-2008 [26]
      The goal is to obtain liquid limit, plastic limit, and plasticity index values.
   e. Laboratory compaction testing equipment refers to SNI 1742-2008 [27]
      The aim is to obtain the optimum moisture content and maximum dry weight.
   f. Soil CBR testing tool refers to SNI 1744-2012 [28]
      The goal is to get the CBR value of the soil.

5. Data Analysis Techniques.
   The soil that has been taken in the field, tests the physical and mechanical properties of the original soil. The gypsum waste was crushed using a beater, and then sieved using a No.200 sieve. Mixing clay soil with variations of gypsum waste is adjusted to the percentage of gypsum waste used, then curing for 7 days by putting it in a plastic bag. After that, the CBR testing of the stabilized soil can be carried out and then the data analysis of the laboratory test results is carried out.

4. Results and Discussions

4.1 Original Soil Testing

The results of the laboratory testing of native soil are presented in the following Table:

Table 2. Original Soil Testing Results

Description	Original Soil	
	Results	Unit
Specific gravity	2.657	gr/cm^3
Water content	29.86	%
Liquid Limit (LL)	43.24	%
Plastic Limit (PL)	2.69	%
Plasticity Index (PI)	18.56	%
Optimum Moisture Content	15.10	%
Maximum dry weight	1.63	gr/cm^3
CBR	2.20	%

Source: Research Data (2024)

The result of the original soil specific gravity test is 2.657 gr/cm3, based on [29] the soil sample is categorized as organic clay. For the plasticity index value obtained of 18.56%

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where the value > 17% is categorized as clay [29]. The results of the original soil tests above corroborate that the soil samples at the research site belong to the clay soil type from the specific gravity and plasticity index values obtained.

4.2 XRF Testing on Gypsum Waste

XRF testing on gypsum was carried out at the Chemistry Laboratory of Padang State University. The results of X-ray fluorescence (XRF) testing of gypsum are as in the following Table:

Table 3. X-Ray Fluorescence Testing Results of Gypsum

No	Composition	Concentration (%)
1	SiO_2	0.884
2	Al_2O_3	1.14
3	Fe_2O_3	0.238
4	K_2O	0
5	K	0
6	Ca	62.179
7	CaO	43.803

Source: Research Data (2024)

The calcium (Ca) content in gypsum waste was found to be 62.179% and the calcium oxide (CaO) content was 43.803. The pozzolanic reaction that occurs is a long-term reaction between calcium hydroxide and silicate. When calcium hydroxide produced by gypsum hydrates with soluble silicate (SiO2) and alumina (Al2O3) to form calcium silicate hydrate (CSH) and calcium aluminate hydrate (CAH) additives, the cement gel will bind the soil [4].

4.3 USCS (Unified Soil Classification System) Method Soil Classification

Soil classification aims to determine the type of soil that we have tested in the laboratory. USCS method soil classification can be seen in the following Figure:

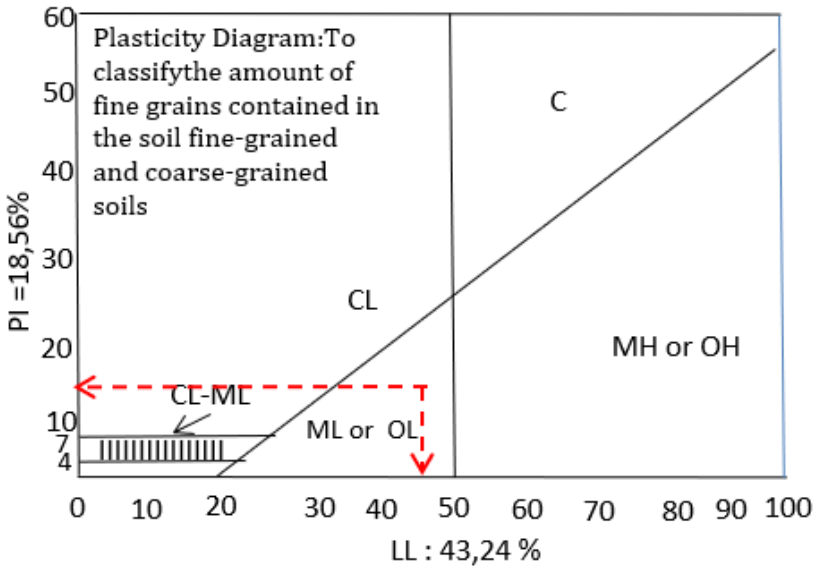

Figure 2. USCS method native soil classification

From the Figure based on the Liquid Limit (LL) value and the Plasticity Index (PL) value, the soil is classified as ML or OL, namely non-organic silt [29]. Because the soil sample does not contain organics, the soil is ML type, which is silt with low clay content [30].

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4.4 Stabilization of clay soil with gypsum waste

1. Specific gravity testing of stabilized soil

The results of the specific gravity test stabilized with 5%, 10%, 15%, and 20% gypsum waste are presented in the following Figure:

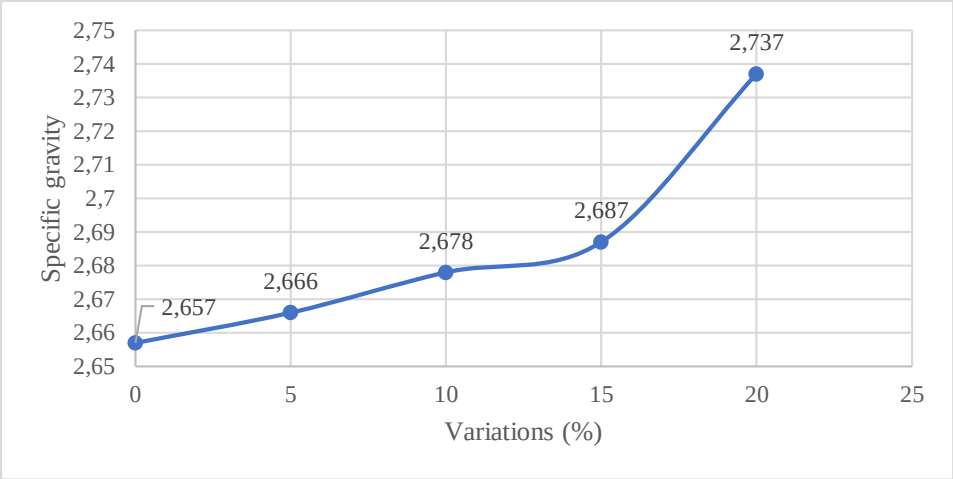

Figure 3. Specific gravity value of gypsum waste stabilized soil

Mixing gypsum powder can increase the specific gravity of the soil from 2.657 to 2.737 [4].

2. Atterberg limits test with gypsum waste mixture

The plasticity index (PI) value of clay stabilization with gypsum waste is presented in the following Figure:

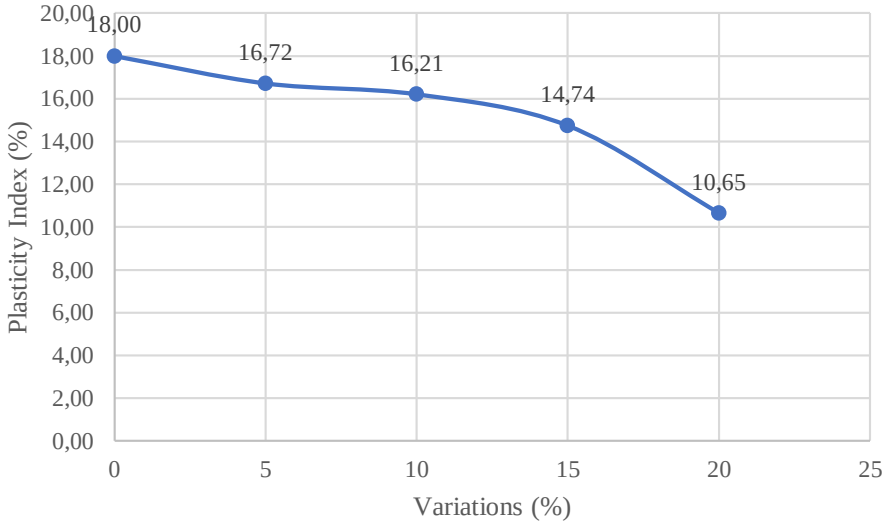

Figure 4. Plasticity index value of gypsum waste stabilized soil

The plasticity index value decreased due to mixing with gypsum waste. The pozzolanic reaction that occurs causes the cement gel to bind to the soil [4] and absorb the water in the clay soil [16].

3. CBR testing of clay stabilization with gypsum waste

The results of CBR testing of soil that has been stabilized with gypsum waste are presented in the following Figure:

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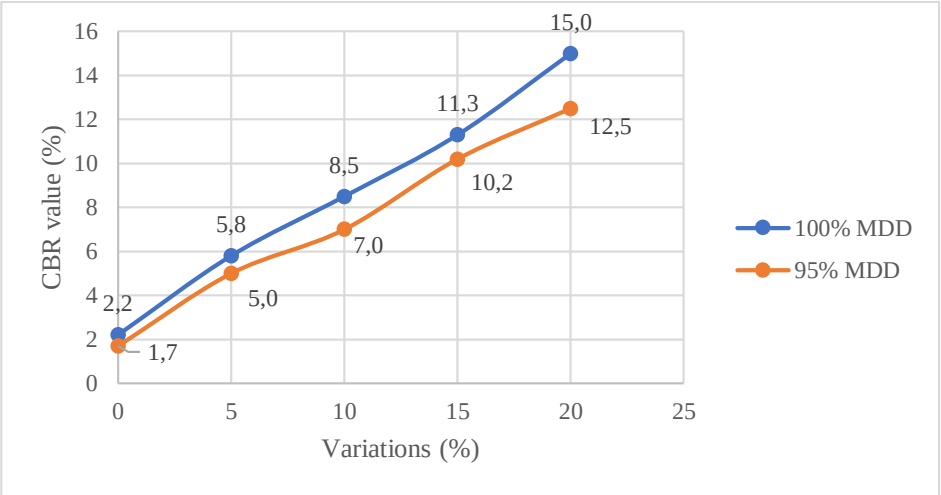

Figure 5. CBR value of stabilized clay with gypsum waste

There is an increase in the CBR value of clay soil that has been stabilized with a mixture of gypsum waste. The highest value of CBR occurs in a mixture with 20% gypsum waste, where the CBR value reaches 12.5%. This has met the standards set out in the 2018 Bina Marga Specification which requires that the CBR value for good soil-bearing capacity is > 6%.

4.5 Correlation of Gypsum Waste Mixture with CBR

The correlation value between the variation of gypsum powder and the California Bearing Ratio (CBR) can be seen in the following Table:

Table 4. Recapitulation of Correlation Relationship of CBR Value of Gypsum Waste Stabilized Soil

No	Campuran Variasi Gypsum (%)	Nilai CBR (%) 95% MDD
1	Tanah Asli	1,7
2	Tanah + *Gypsum* 5	5,0
3	Tanah + *Gypsum* 10	7,0
4	Tanah + *Gypsum* 15	10,2
5	Tanah + *Gypsum* 20	12,5

The effect of the addition of gypsum waste has increased the value of the California Bearing Ratio (CBR). The correlation value can be seen from the graph in the following Figure :

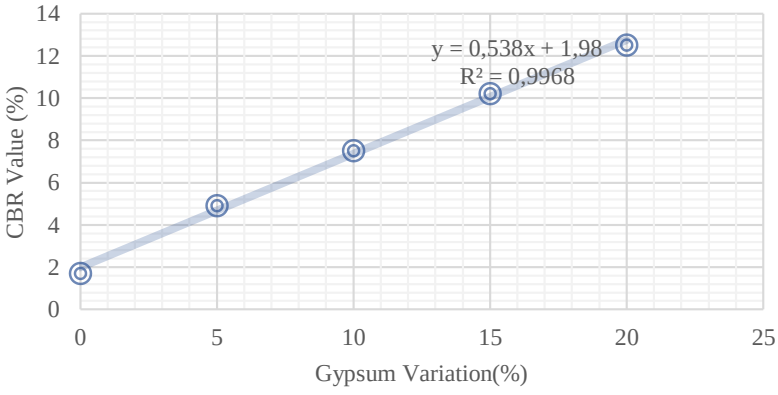

Figure 6. Correlation graph with regression

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From the results of the equation obtained from the graph above, namely:
$y = 0{,}538x - 1{,}98$
$R^2 = 0.9968$
$R^2 = \sqrt{0{,}9968}$
$R = 0{,}9983$

The regression model (R^2) is categorized as very good> 0.75 because the R2 value obtained is 0.9968 with the correlation obtained being very strong 0.80 - 1.00 [31]. So the results of the equation obtained show a positive relationship, which is the value of gypsum waste mixture increases with increasing California Bearing Ratio (CBR) value.

5. Conclusion and Suggestion

5.1 Conclusion

Based on the results of laboratory CBR testing, it can be concluded that the addition of 5%, 10%, 15%, and 20% gypsum waste can increase the CBR value. The increase occurs from the CBR value of 1.70%, namely the original soil CBR to 12.50% in the 20% variation of gypsum waste. The effect of stabilization of clay soil with gypsum waste obtained a very strong correlation where the value of R2 0.9968 > 0.75.

5.2 Suggestion

The research suggestions on the addition of gypsum waste are as follows:

1. For research needs, it can be used as a reference for further research.
2. It is necessary to conduct research for other tests such as consolidation testing using gypsum waste.
3. Further research needs to be done by increasing the variation of gypsum waste on the CBR value.

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