Jurnal Aplikasi Teknik Sipil
Volume 23, Nomor 2, Mei 2025

Journal homepage: http://iptek.its.ac.id/index.php/jats

Behavior Swelling-Shrinkage of Residual Soils as Chemically Stabilized

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Info Artikel
Diajukan 10 September 2024
Diperbaiki 20 Mei 2025
Disetujui 20 Mei 2025

Keywords: residual soil, selmut, swelling-shrinkage.

Abstract

The soils of Balikpapan belong to the soft to medium soil group, consisting of residual and sedimentary soils. Residual soil generally has granules in the silty soil group. Residual soil has a high shear strength when dry, shrinks when wet, and has a large capacity, so this soil has a low bearing capacity when wet. Potential swelling and shrinkage can occur due to changes in soil volume caused by changes in the level of liquid in the soil cavity. Soil swelling and shrinkage can cause damage to the building structure. Helmut is a blend of chemicals that act as soil stabilizers, such as lime and polymers. Helmut is a new chemical ingredient being developed by researchers. The soil stabilization method was to mix the soil with additives such as Helmut. The mixing of the original Balikpapan soil with the Helmut additive in the laboratory was manually done by adding the additive materials at 1, 2, 4, 6, 8, and 10% to the dry weight ratio of the soil and the optimum moisture content. The results showed that the Balikpapan soil had good physical and mechanical properties; the potential for shrinkage was also low, as indicated by a low activity value of A = 0.365 and a shrinkage limit of 16.99%. Soil stabilized with Helmut additives showed improved physical and mechanical properties, and soil activity decreased. The swelling potential value decreases with the addition 6% maximum of Helmut. Therefore the activity (A) calculation show that the lowest activity value of 0.23 was obtained with the addition of Helmut 6%.

Kata kunci: tanah residual, helmut, kembang-susut tanah

Abstrak

Tanah di wilayah Balikpapan tergolong ke dalam tanah lunak sampai dengan medium, terdiri atas tanah sedimen dan residual. Tanah residual memiliki kuat tekan yang tinggi saat kering dan menurun saat basah, sehingga tanah jenis ini mempunyai permasalahan daya dukung saat kondisi basah. Potensi kembang-susut tanah dapat terjadi karena perubahan volume tanah dimana hal ini disebabkan oleh perubahan air dalam tanah. Variasi kembang-susut yang besar dapat menyebabkan kerusakan pada infrastruktur di atas tanah. Pada penelitian ini untuk menstabilisasi tanah digunakan bahan kimiawi bernama Helmut. Helmut merupakan bahan stabilisasi hasil karya peneliti, berupa campuran beberapa bahan kimia. Tanah residual Balikpapan di campur dengan Helmut dengan variasi 1, 2, 4, 6, 8, dan 10% dari berat kering tanah. Penelitian dilakukan dilaboratorium Transportasi dan Geoteknik DTIS ITS. Pengujian sifat fisik dan mekanis dilakukan pada tanah inisial dan tanah yang telah distabilisasi. Hasil penelitian menunjukkan tanah residual Balikpapa kondisi awal mempunyai propertis fisik dan mekanis yang cukup baik, dengan nilai Aktivitas A = 0,365 dan batas kerut 16,99%. Tanah yang distabilisasi dengan Helmut menunjukkan perbaikan sifat fisik dan mekanisnya, secara khusus terlihat penurunan nilai Aktivitas tanah. Potensi swelling tanah menurun dengan penambahan Helmut maksimal 6%. Demikian juga Aktivitas (A) menurun maksimal saat penambahan Helmut sebesar 6%.

1. Introduction

Balikpapan's soils belong to the soft to medium soil group, consisting of residual and sedimentary soils. Residual soil generally has granules in the silty soil group. Residual soil has high shear strength when dry, expansion potential, shrinkage when wet, and large capacity [1]. Due to its good mechanical soil properties, many structures could be built on residual soil [2]. This soil, therefore, has a low bearing capacity in wet conditions; swelling and shrinkage can occur due to changes in soil volume caused by changes in the level of liquid in the soil void [3]. Soil swelling can cause compressive or uplift forces on the building structure, while soil shrinkage can cause settlement differentiation. This problem can be overcome by improving the bearing capacity of the soil and reducing its ability to compress [4].

Soil improvement methods have been carried out, such as mechanical improvements and improvements with chemical stabilization [5]. Mechanical soil reinforcement is performed

by preloading and installing a micropile, stone column, or geotextile. In contrast, the soil stabilization method developed for soft soil is the addition of chemicals such as lime or cement [6]. This paper presents the swelling and shrinkage characteristics of chemically stabilized residual soil with Helmut.

Researchers are developing Helmut, a stabilizer that can potentially improve soft and expansive soil problems. Helmut is a chemical ingredient made from several materials, namely polyvinyl acrylic acetate and a $Ca(OH)_2$ solvent. This produces calcium silicate and water, which are essential for stabilization.

Helmut's additives improve soil properties through a variety of reaction mechanisms, including the formation of complex and dense $C_aS_iO_3$-rich particles from the reaction between sodium silicate and $Ca(OH)_2$, the enhancement of inter-particle attraction through divalent cation exchange reactions at the soil surface, and the absorption, filling and binding of soil particles and voids by the organic polymer matrix.

This study will test the influence of Helmut on the stabilization of residual soil in Balikpapan and the swelling and shrinking behavior of residual soil in Balikpapan after stabilization with Helmut. The percentage of Helmut mixed with soil is 1%, 2%, 4%, 6%, 8%, and 10% of the weight of the dry land volume. The economic side for the large percentage selection is considered, and the physical and mechanical properties are tested in the laboratory using the applicable Indonesian National Standard.

2. Research Method

This research is experimental and carried out in the field and laboratory. The field research was carried out by collecting disturbed and undisturbed soil samples. Meanwhile, laboratory research was carried out by testing the physical and mechanical properties of the soil. Once the laboratory results were obtained, they were analyzed to determine the effect of the addition of the Helmut additive on the potential for soil shrinkage for pre- and post-stabilization conditions.

Helmut is a new soil stabilizer currently being developed by researchers. Helmut is made from a mixture of several materials, with a composition of polyvinyl acrylic acetate (2:1) and a Ca(OH)2 solution solvent. The presence of organic polymers (polyvinyl acrylic acetate and polyvinyl acetate), a silica source (Na2SiO3), and alkaline/basic compounds (Ca(OH)2), as well as a cation source (CaCl2), plays a critical role. The compound Ca(OH)2 is obtained by dissolving limestone (CaCO3). The basic compound Ca(OH)2 acts as a chemical reactant when the materials are mixed.

The baseline tests were taken directly from the field using undisturbed soil, while the stabilized soil tests were carried out on reworked soil. The soil was mixed with 1,2,4,6,8, and 10% of its dry weight. A large diameter sample of 10 cm x 20 cm was then taken. The sampled soil was left to stand for more than 2x24 hours before being tested again.

3. Result and Discussion

This research is experimental and carried out in the field and laboratory. Field research was carried out by sampling disturbed and undisturbed soil. Laboratory research was conducted by testing the physical and mechanical properties of the soil. After obtaining laboratory results, the results were analyzed regarding the effect of adding Helmut additive on the potential for soil shrinkage for conditions before and after stabilization.

A. Results of Testing Physical Properties of Soil Initial Conditions

The soil physical property test results consist of gravimetric volume, moisture content, soil unit weight, specific gravity, void ratio, and degree of saturation. Other data are the Atterberg boundary data of the soil, which include liquid limit, plastic limit, shrinkage limit, soil plasticity index, and soil expansion potential. The initial condition test results are shown in ***Table 1.***

Table 1. *Results of initial condition test*

Test Type	Unit	Results
Gravimetry and Volumetry		1
1. Specific Gravity		2.49
2. Water content (w)	%	44.16
3. Soil Unit Weight, γt	gr/cm3	1.58
4. Dry Unit Weight, γd	gr/cm3	1.10
5. Void ratio, e		1.09
6. Shrinkage Limit (SL)	(%)	17.05
7. Liquid Limit (LL)	(%)	50.24
8. Plastic limit (PL)	(%)	31.37
9. Plasticity Index	(%)	18.87
10. Activity		0.37
11. Swelling Potential		4.73

The results of the soil tests show that the soil had quite good physical characteristics. The soil parameters showed moderate values. Otherwise, the soil plasticity value showed good values. According to [7], soils with mineral activity greater than 1.25 (A>1.25) are prone to shrinkage when the water content changes. The swelling potential value shows a pretty good value, which is 4.73. The initial condition parameter was used to compare and determine the optimum condition after stabilizing the residual soil.

*Meanwhile, **Table 2** shows the results of the sieve and hydrometer analyses. The content of silt and clay fractions was close to 50%.*

***Table 2.** Results of sieve analysis and hydrometer testing*

Sieve Analysis	Unit	Value
1. Gravel Fraction (Gravel)	(%)	0.00
2. Sand Fraction (Sand)	(%)	26.11
3. Silt Fraction (Silt)	(%)	23.52
4. Clay Fraction (Clay)	(%)	50.37

B. Mechanical Properties of Soil Test Results during Initial Conditions

*The mechanical properties of Balikpapan soil were tested during the initial conditions at a depth of 0.5 meters from the ground to calculate the cohesion value (c) and the angle of internal friction. Direct shear was used to test the parameters. The results of testing the mechanical parameters of Balikpapan soil at initial conditions are shown in **Table 3**.*

***Table 3.** Mechanical results of initial conditions*

Test Type	Unit	Value
1. Cohesion	Kg/cm^2	0.192
2. Internal friction angle	^{0} (degree)	12

The results of the soil tests on the mechanical properties of the initial soil conditions showed a low cohesion value and an excellent angle of internal friction. This is due to the soil's significant amount of silt and clay.

C. Characteristics of swelling and shrinkage soil after stabilization with Helmut

***Figure 1** shows the results of testing Balikpapan soil's swelling and shrinkage characteristics stabilized with different percentages of Helmut.*

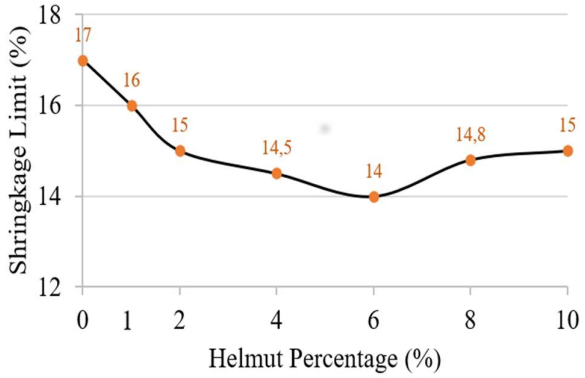

***Figure 1.** Graph comparison of shrinkage limit value with Helmut percentage*

*From **Figure 1**, it can be seen that there is a decrease in the shrinkage limit of the soil as Helmut content is added*99 *to the percentage. The analysis shows that the stabilized soil has a lower shrinkage limit than the natural soil. Reducing the soil's shrinkage limit will increase the soil's strength. This is because the lower the shrinkage limit, the harder it is for the soil to change volume. Furthermore, the higher the shrinkage limit, the more water is needed to change the volume [7].*

*The swelling potential of the stabilized soils was also tested at a depth of 0.5 meters from the soil surface. The results of the Balikpapan soil swelling potential and activity test are shown in **Figure 2** and **Table 4.***

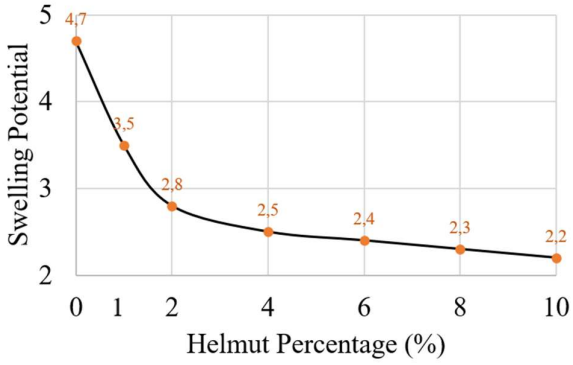

***Figure 2.** Graph comparison of swelling potential with Helmut percentage*

***Table 4.** Results of calculation of clay mineral activities due to the addition of Helmut*

Helmut percentage	Plasticity Index	Number of clay minerals	Activity
(%)	(%)	(%)	
1	19.87	50,37	0.33
2	18.06		0.30
4	17.57		0.26
6	16.63		0.23
8	17.65		0.26
10	18.95		0.27

***Figure 2** shows that the swelling potential value decreases with the addition of Helmut. Adding about 6% Helmut significantly reduced the soil's swelling potential value, while adding more than 6% Helmut had no significant effect.*

Stabilization strengthens the soil bond, thereby reducing the soil's swell-shrink properties. [4] found that fly ash added to clay soils induces hydration, increasing soil volume grain and particle orientation. Based on the test results, the stabilized soil has an activity value of less than 1.25. [7]

states that soils with mineral activity above 1.25 (A>1.25) are prone to shrinkage when water content changes.

The results of the activity calculation show that the lowest activity value of 0.23 was obtained with the addition of Helmut 6%. In comparison, the highest activity was obtained when the soil was mixed with Helmut 1%, with an activity value of 0.33. Based on these calculations, it can be concluded that the swelling potential of the Balikpapan soil stabilized with Helmut is in the low potential category. Trends in soil activity values are shown in ***Figure 3****.*

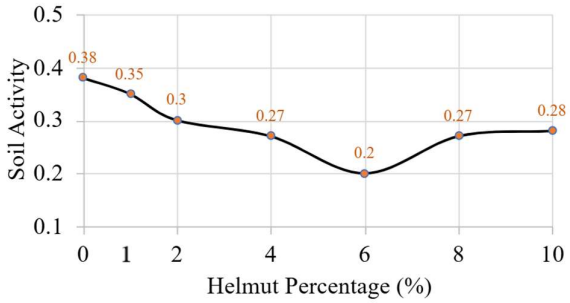

Figure 3. *Comparison of soil activity value during initial conditions and after stabilization with Helmut*

According to ***Figure 3****, the optimum soil condition was achieved when stabilized with 6% Helmut. The optimum condition is when the soil has the least active value, so the potential for expansion is less. This shows that the Helmut chemical plays a role in reducing the swelling potential of the Balikpapan soil because the calcium silicate content, which can fill the voids in the soil particles, increases the strength and hardness of the soil. In addition, the water involved in the reaction between* $Ceta(OH)_2$ *and* Na_2SiO_3*, which is also the constituent of Helmut, will act as a restraint on the structure of the silicate, which also has an impact on reducing its swelling [8].*

4. Conclusion

Based on the test results conducted in the laboratory, the following conclusions were obtained:

1. *In its initial condition, the Balikpapan residual soil had a value of Gs = 2.49; wc = 44.16%, void ratio (e) = 1.09; IP = 18.87%; Cohesion value (c) = 0.192 kg / cm2; and an internal friction ratio* 12^0*; swelling potential seen from activity of 0.37. Regarding the potential for swelling, if the activity value is < 0.75, it can be said that the potential for swelling is low.*
2. *Soil stabilization with Helmut shows improved physical, mechanical, and soil shrinkage potential. Adding Helmut to the soil has reduced the potential for soil shrinkage and swelling.*
3. *The optimum level of Helmut added was 6%. At levels above 6%, the addition of Helmut did not show significant results.*

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