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Research paper

Effect of Propylene Glycol and Laterite on California Bearing Ratio of Clay Shale

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Abstract

Clay shale in natural condition has a very high strength. But due to weathering caused by exposure with air and water, its strength decreased significantly. Propylene glycol is established as an effective shale inhibitor in water-based muds. The effect mixing propylene glycol with clay shale to its strength is needs to be discussed. Sample of Citereup clay shale has been mixed with propylene glycol with ratio 0.3, 0.5, and 0.7 of its optimum water content. California Bearing Ratio test have been performed to determine clay shale bearing strength. Result from study indicate that clay shale stabilization using 30% propylene glycol can increase strength in unsoaked condition. Laterite soil mix were also give additional bearing strength to clay shale specimen.

Keywords. *Clay shale, Soil stabilization, propylene glycol, CBR, triaxial test.* MSC. 65K10, 62P05, 94D05**.**

1. Introduction

Clay shale is one of problematic soil in geotechnical engineering. Clay shale is formed from claystone that is easily weathered by exposure to air and water. In natural conditions, the clay shale is usually hard & rigid, and difficult to dig without mechanical equipment. Degradation of the clay shale soil that originally led the natural form such as rocks, can be changed until it resembles fine-grained soil.

The wet-dry cycle in natural conditions is a major cause of weathering of clay shale. The instability of these strength is influenced by water absorption and hydration in clays. When water is in contact with clay shales, water absorption occurs directly. This causes hydration and expanding clay shales that cause changes in stress and/or volume increase. The addition of stress leads to cracks in rock formations, whereas the addition of volume leads to a decrease in soil mechanical strength, development, and disintegration as presented in Fig. 1.

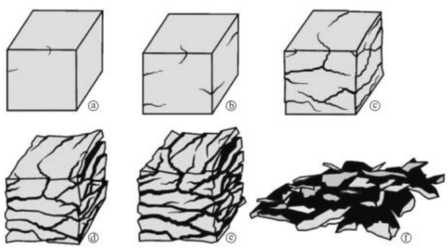

Fig. 1 Illustration of general appearance of the body slaking mode of mudrocks under exposure condition[1]

However, the weathering process can lead to significant reductions in strength[2], [3]. Claystone shear strength is also drastically reduced in very softened weathered conditions when in wet and submerged conditions [4]. Clay shales often cause problems in geotechnical engineering, such as in the selection of embankment material, the carrying capacity of deep & shallow foundations, the stability of the natural & artificial slope, and others. Improper planning of the clay soil may cause damage to the built-in infrastructure. Several problems caused by the clay shale found several times in Indonesia such as Cipularang toll road [5], the development area of Education Training Center and National Sports School (P3SON) at Bukit Hambalang Bogor, and on Semarang-Bawen[6].

Several methods were developed to improve the strength of the problematic soil to be used as construction materials. Chemicals used as soil stabilization agents are classified as inorganic and organic. Inorganic materials such as cement, lime, fly ash, and mixtures have been used for soil reinforcement [7]–[10].

Another way that can be done to improve the stability of degraded or disrupted flake clays is to add polymer solution i.e. propylene glycol. Propylene Glycol is a polymer developed as an inhibitor at the time of drilling in the shale layer [11]. These polymers are also more environmentally friendly than other inhibitory solutions so many are beginning to be used in field applications. Propylene Glycol is used as a stabilizing agent in clay-sand mixtures [12]. Propylene Glycol is commonly used as a drilling fluid because of its inhibitory properties to the soil. Not many have tested the effect of propylene glycol on soil strength characteristics.

In a previous study [13] shown the potential of shale loam stabilization using propylene glycol. The results of this study indicate that organic polymeric materials have potential as a safe stabilizing agent for ecology used as soil strength enhancers, particularly in clay shale.

Based on the above description, a stabilization material is needed that effectively increases the strength of clay clays and is environmentally friendly. In this study we want to know more influence about the effect of variation of amount of propylene glycol used to increase soil bearing capacity. In this study also done addition of laterite soil that has a lot of clay content to uniform gradations of clay grain clay, so the grains are filling each void and can occur bonds between particles better.

2. Methodology

2.1. Material Characterization

The soil selected in this study was clay shale material. Samples were gray colored, created from weathered claystone. The sample location was same like previous study[13] at Citereup, Bogor District, West Java Indonesia. The reason this soil was selected is that there was an infrastructure failure caused by exposed clay shale. Table I presents the index properties of this material.

Table I Clay shale properties

Properties	Clay Shale
Specific Gravity (Gs)	2.75
Liquid Limit (%)	31.77
Plastic Limit (%)	20.70
Plasticity index, PI (%)	11.07
Sand (%)	1
Silt (%)	80.27
Clay (%)	18.73

2.2. Propylene Glycol

Propylene Glycol (PG) is a commonly available solution in chemicals stores. Physical form of Propylene Glycol was thick, clear and odorless. Variations of propylene glycol mixture used in this study were 30%, 50% and 70% of the optimum water content of clay shales. This compound was chosen for several factors: 1) Non-toxic so environmentally friendly; 2) Easily soluble in water; 3) Less expensive than the derivative polymers

2.3. California Bearing Ratio Test

Testing performed according to the current edition of the American Society for Testing and Materials (ASTM), volume 4.08. Standard proctor compaction test (ASTM D698) were performed on the clay shale and clay shale-laterite mixture material specimen. The proctor samples were first oven dried, and each proctor soil specimen was weighed to the nearest gram. Water added and blended by hand until uniform consistency reached. The samples then allowed to cure for at least 24 hours to ensure all void was filled with water. This procedure was used in all subsequent phases of testing.
The maximum dry density an optimum moisture content for each sample were taken and this information was used to mold the CBR specimen. This time some of water were replaced with propylene glycol. The dosage of propylene glycol the calculated weighed with ratio of 0.3, 0.5, and 0.7 to its optimum water content.
The CBR tests were performed according to ASTM D1833. The CBR specimens were molded to a density equal to approximately 100 percent of the clay shale or clay shale-laterite maximum dry density, approximately at its optimum water content. The samples were molded in 6-inch mold in diameter with standard hammer. After molded, the specimens then were tested using CBR machine as presented in Fig. 2. This test called unsoaked CBR test. Deflection readings were taken with dial gauge and load was obtained from proving ring. CBR value then calculated according to ASTM D1883, and the CBR value obtained.
After unsoaked CBR test performed, the CBR specimens were placed in a water bath in a controlled temperature environment and allowed to soak for a period 96 hours. A surcharge stress about 3.64 kPa was applied using steel weights volume change measurement were taken to obtain swelling behavior with dial gauge. After 96 hours soaking period, CBR soaked test were performed.

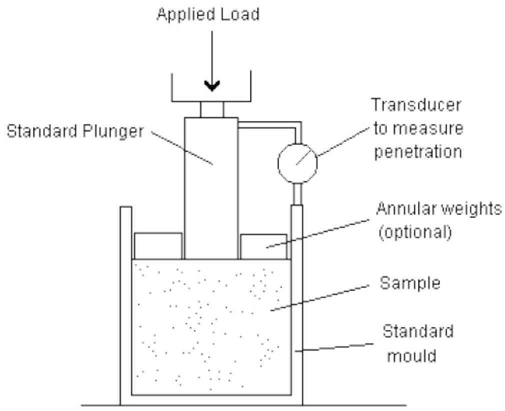

Fig. 2 California Bearing Ratio tester

3.Results and Discussions

3.1.CBR Results

From the proctor test, obtained maximum dry density for clay shale samples are 1.91 gr/cm^3 and the optimum moisture content were 13.4%. Table II presents the CBR test results. No corrections to CBR values were required because all plots of penetration versus stress were initially linear. An increase in propylene glycol content were actually tended to decrease the CBR value, not as expected. CBR value also dropped in soaked condition. In test, soaked specimen were very soft and can penetrated easily using finger.

Table II Initial CBR test results

Material	Average swell, %	CBR value	
		un-soaked	soaked
Clay shale	1.524	12.3856	3.612467
Clay shale + 30% Propylene glycol	1.118	16.2561	2.838367
Clay shale + 50% Propylene glycol	0.700	10.8374	1.5482
Clay shale + 70% Propylene glycol	0.530	9.2892	0.516067

Propylene glycol in liquid form, it makes soil particle separated and does not make bond between it and make density of the specimen decreased. However, increase in propylene glycol content decrease swelling activity up to 60% compared to the original clay shale.
Likewise, use of swell measurements as indicator to predict CBR value of clay shale specimen does not seem appear to be correlated. Usually, smaller swelling activity tend to have better CBR value. But it does not happen in clay shale material.

3.2.Supplemental study

In order to make gradation of grain size distribution smoother, samples of clay shales were mixed with laterite soil that have many clay sized particles. Laterite were taken from Depok, Indonesia. Material properties of the laterite soil presented in Table III

Table III Laterite soil properties

Properties	Laterite
Specific Gravity (Gs)	2.7
Liquid Limit (%)	90.92
Plastic Limit (%)	44.51
Plasticity index, PI (%)	54.41
Sand (%)	3.54
Silt (%)	57
Clay (%)	39.31

The test procedures used for this phase of testing were same as those used for the initial test. The difference is clay shale sample were mixed with 10% laterite soil, considering to clay shale dry weight (γ_{dry}). Proctor test were performed to identify the maximum dry density and optimum moisture content for molding the specimen for CBR tests. CBR unsoaked and soaked were also performed to this samples.

Table IV Supplemental CBR study results

Material	Average swell, %	CBR value	
		un-soaked	soaked
Clay shale	1.524[1]	12.385[1]	3.612[1]
Clay shale + Laterite	2.743	17.030	1.032
Clay shale + 10% Laterite + 30% Propylene glycol	1.526	15.482	0.774
Clay shale + 10% Laterite + 30% Propylene glycol	0.809	13.160	0.516
Clay shale + 10% Laterite + 30% Propylene glycol	0.464	10.837	0.310

[1]Test results from initial study

Table IV presents the CBR test results. The control specimen test results are included for comparison. In all instances, addition of propylene glycol does not improve the clay shale-laterite soil mixture.

4.Discussion of the result

The AASHTO Guide for Design of Pavement Structure recommend that soil used in pavement should have minimum CBR value around 5 to give good performance. This study indicates that clay shale material is not a good construction material especially in soaked condition. This possibly caused by its sensitivity to water that make it disintegrated and swell as we see in CBR results above.

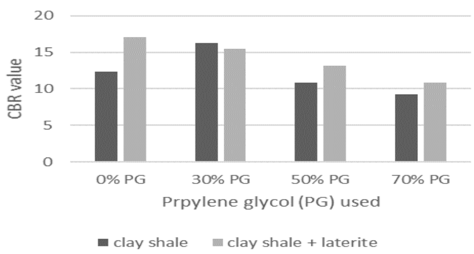

Fig. 3 CBR unsoaked value comparison of clay shale and clay shale+laterite specimen

As presented in Fig. 3, clay shale mixed with laterite specimen have slightly higher CBR unsoaked value compared to clay shale only soil, although still have a small CBR soaked value. Solid material (laterite) can give more additional strength rather than liquid material (propylene glycol).

Increasing in propylene glycol content can Reduce swelling potential of clay shale. As explained in previous study, the mechanism of glycol to act as an inhibitor is by interfering hydrogen bonds between the water and the surface of the clay particles. The cause of the shale clays is unstable when interacting with water due to its strong tendency to absorb water (hydration), leading to development and dispersion. This affects the hydrogen bond formation (H --- O) with water and silica or alumina groups on the surface of the shale clay. Glycol can also compete with water at the time of hydration around the cation that is absorbed in the shale clay, which also affects the hydrogen bond.[14]

This results of study were different with previous research[13]. In that research 75% propylene glycol can increase CBR soaked value up to 100%. This difference possibly caused by: 1) Different disintegration degree of soil, caused material from previous study was taken in dry season, while material used in this study was taken in rainy season; 2) different spot of material source. Need mineral identification to make sure the material used in this study is same to the previous study.

As discussed before, clay shale is not good in soaked condition, pavement with subgrade from clay shale soil is more likely to have a good drainage to prevent clay shale from contact with water for long period.

5.Conclusions

The addition of propylene glycol not significantly improved the CBR value of the soils tested. The improvement just happens at clay shale sample using 30% propylene glycol in unsoaked condition. At soaked condition not showing any improvement, addition of propylene glycol content tend to have an optimum content to improve clay shale strength. Propylene glycol only reduce the swelling activity of the clay shale soil.

Clay shale bearing strength more affected by laterite. Solid material (i.e. laterite soil) were giving more additional strength compared to liquid material (propylene glycol). Need a follow up study for another additive material to improve clay shale strength, especially in shear strength such as triaxial test.

References

[1] I. A. Sadisun, Bandono, H. Shimada, M. Ichinose, dan K. Matsui, “Physical Disintegration Characterization of Mudrocks Subjected to Slaking Exposure and Immersion Tests,” *Indones. J. Geosci.*, vol. 5, no. 4, hal. 219–225, 2010.

[2] I. M. Alatas, S. A. Kamaruddin, R. Nazir, M. Irsyam, dan A. Himawan, “Shear Strength Degradation of Semarang Bawen Clay Shale Due to Weathering Process,” *J. Teknol.*, vol. 11, hal. 109–118, 2015.

[3] I. A. Sadisun, H. Shimada, dan K. Matsui, “Determination of Strength Degradation of Subang Formation Claystone Due to Weathering,” *Earth Sci.*, no. SEPTEMBER, hal. 37–46, 2001.

[4] T. D. Stark dan J. M. Duncan, “Mechanisms of strength loss in stiff clays,” *J. Geotech. Eng.*, vol. 117, no. 1, hal. 139–154, 1991.

[5] A. M. A. Putera, S. Pramusandi, dan B. Damianto, “Identification and classification of clayshale characteristic and some considerations for slope stability,” *African J. Environ. Sci. Technol.*, vol. 11, no. 4, hal. 163–197, 2017.

[6] I. A. Sadisun, R. D. Kartiko, A. Kesumaningtyas, T. E. Utami, dan E. Sucipta, “Shear Strength Reduction of Tertiary Jatiluhur- Subang Claystones Due to Swelling Processes,” no. SEPTEMBER 2015, hal. 1–4, 2016.

[7] F. G. Bell, “Cement Stabilization and Clay Soils, with Examples,” *Environmental & Engineering Geoscience*, vol. I, no. No. 2. hal. 139–151, 1995.

[8] J. D. Mckinley, H. R. Thomas, K. P. Williams, dan J. M. Reid, “Chemical analysis of contaminated soil strengthened by the addition of lime,” *Eng. Geol.*, vol. 60, no. 1–4, hal. 181–192, 2001.

[9] D. J. White dan P. C. Taylor, “A laboratory study of the effects of bio-stabilization on geomaterials by Shengting Li A thesis submitted to the graduate faculty In partial fulfillment of the requirements for the degree of MASTER OF SCIENCE Major : Civil Engineering (Geotechnical Engin,” 2013.

[10] Y. Cai, B. Shi, C. W. W. Ng, dan C. sheng Tang, “Effect of polypropylene fibre and lime admixture on engineering properties of clayey soil,” *Eng. Geol.*, vol. 87, no. 3–4, hal. 230–240, 2006.

[11] T. S. Cortner, P. A. May, dan R. P. Collins, “Dry Drilling Fluid Additives And Methods Relating Thereto,” 2012.

[12] J. Liu, B. Shi, K. Gu, H. Jiang, dan H. I. Inyang, “Effect of polyurethane on the stability of sand-clay mixtures,” *Bull. Eng. Geol. Environ.*, vol. 71, no. 3, hal. 537–544, 2012.

[13] R. Lesmana, “Stabilisasi Lempung Serpih yang Mengalami Pelapukan dengan Propylene Glycol dan Kalium Klorida sebagai Alternatif Material Timbunan,” 2017.

[14] M. S. Aston dan G. P. Elliott, “Water-based glycol drilling muds: Shale inhibition mechanisms,” *Eur. Pet. Conf.*, no. 1/-, hal. 107–113, 1994.