Landslides induced by slaking of geomaterial

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Abstract. The geological event that happens because of an unbalance between shear strength and shear stress on rock mass is known as a landslide. This usually occurs due to improper handling of the exposed material. The landslide occurs because of the reaction to reduce the burden it bears so that the mass of the rock will move rock mass from the higher elevation to lower elevation. Many landslides, in west java, Indonesia occurred on exposed clay shale that is protected by soldier pile with 3m in distance between pile. On top of the clay shale, there is a building which gives an additional load on the clay shale. To determine the effect of water and temperature on clay shale, static slaking index test was conducted. With a submerge variation, it was found that the slaking index value ranged from 2.17% to 12.0% with the slaking classification from very low to medium. The size distribution was produced from 1/4 and 1/2 sample submerge show bigger rock breakage than rock with 3/4 sample submerge and sample fully submerge. Observations of the sample in room temperature without contact of water and no additional mass were also done. The sample was still intact until the end of research work.

1 Introduction

Landslide is a geological phenomenon that occurs because of the unbalance between shear strength and shear stress in the rock mass. A lot of landslide cases happen due to improper handling of exposed materials. Landslide cases happen when rock or soil mass not stable, so it produces gravitational force and to reduce the mass it holds, that rock mass will move from the upper rock to rock with the lower elevation.

Rock that needs special treatment is clay shale with make part of the infrastructure. Clay shale in general located in the water-unsaturated zone, because the effect of capillarity is more involved in the area and depends on surface water, as well as the behavior of shale is included as transition material between soil and rock [1]. Capillarity effect is very influential on the strength of clay shale. Capillarity comes from negative tension and is able to cray the clay shale if the clay shale bond is not sufficient.

Due to the degradation, clay shale can be slaked, if the material was left in the open air or in contact with air and water.

Clay shale mechanical properties are very intriguing. When in a dry condition, it shrinks and hardened, but when in contact with water, it swells and to some extent loss it shear strength hence the sudden drop in its strength, even its own weight have an impact. Due to swelling and shrinking of a rock are strongly influenced by climate and weather, and can change the shale from rocks to the soil, Therefore shale can easily decrease in

durability over time when there is a direct contact with air and water.

Static slaking index tests were done to discover how water and temperature influence on clay shale. This test was done with a wet and dry condition in two cycles. Using varying submerging water sizes, the amount of water content of each clay shale sample will be different, this will have an impact on the size distribution of rock breakage. While sample that left in natural condition did not get the wet and dry treatment, its condition remained intact for 10 months of research, degradation progressed very slowly.

2 Landslide in clay shale layer

Landslide cases that just happen in west java, Indonesia is a landslide in clay shale layer. Excavation of clay shale was done for the purpose of development of a building, but near the location has been standing other buildings for more than five years. With the removal of this clay shale layer, it can provide a clay shale opportunity to release the stress.

Field observations show that exposed clay shale has laminate with a lot of fissility and the increasingly widespread cracks. As shown in Fig. 1. Clay shale is a rock with a fissile and laminated characteristic. Resulting rocks consist of many thin that can easily split into thin pieces along the laminate, so that clay shale has the properties that are easily destroyed and expansive swelling if exposed to water. Then clay shale will change from rock that originally hard to be a weak rock. The process of this change can take place within days, weeks,

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months or years for clay shale that has been unveiled. Clay shale slope that is excavated and exposed, then protected by soldier pile 800 mm diameters with a 3m distance between pile (Fig. 2). Tropical condition resulted in a temperature effect of 23°C - 32°C and very high rainfall with an average annual rainfall of 4000 mm. The opening process of clay shale gives clay shale a change for slaking. The repetitive effect of shrink and swell will lead to instability resulting in loss of shear strength.

Fig. 1. The condition of clay shale that has been exposed

Fig. 2. Clay shale wall condition with soldier pile

Fig. 3 shows a landslide after 2 years of exposure. Clay shale pushes some of the soldier piles and causes a collapse of the wall. The thing that accelerates the landslide is at the bottom of the road, where the culvert broke, resulting in seepage of water on the slope. This proves that water greatly affects the durability of clay shale.

The impact of this landslide is the destruction of the road above the clay shale layer, the building floor is heaving and the building wall is cracked.

Fig. 3. Clay shale layer landslide

Fig. 4. The impact of clay shale landslide on the neighbor building

With clay shale properties that are easily destroyed and swelling, and expansive if exposed to water, then a quick handler is done by covering the surface of clay shale so it's not filled by rainwater. Temporary closure of exposed clay shale is by using a waterproof material such as tarpaulin for subsequent wall will be grouting and closed with shotcrete and monitoring the movement of clay shale by using inclinometer which is read every day during the movement is still large and then readings can be done every week when the movement has been begun to decrease.

Fig. 5. How to handle landslide

3 Testing method

Slaking index test is testing on rocks in the form of observation of rock behavior that can be used to investigate the process and the mechanism from clay shale with more detail. This slaking static test is a development from modified slake index testing that had been done by Deo [2], Paul M Santi [3] and further developed by Imam A Sadisun et al. [5].

The concept of the slaking index test (I_s), is using a wet-dry cycle. However, the sample was left submerged and left in an open air with a room temperature of 24°C - 26°C.

The testing procedure that is recommended by Imam A Sadisun [4] is by drying the rock sample first inside the oven for 24 hours at the temperature of 105°C. Next, the wet-dry cycle's done by submerging it with water for 48 hours, then filtered by using a # 10 (2 mm) sieve size. Samples retained on sieve # 10 were dried in an oven at 105°C for 24 hours for the next cycle. While sample that passed on sieve # 10 was dried and weighted.

The variation on how much water needed to submerge for slaking static test was done with a purpose of discovering how fast the sample absorbs water and will give a reaction to decrease the rock strength.

In general specimen preparation doesn't need a certain dimension, and can be in cylinder, cube or irregular shape.

The loss percentage sample to initial oven-dried mass is calculated and recorded as a slaking index value (I_s) for that cycle, or it can be defined as an equation:

$$I_s = \frac{W_x - W_{x'}}{W_x - B} \times 100\% \quad \dots\dots\dots(1)$$

where W_x = total mass and oven dried material, $W_{x'}$ = total mass and oven dried material retained on the 2.00 mm sieve, B = total mass container.

On the last drying cycle, it was done by using a sieve size of # 1,5 (38,1 mm) - # 10 (2 mm). each weight held is weighed. The stuck percentage is calculated by dividing the weight held by the total weight of the sample. This grain size distribution shows the degree of clay shale disintegration.

Table 1. Class value and classification obtained from single cycle of slaking index test [5]
(Imam A Sadisun, 2002)

Class	Slaking Index (%)	Classification
1	0 - 5	Very Low
2	5 - 10	Low
3	10 - 25	Medium
4	25 - 50	High
5	50 - 75	Very High
6	75 - 100	Extremely High

4 Testing method

Index properties of materials were tested prior to testing. Usually done before starting the slaking index test, first test the plasticity. Similarly, in this test Atterberg limit test has been done to get the value of the plastic index. The A curve in Fig. 6, shows the value of the liquid limit and the plastic index. With the value of Plastic Index (IP) 4 - 12, the clay shale sample tested is included in rock classification having CL character that is clay with the liquid limit value below 50%.

Fig. 6. Index plasticity result grouping in chart A

In this slaking index static, also conducted observations on rock samples are left in the open air with natural temperature 27 °C - 31 °C (tropical average temperature) without dry and wet condition so that the sample is not disturbed or affected by water and loading pressure. Observation result after 10 months, shown that clay shale still intact, with no visible crack. A delicate and very thin crack appears in some parts only. Fig. 7.a. during left in the open rock samples did not crack, 7. b. rock sample already has a crack from the beginning, because it does not get the influence of water and loading, this condition persists and not destroyed.

From the observations on the samples left in the open it can be seen that if one of the factors causing the weakening of clay shale in the form of temperature and water is eliminated, the process of weakening clay shale will run very slowly.

Fig. 7. Rock sample left in the open air

The result variation of the used amount of water for submerging the sample in static slaking test results with a static index value such as in Fig. 8. Based on the grading and classification of slaking index by Imam A Sadisun, 2002, on the 1st cycle of the slaking Indexes (I_s), variations for submerging 1/4 clay shale rock with the I_s value of 2,49% - 4,57%, were classified as class 1 of very low classification, variations for submerging 1/2

clay shale rock with the I_s value of 2,39 % - 5,09%, were classified in class 1, very low classification, variations for submerging 3/4 clay shale rock with the I_s value of 2,17 % - 4,31 %, are class 1, very low classification, and sample variations that submerge fully with the I_s value of 2,6 % - 12,0 %, are classified in class 1 until class 3 ie from very low to medium classification. In the first cycle, all of the samples seemed to show no significant slaking, but after the second cycle, in the test sample a significant decrease of rock strength began to occur, this is marked by the number of cracks that began to disintegrate. If the process of wetting and drying repeatedly, then clay shale began to show weakness. This curve shows the occurrence of weakening acceleration of clay shale with a weak plasticity index.

8.a. submerging 1/4 of the sample

8.b. submerging 1/2 of the sample

8.c. submerging 3/4 of the sample

8.d. submerge fully

Fig. 8. Results of slaking index testings

The curve in Fig. 8 shows that water has a big impact. Capillary absorption process takes place quickly for crack that has arisen. Water quickly filled the gap,

filling the room and pushes the wall, until it finally destroyed. Like most substances, rock expands as it heats up and shrinks as it cools. By heating the rock in the oven, the rock thermally-expanded. Then, by dunking it into the water the surface layer of the rock cool down but the middle part still has still need sometimes to get cool down as the result the surface of the rock shrink while the middle part expanding putting the rock in a lot of stress resulting with a crack. By doing this test over and over again the crack becomes apparent.

Slaking process and size distribution can be seen in Fig. 9. The amount of water that sample received influence with the size of rock breakage. 9.a and 9.b have a breakage size from 1,5 inc (38,1 mm) until smaller than # 10 (2 mm). In the first cycle, a sample showing a hair-thin of a gap and showing no symptoms will collapse. Next cycle shows that the sample collapses slowly but loss only a tiny bit of material in the bottom # 10 (2 mm). Material that collapses only happen in the submerged part of the sample

9.a. submerging 1/4 of the sample

9.b. submerging 1/2 of the sample

Fig. 9. Typical fragmentation of the sample slaking static

Fig. 10 a and b show sample that submerge 3/4 of the sample and the water-saturated sample of the particles will be dispersed rapidly. Immediately after the drying process the sample is then soaked, the sample collapse and has a rock breakage size ranging from 0,5 inch (12.7 mm) to less than # 10 (2mm).

By doing this submergence variation in the test, then it can be shown that the material will be weakened and destroyed on the condition of the material that contains a lot of water.

10.a. submerging $\frac{3}{4}$ of the sample

10.b. submerge fully

Fig. 10. Typical fragmentation of the sample slaking static

6 Conclusion

1. Landslide happens on the slopes of clay shale on which there are buildings and roads. Slopes wall that is protected by soldier pile. Clay shale condition was left exposed, causing temperature and water to provide a substantial role in accelerating sliding.
2. From the observations on the samples left in the open it can be seen that if one of the factors causing the weakening of clay shale in the form of temperature and water is eliminated, the process of weakening clay shale will run very slowly.
3. Slaking index test with submerging variation shows that clay shale was classified in medium to high slaking properties with the value of index slaking (Is) of 2,17% to 12,0%. Changes in the weakness of the sample in the first and second cycles decelerated. This was proved by increasing value of the slaking index, which is not large from the first cycle to the second cycle.
4. The submerge level of the sample affects the rock breakage. Where $\frac{1}{4}$ and $\frac{1}{2}$ submerge sample have bigger breakage which is start from 1,5 inch (38,1 mm) while $\frac{3}{4}$ and sample that are submerged fully has a smaller breakage which is start from 0,5 inch (12,7 mm). This shows that water has a huge part in weakening clay shale.

Reference

1. Abul Hasnat M. Shamim• Takeo Akae, *Effect of Initial Water Content on Saturated Hydraulic Conductivity in Desalinization with Slaking and Drying*, Paddy Water Environ, 2011, 9:221–228
2. E.I. Stavridakis and T.N. Hatzigogos, *Influence of Liquid Limit and Slaking on Cement Stabilized Clayey Admixtures*, Geotechnical and Geological Engineering17: 145–154, 1999.
3. Engin C. Koncagu" I, Paul M. Santi, *Predicting the unconfined compressive strength of the Breathitt shale using slake durability, Shore hardness and rock structural properties*, Department of Geological and Petroleum Engineering, School of Mines and Metallurgy, University of Missouri-Rolla, 1870 Miner Circle, 129 V.H, 1998
4. Idrus M Alatas, Samira A Kamaruddin, Ramli Nazir, Masyhur Irsyam, Agus Himawan, *Shear Strength Degradation of Semarang Bawen Clay Shale Due To Weathering Process*, Jurnal Teknologi, 2015
5. Imam A. Sadisun, Hideki Shimada, Masamoto Ichinose, and Kikuo Matsui; *Evaluation of Physical Deterioration of Slake-Prone Rock Subjected to Static Slaking Test*, The 11th Japan National Symposium for Rock Mechanics 2002
6. I. A. Sadisun & Bandonno, H. Shimada, M. Ichinose & K. Matsui, *Slope Instability of Road Cuts Due to Rock Slaking*, 12th Asian Regional Conf. on Soil Mechanics & Geotechnical Engineering, Leung et al. (eds) © 2003
7. I.A. Sadisun, H. Shimada, M. Ichinose and K. Matsui, *Study on the Physical Disintegration Characteristics of Subang Claystone Subjected to a Modified Slaking Index Test*, I Geotechnical and Geological Engineering (2005) 23: 199–218
8. Jianfeng Qi, Wanghua Sui. Ying Liu, Dingyang Zhang, *Slaking Process and Mechanisms Under Static Wetting and Drying Cycles Slaking Tests in a Red Strata Mudstone*, Geotech Geol Eng (2015), 33:959–972
9. J.L.Walkinshaw, PM. Santi, *Shale and Other Degradable Materials*, Chap.21 Landslides Investigation and Mitigation, National Academy Washington DC,1996.
10. M. Heidari, B. Rafiei., Y. Mohebbi, M. Torabi-Kaveh, *Assessing the Behavior of Clay-Bearing Rocks Using Static and Dynamic Slaking Indices*, Geotech Geol Eng (2015) 33:1017–1030
11. Putera Agung M. A.*, Pramusandi S., and Damianto B, *Identification and classification of clay shale characteristic and some considerations for slope-stability*, African Journal of Environmental Science and Technology, Vol. 11(4), pp. 163-197, April 2017.
12. Robert L. Virta, *Clay And Shale*, U.S. Geological Survey Minerals Yearbook, 2001
13. T. P. Gautam• A. Shakoor, *Comparing the Slaking of Clay-Bearing Rocks Under Laboratory*

Conditions to Slaking Under Natural Climatic Conditions, Rock Mech Rock Eng (2016) 49:19–31

14. T. Durmeková & R. Holzer, *Weak rocks in engineering practice*, Conference Paper · January 2003.
15. Tse, Akaha Celestine¹ and Eyang, Felicia Ngon, *Geotechnical Properties and Slaking Characteristics of Shales in the Calabar Flank, Southeastern Nigeria*, Journal of Earth Sciences and Geotechnical Engineering, vol. 6, no.1, 2016.