International Journal of GEOMATE, July, 2017, Vol.13, Issue 35, pp.54-59
Geotec., Const. Mat. & Env., ISSN:2186-2990, Japan, DOI: http://dx.doi.org/10.21660/2017.35.6658

INFLUENCE OF CLAYSTONE DETERIORATION ON SHEAR STRENGTH OF BACKFILL

* Pisut Rodvinij [1] and Pitiwat Wattanachai [1]

[1]Faculty of Engineering, Chiang Mai University, Thailand

*Corresponding Author, Received: 14 June 2016, Revised: 12 July 2016, Accepted: 22 Nov. 2016

ABSTRACT: Claystone in Mae Moh mine after excavation has been used as a backfill material to counterweight instability slope. However, claystone deteriorates when it has been exposed to wet-dry process in the natural condition. The investigation on the properties of claystone under natural condition and control condition can clarify the deterioration effect due to wet-dry process. Deterioration can be defined as the alteration process on size distribution and strength of claystone. Sieve analysis test and unconfined compression test were conducted on claystone samples to investigate the deterioration effect on size distribution and strength of claystone. Claystone exposed to natural condition having a decrease of an average particle size (D_{50}) to be approximately 50 mm in 12 weeks and unconfined compressive strength of claystone was decreased 45% in 3 weeks. In contrast, claystone under control condition gave the same size distribution and unconfined compressive strength slightly decreased. Thus, the result demonstrated wet-dry process in natural condition was the main cause of claystone deterioration. The decrease on size distribution of claystone due to deterioration can be the cause of reduced on backfill shear strength. In order to clarify this assumption, direct shear test was conducted on 3 different particle sizes of claystone to simulate the effect of size reduction on shear strength of backfill. The experimental results demonstrated shear strength of the larger particle size samples was higher than the smaller especially under high normal stress. In conclusion, the deterioration of claystone significantly affects on shear strength of backfill.

Keywords: claystone, deterioration, shear strength, size distribution, unconfined compressive strength

1. INTRODUCTION

Study area located at the northeast side of the pit wall in Mae Moh mine, called area 4.1. This area will become problematic because a normal fault separated the layers have been displaced in a dip direction to the normal fault. Fig. 1 shows a cross section of area 4.1. According to the mine plan, K and Q seams (green layer and red layer in Fig.1) of lignite must be excavated [1]. K and Q lignite layers have supported the potential mass (gray layer in Fig.1). Thus, after excavating K and Q seams of lignite, the potential mass over the lignite layer becomes a sliding. The suitable method to solve this problem is cut and fill method.

The cut and fill method was used to excavate lignite in this area. The area will be mined and partially undercut. Thus, the G1 weak plane interface is also partially daylight. After completion of mining, backfilling will begin to support the slope face and maintaining adequate room for mining activities. The mining- backfilling cycle is iterative until all the lignite in area 4.1 is completely mined out. It is necessary to fill the current pit and cut the neighboring slope in subsequent procedure [1], [2].

Claystone has been used as a backfill material to counterweight and supported the potential mass. However, claystone deteriorated when it has been exposed to weather change. The deterioration of claystone can be the cause of reduced in the stability of backfill slopes. Deterioration can be defined as the alteration process of claystone occurring under the direct influence of atmosphere and hydrosphere [3]. The alteration process can be in form of either physical and/or chemical deterioration. The physical deterioration causes disintegration (or breakdown) of original fabrics and also imposes new fabric features. While the chemical deterioration, which usually takes a long time, forms discoloration of the affected rock and change in mineralogy [4].

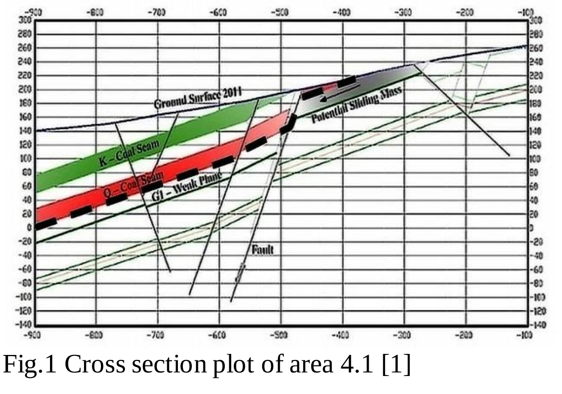

Fig.1 Cross section plot of area 4.1 [1]

In its fresh condition, claystone usually stiff or hard and quite difficult to excavate without mechanical equipment. The occurrence of physical and chemical changes in deterioration process can lead to significant reduction in strength value [5]. Moreover, claystones have specific characteristics, mainly found to exhibit slake-deterioration within a short period of time when exposed to the atmosphere and/or moistened. This will induce some significant problems in varied engineering activities [6].

Shear strength behavior of claystone backfill was similar to rockfill or granular soil that most depend on friction angle [7]. Thus, the decrease on size distribution of claystone due to deterioration can be lead to the reduced friction angle of backfill. Eventually, stability of claystone backfill can be reduced due to deterioration of claystone.

2. SCOPE

The investigation on claystone properties under the natural condition and control condition can characterize the deterioration behaviors of claystone. Natural condition, claystone samples were exposed to the natural weathering process. In contrast, claystone samples under control condition were located in laboratory room (The temperature was between 25-28 °C) and they were not exposed to the weather change. The alteration process of claystone under two different conditions can be suggested that wet-dry process in natural condition was the causes of claystone deterioration. The alteration process on the size distribution of claystone was investigated by sieve analysis test. The alteration process on strength of claystone was investigated by unconfined compression test. The influence of claystone deterioration on shear strength of backfill was investigated by shear strength test. Direct shear test was conducted on 3 different particle sizes of claystone samples in order to simulate the decrease of claystone particle size due to the deterioration affected shear strength of backfill.

3. VISUAL CHARACTERISTIC OF DETERIORATED CLAYSTONE

Physical characteristics of the deteriorated claystone can be observed by visible. Claystone samples were exposed to the natural weathering process during 0-9 weeks. Claystone samples dimension between 10-25 cm were collected from Mae Moh mine. The deterioration effect on a characteristic of claystone in natural condition was shown in Fig. 2. When time passed, the deterioration effect was demonstrated by breakdown of original claystone.

Physical characteristics of original claystone are generally gray and it is relatively stiff or hard. After claystone exposed to natural weathering process in 1 week, it was starting to intensively slake and generally followed by noticeable heaving. Some of claystone samples were started break to small particles and showed some visible fractures on the samples. In 3 weeks, the visible fractures on claystone were increased and most of the samples disintegrated into small pieces. When the samples were in natural condition during 6-9 weeks, almost all of claystone samples was broken down into very small pieces and could not classify the pieces of the sample before breakdown.

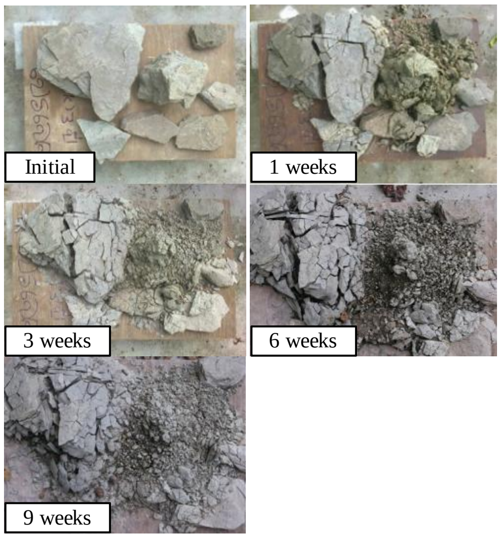

Fig.2 Deterioration effect on characteristic of claystone under natural condition

4. THE EFFECT OF DETERIORATION ON SIZE DISTRIBUTION OF CLAYSTONE

The physical characteristic of deteriorated claystone demonstrated breakdown of claystone when exposed to natural weathering processes. Size distribution of claystone backfill was changed due to deterioration effect. In order to investigate the deterioration effect on size distribution of claystone. Sieve analysis was conducted on claystone samples in a natural condition and a control condition during 1-12 weeks to clarify the alteration of size distribution.

Fig. 3 indicated the size distribution of claystone decreased under natural environment during 1-12 weeks. Size distribution of the samples was decreased with increasing elapse time. Considering the average particle size (D_{50}) of claystone samples, D_{50} of claystone samples decreased from 60.0 mm remaining to 9.0 mm in 12 weeks. The deterioration greatly affected during 2 weeks as D_{50} of the samples in 2 weeks was decreased from the first week approximately 40 mm. After 2 weeks, the average particle size of claystone was slightly decreased as D_{50} of the samples was decreased approximately 11 mm during 2-12 weeks.

In contrast, claystone under control condition gave the same size distribution when the time passed as shown in Fig 4. The results can be concluded that claystone deteriorated specifically under natural condition. Thus, wet-dry process in natural condition was the main cause of claystone deterioration.

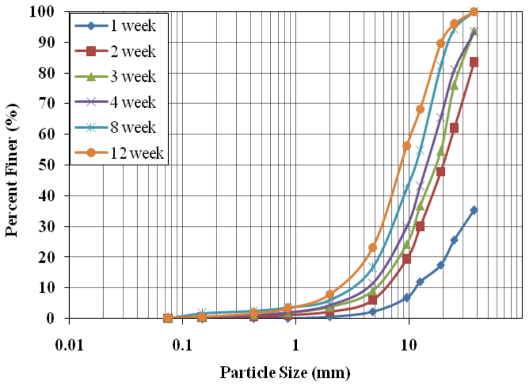

Fig.3 Size distribution of claystone samples under natural condition

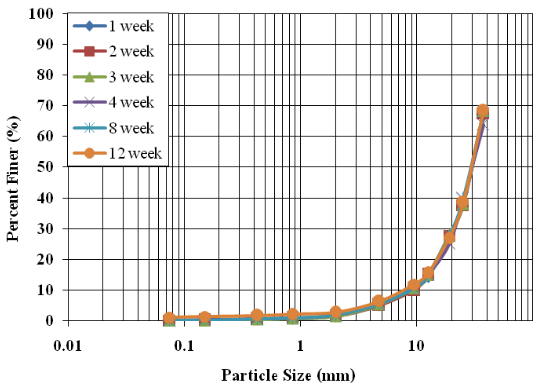

Fig.4 Size distribution of claystone samples under control condition

5. THE EFFECT OF DETERIORATION ON STRENGTH OF CLAYSTONE

In fresh condition, claystone is usually stiff or hard materials. However, the deterioration process can lead to significant reduction in strength value [5]. In order to investigate the deterioration effect on strength of claystone, unconfined compression test was conducted on claystone samples under a natural condition and a control condition during 1-12 weeks to reconfirm a strength reduction of claystone. Size of trimmed claystone specimens that used in this test was 5 cm in diameter and 10 cm height as shown in Fig 5.

The experimental results of the deterioration effect on a strength of claystone were shown in Fig. 6. Unconfined compressive strength of claystone samples under natural condition decreased from 3.2 MPa remaining to 1.8 MPa or reduced approximately 45% in 3 weeks. After 3 weeks could not be prepared the specimens for the dimension that used in the test because claystone specimens deteriorated into small pieces.

Fig.5 Unconfined compression test on claystone

On the other hands, the strength of claystone samples under control condition decreased from 2.8 MPa remaining to 2.4 MPa or reduced approximately 15% in 4 weeks. After 4 weeks, the strength of samples was slightly decreased. Unconfined compressive strength was remaining 2.1 MPa in 12 weeks. Hence, unconfined compressive strength of claystone samples in control condition has decreased approximately 25% during 12 weeks.

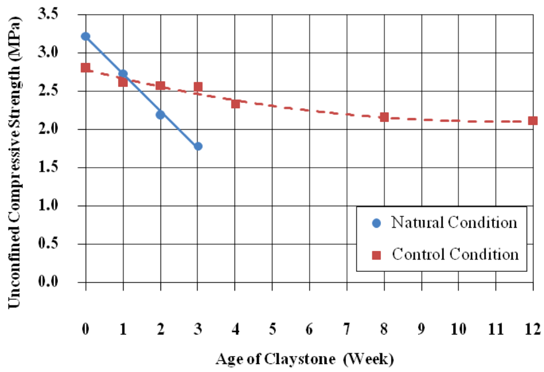

Fig.6 The results of unconfined compression test

Considering the age of samples at 3 weeks, unconfined compressive strength of the samples under natural condition reduced approximately 45% but unconfined compressive strength of the samples under control condition reduced approximately 10%. Thus, the strength reduction rate of claystone under natural condition was higher than claystone under control condition. The results can demonstrate the influence of wet-dry process due to weather change extremely affected the strength of claystone.

6. SHEAR STRENGTH OF CLAYSTONE BACKFILL

Shear strength of claystone backfill mostly depends on friction angle of materials. Thus, the decrease of size distribution due to claystone deterioration can lead to reduce shear strength of backfill. In order to verify the decrease of particle size affect to shear strength of backfill, direct shear test was conducted on the various particle sizes of claystone samples. The experimental results from this test can demonstrate the deterioration effect on shear strength of backfill.

Table 1 Size of claystone samples

Size of samples	D_{50} (mm)
Passing sieve 25.4 mm retained on sieve 19.0 mm (50%) + Passing sieve 19.0 mm retained on sieve 12.7 mm (50%)	19.0
Passing sieve 12.7 mm retained on sieve 9.5 mm (50%) + Passing sieve 9.5 mm retained on sieve 4.75 mm (50%)	9.5
Passing sieve 4.75 mm retained on sieve 2.0 mm (50%) + Passing sieve 2.0 mm retained on sieve 0.85 mm (50%)	2.0

Direct shear test was carried out on the samples to obtain shear strength properties under unconsolidated undrained condition. Size of claystone samples was prepared according to table 1 and a normal stress that used in this test was 0-930 kPa. Direct shear test was conducted on 6 inches in diameter of specimen by rock direct shear testing machine as shown in Fig 7, Fig 8 and compacted specimens at moisture contents same as sampled in the field (moisture contents at 26%).

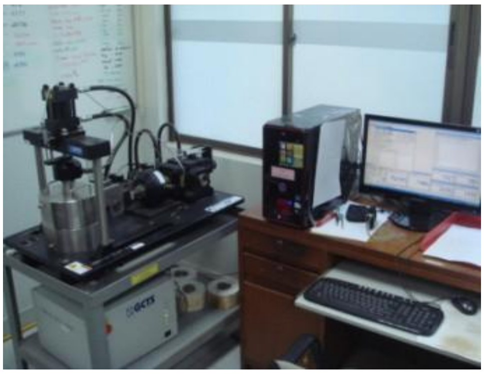

Fig.7 Rock direct shear testing machine

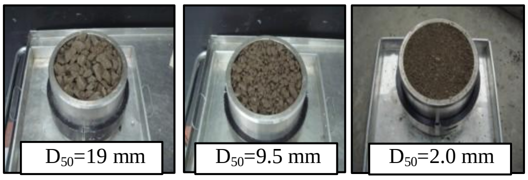

Fig.8 Claystone samples prepared for direct shear test

6.1 The Reduction of Claystone Particle Size Affects to Shear Strength of Backfill

Shear strength characteristic of claystone backfill was similar to granular soil or rockfill. Thus, shear strength behavior is actually nonlinear. This nonlinear can be approximated a straight line in the range of low normal stress (0-254 kPa) and a straight line in the range of high normal stress (254-930 kPa). The higher effective normal stress will yield lower values of friction angle.

Fig 9 shows the reduction of particle size affect to shear strength of backfill. Shear strength envelope of the samples at D_{50} equal to 19.0 mm was higher than the samples at D_{50} equal to 9.5 mm and 2.0 mm, especially under high normal stress. Under low normal stress, shear strength envelope of the samples at D_{50} equal to 19.0 mm, 9.5 mm and 2.0 mm was similar. The maximum shear stress of the samples at D_{50} equal to 19.0 mm was higher than the samples at D_{50} equal to 9.5 mm and 2.0 mm approximately 120 kPa and 140 kPa respectively.

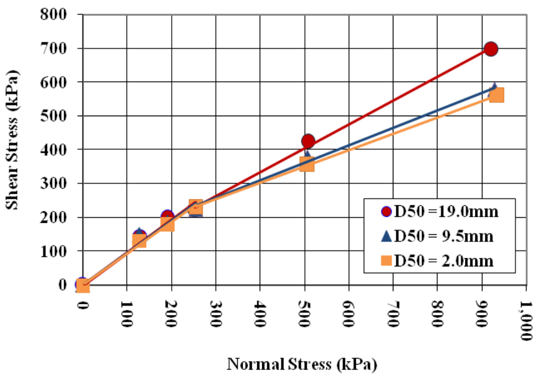

Fig.9 The various particle sizes of claystone affect to shear strength of backfill

6.2 The Influence of Deterioration Affects to Shear Strength Parameter

Shear strength parameter of claystone backfill samples at various particle sizes consists of cohesion and friction angle was shown in Table 2.

Table 2 Shear strength parameter of the samples

D_{50} (mm)	Low Normal Stress (0-254 kPa)		High Normal Stress (254-930 kPa)	
	c (kPa)	ϕ (°)	c (kPa)	ϕ (°)
19.0	0	44.1	53	35
9.5	0	43.8	103	27
2.0	0	43.1	109	26

Table 2 shown friction angle of the samples at D_{50} equal to 19.0 mm was more than the samples at D_{50} equal to 2.0 mm approximately 1° under low normal stress. Under high normal stress, friction angle of the samples at D_{50} equal to 19.0 mm was more than the samples at D_{50} equal to 9.5 mm and 2.0 mm approximately 8° and 9° respectively. Cohesion of the samples at D_{50} equal to 19.0 mm was less than the samples at D_{50} equal to 9.5 mm and 2.0 mm approximately 50 kPa and 56 kPa respectively.

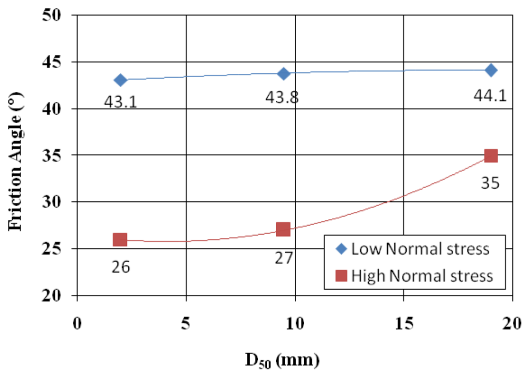

Fig.10 Relationship between friction angle and D_{50}

Fig. 10 shown the correlation between friction angle and D_{50} of the samples. Friction angle reduced by the decline of claystone particle sizes. Under low normal stress, friction angle was slightly decreased when the particle size of claystone was smaller. In contrast, friction angle of the samples under high normal stress was rapidly decreasing when D_{50} of the samples equal to 19.5 mm reduced to 9.5 mm. However, the average particle size of the samples which lower than 9.5 mm, a trend of friction angle was slightly decreased.

Fig. 11 shown the correlation between cohesion and D_{50} of the samples under high normal stress. A cohesion was rapidly increasing when D_{50} of the samples equal to 19.5 mm reduced to 9.5 mm. However, D_{50} of the samples which lower than 9.5 mm, a trend of cohesion was slightly increased.

The results can be described the decrease of claystone particle size due to deterioration was a cause of reduced in the value of friction angle. A reduction in the value of a friction angle is responsible for most of the shear strength reduction of claystone backfill.

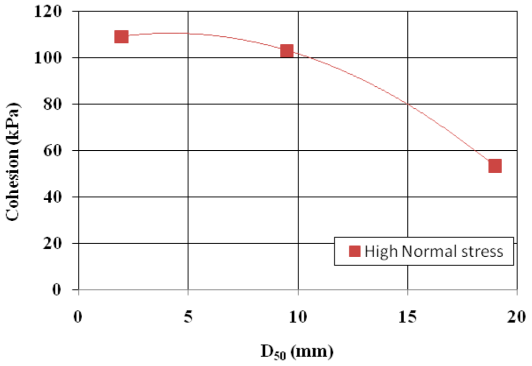

Fig.11 Relationship between cohesion and D_{50}

7. CONCLUSION

Claystone has been used as backfill material to counterweight and supported instability slope in Mae Moh mine. In its fresh condition, claystone usually stiff or hard. However, claystone deteriorated when it has been exposed to weather change. The deterioration of claystone can be the cause of reduced in the shear strength of backfill.

Deterioration can be defined as the alteration process on size distribution and strength of claystone. Size distribution and strength of claystone under natural condition decreased due to deterioration effect. In contrast, claystone under control condition (not exposed to the weather change) can maintain size distribution and strength. The investigation on claystone properties suggested that the deterioration effect occurs only under natural condition due to claystone has been exposed to wet-dry process in a natural.

Stability of claystone backfill slope depended on shear strength of backfill material. The reduction on size distribution of claystone due to deterioration can be the cause of reduced backfill shear strength. The experimental results from direct shear test demonstrated shear strength of backfill reduced by the decline of claystone particle size, especially under high normal stress. Overview of this study can be concluded that claystone deteriorated under natural condition due to wet-dry process and the deterioration of claystone significantly affects to decrease shear strength of backfill.

8. REFERENCES

[1] Leelasuksaree C, Mavong N, Khosravi M H, Pipatpongsa T, "Physical and Numerical Models of Undercut Slope Lying on Steeply

Inclined Bedding Plane", 17th National Convention on Civil Engineering, 2012, pp. GTE045-1 -GTE045-10.

[2] Mavong N, Tunkeaw S, Mungpayabal N, Boonsritun N, "Mining Plan and Progressive Excavation in Lowwall Area 4.1 of Mae Moh Mine", International Symposium on Earthquake Hazard Potential and Preparedness for Safety in Coal Mining, 2011.

[3] Sounders M K, and Fookes P G, "A review of the relationship of rock weathering and climate and its significance to foundation engineering", Eng. Geol, 4, 1970, pp. 289-325.

[4] Sadisun I A, Shimada H, Matsui K, "Characterization of Weathered Claystone and Their Engineering Significance", Indonesian Scientific Meeting 2000, 2000, pp. 1-8.

[5] Sadisun I A, Shimada H, Matsui K, "Determination of Strength of Subang Formation Claystone Due to Weathering", Proceeding of the 3rd Asian Symposium on Geology and the Environment (ASEGE), 2001, pp. 37-46.

[6] Sadisun I A, Shimada H, Ichinose M, Matsui K, "Study on the physical disintegration characteristics of Subang claystone subjected to modified slaking index test", Geotechnical and Geological Engineers, 2005, pp. 199-218.

[7] Das Braja M, "Shear Strength of Soil", Advanced Soil Mechanics, Singapore : McGraw-Hill, 1985, pp. 402-416.

[8] Budhu M, "Some Causes of Slope Failure", Soil Mechanics and Foundation, New Jersey : John Wiley & Sons, 2000, pp. 525-528.

[9] Chowdury R, Flentie P, Bhattacharya G, "Natural Slope-Factors Affecting Stability and Weathering", Geotechnical Slope Analysis, London : Taylor & Francis, 2010, pp. 13-38.

[10] Mitchell J K, Soga K, "Physical Process of Weathering", Fundamentals of Soil Behavior, New Jersey : John Wiley & Sons, 2005, pp. 8.

[11] Naderian A R, William D J, "Bearing Capacity of Open-Cut Coal-Mine Backfill Material" Transactions of the Institution of Mining and Metallurgy, Section A-Mining Industry, 1997, pp. A30-A34.

[12] Shakoor A, Gautam T P, "Assessing the Slaking Behavior of Clay-Bearing Rock", 10th Annual Technical Forum Geohazards Impacting Transportation in the Appalachian Region, 2010.

Copyright © Int. J. of GEOMATE. All rights reserved, including the making of copies unless permission is obtained from the copyright proprietors.