

Re-weathering of stabilized clay shale with portland cement behavior

Alatas Idrus M^{1,}, Simatupang Pintor T², Kuswaya Wawan¹, and Panji¹*

¹Department of Civil Engineering, Institut Sains dan Teknologi Nasional, Jakarta, Indonesia

²Department of Civil Engineering, Universitas Mercu Buana, Jakarta, Indonesia

Abstract. Clay shale is a claystone which in fresh condition has a very high shear strength. When it reacts with the atmosphere or hydrosphere it will weather so that the shear strength of clay shale will drop drastically. The weathering potential of clay shale is generally done by the slake durability test and the weathering process is measured by disintegration ratio test (D_R). The strength of clay shale that has fully weathered will increase again when it is stabilized with a minimum of 6% PC (Portland Cement). It was found from the wetting drying cycle process testing that durability of re-weathering of stabilized clay shale with PC is increased compared to natural clay shale. Disintegration ratio of natural clay shale D_R was smaller than stabilized clay shale with 6% PC. Additionally, more than 6% PC increased the durability of re-weathering of clay shale.

1 Introduction

The number of geotechnical failures to infrastructure construction in Indonesia over the last 10 years has been due to a lack of proper understanding of the properties of clay shale soil, which is quite different with other soil. Clay shale is a type of clay stone where the geological process history of the formation suffered a high pressure for a lengthy period. In the natural state, clay shale layer underneath of the other soil formation has high shear strength [1]. The strength can survive well as long as it is not related to atmosphere and hydrosphere or, in other words, it is always covered by an overburden of impermeable other type soil layers.

The weathering process causes the decreasing of clay shale shear strength by the clay shale layer reacting with the atmosphere or hydrosphere for several reasons, mainly due to excavation activities. Also, weathering also occurs due to geological processes, such as an earthquake, which causes the fault on the clay shale layer up to the ground surface, then it is penetrated by water and, finally, the clay shale formation makes contact with the hydrosphere [2].

Weathering on clay shale will occur more quickly when the frequency of clay shale contact with atmosphere and hydrosphere is more common. The rainy and drought cycle that often occurs in tropical areas causes faster weathering of clay shale [3, 4]. The

* Corresponding author: hb_idrus@yahoo.com

occurrence of weathering on clay shale will automatically decrease clay shale shear strength. The decrease in shear strength of clay shale occurs in the state of the peak strength and the residual strength [5, 6].

The effort to improve fully weathered clay shale, especially on road infrastructure projects, stabilization using Portland Cement (PC) is common popular. This paper will discuss how clay shale behavior is fully weathered if recompacted with and without using Portland Cement (PC), as illustrated in Fig. 1.

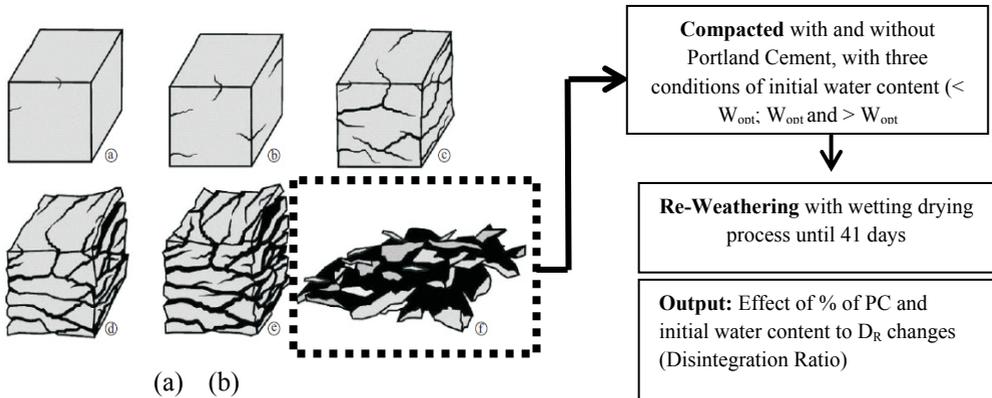


Fig. 1. The illustration of first weathering (a) until fully weathered (b), and continuing with compacted and measured weathering effect with Disintegration Ratio Test.

2 Disintegration Ratio (D_R)

Changes in the physical properties of clay shale due to weathering are visible in the composition of the grain size graph. Initially, the size of its large grain becomes smaller, as is presented in the cumulative percentage graph marked with the size of the grains. From this graph, the disintegration ratio (D_R) can be determined by calculating the ratio of the area of the field at the initial conditions divided by the area of the field when the weathering changes [3]. This can be seen in Fig. 2 below.

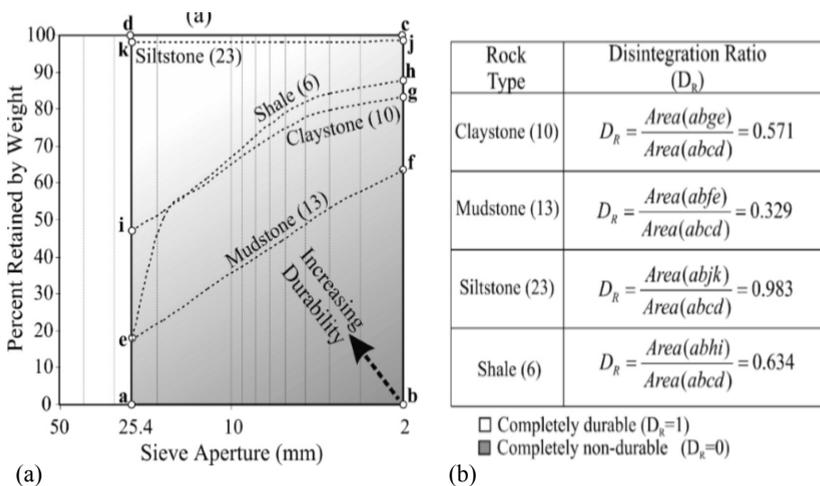


Fig. 2. (a) Fragment size distribution curves for some clay-bearing rocks and (b) mathematical derivation of the disintegration ratio [3].

After each month of exposure to natural climatic conditions, one replicate sample of each of the four types of clay-bearing rocks was taken to the laboratory, oven-dried at 50°C, and its grain size distribution determined. Fig. 3 is an example of the disintegration behavior of a claystone sample after varying periods of exposure to natural climatic conditions. Grain size distributions were used to quantify the amount of disintegration of each sample in terms of D_R , after varying periods of exposure to natural conditions [7].



Fig. 3. Disintegration of a claystone sample after exposure to natural climatic conditions [7].

3 Laboratory program for re-weathering of clay shale

Research in the laboratory is generally designed to be able to find out the full weathered effect after it has been compacted with and without adding a Portland Cement percentage. Percentage of PC usage (0%, 3%, 6%, 9% and 12%) as well as variations in water content when clay shale is compressed into variables are observed for changes in weathering. The weathering change parameter is seen from the change of disintegration ratio (D_R), while the variation of water content during compaction was less than 3% of optimum, at optimum and more than 3% of optimum. Compacted clay shale samples with different moisture and percentage of PCs, were placed respectively in different dishes then wetting and drying processes scheduled, as shown in Table 1. The clay shale soil samples were taken from Semarang-Bawen Toll Road and Hambalang locations.

Table 1. Wetting drying schedule.

Activity	Day																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Drying	<	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	>
Wetting*)					*)				*)				*)				*)				*)
Activity	Day																				
	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	
Drying	<	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	>
Wetting*)				*)				*)				*)				*)				*)	

Remarks: *) 5-minutes soaked samples and continuing with drying process. On day 9, 13, 17, 21, 25, 29, 33, 39 and 41, disintegration test by GSD and taking pictures samples were done before soaking samples.

Re-weathering of clay shale samples indicated a unique behavior after compaction with variations in the use of Portland Cement percentages and different moisture content. In general, both water content and PC percentage variables affected the re-weathering of clay the shale process. The weathering process of clay shale samples taken from fresh clay shale to be fully weathered can be seen in Fig. 4. Weathering was observed for physical changes from both clay shale origin with wetting and drying process up to 80 days with two wettings (5 minutes soaked) every eight days of observation. On the 80th day, it appears that the entire clay shale has completely fully weathered with the D_R approaching the 0,000 [8].



Fig. 4 Changes in the physical form of clay shale samples due to the drying-wetting cycles soaked twice for every eight days [8].

4 Re-weathering behavior of Hambalang clay shale

The drying of the sample was undertaken for 41 days in open air protected from rainwater by placing a sample in a room protected by transparent plastic, allowing sunlight to penetrate and illuminate the sample and water, but protected from rainwater, as seen in Fig. 5, for the first-day condition. Once every four days, the samples were immersed for five minutes and then proceeded to the drying process [8, 9]. Weathering was observed and measured after wetting at 9, 13, 17, 21, 25, 29, 33, 37, and 41 days.

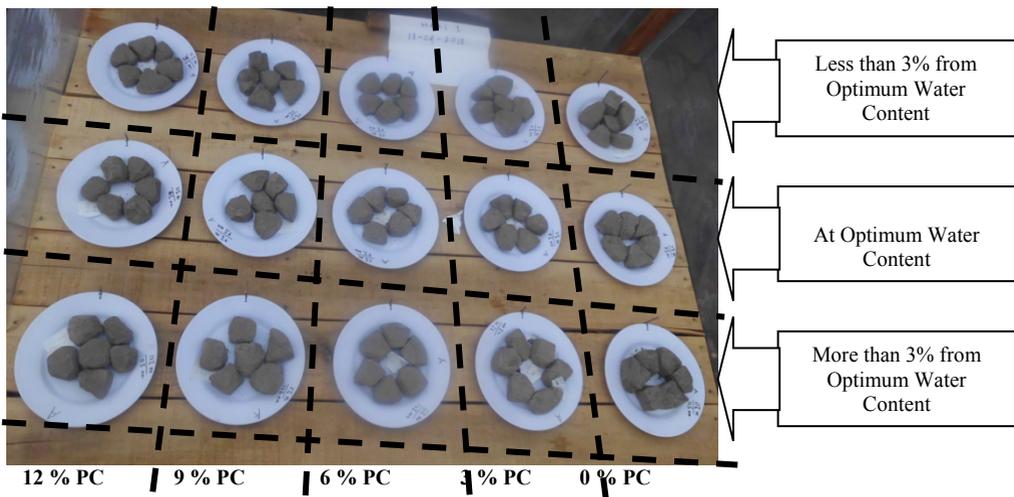


Fig. 5. Initial condition for all clay shale samples, with % PC variation and initial water content.

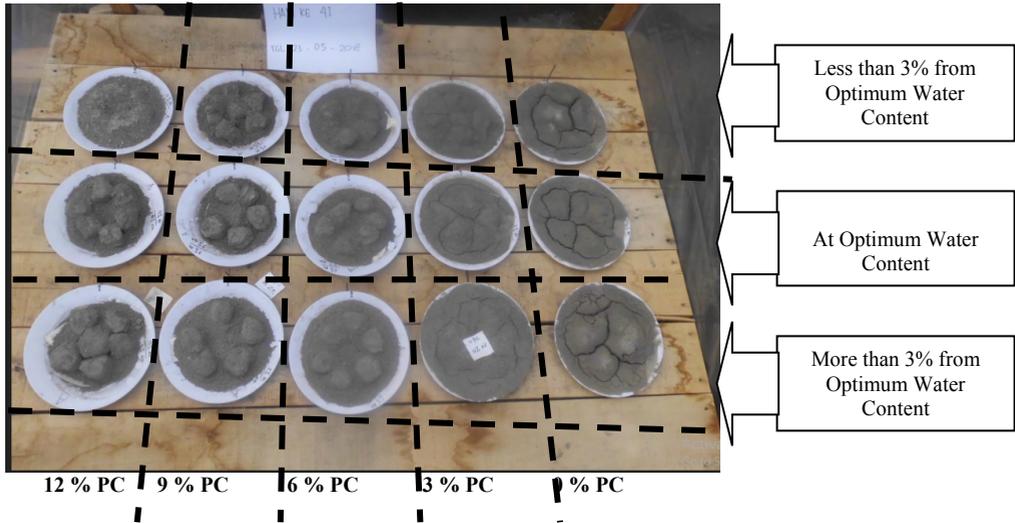


Fig. 6. Final condition after 41 days of wetting-drying cycles for all clay shale samples, with %PC variation and initial water content.

Fig. 6 shows the weathering occurred for Hambalang clay shale until the end of the 9th cycle (Day 41). The figure shows that the concentration of Portland Cement has a significant influence on the re-weathering process. Increasing percentage of PC to stabilized clay shale shows a better resilience to re-weathering. However, 6% PC indicates a good agreement to resist weathering.

4.1 Re-weathering of clay shale without stabilization material

Recompacting the fully weathered clay shale without material stabilization of Portland Cement when continued to first wetting cycle shows a dramatic decreasing of disintegration ratio (D_R), as shown in Fig. 7.

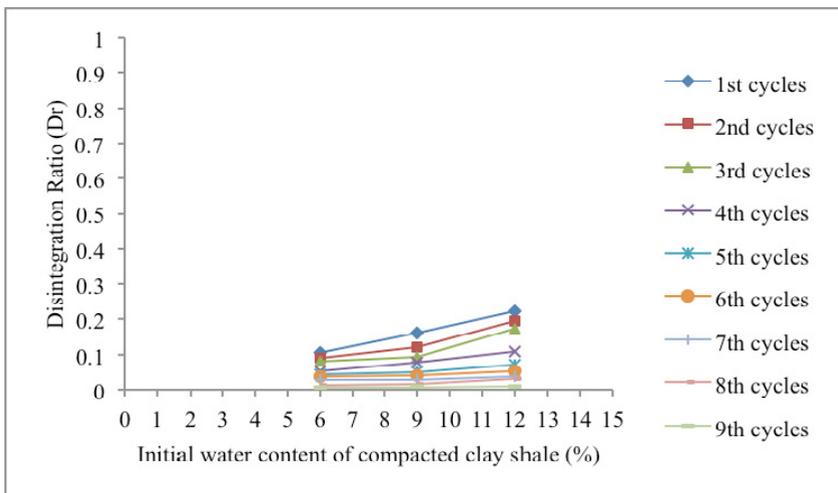


Fig. 7. Disintegration ratio (D_R) of re-compacted clay shale without PC stabilization material.

The behavior of recompacting clay shale samples without stabilization material for the first cycle of wetting-drying shows a decreasing of D_R from original state 1.00 to 0.15. It means more than 85% material weathered for the first cycle (completely non-durable). Without stabilization material, recompacting clay shale will be easily weathered. Nevertheless, the influence of water content for less and more 3% of optimum water content does not affect the durability behavior of clay shale.

4.2 Re-weathering of clay shale with stabilization material

The re-weathering behavior of clay shale with stabilization material shows significant effects after recompacting. Variations in the percentage of material stabilization indicate a significant change to disintegration ratio the more the PC percentage, the more durable against weathering behavior. It can be seen that D_R changes drastically for percentages of 3% and 6% (Fig. 8 and Fig. 9), 9% and 12% PC (Fig. 10 and Fig. 11).

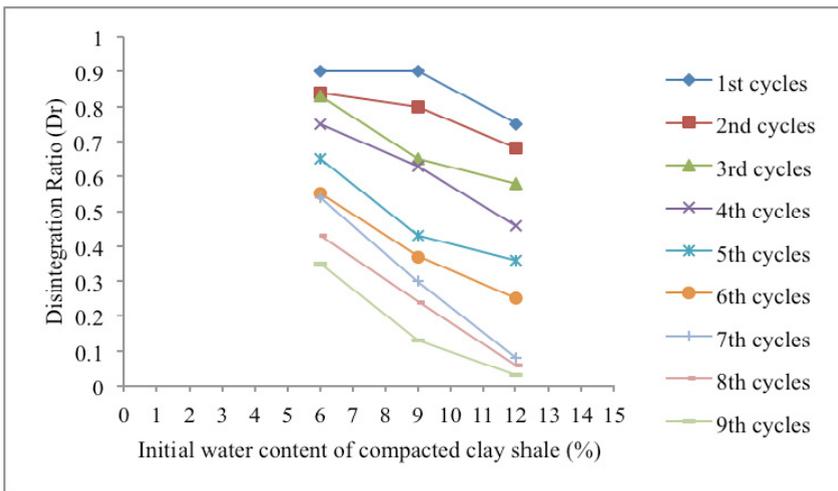


Fig. 8. Disintegration ratio (D_R) of re-compacted clay shale with 3% PC stabilization material.

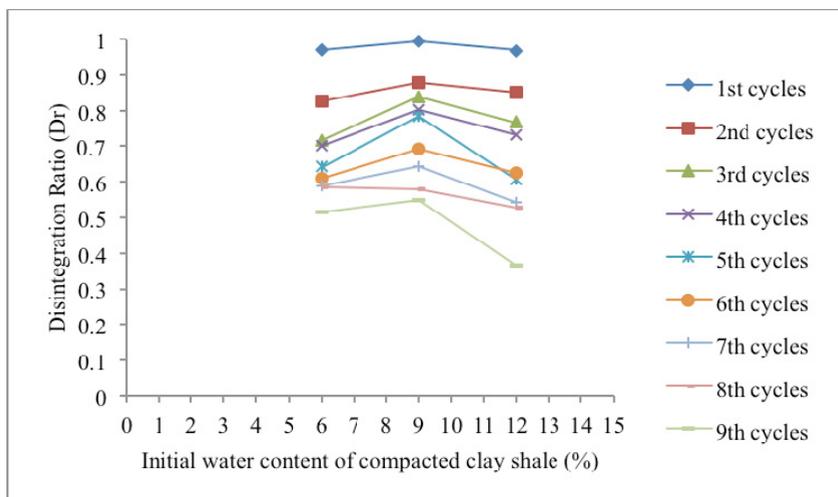


Fig. 9. Disintegration ratio (D_R) of re-compacted clay shale with 6% PC stabilization material.

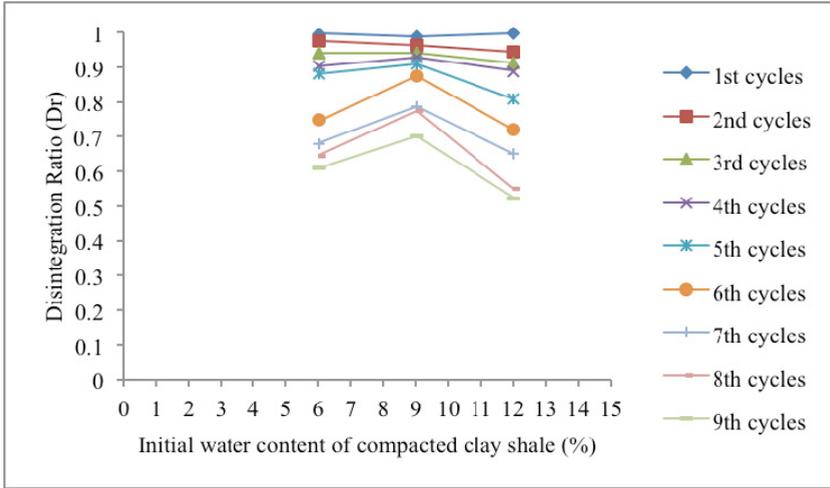


Fig. 10. Disintegration ratio (D_R) of re-compacted clay shale with 9% PC stabilization material.

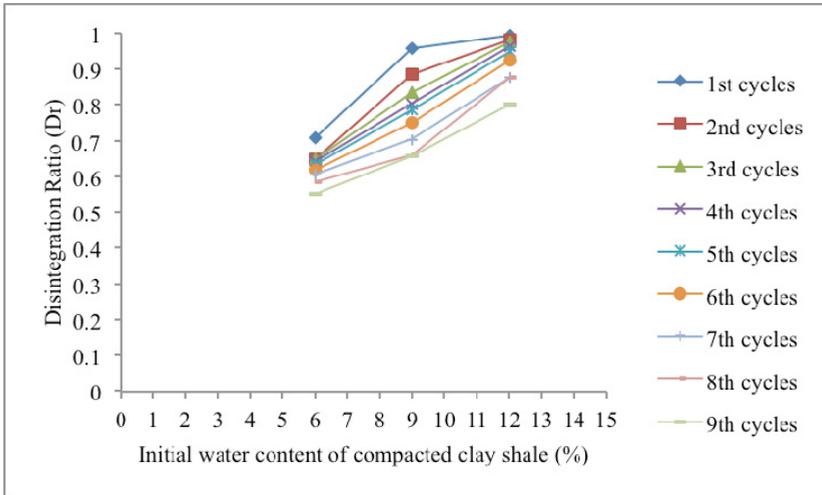


Fig. 11. Disintegration ratio (D_R) of re-compacted clay shale with 12% PC stabilization material.

Table 2. Correlation between disintegration ratio (D_R) with variation of % PC at optimum water content.

Percentage of PC (%)	D_R in percentage of PC (%) versus wetting-drying cycle times in optimum water content									
	0	1	2	3	4	5	6	7	8	9
$D_R \rightarrow$	0	1	2	3	4	5	6	7	8	9
0 %	1.000	0.158	0.118	0.091	0.075	0.051	0.030	0.020	0.012	0.007
3 %	1.000	0.908	0.795	0.652	0.633	0.430	0.366	0.296	0.233	0.119
6 %	1.000	0.993	0.878	0.840	0.802	0.785	0.693	0.645	0.579	0.549
9 %	1.000	0.988	0.963	0.940	0.926	0.908	0.875	0.786	0.773	0.700
12 %	1.000	0.958	0.958	0.958	0.958	0.958	0.958	0.958	0.958	0.958

Table 2 and Fig. 12 present the result of change disintegration ratio (D_R) to clay shale for various percentage of stabilization material when compacted at optimum moisture content. Disintegration ratio (D_R) change was observed up to the 9th cycle or on the 41st day. Sample without stabilization material on the 9th cycle gives $D_R = 0.007$ (completely non-durable). With 3% stabilization material, it obtained $D_R = 0.119$, while for 6% stabilization material, $D_R = 0.549$ (moderate durable), 9% stabilization material $D_R = 0.700$ (well-durable), and 12% stabilization material $D_R = 0.958$ (completely durable). From Fig. 8, Fig. 9 and Fig. 10 as shown earlier, recompacting at optimum moisture content indicated a better durability against re-weathering. However, 12% stabilization material indicated a better durability against re-weathering for compaction at 3% higher than optimum water content.

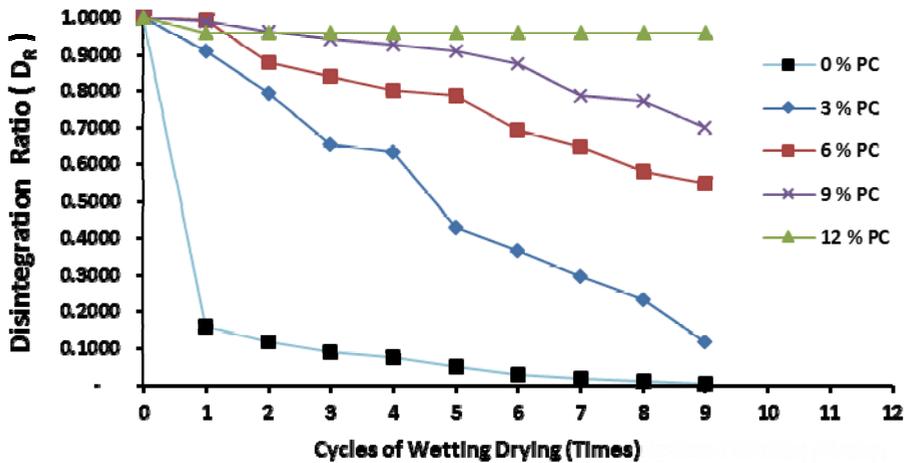


Fig. 12. Correlation between disintegration ratio (D_R) and variety of stabilization material up to 9th cycle of the wetting-drying processes.

5 Conclusions

Results of this research are mainly expected for application on ground improvement programs for infrastructure projects. A better understanding of the re-weathering behavior of clay shale may accelerate the time duration of construction. The main conclusions from previous discussions can be drawn as follows. This research indicates that stabilized clay shale with PC can be used effectively to reduce the re-weathering process. Recompacting natural clay soil without stabilization material at the first cycle of wetting-drying processes reduced D_R to 0.158, which means that more than 85% of the compacted soil will weather again. Application of 6% stabilization material is sufficiently economical to maintain a compacted clay shale against re-weathering. Recompacting stabilized clay shale with PC at optimum water content gives high durability against weathering behavior. Application of more than 6% stabilization material will significantly increase clay shale durability against re-weathering effects.

The authors extend their gratitude and highest appreciation to the chair and staff of ISTN Soil Mechanics Laboratory Jakarta, and to everyone who has been involved in these research activities.

References

1. A. Sadisun, Bandonu, H. Shimada, M. Ichinose, K. Matsui, *Jurnal Geologi Indonesia* **5**, 4 (2010)
2. M. Irsyam, E. Susila, A. Himawan, *Proc. of Intenational Symposium on Geotechnical Engineering, Ground Improvement, and Geosynthetics for Human Security and Environmental Preservation* (2007)
3. Z.A. Erguler, A. Shakoor, *Env. & Eng. Geoscience* **15**, 2 (2009)
1. M. Alatas, S.A. Kamaruddin, R. Nazir, M. Irsyam, *Jurnal Teknologi-UTM* **78**, (2016)
4. M. Alatas, S.A. Kamaruddin, R. Nazir, M. Irsyam, A. Himawan, *Jurnal Teknologi-UTM* **77**, 11 (2015)
5. E. Gartung, *Proc. of Symposium Geotechnical Engineering Division* (1986)
6. A. Shakoor, T.P. Gautam, *Env. & Eng. Geoscience* **21**, 3 (2015)
1. M. Alatas, *Kesan luhuhawa terhadap kekuatan ricih syal lempung dalam penentuan parameter kestabilan Cerun* (Universiti Teknologi Malaysia, Johor Baharu, 2017)
7. E.E. Alonso, J.A. Pineda, *Proc. of the VI South American Conference in Rock Mechanics* (2006)