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Prevention of Mud Pumping in Railway Embankment A Case Study from Baeng Pra-Pitsanuloke, Thailand

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Abstract

This research focused on prevention of mud pumping in the railway embankment from Baeng Pra to Pitsanuloke using fly ash and type I Portland cement. Atterberg's limits, Unconfined Compressive Strength (UCS), and California Bearing Ratio (CBR) were performed in laboratory. Factors affecting mud pumping are also taken into consideration. Besides, different mixing proportions among in-situ soil : fly ash, in-situ soil : fly ash : type I Portland cement in gram were mixed and cured from 0 to 56 days. From test results, it was found that the mixing proportions between in-situ soil : fly ash of 100:35 and in-situ soil : fly ash : type I Portland cement of 100:50:2:5 give the best results in term of UCS and CBR. In addition, both mixings were implemented in the field to replace the existing embankment. In order to monitor pressure beneath the tested embankment, earth pressure cells were installed at 70 centimeters depth prior to placing the mixes. It was found that pressure under test embankment treated by fly ash, fly ash-cement are reduced to 42% and 87% compared with the compacted soil without treatment.

1. Introduction

Mud pumping along the railway embankment From Baeng Pra to Pitsanuloke which often takes place during the raining season due to seepage and the high water table. The alignment is shown in Figure 1. The embankment is then soft, which allow the ties to move upward and downward. When the train ran over the embankment, the impact load pushed down the ties, which are laid on top of ballast. Thereby, the excess pore pressure in the embankment increased. Instantaneously, after the train passes by, the ties will suddenly rise up to normal position. This phenomenon will lead to soil

Figure 1 Location of Baeng Pra-Pitsanuloke

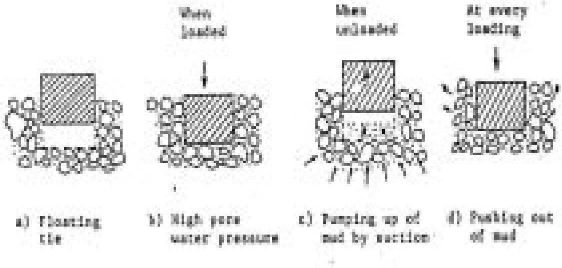

Figure 2 Behavior of Mud pumping (Tadatoshi 1977)

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** Research and Analysis Division, State Railway Authority of Thailand suction, and followed by mud pumping, and appeared on the ballast surface as shown in Figure 2. The repetition load from the train cause severe damage to the railway structures. Excessive settlement, which is the major factor of train accidents, finally occurred.

2. Testing Program

The purpose of this research is to investigate the engineering properties of soil-fly ash and soil-fly ash-cement mixed in the laboratory. The strength of fly-ash and fly-ash-cement stabilized soils is mainly obtained by the formation of the cement products such as CSH ($CaO-SiO_2- H_2O$) and CAH ($CaO-Al_2O_3-H_2O$). Soil samples were obtained from the site of Baeng Pra-Pitsanuloke railway line. Fly ash was obtained from electrical power plant which is locally available in Lampang Province, Thailand. The physical properties of fly-ash are tabulated in Table 1 (Kokkumhaeng, 1996). The soil-fly ash mixing proportions adopted for the mix were 100:00, 100:05, 100:15, 100:30, 100:35, 100:40, 100:45, 100:50, 100:60 and 100:70. While the soil- fly ash-cement mixing proportions adopted for the mix were 100:05:0.25, 100:15:0.75, 100:30:1.25, 100:50:2.5, 100:60:3.00 and 100:70:3.50. The mixing proportion is defined as the weight of dry soil to the weight of fly ash and cement in gram. Atterberg,s limits and standard Proctor tests were conducted on the soil samples. Standard Proctor, Unconfined Compression Test as well as California Bearing Ratio were conducted on the specimens at 0, 3, 7, 14, 28 and 56 days after mixing.

Table 1 Physical properties of fly ash

Description	Unit	Mae-Moh fly-ash
Pozzolanic activity	-	Very high
PH	-	11.1 - 12.4
Specific Gravity	-	2.2 - 2.5
Natural Density	ton/cu.m.	1.07 - 1.15
Initial Moisture	%	0.3 - 0.4
Maximum Dry Density	ton/cu.m.	1.65 - 1.70
Quantity of fly-ash at maximum dry density	%	11.0 - 13.0
Compressive Strength	Mpa	15.0 - 20.0
Cohesion	Mpa	0.5 - 2.0
Friction angle	Degree	32.0 - 38.0

Table 2 Comparison between soil sample and specification of mud pumping soil

Descriptions	Specification	Soil sample
California Bearing Ratio (CBR)	< 40%	27%
% Passing#40 sieve (0.42 mm ASTM sieve)	> 40%	93.7%
% Passing#200 sieve (0.074 mm ASTM sieve)	> 20%	77%
Liquid Limit	> 35%	43%
Plastic Index	> 9	21

3. Characteristics of in-Situ Soil

The soil sample was excavated from Baeng Pra-Pitsanuloke railway line. Physical properties of the soil include specific gravity Gs = 2.81, Liquid Limit = 43%, Plasticity Index = 21%. Natural moisture content of the soil is 13%. Using unified soil classification system, the soil sample was classified as inorganic clays of low to medium plasticity (CL). Fly ash and type I Portland cement were used as stabilizing agents. Comparison between the soil sample and specification of mud pumping soil are tabulated in table 2. (Tadatoshi 1997)

4. Test Results

4.1 Standard Compaction Test

The mentioned mixing proportions between in-situ soil and fly with different moisture content were mixed and compacted according to ASTM:D 698-91 (ASTM 1989). The optimum moisture content obtained from the laboratory was used for preparing UCS and CBR specimens. Figure 3 and 4 show relationship between maximum dry density and optimum moisture content of in-situ soil stabilized by fly-ash and in-situ soil stabilized by fly-ash with cement.

4.2 Unconfined Compressive Strength (UCS)

Unconfined Compressive Strength tests were performed on a compacted cylindrical sample of 2.8 inch (71 mm) diameter by 5.6 inch (142 mm) high. The mould used for compaction was locally fabricated with the requirement of ASTM D 1632 (ASTM 1989). The design moisture content and compacted dry density of the samples were equal to ω_{opt} and ω_{max}, respectively, achieved in standard compaction test. The relationships between curing time and UCS of soil-fly ash specimens are illustrated in Figure 5. It is clear that the UCS increases with increasing curing time. With the same amount of curing time, the specimen with a mixing proportion of 100:35 indicates highest UCS. This is due to the fact that cementing properties of fly ash is limited. Therefore, when in-situ soil was mixed with fly ash, the cementing mechanisms of fly ash will fully be effective up to certain limit because the strength is mainly govern by the pozzolanic reaction. Beyond this limit, additional fly ash will have no influence on UCS.

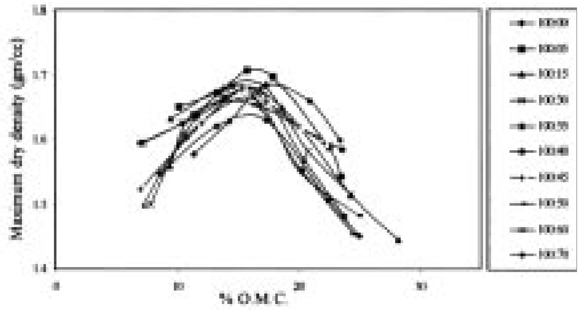

Figure 3 Relationship between (dmax, and OMC of in-situ soil stabilized by fly-ash

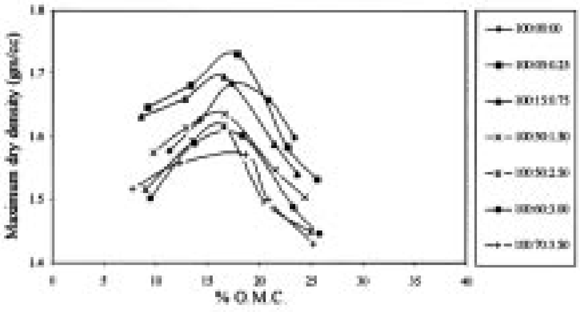

Figure 4 Relationship between (dmax, and OMC of in-situ soil stabilized by fly-ash

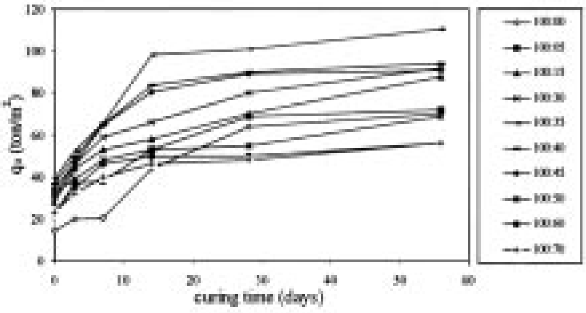

Figure 5 Relationship between curing time and UCS of in-situ soil stabilized by fly ash

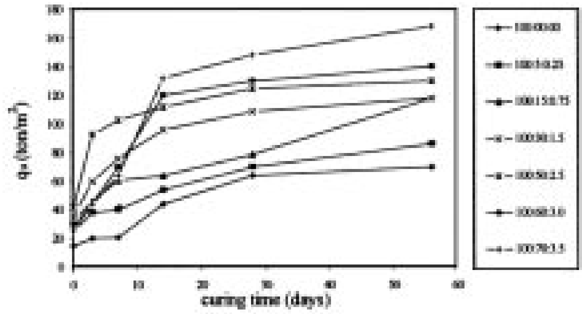

Figure 6 Relationship between curing time and

Figure 6 shows relationship between curing period and UCS of in-situ soil a stabilized by fly ash and type I Portland cement. It was found that a mixing proportion of 100:70:3.5 indicated highest UCS than others (Kevan D.Sharp 1993). Strength development is partly due to pozzolanic reaction by fly ash. The additional strength stills develops as long as cement content is available. Portland cement contains tricalcium silicate (C_3S), dicalcium silicate (C_2S), tricalcium aluminate (C_3A) and a solid solution descriped as tetracalcuim alumino-ferrite (C_4A) (Lea, 1956). These four main constituent are major strength producing compound. Fly-ash containing a sufficient amount of base-soluable silica are reactive fly-ashes. The base-soluble silica reacts with lime in the present of water and produces cementitious compounds, leading to development of strength (Helmeth, 1987). However, cement content play a key role on strength development. The UCS is therefore increased with increasing of cement content. Although, the proportions of 100:50:2.5 and 100:60:3.0 indicate UCS lower than the proportion of 100:70:3.5 but the proportion of 100:50:2.5 indicates that UCS in early stages develop very rapidly. This is remarkably behavior for soil improvement.

4.3 California Bearing Ratio (CBR)

In order to investigate CBR-curing time relationships for stabilized samples, CBR tests were performed on samples compacted according to standard compaction tests. A bearing test on the sample was performed following the procedure outline in ASTM D1883 (ASTM, 1989). Figure 7 shows the relationship between curing time and CBR of soil samples stabilized by fly ash. It can be seen that CBR increases with increasing of curing time. Besides, the proportion between soil samples and fly ash of 100:35 indicate markedly CBR with the same amount of curing time which conforming to UCS. This aforementioned proportion was then selected to stabilize in the field.

Figure 8 shows relationship between curing time and CBR if in-situ soil mixed by fly ash and type I Portland cement. It can be seen that CBR increased remarkably from 0 to 14 days with average of 60%. Moreover, it revealed that the proportions of 100:50:2.5, 100:60:3.0 and 100:70:3.5 indicate the same CBR at 56 days. However, the increment of CBR from 0 to 14 days of mixing proportion of 100:50:2.5 is higher than both of the mixing proportion of 100:50:2.5 was selected to stabilize railway embankment.

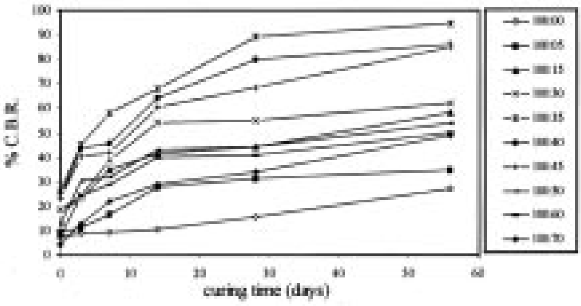

Figure 7 Relationship between curing time and CBR of in-situ soil stabilized by fly-ash

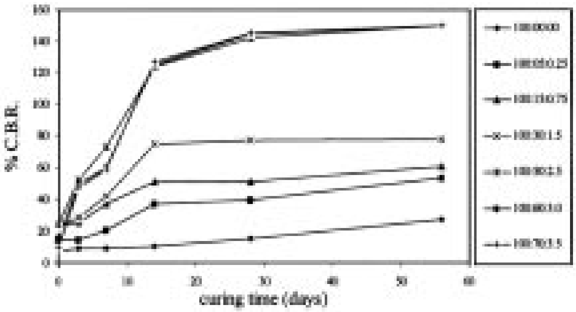

Figure 8 Relationship between curing time and CBR of in-situ soil stabilized by fly-ash and type I Porland cemen

Figure 9 Mud pumping appeared along Baeng Pra - Pitsanuloke

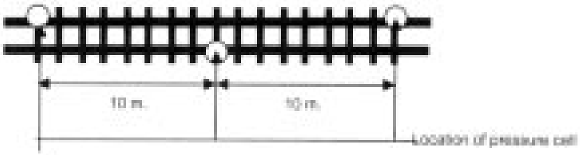

Figure 10 Location of pressure cell

5. Field Tested Embankment

To investigate the effectiveness of laboratory test results, the selected mixing were implemented in the field. Three tested sections were prepared along Baeng Pra to Pitsanuloke railroad as shown in Figure 9. The

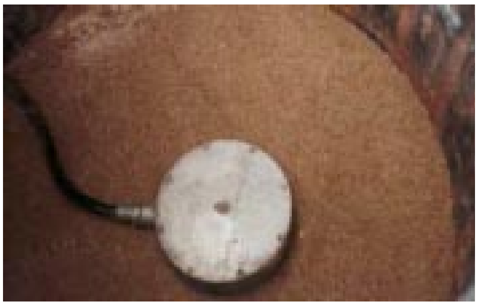

Figure 11 Pressure cell was installed beneath treated embankment

Figure 12 Removing of existing embankment

Figure 13 Depth checking before embankment Construction

Figure 14 Placing of Plastic sheet to prevent moisture from original ground

Figure 15 Mixing and Placing tested embankment

Figure 16 Compaction of test embankment

length of each tested section is 10 meters as shown in Figure 10. In order to monitor the pressure beneath tested the embankment due to train moving load, the existing embankment was excavated and earth pressure cells (Figure 11) were installed at 70 cm depth under the ties as shown in Figure 12 and 13. Plastic sheet was laid to prevent the moisture from original ground as shown in Figure 14. Thereby, the selected proportions were mixed in place and compacted in 3 lifts as shown in Figure 15.

On the other hand, the in-situ soil was mixed properly railway line and compacted as a dummy-tested section. The quality control of tested embankment was made by field density test for every lift of 90% standard Proctor test as shown in Figure 16. Figure 17 shows the completed test embankment. The earth pressure cells were monitored every 15 days.

6. Field Test Results

According to the monitoring of pressure cells, it was found that the average pressures under three test sections are 11.9 kPa, 6.9 kPa and 1.5 kPa. In

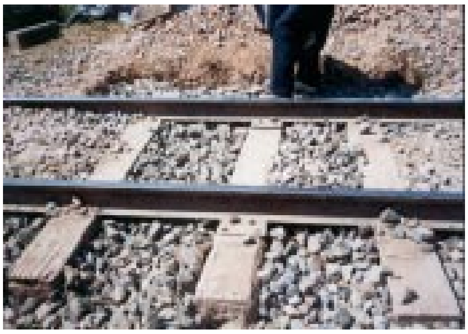

Figure 17 Completed test embankment

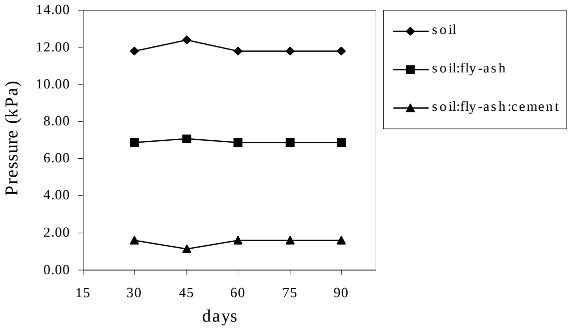

Figure 18 Relationship between pressure beneath test embankment in different time

percent, the average pressure of fly-ash-treated-soil and fly ash with cement-treated soil are 42% and 87.23% lower than dummy section as shown in Figure 18. It can be concluded that fly-ash-and-cement-treated-soil can be used to prevent mud pumping because the pressure under test embankment was largely reduced. As a consequence, the influence of excess-pore water pressure in original ground due to moving load on mud pumping is therefore insignificant. Hence, mud pumping reduces or disappears.

7. Conclusions

Based on the analysis of the test results both in laboratory and field, the following conclusions are drawn.

(1) The soil in the existing roadway embankment from Baeng Pra to Pitsanuloke may exhibit mud pumping behaviour specially during rainy season.

(2) Both fly-ash-treated-soil and fly ash with type I Portland cement-treated soil can be used to prevent mud pumping. However, the latter indicates better results than the former.

(3) Pressures under test embankment treated by fly ash, fly ash with cement are reduced to 42% and 87% compared with the compacted soil without treatment.

8. Acknowledgement

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References

1. ASTM Soil and Rock. Building Stones. Geotextiles. *Annual Book of ASTM Standard.* 04.08. 1989.
2. Helmath, R. *Fly ash in cement and concrete. Portland cement Association.* Research and Development Laboratories, Skolie, IL. 1987.
3. Kevan, D.S. "Fly ash for Soil Improvement." *American Society of Civil Engineering.* : 119,. 1993.
4. Lea, F.M. *The chemistry of cement and concrete. Edward Arnod.* London. : *Publishers.* Ltd., 1956.
5. Kokkumhaeng, S. "Potential of fly-ash for Application." *Civil Engineering Journal.* (in Thai). 2 (1996). : 31-39.
6. Takatoshi, I. "Measures for Stabilization of Railway Earth Structure." *Japan Railway Technical Service. :* 290. (1997).