CHEMICAL AND MINERALOGICAL ASPECTS OF LIME STABILIZATION

Member	K. Era	Saga University
Member	B. Buensuceso	Saga University
Member	K. Matsuda	Calceed Co. Ltd.
Member	N. Miura	Saga University

I INTRODUCTION

This paper presents a comparative study of the chemical and mineralogical properties of soft Ariake clay and Bangkok clay, which may influence the effects of lime stabilization. The base clays were obtained from the Kawasoe district, Saga, and from the AIT Campus, Bangkok. The procedures for chemical tests were as recommended by the manual prepared by the Committee for Soil Standard Analysis and Measurement (CSSAM, 1990). The mineralogy of both clays were determined by X-ray Diffraction Analysis.

II COMPARISON OF PHYSICAL PROPERTIES

Taniguchi et al (1992) previously reported on the differences in the relative strength increase and also the characteristics of the strength development with time of CaO-stabilized soft Ariake clay and soft Bangkok clay. For the same lime content of 10% CaO, the unconfined strength of stabilized Ariake clay was 11 kgf/cm^2, while that of stabilized Bangkok clay was only 1.2 kgf/cm^2. A comparison between the physical properties, see Table 1, reveals that in general, the two clays have very similar physical properties, except for the higher water content and sensitivity of Ariake clay. The higher strength gain of Ariake clay, however, cannot be attributed to these properties since high mixing water content and sensitivity have, in fact, been reported to result to lower strength gain (Locat et al, 1990).

III CHEMICAL AND MINERALOGICAL PROPERTIES

Some chemical and mineralogical properties of Ariake (Kawasoe) clay and Bangkok clay are summarized in Table 2. The following differences, which may be contributing factors to the higher strength gain of Ariake clay, are discussed.

(A) Organic content and pH: The ideal condition for lime clay reactions is high pH (pH>12) at which the solubility of the pozzolans in the clay is high (Broms, 1984). Bangkok clay is highly organic (2.5%), and therefore, has high acidity (pH=5.8), while Ariake clay is alkaline (pH=8.4) and has low organic content (0.9%). For acidic soils, a large portion of the lime is needed to first neutralize the acidity, thereby leaving lesser amounts of lime available to further increase the pH. For the same lime content of 10%, higher pH conditions will be attained for Ariake clay. High amounts of lime are need to stabilize organic soils, but excessive lime dosage may, in turn, retard the stabilization (Miura et al, 1988). For organic soils, the use of gypsum as a secondary additive is recommended (Broms, 1984).

(B) Salt content and electrical conductivity: Broms (1984) reported that for highly saline soils, e.g. marine clays, the immediate increase in strength due to lime stabilization is low since the clays have highly flocculated structures. Bangkok clay is saline, with a total soluble salt content of 0.16% (8.1 meq/l), and electrical conductivity (EC) of 2.1 mmho/cm, which suggests that the porewater contains a moderate amount of soluble cations. These cations in the porewater were identified as mainly Ca^{2+}=7.4 meq/l and Mg^{2+}=9.9 meq/l. Ariake clay has low salt content (0.02%) and lower EC=1.47 mmho/cm, with the porewater containing mainly Na^{+}=10 meq/l.

(C) Exchangeable cations: The effects of lime stabilization depend on the replacement of existing cations between silicate sheets of the clay minerals with Ca^{2+}, the order of replaceability of cations being: $Fe^{3+}>Al^{3+}>Ca^{2+}>Mg^{2+}>K^{+}>Na^{+}$. A high quantity of weaker exchangeable monovalent cations or Mg^{2+} which can easily be replaced by Ca^{2+} is an advantage. With effective cation exchange, the flocculation and pozzolanic reactions are allowed to occur. Ariake clay contains a high amount of exchangeable cations, in particular Mg^{2+}=16.83 meq/100g and Ca^{2+}=17.6 meq/100g. Most of these exchangeable cations are weakly-held, based on the Cation Exchange Capacity (CEC) of 32.3 meq/100g. On the other hand, Bangkok clay has lower quantity of exchangeable cations (mainly Mg^{2+}=6.1 meq/100g and Ca^{2+}=6.6 meq/100g); furthermore, based on its CEC= 26.8 meq/100g, it is found that a considerable quantity of the exchangeable cations of Bangkok clay are not easily replaced by Ca^{2+}.

(D) Clay mineralogy: In terms of the strength increase, lime stabilization causes higher strength increases for montmorillonites than in kaolinites (Lee et al, 1982). They explained that following the saturation of the interlayer positions between the silicate sheets with Ca^{2+}, the structure of kaolinite mineral deteriorates without the formation of new crystalline phases, thus low strength is developed. Bangkok clay contains predominantly kaolinite and illite minerals, while Ariake clay is mainly montmorillonite and illite, with some traces of halloysite and muscovite. Furthermore, being predominantly montmorrilonitic, Ariake clay has a higher specific surface area, which may also be a contributing factor to the higher strength increase.

Table 1 Physical properties of Ariake and Bangkok clays

		Bangkok	Ariake
ω (%)		90	128
ωL (%)		104	98
ωp (%)		41	38
I P (%)		63	60
L I		0.62	1.50
Grain Size Distribution	Clay(%)	70	71
	Silt(%)	27	28
	Sand(%)	3	1
ρt (g/cm^3)		1.48	1.45
Activity		0.90	1.10
G s		2.68	2.64
Void ratio		2.3	3.12
Sensitivity		7.3	20
q u (kgf/cm^2)		0.31	0.20
C c		1.00	0.94
Color		Dark Gray	Dark Gray

Table 2 Chemical and mineralogical properties of Ariake and Bangkok clays

		Bangkok	Ariake
Soil pH		5.8	8.4
Organic Carbon (%)		2.47	0.90
Total Soluble Salt Content (%)		0.16	0.02
EC (mmho/cm)		2.10	1.47
Cations in Porewater	Na (meq/l)	3.09	10.00
	K (meq/l)	0.43	1.64
	Mg (meq/l)	9.90	2.92
	Ca (meq/l)	7.44	1.95
Exchangeable Cations	Na (meq/100g)	3.15	4.78
	K (meq/100g)	2.04	4.77
	Mg (meq/100g)	6.10	16.83
	Ca (meq/100g)	6.60	17.60
CEC (meq/100g)		26.8	32.34
Clay Mineral		Kaolinite Illite	Montmorillonite Illite

IV CONCLUSIONS

The chemical and mineralogical properties of Bangkok and Ariake clay were compared, in order to explain the differences in their strength development after lime stabilization. Factors contributing to the higher strength of lime stabilized Ariake clay are: (1) high pH, (2) low organic content, (3) higher quantity of exchangeable cations, (4) low salt content and electrical conductivity, and (5) mineralogy being predominantly montmorillonite.

REFERENCES

(1) Broms, B. (1984). "The lime column method". Sem. Soil Impr. and Const. Tech. in Soft Ground. Singapore. pp. 120–133.

(2) CSSAM (1990). Manual for soil standard analysis and measurement. (in Japanese).

(3) Lee, S.L., Ramaswamy, S.D. & Aziz, M.A. (1982). "A study of soil types suitable for stabilization with lime". Proc. 7th SEAGC. Hongkong. pp. 615–629.

(4) Locat, J., Berube, M. & Choquette, M. (1990). "Laboratory investigations on the lime stabilization of sensitive clays: shear strength development". Can. Geot. J. Vol. 27, pp. 294–304.

(5) Miura, N., Taesiri, Y., Koga, Y. & Nishida, K. (1988). "Practice of soil improvement of Ariake clay by mixing admixtures". Proc. Int. Sym. on Shallow Sea and Low Land. pp. 175–184.

(6) Taniguchi, Y., Buensuceso, B.R., Akamine, T. & Matsuda, K. (1992). "Strength development with time of lime stabilized Ariake clay". Proc. Annual Mtg. JSCE. (Seibu Branch). pp. 570–571.