GROUND IMPROVEMENT WITH LOW-GRADE LIME AND PLASTIC WASTE MATERIALS

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I INTRODUCTION

The objective of this research was to investigate the use of an industrial by-product in the stabilization of soft Ariake clay. This low-grade lime, called CaL, is produced from the reaction of calcium hydroxide slurry and hydrochloric acid gas, a harmful industrial discharge from incinerators:

$$2Ca[OH]_2 + 2HCl \dashrightarrow CaCl_2 \cdot Ca[OH]_2 \cdot H_2O + H_2O$$

The chemical composition of CaL is: $Ca[OH]_2$ (52.24%), $CaCl_2$ (28.69%), $CaCO_3$ (5.5%), and others (13.57%). It is widely known that calcium hydroxide effectively stabilizes soft clays, while calcium chloride, an inorganic salt, also has properties which can be of advantage in geotechnical engineering (Hausmann, 1990), e.g. in moisture control during construction and also control of dust generated on unpaved roads. In addition, the stabilization with admixtures plus plastic waste materials, was also investigated. Plastic waste materials obtained from disposed car bumpers, with approximate size of 4mm and weighing approximately 0.9 g/cm^3, were mixed with the stabilized soil. Such utilization of waste products would be economically and environmentally advantageous, inasmuch as the disposal of these wastes are very costly.

II EXPERIMENTAL DETAILS

The experimental program includes unconfined compression tests, CBR tests, and oedometer consolidation tests. The base clay used was soft Ariake clay taken from Kawasoe District, Saga, with the following properties: ω=121%; ω_L=93%; I_p=56%; and G_s=2.64. Stabilization with CaL was done with 20%, 30% and 40% admixture contents (% of dry weight of soil). To compare the effects of CaL with those of $Ca[OH]_2$, specimens with 11%, 16% and 21% $Ca[OH]_2$ were also tested; these lime contents were selected considering that CaL contains 52% of $Ca[OH]_2$. In addition, the effects of $CaCl_2$ were studied by testing specimens with both $Ca[OH]_2$ and 6%, 9% and 12% laboratory-grade $CaCl_2$. The second part of the investigations involved the stabilization with 20% CaL and 10% $Ca[OH]_2$ plus 10% and 20% plastic material (% of dry weight). The water content of the base clay was adjusted to 150% prior to the mixing. The procedures for specimen preparation were as recommended by JSSMFE (1990). All tests were carried out after a curing period of 28 days.

III RESULTS AND DISCUSSIONS

(A) Stabilization with low-grade lime: A summary of the improvements resulting from the stabilization with CaL, after a curing time of 28 days, is presented in Table 1. In general, stabilization with CaL led to the increase in the strength of the clay, with higher strength gain for higher lime content. The addition of 40% CaL resulted to a large relative strength increase, with q_u=9.5 kgf/cm^2 as compared with the strength of soft clay of 0.2 kgf/cm^2. The improvement in strength is also shown by the increase in the CBR (California Bearing Ratio) after stabilization with CaL. The CBR values, which reflect the soil resistance to penetration prior to its ultimate strength, were 7.8%, 32.3% and 40.2% for CaL contents of 20%, 30% and 40%. The improvement in CBR suggests the possibility of using CaL stabilized soil as subgrade and base course materials for road construction.

The compressibility characteristics of the clay is also improved by CaL, as manifested by the higher preconsolidation pressure, p_c (more than 20 times that of the base clay). CaL-stabilized clays will therefore have relatively small deformations under normal traffic loads. In addition, the coefficient of consolidation (c_v) of stabilized soil was found to be more than 10 times that of the base clay, suggesting higher permeability after improvement.

The strength improvement that was seen for 40% lime content is comparable to the effect of adding 11% $Ca[OH]_2$, see Table 1. Actually, 40% of CaL would contain an equivalent of 21% $Ca[OH]_2$, since CaL comprises of 52% $Ca[OH]_2$. The effect of calcium chloride (CaL also contains 28% $CaCl_2$), however, is to lower the strength. For example, Table 1 shows that the strength of soil stabilized with 11% $Ca[OH]_2$ is 10.7 kgf/cm^2, while the addition of 6% $CaCl_2$ reduced the strength to 5.2 kgf/cm^2.

(B) Stabilization with lime and plastic material: Table 2 presents the improvements when the stabilization was carried out with CaL plus plastic material, and also $Ca[OH]_2$ plus plastic material. In general, the strength and compressibility characteristics were also improved with this method of stabilization. The addition of 10% plastic material together with either CaL or $Ca[OH]_2$ is preferable, as compared with 20% plastic material content. With 20% CaL plus 10% plastic, q_u=4.1 kgf/cm², and CBR=21.9%; the compressibility was also improved with C_c=0.12 and $c_v=10^3$ cm²/d. For 10% $Ca[OH]_2$ plus 10% plastic, q_u=8.0 kgf/cm² and CBR=28.1%. Although stabilization with admixture alone resulted to higher improvements than with plastic material, the density was lower (ρ_t~1.35 g/cm³) when plastic was used in the stabilization. These results are encouraging, as they show that it may be possible to use plastic waste materials in construction.

IV CONCLUSIONS

The results presented in this paper showed that a low-grade lime, CaL, which is a waste industrial by-product, may be used to effectively improve the properties of soft clays. Stabilization with 40% CaL resulted in a large increase in strength and CBR, and also to the reduction of the compressibility. However, the effect of the $CaCl_2$ in the CaL was to lower the strength gain by about 30 to 40%. The use of 10% plastic waste material together with CaL or $Ca[OH]_2$ was also shown to result in improvements of the properties of the soft clay. These findings are very interesting because they bring about the possible utilization of waste materials in construction works. However, the disadvantageous aspects of calcium chloride, e.g. its corrosive effects on motor vehicles, damage to vegetation along stabilized roads, and the salt's possible migration into the lower soil layers, must still be studied in detail.

REFERENCES

(1) Hausmann, M.R. (1990). Engineering principles of ground modification. McGraw-Hill Publ. Co.. Singapore.

(2) JSSMFE (1990). Methods and details of soil testing. Published by the JSSMFE (in Japanese).

Table 1 Properties of soil stabilized with CaL and $Ca(OH)_2$

	w %	ρ_t g/cm³	CBR %	p_c kgf/cm²	C_c	Cv cm²/d	q_u kgf/cm²	ε_f %
Ariake clay (w_L=120-130%)	150	1.439		0.4	0.94	2.0×10²	0.2	5.0
CAL 20%	123.5	1.391	7.8	8.5	0.22	2.0×10³	3.3	1.5
30%	113.8	1.395	32.3	13.0	0.15	2.3×10³	7.0	1.4
40%	109.8	1.424	40.2	15.0	0.05	2.5×10³	9.5	1.5
$Ca(OH)_2$ 11%	126.4	1.362					10.7	1.4
$Ca(OH)_2$ 11% + $CaCl_2$ 6%	126.9	1.384					5.2	2.1

Table 2 Properties of stabilized soil with plastic waste materials

	w %	ρ_t g/cm³	CBR %	p_c kg/cm²	C_c	Cv cm²/d	q_u kgf/cm²	ε_f %
CAL 20% + PLASTIC 10%	106.4	1.382	21.9	6.2	0.12	1.8×10³	4.1	2.5
20%	102.4	1.336	15.6	5.7	0.13	1.5×10³	2.8	2.4
$Ca(OH)_2$ 10% + PLASTIC 10%	114.2	1.359	28.1				8.0	1.3
20%	101.5	1.335	22.8				7.5	1.3