Design and construction of waste lime landfill construction

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ABSTRACT: This study was carried out to analyze the settlement behavior, design and construction of waste lime landfill. The principal ingredient of the waste lime is $CaCO_3$ which the 24% of limestone is included. It is consisted mostly property of organic silty clay and it can be classified as MH-OH by the USCS. Based on the behavior analysis for settlement and stress for this landfill, the secondary compressive index by consolidation test has similar to the organic clay. By a multiple linear regression analysis for waste lime properties, the equation with compression index, moisture content, liquid limit and initial void ratio was derived. It was also derived from these indices for an empirical equation to estimate the settlement of waste landfill for the primary consolidation settlement (S_c) and the total settlement (S_t). The later part of this paper describes the design of bottom liner and top liner systems with utilizing various geosynthetics. The schematic diagram of waste lime landfill is presented. At present time, the second stage of construction work is being progressed.

1 INTRODUCTION

In the case of waste lime which is produced from the chemical plant and the fertilizer factory as a by-product, the rate of recycling is excessively low level, so it has been accumulated around site of a plant or a factory during the past 30 years in Incheon, South Korea. The total amount of waste lime is 8,011,411 m^3 and total dry weight of waste is 46,161,000 kN with the specific gravity of 2.2 and the unit weight of 15.6 kN/m^3. The accumulation of a waste lime in the field destroys the townscape aesthetically and makes some problems for land development and city planning.

On the strategy for how to deal with this waste lime, it has been used for reclaiming land from the sea as a compound of manure with lime, a ground stabilizer, and a construction supplement material in foreign countries. It has been studied to apply as a counteractive material of sodic soil or a cover soil of waste landfill by now. In regard to case study about waste lime, Shin et al. (1996) studied the ground dynamic properties of waste lime, and presented it can apply to road with subbase material or soft ground with mixing dredged soil. It was reported that the sludge of waste lime with fly ash could use to bank materials (Maher et al. 1993). Arman and Munfakh (1972) introduced the result of case study of stabilization with waste lime in ground of organic clay soil. However, it has been not traced tends of long-term settlement of waste lime or behavior characteristics of waste lime landfill to its source. It needs to study about property of waste lime and to study about consolidation theory for waste lime.

This research was studied about properties of waste lime and the settlement of characteristics in the waste lime landfill. Based on subsurface investigation, monitoring, experimental data and laboratory test of the waste lime landfill, the correlation analysis was carried out for analyzing behavior of waste lime, so that it was suggested the consolidation equation of waste lime. Caused approximately 100,000 ton for a year, the waste lime has been filled in the site for reclamation and used as a settling pond to deposit lime for constructing landfill. The area of the waste lime landfill is about 34 ha and the volume of it is 4,810,000 m^3. An aero view of the site is shown in Figure 1.

Figure 1. Aero view of waste lime landfill site

2 PHYSICAL PROPERTIES

The waste lime is a nonorganic sludge which was created in ammonia-soda process called Solvay method for the production of soda ash (Na_2CO_3). The Solvay process produces soda ash from brine with sodium chloride (NaCl) and from limestone with calcium carbonate ($CaCO_3$). The overall process is

$$NaCl + CaCO_3 \rightarrow Na_2CO_3 + CaCl_2$$

It is mainly consisted with 70% of calcium and 10% of magnesium, and silica compounds. The sludge was classified with non-dehydrating deposit and dehydrated cake. The physical test result was classified by initial void ratio with less than 1.5, 1.8 and more than 1.8 after carrying out the laboratory test for finding property.

Water contents were distributed in 53.9 ~ 65.1%, 67.8 ~ 79.3%, 81.9 ~ 94.8% initial void ratio, respectively. According to increasing initial void ratio, the water content of waste lime intends to increase. Figure 2 shows the physical test result of waste lime. Liquid limits indicate 57.5 ~ 67.1%, 81.9 ~ 84.2%, 83.58 ~ ~96.5% by the initial void ratio, respectively.

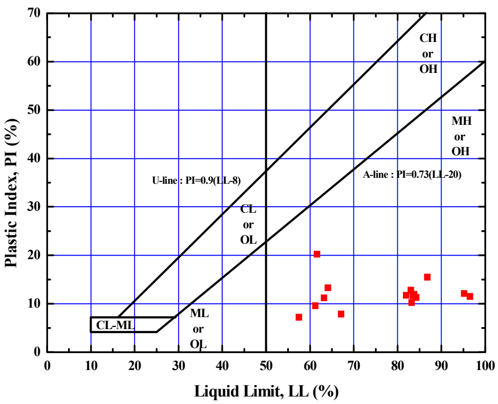

Figure 2. Physical test results of waste lime

Plastic limits show 7.2 ~ 20.2%, 10.2 ~ 11.9%, 11.5 ~ 15.5% as to the void ratio. The percent of finer at No. 200 sieve shows more than 90% of passing rate. As a result, most of the waste lime was classified to the high plastic organic soil with MH-OH on Unified Soil Classification System.

3 MECHANICAL PROPERTIES

The undisturbed soil specimen sampled in the field was carried out consolidation test with KS F 2316. Table 1 describes the test result of standard consolidation test.

Table 1. Result of standard consolidation test

Classification	P_c (kgf/cm^2)	P_0 (kgf/cm^2)	e_0	C_c	C_s	C_a
Less than 1.8 of void ratio	0.44	1.045	1.679	0.602	0.063	0.014
More than 1.8 of void ratio	0.41	1.025	1.951	0.621	0.052	0.010

The Pre-consolidation pressures exist between 0.28 kgf/m^2 and 0.43 kgf/m^2 in less than 1.5 of the void ratio. It exists in 0.36 ~ 0.45 kgf/m^2, 0.38 ~ 0.53 kgf/m^2 in less than 1.8 and more than 1.8, respectively. According to increasing the void ratio, the pre-consolidation pressure intended to increase gradually. The compression indexes indicate in between 0.594 and 0.61 at less than 1.8 of void ratio, and 0.621 ~ 0.725 at more than 1.8 of the void ratio. As the void ratio tends to increase upward, the compression index also shows a tendency to increase.

The properties of waste lime are similar to organic silty clay, no. 11, Boston blue clay, no. 9 in the graph (Mesri 1973). As a result, the test result of consolidation with waste lime for calculating total settlement in the site is plotted in Figure 3.

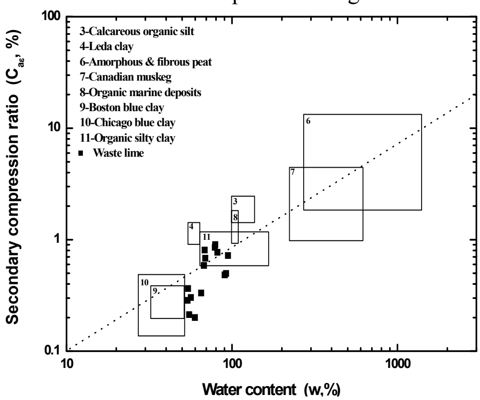

Figure 3. Distribution of C_a

The total settlement of waste landfill site is caused from 16.1 ~ 67.8 cm by height of banking in less than 1.5 of initial void ratio, 39.5 ~ 150.8 cm in less than 1.8 and 47.0 ~ 178.9 cm in more than 1.8 of it. No relationship between initial void ratio and settlement is shown from the data. The secondary settlement is caused approximately 8.5 ~ 8.3 cm by height of bank in less than 1.5 of the void ratio. The secondary settlement is caused high due to organic material which is contained about 18.85% in waste lime.

4 CORRELATION OF DISTRIBUTION

Relation of the distribution with the physical properties was produced in between soil properties, consolidation coefficient, and strength using the SPSS (statistical package for the social sciences ver. 14.3). The results of regression analysis between modified compression indexes, moisture contents, and liquid limits are tabulated in Table 2.

Table 2. Regression analysis of c_c'

Element	Modified Compression Index(c_c')	
	Regression distribution	R^2
e_0	$c_c = 0.55903\ \ e_0 - 0.3778$	0.81452
w_n	$c_c = 0.01\ \ w_n - 0.17718$	0.70753
LL	$c_c = 0.01197\ \ LL - 0.3863$	0.84148

Binary logistic analysis realized to get an optimum regression model from sample data. It is not close correlation. However, it shows good correlation as 0.973~0.975 by method of multinomial distribution of regression analysis.

Based on this result about correlation, the settlement equations are derived by height of waste lime (H), initial void ratio (e_0), and compression index (c_c). Three equations for the primary consolidation settlement, secondary settlement, and total settlement calculated as follows,

$$S_c = 24.4H + 14.4e_0 + 166.9c_c - 87(R^2 = 0.917)$$
$$S_a = 2.3H - 8.4e_0 + 242.7c_a + 26.27(R^2 = 0.205)$$
$$S_t = 26.7H + 1.88e_0 + 179.5c_c - 70.1(R^2 = 0.940)$$

5 DESIGN OF LANDFILL LINING SYSTEM

A bottom and top liner systems with utilizing various geosynthetics are adopted for design and construction of waste lime landfill. The schematic diagram of waste lime landfill is presented in Figure 4.

The bottom liner system is constructed with a thickness of 0.5m clay and 0.2mm HDPE sheet. The water content was controlled around 26% by potentiometer with protrusion and the compaction was carried about 1.57 ton/m^3 of dry unit weight by kneading compaction with the lift thickness of 0.5m waste lime. Therefore, the permeability was controlled as 1x10^{-7} cm/sec.

The side slope liner system is difficult to work with placing the compacted clay. Thus, an artificial liner which is consisted with 2mm thickness of high density poly ethylene (HDPE) and 6mm thickness of geosynthetic clay liner (GCL) was installed. Geocomposite with 1/30,000 m^2/sec degree of seepage and nonwoven geotextile spread in ground water exclusion layer and collection and drainage system of leachate.

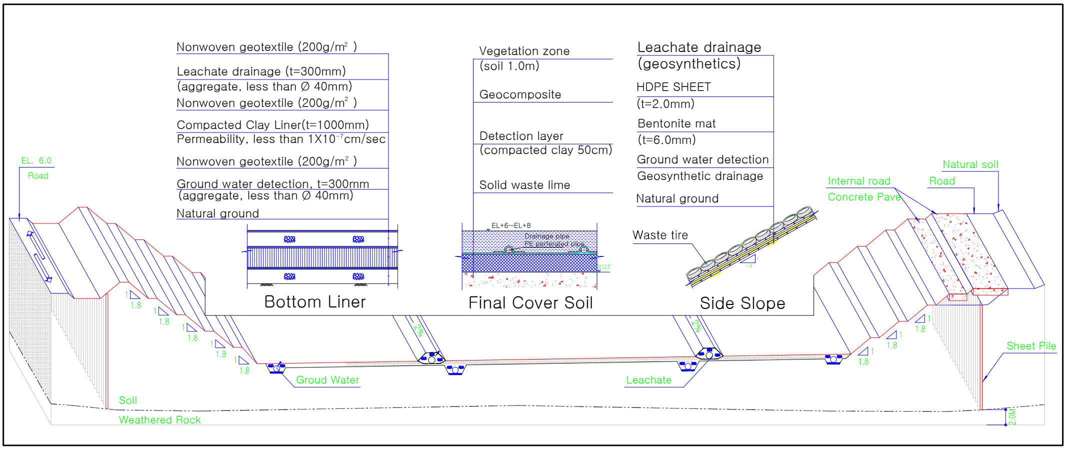

Figure 4. Schematic diagram of waste lime landfill

The top layer is composed with 50cm compacted clay liner for discharging surface water on the solid waste lime, geocomposite, and 1.0m thickness cover soil for formation of vegetation zone.

The permeability of compacted waste lime in landfill is very low about 2~5 x 10^{-7} cm/sec, so that the amount of leachate is not much due to low seepage into waste lime. The leachate collection system was installed 300mm PE perforated pipe which warped by aggregate of 30cm thickness with 5% gradient. It was located on the bottom layer and covered with geonet. Figure 5 shows the leachate collection system.

Figure 5. Leachate collection system

6 CONCLUSIONS

This study was carried out the physical and mechanical laboratory tests to analysis consolidation characteristics of waste lime and proceeded to analyze the regression analysis about settlement in waste lime landfill site. The top and bottom liner systems for waste lime landfill are also reported. Based on the analysis, laboratory consolidation test, and field observation of landfill site, the following conclusions are drawn.

1. As a result of correlation analysis in soil properties, compression index (C_c), initial void ratio (e_0), moisture content (w), and liquid limit (LL) in regard to the settlement, it has very close correlation as derived

$$C_c = 0.1863e_0 + 0.003w_n + 0.00399LL - 0.31118$$

2. The correlation equation about settlement (S_c) with modified compression index (c_{cwl}) can be derived as

$$C_{cwl} = \frac{0.0049w_n + 0.003LL - 0.194}{1 + 0.0412w_n}$$

$$S_c = C_{cwl} H \log \frac{p + \Delta p_0}{p_0}$$

3. According to initial void ratio (e_0), compression index (C_c) and height of waste lime (H), empirical the consolidation equations for settlement and total settlement are proposed.

4. The waste lime produced from the chemical factory as a by-product is successfully landfilled with utilizing modern landfill construction technology.

5. From the observation of the first stage landfill construction work, the geosynthetics used in this particular project gives an enhancement of slope stability and stability of landfill itself. It can increase the maximum waste lime filling capacity in the limited landfill site.

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