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Applications of Air-Foamed Stabilized Soil as Potential Subgrade Material of Railway Track

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Abstract

In these days, use of proper soils for construction materials become more limited, but wasted soils are abundant; therefore, the method which can use wasted soil such as soft clay has been investigated. Air-foamed stabilized soil has been used widely, but never been used as a subgrade material. The aim of this study is to verify the use of air-foamed stabilized soil as the subgrade construction material. Several wasted soils such as soft clay was selected to make air-foamed stabilized soil mixtures. The air-foamed stabilized mixture design was conducted to find the optimum quantity of stabilizing agent (cement) and air-foamed, and the effect of cement quantity and air-foamed quantity on strength of air-foamed stabilized soil mixtures base on the test results of unconfined compression test was investigated. As the quantity of cement is increased, the strength is increased, but the quantity of air-foamed is increased and the strength is decreased. Elastic moduli based on unconfined compression strength were obtained to use as subgrade of railway track design.

Keywords: *Air-foamed stabilized soil, Railway, Compressive strength, Subgrade*

1. Introduction

In these days, use of good construction materials such as sand and gravel has been limited; however, a lot of wasted soils such as dredged soil and soft clay are abundant because of development of sea shore area. Specially, the west coast of Korea has a lot of soft clay and causes many problems such as settlement and expansion which can be detrimental to infrastructures; therefore, improvement for the dredged and soft clay soils has been needed.

Air-foamed stabilized soil is suitable to use in many field such as backfilling material, land reclamation material, embankment material and for refilling due to its low weight and fast placing because of its flowing ability and no compaction needed with this material (Tsuchida and Egashira, 2004). It is confirmed that air-foamed stabilized materials were stable for a long period (about 10 years) by preventing deterioration factors such as desiccation and alternating wetting-drying, and its strength shows the increasing tendency with time (Watabe *et al*., 2007). The unconfined compressive strengths of lightweight soils increased with an increase in cement content, but decreased with increases in water content and air-foamed content. The density tends to increase by defoaming of air-foamed before hardening (Tsuchida and Egashira, 2004).

In this study, the applicability of air-foameded stabilized soil for subgrade of railway track was investigated. To make air-foamed stabilized soil, air-foamed bubble content was kept constant at 20% (by volume of source soil), while the quantity of cement contents (5%, 10%, 15% and 20% by weight of source soil) was varied in each mixture. The unconfined compressive strength of air-foamed stabilized soil was conducted and analyzed. The elastic modulus of air-foamed stabilized soil was estimated based on the relationship between unconfined compressive strength and elastic modulus.

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Table 1 Physical Properties of Dredged Soil

Liquid limit W_L (%)	Plastic limit W_P (%)	Plastic index I_P	Soil particle density (g/cm^3)	Percent passing #200 sieve (%)	USCS
44-48	23-24	22-25	2.65	91.3	CL

Table 2 Mixing Conditions

Type	Mixing condition
Cement (%*)	5, 10, 15, 20
Air-foamed (%**)	20

* Percentage by weight of source soil
** Percentage by volume of source soil

2. Description of Soil and Physical Properties of Soil

The geotechnical properties of the dredged clayey soil are listed in Table 1. The dredged soil is classified as low plasticity clay, CL, according to the Unified Soil Classification System (USCS).

3. Mix Design and Preparation Sample

3.1 Mix proportion

Portland cement was used in this study as a stabilizing agent. A foaming agent that expands 25 times in volume, similar to shaving cream, was used as the lightening material.

Several types of specimen were prepared. Various mixing conditions were used to investigate the effects on the compressive strength of various levels of cement. The quantity of air-foamed bubbles was kept constant at 20% by volume of source soil. Water added was adjusted so that the mixture before adding air-foamed obtains the density 1.4 g/cm^3.

3.2 Preparation sample

The air-foamed stabilized soil was prepared as follows. The source soil was first placed in the mixer. Water was added according to the quantity of water determined. Cement was added and after then the slurry mixture was mixed into homogenous slurry. During the same time, air-foamed was prepared using a foaming agent mixed with water. The optimal ratio between foaming agent and water was 1:20 and they were mixed thoroughly in air-foamed mixing device with careful control of air pressure in order to get homogeneous air-foamed mixture. The density of air-foamed was controlled at 0.047 g/cm^3. Then the prepared air-foamed was slowly added into slurry and the mixing continued until the air-foamed bubbles evenly distributed within slurry. With another 5 minutes mixing, the mixture with air-foamed was produced in a slurry form. The whole mixing process took around 15 minutes.

After a thorough mixing, slurry was cast into specimens for unconfined compression tests. PVC pipe molds with 120 mm in height and 50 mm in inner diameter were used and covered with a plastic sheet to prevent moisture loss from the samples. All specimens were cured in the atmosphere at room condition (approximately 20ºC) until the date of testing (7, 14, 28 days).

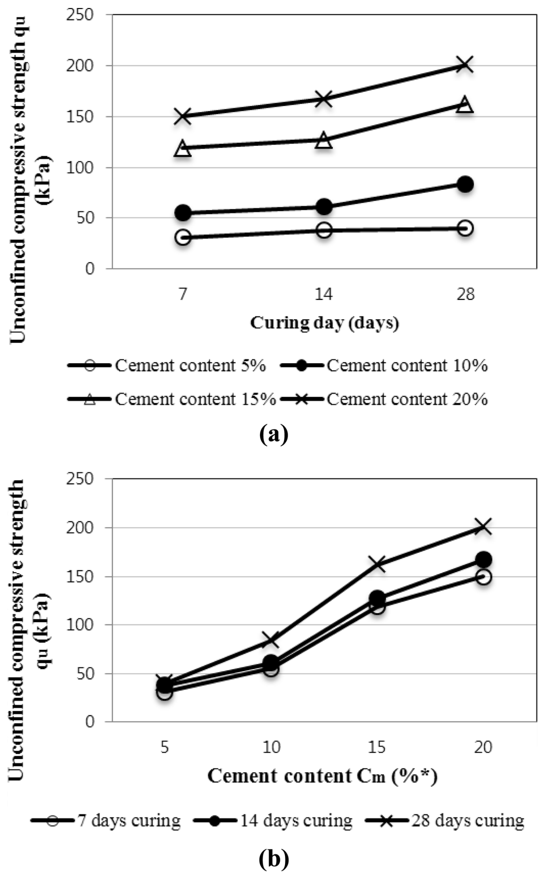

Fig. 1. The effect of (a) curing day and (b) cement content to the unconfined compressive strength (q_u).

4. Testing and Analysis

4.1 Unconfined compression test

After curing, the dimension of specimens was measured to determine the volume. The mass of the specimen was weighted and the density of the specimens was calculated. The unconfined compression test was conducted to measure the compressive strength. The test was conducted and the results were plotted in Fig. 1.

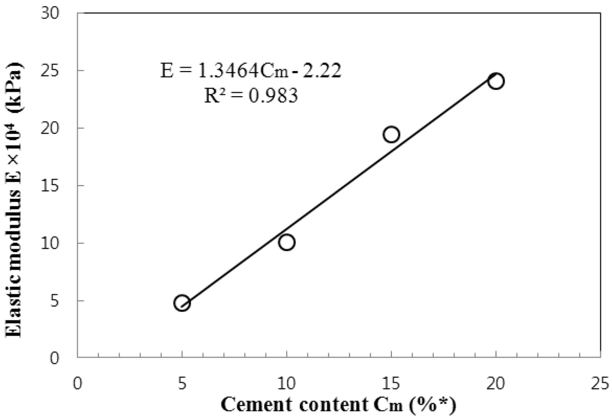

Fig. 2 Relationship between Cement Content and Elastic Modulus with 28 days Air Curing

4.2 Analysis

Fig. 1(a) shows the unconfined compressive strength as a function of curing time. The value of unconfined compressive strength of the air-foamed stabilized soil mixture rapidly increased at the beginning of the curing time due to the cementation effect and then increased more gradually after 7 days. And after 28 days, it still tends to increase.

Fig. 1(b) illustrates the effect of cement content for three curing times to the unconfined compressive strength. The unconfined compressive strength increases when the quantity of cement content increases. In term of our study, (5% to 20% cement content) the unconfined compressive strength has no peak and it continues to increase with the increasing of cement content. The quantity of cement content increase, the curing days affect more to the unconfined compressive strength because of the effect of cement.

In our research, the elastic modulus (E) of subgrade was use to investigate the performance of subgrade under the railway track. The dredged soil or soft clay after treated has the properties of cement-treated soil. So, the elastic modulus can be estimated corresponding to cement-treated soil based on the unconfined compressive strength at 28 days of curing in accordance with ASTM D 1633.

The relationship between cement content and elastic modulus of air-foamed stabilized soil is indicated in Fig. 2. The elastic modulus was calculated from the relationship with unconfined compressive strength by the equation, $E = 1200 \times q_u$. Fig. 2 shows that every 5% cement content was increased, the elastic modulus linearly increased about 67000 kPa and it continues to increase with the increasing of cement content according to the following equation:

$$E = (1.3464C_m - 2.22) \times 10^4 \text{ ; with } R^2 = 0.983 \qquad (1)$$

5. Conclusion

The series of analysis were performed to evaluate the applicability of air-foamed stabilized soil made of clay as subgrade layer of railway track. Based on the limited studies, the following conclusions were made:

For the purpose of utilization of clay soil, soil strength can be improved by adjusting the appropriate quantity of cement content.

The elastic modulus of air-foamed stabilized soil can be calculated corresponding to cement-treated soil based on the unconfined compressive strength at 28 days, and it continues to increase with the increasing of cement.

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