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Performance evaluation of road embankment constructed using lightweight soils on an unimproved soft soil layer

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ABSTRACT

This study was conducted to determine the performance of lightweight air-mixed soil (LWS) for expanded road construction for a short-term period without any soft ground improvement. The unconfined compression strength and capillary rise of lightweight soil and the settlement of the soft ground were measured. The unconfined compression strengths of the samples cured at the site for 1 or 5 months all satisfied the required target strength of 500 kPa. However, the homogeneity of construction was not verified because the values of strength depended on the sampling location. In addition, the strength difference between the laboratory and site samples was found to be approximately 19%, and thus, it should be considered for mixing design. The capillary rise was approximately 20 cm for 70 h because of the numerous tiny pores inside the lightweight soil. This phenomenon changes the density of the LWS. The relationship between the settlement time and the settlement of the soft ground underneath the expanded embankment was estimated by using the monitored data and back analysis. The current average consolidation ratio and the final settlement after 120 months were estimated to be approximately 32% and 4.5 cm, respectively. This settlement is much less than the allowable settlement of 10 cm. Consequently, the LWS used in this site was successfully applied to reduce settlement and ensure stability.

1. Introduction

In the 1990s, expanded polystyrene (EPS) was mainly used for lightweight banking in Korea. EPS is a styrene monomer (liquid) neutralizing agent produced during the course of refining oil, and its main raw materials are polystyrene (solid) and a gas-forming agent added to the polystyrene. EPS is used for backfilling of the transition zone between embankment and abutment because its density is as low as 1/100 that of soil, which leads to a reduction of surcharge and settlement (Korea Institute of Construction Technology, 1996). In addition, EPS is used for the various constructions because of its relative high strength. Since EPS was first adopted as a backfill of bridge-embankment transition zones in 1993, it has been frequently used for road expansion and backfill. However, many problems, such as long-term compressibility (creep) (Figure 1), block shattering and faulting settlement by the plastic deformation of EPS, have been found. Recently, several researchers have tried to apply lightweight soils mixed with air bubbles in Korea (Kim and Lee, 2002; Yoon and Kim, 2004; Yoon and You, 2004, 2005; Im et al., 2007).

A lightweight air-mixed soil (LWS) is prepared by mixing air bubbles and water with construction disposal or in-situ soils and cement. The density of soil slurry can be adjustable in the range of around 10 kN/m^3, but the control of the density may be limited to meet the required conditions due to the effect of quality control factors (for instance, compression strength, slump, and dissipation air bubbles). LWS has several advantages. First, it is able to reduce the load on the ground because it is lighter than soil, and it can be transferred by pumping because its fluidity is high. In addition, it is easy to construct because it does not require a compaction process. It has been recognized as an effective material for banking on soft ground, backfilling retaining walls, backfilling structures, stuffing settlement ground and so on (Figure 2). Due to these advantages, it has many potential uses (Hayashi et al., 2002; Miki et al., 2003; High Grade Soil Research Consortium, 2005; Yajima and Mydin, 2006; Jamnongpipatkul et al., 2009; Hwang et al., 2010).

According to the previous studies on LWS, the compression strength of LWS is generally influenced by the initial moisture content of the soil sample, the cement percentage, the air bubble percentage and the curing method because it is a mixture material (Kim and Lee, 2002). Yoon and Kim (2004) developed a method to estimate the unconfined compression strength of LWS in accordance with the mixing combination by considering the factors affecting quality. In the study of Yoon and You (2004), a regression equation

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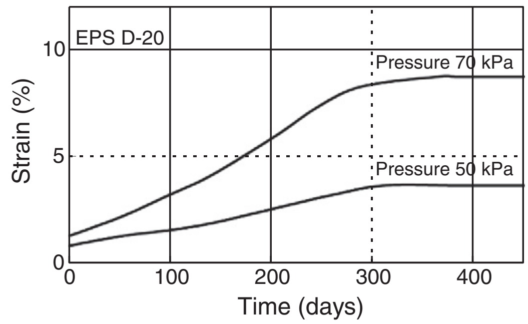

Fig. 1. Creep behavior of EPS (Korea Express Corporation Research Institute, 1994).

for the unconfined compression strength expressed in terms of a normalized coefficient and the initial moisture content of in-situ soil, cement percentage and air bubble percentages were established. This study also showed that the normalized coefficient significantly depends on the soil used for preparing the lightweight air-mixed soil. The variation in the unconfined compression strength of LWS might be because the constituents of the in-situ soil were different. For the unconfined compression strength by the height of construction, if a coefficient of curvature of the in-situ soil increases, then the difference in the density and strength between the upper part and lower part of the constructed LWS also increases. If the coefficient of curvature changes drastically, then the percentage of coarse grained soils is high, and the dissipation rate of air bubbles is high. Therefore, it was suggested that construction be restricted to certain in-situ soils when using such a soil (Song et al., 2008). Similar studies focused on the strength in the laboratory and were conducted by other researchers (Hayashi et al., 2002; Yajima and Mydin, 2006).

In the previous research, the compression strength of the material is mainly studied via laboratory experiments. The studies of the application of LWS in the field have been very limited. For instance, for LWS constructed in the field, few studies on the verification of the compression strength, capillary rise due to ground water, and settlement monitoring are available. These factors are very important to take into account when LWS is used in the field, and thus, they should be carefully studied.

Therefore, this research aims to determine the behavioral characteristics of an expanded road constructed by LWS with a slurry density of 10 kN/m^3 over the short term without any soft ground improvement. In particular, the compression strength and capillary rise of the LWS and the settlement behavior of the ground using LWS are considered.

2. Field condition, manufacture LWS, and monitoring plan

2.1. Site description

The site was a road expansion area located in Kyoungsangnamdo. The road was originally composed of 2 lanes, and it was planned to expand it to four lanes and to connect it with an IC ramp. The specific site is at the IC Ramp A 0 + 050 station, as shown in Fig. 3. The geological conditions of this site are shown in Fig. 4, in which soil strata, from the top layer, are paddy soil, silty sand and soft silty clay. The paddy soil depth is approximately 1 m, the sand layer is approximately 10 m, and the clay layer is approximately 10 m. This clay layer is very soft so that long-term settlement is expected.

To construct a ramp as quickly as possible, the LWS method was used without any soft soil improvement underneath the embankment layer. EPS was also used at a very small portion of the embankment to

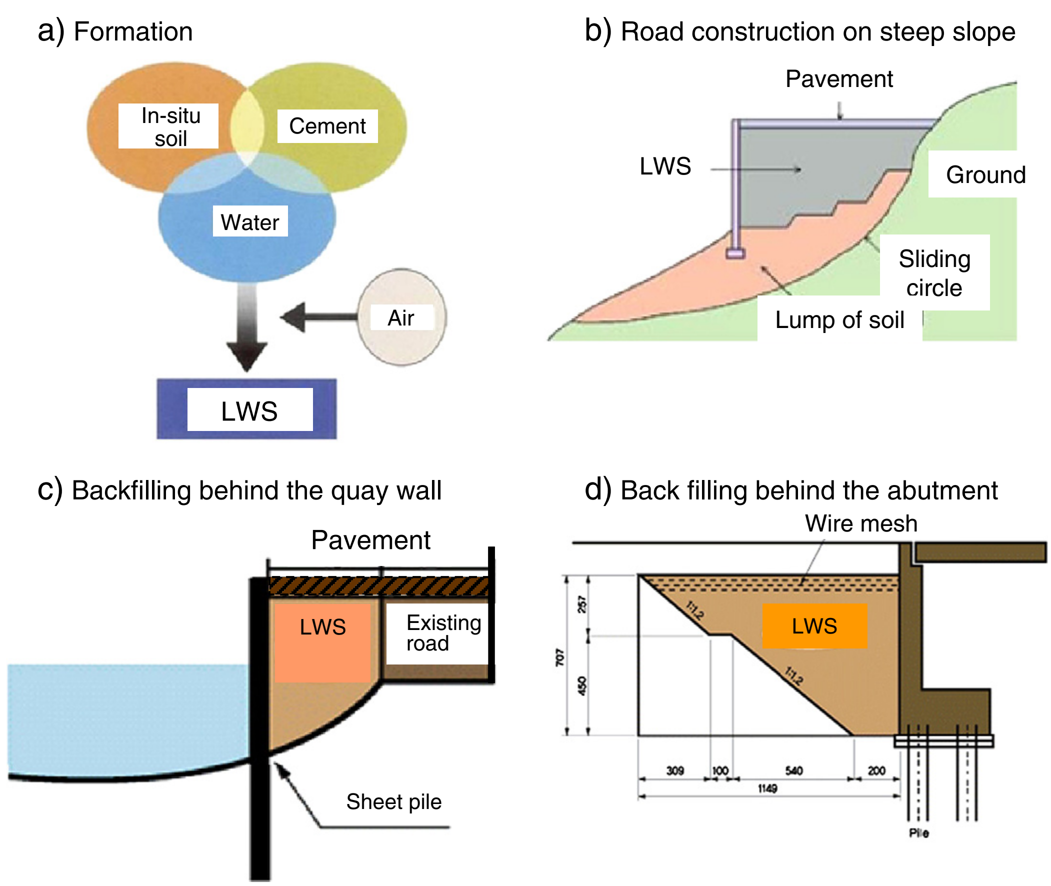

Fig. 2. Formation and applications of LWS.