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Effect of soil compaction on behavior of a geocomposite for erosion control

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ABSTRACT: The authors examined an erosion control method for slopes by using a geocomposite. In this method, the roots of the vegetation are supported with soil filled into a geocomposite by compaction. The authors investigated the effects of compaction conditions on the density of the soil filled into the geocomposite by performing laboratory tests. This paper gives an outline of the erosion control method and the laboratory test results. An evaluation method to explain the laboratory test results is proposed.

1 INTRODUCTION

Erosion control is an important issue in the construction and maintenance of sloped river walls. To date, many erosion control methods have been developed. Geosynthetics are often used as erosion control materials. However, testing, design, and quality control methods for these materials have not been sufficiently developed.

Erosion control with geosynthetics can be grouped into slope erosion control and channel or ditch erosion control. On the other hand, the geosynthetics for erosion control can be grouped into temporary and permanent materials (Koerner, 2005). The authors examined the slope erosion control method using a permanent material. In a series of the research, laboratory test was performed to develop practical construction method. The outline of an erosion control method and the laboratory test results have been given in this paper. Further, an evaluation method to explain the laboratory test results has been proposed.

2 EROSION CONTROL METHOD WITH A GEOCOMPOSITE

The authors focused on an erosion control method using a geocomposite to support vegetation. The outline of this method has been shown in Figure 1. The roots of the vegetation are supported by soil filled into the geocomposite. An example of a geocomposite used in this method is shown in Figure 1. This is a composite product of the PP geonet and three-dimensional PE geomat. This method has been examined in detail at the research project of the Public Work Research Institute (PWRI, 2001). The main construction scheme is as follows. First, a geocomposite is placed on a prepared soil subgrade

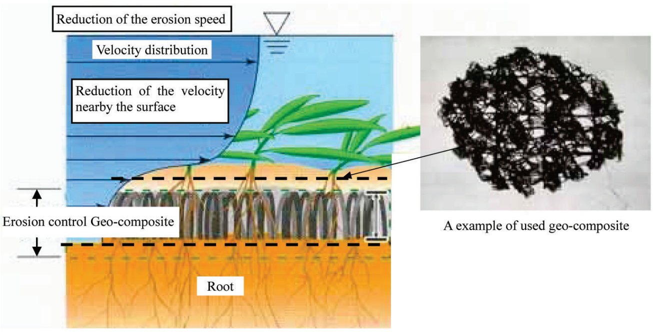

Figure 1. Outline of the erosion control method for river walls by using geosynthetics (after PWRI report, 2001).

(a) Installed geocomposite

(b) Spraying of soil

(c) Compaction of soil

(d) Completion

Figure 2. Construction process.

by pinning it to the soil with U-shaped pins or small ground anchors (see Figure 2a). Next, the soil premixed with the vegetation seeds and fertilizer is sprayed (see Figure 2b). The soil is then compacted and filled into the geocomposite (see Figure 2c).

One or two months later (this period depends on the type of vegetation), the vegetation covers the surface of the soil subgrade (see Figure 2d). This procedure is not performed in the rainy season.

In the erosion control method using a geocomposite, a close contact between the geocomposite and the soil subgrade is important This condition may be affected by soil compaction conditions. However, the effect of compaction conditions cannot be sufficiently evaluated by conventional design methods. The authors performed laboratory tests in order to develop a practical construction method.

3 LABORATORY COMPACTION TEST

3.1 *Compaction test of multilayer samples consisting of soil and geocomposite*

The authors examined the effect of compaction conditions such as water content and compaction energy on the dry density of the soil filled in the geocomposite. A cross-sectional view of the laboratory compaction test sample is shown in Figure 3. Steel cylinder for CBR test was used. The compaction tests were performed using three-layer samples consisting of two layers of soil and one layer of geocomposite.

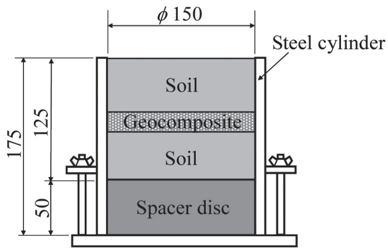

Figure 3. Laboratory compaction test.

The three layers in the cylinder were compacted with a metal rammer with a weight of 5.5 kg. Each of the three layers received 55 blows from rammer falling freely from a height of 30 cm above elevation of each finally compacted layer. The compaction energy *Ec* was controlled by the number of blows. Compaction at the middle layer was performed for sandwich layer of soil and geocomposite.

The soil sample used in the tests was river sand composed of angular- to sub-angular particles with a specific gravity of 2.66. The average grain size D_{50} was approximately 2.0 mm and the uniformity coefficient U_c was 3.1. The geocomposite used in the tests was the composite product of the PP geonet and PE geomat having a three-dimensional mesh, as shown in Figure 1.

3.2 *Analysis method of test results*

To estimate the dry density of the soil filled in the geocomposite, a calculation method was developed

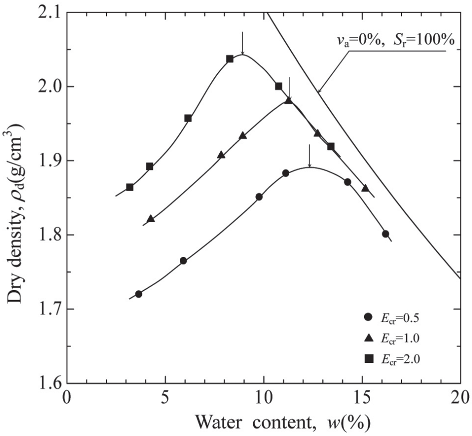

Figure 4. Water content – dry density graph for soil alone.

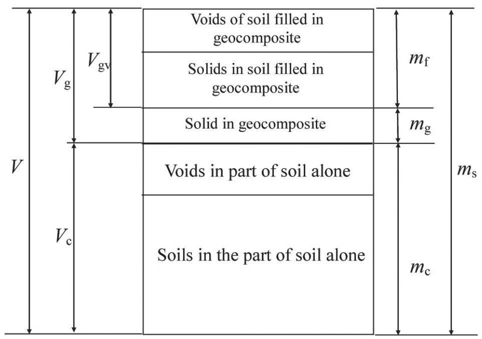

Figure 5. Volumetric and weight relationship between the soil and geocomposite.

for the multilayer compaction test. The equations were are follows. The index is summarized in Figure 5.

(1) The total sample volume V can be expressed as a sum of the volume of the compacted soil alone, i.e., V_c, and the volume of the geocomposite filled with the soil, i.e., V_g ••

$$V = V_c + V_g \tag{1}$$

(2) The total dry weight m_s can be expressed as follows.

$$m_s = m_c + m_f + m_g \tag{2}$$

where, m_c is the dry weight of soil in V_c, m_f is the dry weight of the soil filled in the geocomposite, and m_g is the dry weight of the geocomposite itself.

(3) The average dry density $\bar{\rho}_d$ of the multilayers of the soil and geocomposite, the dry density of the soil layer ρ_d, and the density of the geocomposite layer ρ_d^* can be expressed as follows:

$$\bar{\rho}_d = \frac{m}{V} \tag{3}$$

$$\rho_d = \frac{m_s}{V_c} \tag{4}$$

$$\rho_d^* = \frac{m_f}{V_{gv}} \tag{5}$$

where, V_{gv} is the volume of the void in the geocomposite.

(4) The unit weight of the geocomposite per area w_g and V_{gv} can be expressed as follows:

$$w_g = m_g \frac{t_g}{V_g} \tag{6}$$

$$V_{gv} = \lambda \cdot V_g \tag{7}$$

where, t_g is the thickness of the geocomposite in the no-confining stress condition and λ is the void ratio of the geocomposite.

From equations (1)–(7), ρ_d^* can be expressed as follows:

$$\rho_d^* = \frac{1}{\lambda}\left\{\rho_d - (\rho_d - \bar{\rho}_d)\frac{V}{V_g} - \frac{w_g}{t_g}\right\} \tag{8}$$

where, λ, w_g, and t_g are the material indexes of the geocomposite; V and V_g are the volumes in the initial state of test; $\bar{\rho}_d$ is a measured value in the compaction test for the multilayers of the soil and the geocomposite; and ρ_d can be estimated from the compaction curve of soil alone.

In equation (8), the deformation induced in the geocomposite is not considered. V_g or t_g may decrease by compaction. In addition, ρ_d is assumed to have the same value as that in the test where only soil was used. The value of ρ_d may be affected by the interaction effect between the soil layer and the geocomposite. The authors felt that these effects are not serious and calculated the dry density of the soil in the geocomposite. This effect should be examined in future studies.

3.3 *Test results and discussion*

The relationships between the average dry density $\bar{\rho}_d$ defined in equation (3) and water content are shown in Figure 6. The result of the compaction test for soil alone is also shown in this figure. In this result, the average dry density has been defined without making any distinction between the soil layer and the geocomposite layer. In the case of the geocomposite, the average dry density is lower than that in the test where only soil was used. The difference increased as the water content w got closer to the optimum water content w_{opt}. With regard to the effect of the compaction energy E_c, the dry density also increased as the energy increased.

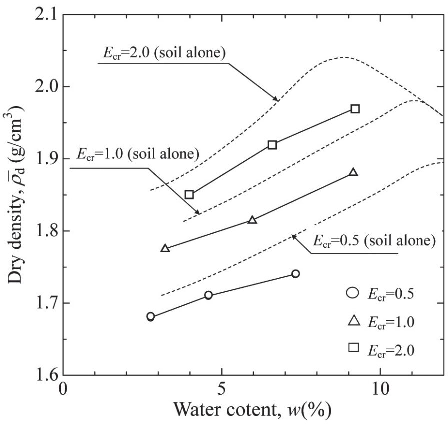

Figure 6. Water content – dry density graph for soil – geocomposite.

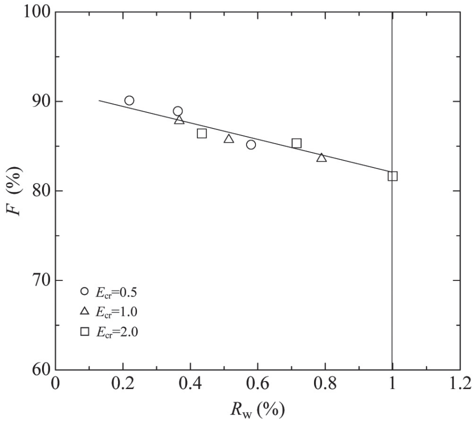

Figure 8. Filling-up ratio vs. relative water content.

In order to evaluate the effect of the compaction conditions by using a simple equation, new parameters were introduced. The definition of these parameters is shown in Figure 7 (a) and (b). The filling-up ratio F (see Figure (a)) is defined as the ratio of the dry density of the soil in the geocomposite to that of the layer with only soil. The relative water content R_w is defined as the ratio of the water content in the multilayer test to the optimum water content of the soil. These values are positive and less than 1.0.

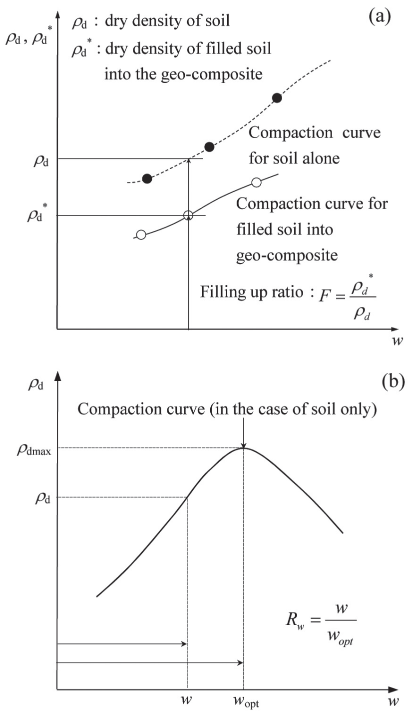

Figure 7. Definition of analysis parameter: (a) Filling-up ratio and (b) Relative water content.

Figure 8 shows the translated results of Figure 7 by using new introduced parameters. The relationship between F and R_w appears to be linear although the compaction condition differs among tests. This can be described by using the following equation:

$$F = F_0 - \alpha \cdot R_w \tag{9}$$

where, F_0 is F at $R_w = 0$ and α is the index showing the effect of the compaction conditions, soil type, and type of geocomposite. Using this relationship, the effect of the compaction condition can be discussed with a limited test case.

4 SUMMARY

In this study, the effects of the compaction conditions on the dry density of soil filled into a geocomposite for erosion control were observed. A method for estimating the dry density of the soil filled in the geocomposite was developed for the multilayer compaction test. The effects of the compaction conditions can be described by a simple equation. A laboratory test should be performed for the wet side and the required filling-up ratio should be examined in future studies.

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