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Influence of Water Content on Shear Behavior of Unsaturated Fouled Ballast

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Abstract

This paper evaluates the synergistic effects of water content and fine fraction on shear behavior of unsaturated fouled ballast by performing a series of triaxial compression tests and water retention tests on fresh and fouled ballasts in unsaturated conditions. As the results, it was revealed that soil-water characteristic curves and relationships between degree of saturation and peak shear strength were seriously affected by intrusion of fouling materials into fresh ballast, and that the decreasing trend of peak strength becomes more remarkable in such a case where both water content and fine fraction increase. These results indicate that for the precise prediction of the long-term performance of transportation infrastructures and the evaluation for mechanical property of railroad ballast under repeated train passages, it is important to take into account the synergistic effects of water content and fine fraction on the deformation-strength characteristics of ballast in accordance with the degree of ballast fouling.

Keywords: railroad ballast, unsaturated soil, triaxial test, water retention test, shear strength

1 Introduction

In ballasted railway tracks, ballast fouling gradually occurs when finer materials mix with fresh or clean ballast due to particle crushing caused by heavy repeated train loads and/or finer material intrusions caused by mud-pumping from the underlying layers under train loading and an infiltration of fines from the surface of railroad ballast (Selig and Waters 1994; Indraratna and Salim 2005; Hossain et al. 2007; Indraratna et al. 2011a). The increase in fine fraction seriously alters the deformation-strength characteristics of the original ballast, depending on the amount of fouling materials mixed with fresh ballast (Raymond and Bathusrt 1994; Indraratna et al. 2001; Cambio and Ge 2007; Lackenby et al. 2007; Indraratna et al. 2011b; Huang and Tutumluer 2011). On the other hand, railroad ballast suffers from the rainfall infiltration and seasonal variations of groundwater level

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observed at thawing season. Those phenomena cause rapid fluctuation in the water content of railroad ballast, which significantly develops cyclic plastic deformation of ballasted track during train passages (Itou et al. 2014). In addition, since the altered grain-size distribution of fouled ballast results in water retentivity characteristics different from fresh ballast, cyclic plastic deformation of railroad ballast becomes more remarkable in case of fouled ballast. However, the mechanical behavior of unsaturated ballast which has maximum particle size of almost 63 mm has not been clarified by laboratory element tests enough so far. This paper evaluates the synergistic effects of water content and fine fraction on shear behavior of unsaturated fouled ballast by performing a series of triaxial compression tests and water retentivety tests on clean and fouled ballasts in unsaturated conditions.

2 Test Apparatus

A schematic diagram of the medium-size triaxial apparatus for unsaturated coarse granular materials is shown in Figure 1. One key feature of the apparatus is the structural design of the cap and pedestal, as shown in Figure 2. Pore water pressure is applied to a specimen through a versapor membrane filter attached to the water plumbing path, while the pore air pressure is applied through a hydrophobic polyflon filter attached to the air supply path in the cap and pedestal. The apparatus can apply the matric suction from both ends of the specimen. Besides, pore water is allowed to drain from both cap and pedestal. Accordingly, the apparatus can reduce the testing time by shortening the length of drainage path to half of the specimen height, in addition to the effect of versapor membrane filter. Here, the versapor membrane filter is a kind of microporous membrane filters made from a hydrophilic acrylic copolymer. Physical properties of the filters are shown in Table 1. Note that the air entry values (AEV) of versapor membrane filters attached to the cap and the pedestal before and after the test were nearly equal. This indicates that the filters suffer little degradation from the wear and tear during triaxial compression tests on coarse granular materials. Besides, the apparatus can apply axial load to a specimen with high accuracy by both the strain control method with a hybrid actuator.

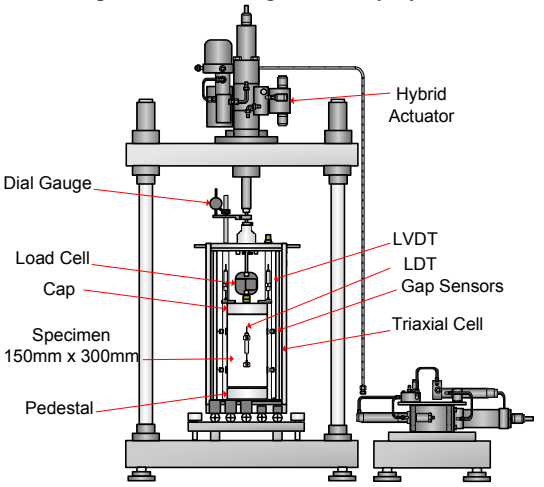

Figure 1: Medium-size triaxial apparatus for unsaturated soils

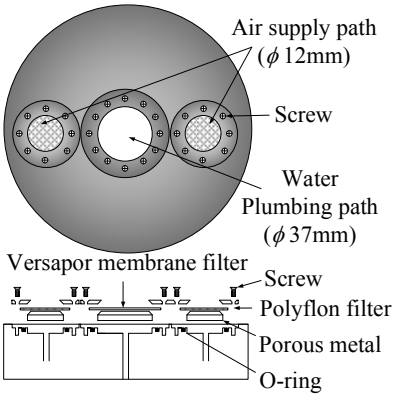

Figure 2: Structure of cap and pedestal

The measurement of stress and strain in a specimen was performed as follows. Axial stress (σ_a) was measured by a load cell installed inside the triaxial cell, and axial strain (ε_a) was obtained by measuring the displacement of cap with displacement transducers. Note that this study employs the corrected value of the axial strain (ε_a) in consideration of the influences of system compliance (SC) and bedding errors (BE) in laboratory element tests on geomaterials because the effect of bedding