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Effects of Principal Stress Axis Rotation on Unsaturated Rail Track Foundation Deterioration

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Abstract

Precise assessment of cyclic plastic deformation of rail track subgrade is essential in designing cost effective rail tracks. Plastic deformation of rail tracks is often underestimated due to the omission of effects of principal stress axis rotation and water content on subgrade deformation. Moisture content of rail track subgrade is influenced by infiltration, seasonal ground water table variation and climate changes. To understand the influence of principal stress axis rotation and moisture content on the plastic deformation of soil, a series of cyclic moving wheel loading tests and cyclic triaxial compression tests were performed on unsaturated Toyoura sand, using a modified multi-ring shear apparatus. Results show that the presence of water in sand affects the cyclic plastic deformation of subgrade of rail tracks, significantly. The subgrade water content variation combined with the principal stress axis rotation further increases the accumulation of the cyclic plastic deformation of subgrade under moving wheel loads. Experimental results further conclude that the conventional experimental methods are unable to accurately assess the rail track deterioration process introduced by water content of rail track subgrade under repeated moving wheel load and highlight the requirements of realistic test methods such as the cyclic moving load multi-ring shear test, the cyclic hollow cylindrical test, or the model test in predicting rail track deterioration process of unsaturated subgrade under moving wheel loads.

Keywords: Rail track, Track deterioration, Unsaturated subgrade, Principal stress axis rotation, Ground water content

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1 Introduction

Seasonal ground water variation in rail track subgrade can introduce serious consequences to the rail industry, where sudden collapse can happen in rail tracks even when subjected to wetting and shrinking cycles(Kodikara, 2012). Such seasonal ground water variation in subgrade results unsaturated conditions in subgrade throughout its lifetime, unless otherwise subgrade is either fully dried or fully saturated by extreme droughts or floods, respectively. Soil type, particle size distribution, drainage condition, fine content, and climate changes can control unsaturated subgrade response, resulting range of complexities in engineering applications (Bishop, 1959, Fredlund et al., 2011). Current knowledge in unsaturated subgrade on the cumulative residual deformation characteristics of rail track subgrade is limited as even conventional guidelines do not account unsaturated subgrade in rai track designs (Burrow et al., 2011, Dareeju et al., 2014). Principal stress axis rotation (PSAR) mainly controls the cumulative residual deformation of rail track subgrade. Significance of PSAR in cumulative residual deformation of rail track subgrade is shown, using laboratory element tests, model tests, field investigations, and numerical analyses(Gräbe and Clayton, 2009, Yang et al., 2009, Hirakawa et al., 2002). Cumulative residual deformation of unsaturated subgrade under effects of PSAR is however still associated with numbers of uncertainties.

Conventional experimental methods such as cyclic triaxial, cyclic direct shear and California bearing ratio tests are unable to replicate actual stress state under moving wheel load conditions, accurately. Therefore, a modified multi-ring shear apparatus is used in this study. Capability of this modified multi-ring shear apparatus to replicate effects of the PSAR on the deformation characteristics of subgrade under moving wheel load was shown by Dareeju et al.(2015). This study examines the effects of soil moisture content and PSAR on the cumulative residual deformation characteristics of unsaturated granular materials.

2 Testing Method

2.1 Test Material

Toyoura sand was used in this study since it was used in model test series and evaluating the capability of the modified multi-ring shear apparatus to replicate actual deformation characteristics of rail track subgrade. Figure 1 shows the moisture-density relationship and the soil-water characteristic curve (SWCC) of Toyoura sand under drying conditions with confining pressure of 49 kN/m^2. According to Figure 1, maximum dry density (MDD) is 1.63 g/cm^3 at optimum water content (OMC) of 14%. Residual water content of Toyoura sand is approximately 2%, which is equal to residual degree of saturation (S_{r0}) of 6.6%, according to Figure 1(b).