学　位　論　文　内　容　の　要　旨

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学　位　論　文　題　名

Effects of freeze-thaw of ballasted track on railway train vibration in cold regions and its evaluation
(凍結融解が有道床軌道の軌道狂いと車体動揺に及ぼす影響とその評価に関する研究)

In the seasonally frozen regions, railway subgrades are subjected to freeze-thaw cycles due to environmental temperature change. The railway track is likely to be deformed during the freezing and thawing processes of subgrades. As a result, the maintenance work for railway track will increase, and train operations will be severely affected.

Due to the different geological and geotechnical conditions (for example, groundwater level, soil physical properties, moisture condition, and the existence of underground structures) along the track line, it can result in track unevenness when the freeze-thaw occurs. For instance, the culvert transition section experiences non-uniform spatial frost heaving and thaw settlement, resulting in track deformation. The present study employed a box culvert transition section of a ballasted track as the research object, and the track deformation induced by the freeze-thaw of railway subgrade was investigated. This study qualitatively and quantitatively studied the influence of freeze-thaw induced track deformation and its influence on the train vibration through freeze-thaw analysis and train vibration analysis. In the freeze-thaw analysis, different types of the buried structure (for example, box culvert, pipe culvert) embedded in the subgrade were selected as an analytical example, as the transition section of buried structure owning complex boundary conditions is likely to experience significant frost heave and thaw settlement. The track surface deformation above the transition section was calculated through finite element analysis, considering the influences of groundwater levels and temperature boundary conditions. Two indices, namely, wavelength and amplitude, were used to quantify the surface deformation. The influence of variation of groundwater level and different seasonal temperatures on the deformation was investigated from the aspects of absolute value. Subsequently, to evaluate the influence of subgrade freeze-thaw induced track deformation on train vibration, the vehicle dynamic analysis was conducted using a vehicle-track model. The calculated absolute value of track deformation was inputted into the vehicle-track model as excitation. Finally, the car body vibration was evaluated from the aspect of safety (minimum vertical wheel-rail force, maximum vertical wheel-rail force, and wheel load reduction rate) and stability (car body acceleration and Sperling index). This study can facilitate understanding the influence of subgrade freeze-thaw on vehicle vibration.

The thesis includes 7 Chapters. Chapter 1 introduces the background, literature review, objectives, and organization of this study. Chapter 2 introduces the freeze-thaw analysis of ballasted track, which include model definition, governing equation, parameters, and boundary conditions. Chapter 3 describes the train vibration analysis on ballasted track during freeze-thaw, which includes vehicle model, wheel-rail contact model, substructure model, model validation, and simulation condition. Chapter 4 evaluates the influence of GWL, temperature, and buried structure type on freeze-thaw induced track

deformation. Chapter 5 discusses the influence of freeze-thaw induced track deformation on train vibration and gives a systematical evaluation of the train vibration from the train operation safety and stability. Chapter 6 discusses the growth of differential ballast settlement under cyclic load considering the influence of freeze-thaw induced track deformation. Finally, Chapter 7 summarizes the conclusions of this study and gives several recommendations for future studies.