Post-print: Dynamic Reinforcement of Weak Compaction Zones and Compaction Blind Zones in Subgrade Layered Filling

Authors: Wang Peng, Jiang Peng, Li Jin, Zuo Shen

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Abstract

During subgrade construction, at locations such as bridge and culvert abutments, high and steep slopes, and areas adjacent to structures, the confined site space and similar factors prevent normal operation of rolling compaction equipment, while the compaction energy of small manual tampers is insufficient. This readily leads to unsatisfactory compaction effects in weak compaction zones or compaction blind zones of the subgrade, thereby inducing a series of subgrade quality issues, with subsequent maintenance and reinforcement construction being difficult and costly. Therefore, research on dynamic reinforcement for weak compaction zones and compaction blind zones holds considerable engineering practical significance. This study, based on analysis and comparison of different subgrade filling processes, vibration compaction theories, dynamic reinforcement technologies, and compaction quality detection methods, employs PLAXIS software to simulate various working conditions, calculating long-term consolidation deformation parameters, excess pore pressure variations, and dynamic responses of the subgrade induced by dynamic loads under multi-parameter influences. Through significance analysis and sensitivity analysis, the primary controlling factors of dynamic compaction effects in layered subgrade filling are investigated. Relying on actual engineering projects, systematic research on dynamic reinforcement through vibration compaction for layered subgrade filling is conducted. By performing dynamic response tests and reinforcement quality evaluation tests on compaction blind zones and weak compaction zones in layered subgrade filling, the stress time-history response, stress distribution patterns, and variation laws of peak acceleration of soil fill under strain rate hardening effects are investigated, the strengthening mechanism of machine-geotechnical mass interaction is analyzed, the energy transfer law of hydraulic hammers is clarified, the influence of tamping actions of different magnitudes on adjacent structures is analyzed, an empirical model for hammer blows versus peak acceleration is established, and peak acceleration is utilized

as a quantitative indicator of bearing capacity, thereby improving the efficiency of tamping operations. Furthermore, when calibrating the relationship curve between Rayleigh wave velocity and longitudinal compaction degree measured through in-situ tests, the influence of water content on Rayleigh wave velocity is considered, and an empirical model for internal longitudinal compaction degree of soil is established through regression fitting, enhancing the detection accuracy of compaction degree based on transient surface waves. Additionally, comprehensive subgrade compaction techniques are discussed and summarized to strengthen the compaction process and develop high-quality and efficient dynamic reinforcement technologies and processes for compaction blind zones and weak compaction zones in layered subgrade filling, aiming to provide certain reference value for highway construction.

Full Text

Preamble

Study on dynamic reinforcing at weak rolling area and rolling blind area for the layered filling of subgrade

Peng Wang1,2, Peng Jiang1,2, Jin Li1,2, Shen Zuo1,2

1 Shandong Key Laboratory of Technologies and Systems for Intelligent Construction Equipment, Shandong Jiaotong University, Jinan Shandong 205357, China
2 School of Transportation and Civil Engineering, Shandong Jiaotong University, Jinan Shandong 205357, China

Abstract

During subgrade construction, locations such as bridge and culvert abutments, steep slopes, and areas adjacent to existing structures are often characterized by limited workspace, which prevents conventional rolling equipment from operating effectively. Concurrently, the compaction energy delivered by small manual tampers is typically insufficient, frequently resulting in inadequate compaction in weak rolling areas and rolling blind zones. Such deficiencies induce a series of subgrade quality issues, while subsequent maintenance and reinforcement construction prove both challenging and costly. Consequently, research into dynamic reinforcement techniques for these problematic zones holds substantial practical engineering significance.

This study systematically investigates dynamic reinforcement for layered subgrade filling by first analyzing and comparing various subgrade filling processes, vibration compaction theories, dynamic reinforcement techniques, and compaction quality assessment methods. Numerical simulations using PLAXIS software are conducted under diverse working conditions to calculate long-term consolidation deformation parameters, excess pore pressure variations, and subgrade dynamic responses induced by dynamic loads under multiple influencing

parameters. Through significance and sensitivity analyses, the primary controlling factors affecting dynamic compaction effectiveness are identified. Based on actual engineering projects, systematic field investigations are performed to examine vibration compaction-based dynamic reinforcement for layered subgrade construction.

Through dynamic response testing and reinforcement quality evaluation in rolling blind zones and weak rolling areas, this research investigates the stress time-history response, stress distribution patterns, and acceleration peak variations in fill materials under strain rate hardening effects. The study analyzes the strengthening mechanism of mechanical-geotechnical interaction, clarifies the energy transfer characteristics of hydraulic tampers, evaluates the influence of various tamping intensities on adjacent structures, and establishes an empirical model relating the number of tamping blows to acceleration peaks. By employing acceleration peak as a quantitative indicator of bearing capacity, the efficiency of compaction operations is significantly enhanced.

Furthermore, in calibrating the relationship between Rayleigh wave velocity and in-situ measured longitudinal compaction degree, the effect of water content on Rayleigh wave velocity is incorporated. An empirical model for internal longitudinal compaction degree is developed through regression analysis, thereby improving the accuracy of compaction degree detection based on transient surface wave methods. This work further synthesizes comprehensive subgrade compaction technologies, optimizes the compaction process, and formulates high-quality, efficient dynamic reinforcement techniques and procedures for rolling blind zones and weak rolling areas in layered subgrade filling, offering valuable references for highway construction projects.

Keywords: Subgrade Engineering; High-Speed Hydraulic Tamper; Dynamic Reinforcement; Dynamic Response; Non-Destructive Testing

Note: Figure translations are in progress. See original paper for figures.