Research on Intelligent Compaction Quality Control Methods for Soil-Rock Mixture Subgrades and Engineering Applications: Postprint

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Abstract

For mountainous highway projects, utilizing local earth-rock materials for embankment construction can significantly reduce transportation costs and improve resource utilization efficiency. However, earth-rock mixed fill materials often face the following problems in engineering applications: (1) The rock particles obtained from construction excavation are generally large, resulting in non-uniform particle sizes in the roadbed fill material. The earth-rock mixture exists in a "dense-suspended structure" state, making it difficult to achieve adequate compaction using conventional methods; (2) Compaction detection methods specified in roadbed specifications, such as the ring knife method and sand cone method, are suitable for fine-grained soils. However, earth-rock mixed fill roadbeds are heterogeneous materials that differ significantly from fine-grained soils in terms of particle size composition, particle size distribution, moisture content, pore distribution, and compaction characteristics. Consequently, conventional compaction quality detection methods and evaluation standards cannot accurately characterize the compaction quality of earth-rock mixed fill roadbeds. To address these issues, this study developed an intelligent compaction system for earth-rock mixed fill roadbeds, comprising both hardware components and software control systems. The hardware primarily includes a high-precision positioning system, compaction sensors, and an intelligent compaction navigation platform; the software mainly consists of an intelligent control system for vibratory rollers and a data processing center. Focusing on the new intelligent compaction equipment, this research investigates the intelligent compaction construction technology for earth-rock mixed fill roadbeds through field experiments. Based on the intelligent compaction platform, real-time acquisition of roller technical parameters, satellite ground reference station parameters, project information, and construction process standards is achieved. By monitoring compaction process parameters, control over three aspects—compaction degree, compaction stability, and compaction uniformity—is realized,

leading to the development of a comprehensive intelligent compaction construction process for earth-rock mixed fill. Regarding the quality detection and evaluation standards for earth-rock mixed fill roadbed construction based on intelligent compaction, this study establishes target value standards for intelligent roadbed compaction. Through field investigations and experiments, a verification method for the correlation between intelligent compaction detection values and conventional compaction detection values is investigated, and a linear regression model is established. The research achievements integrate mechanical engineering, surveying, electronic information, and civil engineering disciplines. Through the development and application of the intelligent compaction system, high-quality, information-based construction for earth-rock mixed fill roadbed compaction has been realized.

Full Text

Research and Engineering Application of Intelligent Compaction Quality Control Methods for Soil-Rock Mixed Subgrade

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Abstract

For mountain highway projects, the in-situ utilization of soil-rock materials for embankment construction can significantly reduce transportation costs and improve resource utilization efficiency. However, soil-rock mixed fill frequently encounters the following challenges in engineering applications: (1) The excavated rock particles are generally large, resulting in non-uniform particle sizes in the subgrade fill. The soil-rock mixture exists in a "dense-suspension structure"state that is difficult to fully compact using conventional methods; (2) Compaction testing methods specified in subgrade standards, such as the ring knife method and sand cone method, are applicable to fine-grained soils. Soil-rock mixed subgrade represents a heterogeneous fill material that differs substantially from fine-grained soils in terms of particle composition, particle size, water content, pore distribution, and compaction characteristics. Consequently, conventional compaction quality testing methods and evaluation criteria cannot accurately characterize the compaction quality of soil-rock mixed subgrade.

To address these issues, this study developed an intelligent compaction system for soil-rock mixed subgrade comprising both hardware and software components. The hardware primarily includes a high-precision positioning system,

compaction sensors, and an intelligent compaction navigation platform, while the software mainly consists of an intelligent control system for vibratory rollers and a data processing center. Centered on this novel intelligent compaction equipment, field tests were conducted to investigate the construction process for intelligent compaction of soil-rock mixed subgrade. Based on the intelligent compaction platform, real-time acquisition of roller technical parameters, satellite ground base station parameters, project information, and construction process standards was achieved. By monitoring compaction process parameters, integrated control of compaction degree, compaction stability, and compaction uniformity was implemented, culminating in a complete set of intelligent compaction construction processes for soil-rock mixed fill. Research on quality inspection and evaluation standards for soil-rock mixed subgrade fill based on intelligent compaction was also conducted to determine target value criteria for intelligent compaction. Through field investigation and testing, a verification method for the correlation between intelligent compaction detection values and conventional compaction detection values was studied, and a linear regression model was established. This research integrates mechanical engineering, surveying, electronic information technology, and civil engineering disciplines. Through the development and application of the intelligent compaction system, high-quality, information-based construction of soil-rock mixed subgrade compaction has been realized.

Keywords: Soil-rock mixed subgrade; Intelligent compaction system; Quality control

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