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Real-Time Quality Monitoring and Control of Highway Compaction

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ABSTRACT

Compaction quality affects the long-term performance of highways, and thus is important in the highway construction. The current practice for compaction quality control primarily relies on the monitoring of rolling parameters such as rolling passes, speed and vibration of rollers, and lift thickness. Soil samples are randomly collected to evaluate the compactness. This practice is subject to two main limitations. First, the compaction monitoring and measurement are not always comprehensive since limited samples are manually collected. Second, compaction information cannot be disseminated to owners, supervisors, contractors, and operators in timely fashion. In this study, intelligent compaction (IC) technology is leveraged to monitor and control highway compaction quality. A new measure of compaction quality, compaction power per unit volume (E), is created and used with other IC measurement values such as compaction meter value (CMV) to achieve more reliable monitoring and assessment. Field experiments were conducted. The results demonstrated that the integration of CMV and E in the regression model leads to a higher coefficient of determination than that of using only CMV or E. A real-time monitoring system is developed, which not only evaluates the compaction quality of the entire area, but also synchronizes the compaction information among owners, supervisors, contractors, and operators in real-time. As such, this system cultivates an integrated "operator–contractor–supervisor–owner" quality control mechanism, which can improve the current highway compaction practice.

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1. Introduction

Years of continual growth in the road construction have given China a vast network of highways which serve as critical links moving people and goods throughout the country. The increasing traffic demand in China requires the acceleration of highway construction. The highway mileage in China increased from 104,000 km in 2013 to 111,450 km in 2014. It is projected that 4700 billion RMB will be invested to further increase the highway mileage to 400,000 km through 2030. However, under such extensive expansion, many highway projects have experienced a litany of undesired quality issues. For example, pavement distresses such as cracking and rutting occur in a short period. A number of highways even structurally failed in half a year. One of the leading cause of these flaws and failures is the poor quality control practice in highway compaction. The inadequate quality control practice often results in a number of quality flaws. For example, pavement thickness is not compliant with the standard, and pavement is not uniformly compacted to the described density. Because the failure and accelerated deterioration of highways cause enormous economic loss, it is imperative to improve the monitoring and control of highway compaction quality.

Compaction quality monitoring and control is critically important in the highway construction, because compaction quality affects the durability and long-term performance of pavement. Ensuring subgrade to be compacted as specified is an essential task in compaction quality control. The current practice in China primarily relies on the monitoring and control of rolling parameters such as rolling passes, speed and vibration of rollers, and lift-thickness. Samples are randomly collected to evaluate the compaction quality [1]. However, this practice is subject to a number of limitations. For instance, the reliability of compaction quality of the entire subgrade is suspicious because only limited samples are collected for testing. The manual sample collection interrupts subsequent activities and can be destructive to the compacted subgrade. The laboratory testing is time-consuming, which cannot provide real-time information of compaction quality. The lack of real-time compaction information can result in insufficient and/or excessive compaction.

Intelligent compaction (IC) technologies have emerged to improve current compaction practice. Specifications pertaining to IC technology applications in the highway construction have also been developed [2]. Despite these advancements, two main challenges still remain to be addressed. First, many IC measurement values such as compaction meter value (CMV) have been adopted to indicate the compactness. However, CMV might not always be adequately reliable in reflecting the compactness. For instance, the relationship between CMV and

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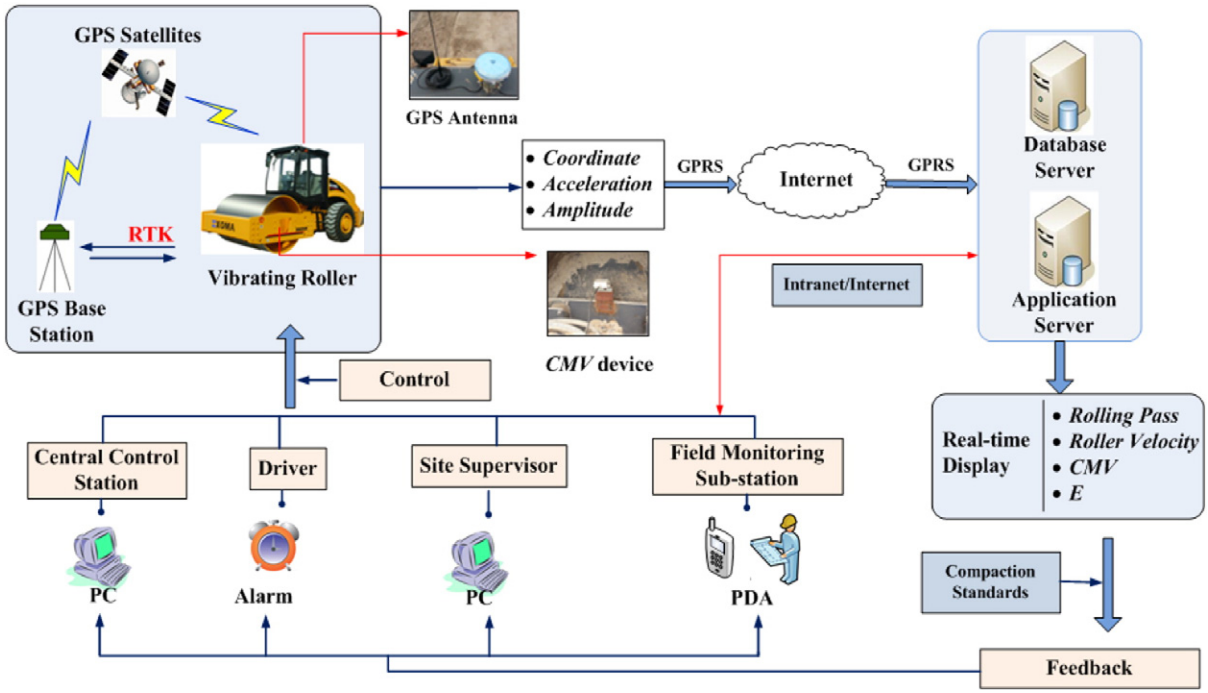

Fig. 1. Real time monitoring for highway compaction quality.

compactness might be adversely affected by the underlying layers [3]. Hence, there is a need to improve the reliability of IC measurement value in estimating compactness. Second, most IC technologies only provide real-time compaction information to machine operators. However, machine operators are often not incentivized to ensure compaction quality. This is particularly true in China, since contractors are often awarded with very low price contract. Compaction quality concerns owners and supervisors, but they usually lack real-time compaction information for continuous and responsive quality control. Thus, there is a need to disseminate the compaction information to operators, contractors, supervisors, and owners in a timely fashion.

To address the first challenge, compaction power per unit volume (E) is created in this study as a new IC measurement value, which can be used with other IC measurement values such as CMV to achieve

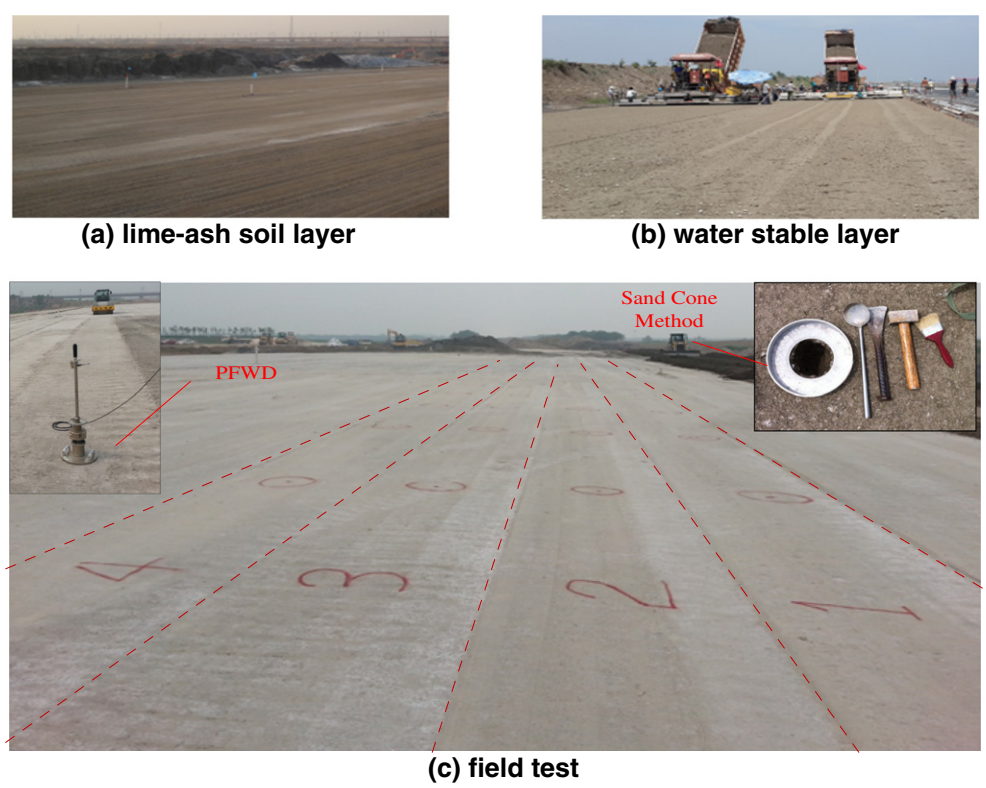

Fig. 2. Filed experiments settings.

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