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Benefit-cost analysis and application of intelligent compaction for transportation

Christopher M. Savan [a], Kam W. Ng [b,*], Khaled Ksaibati [b]

[a] *GDA Engineers, 502 33rd Street, Cody, WY 82414, USA*
[b] *Department of Civil and Architectural Engineering, University of Wyoming, Dept. 3295, 1000 E. University Ave, Laramie, WY 82071, USA*

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ABSTRACT

Conventional test methods for roadway compaction cover less than one percent of roadway; whereas, intelligent compaction (IC) offers a method to measure 100 percent of a roadway. IC offers the ability to increase compaction uniformity of soils and asphalt pavements, which leads to decreased maintenance costs and an extended service life. This paper examines IC technology, how IC quality control and assurance specifications can encourage IC adoption, knowledge and use of IC through survey responses, and benefits and costs of IC. The surveys reveal that a majority of respondents from state departments of transportation have conducted IC demonstration projects, but questions about cost and willingness of policymakers to adopt IC remain a barrier to implementation. The benefit-cost analysis demonstrates that use of IC reduces compaction costs by as much as 54 percent and results in a US$15,385 annual savings per 1.6 km throughout the roadway's life. The framework of the benefit-cost analysis can be readily adopted by transportation agencies to facilitate the implementation of intelligent compaction in future roadway construction.

Introduction

Intelligent compaction (IC) has become a growing method for measuring soil and pavement compaction for roadways in the United States over the past decade. The integration of an accelerometer, global positioning system (GPS), and on-board computer to an IC roller has allowed for 100 percent compaction measurement of a roadway versus less than one percent using conventional compaction measurement devices (Mooney et al., 2010). Many industry professionals and organizations, including the United States Federal Highway Administration (FHWA), have noted the benefits of intelligent compaction in academic papers and industry-oriented magazine articles (Federal Highway Administration, 2013; Beainy et al., 2012). However, a literature review of the benefits and costs of IC by Savan (2014) revealed that there is little quantifiable evidence to support the claim of increased long-term or short-term cost savings by using IC. While it is generally accepted that the improvement of compaction quality using IC would enhance long-term roadway quality, there are no investigations that examine the financial return of improved compaction quality. This paper examines the construction-related costs and roadway lifecycle costs from use of IC. A brief discussion of survey results of professionals in the State of Wyoming and other state Departments of Transportation (DOTs) regarding IC are also included.

A background of IC is provided in the first section of this paper with information about the implementation of IC by state DOTs. Surveys of Wyoming professionals and DOTs

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* Corresponding author.

E-mail addresses: cmsavan@gmail.com (C.M. Savan), kng1@uwyo.edu (K.W. Ng), khaled@uwyo.edu (K. Ksaibati).

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were conducted to provide information about the knowledge that professionals have about IC, perceived barriers to implementation of IC, and how IC is being implemented. A benefit-cost analysis is presented indicating the short-term (construction-based) and long-term (pavement life-cycle) benefits and costs when performing compaction with IC.

Background

Intelligent compaction (IC) rollers provide a method to gather compaction data for 100 percent of the roadway area by measuring soil and pavement stiffness. IC rollers, also known as "intelligent soil compaction systems," are defined by the National Cooperative Highway Research Program (NCHRP), Report 676 as having three characteristics (Mooney et al., 2010):

1. Continuous assessment of mechanistic soil properties (e.g. stiffness) through roller vibration monitoring,
2. On-the-fly modification of vibration amplitude and frequency, and
3. Integrated GPS to provide a complete geographic information system-based record of the site.

Rollers that integrate items one and three from the above definition are also considered IC rollers by several roller manufacturers, but are referred to as "roller-integrated continuous compaction control" in the NCHRP report (Mooney et al., 2010). These types of rollers will be referred to as IC rollers throughout this paper.

FHWA has been promoting IC via its Every Day Counts initiative. The initiative supports local workshops, demonstration projects, development of standard IC specifications, and additional technical assistance for state and local governments to implement IC. State and local transportation agencies are seen as the catalyst to adoption of IC because they provide contractors with Quality Control/ Quality Assurance (QC/QA) specifications for compaction of roadways. Quality control is referred to as the method for testing compaction parameters, such as density and moisture content, by construction crews to verify the quality of the roadway; whereas, quality assurance is referred to as the validation of quality control methods and data through additional compaction testing.

A literature review on current state DOT's draft IC specifications indicates that state and local transportation agencies continue to require conventional compaction testing methods even if IC guidance is provided for roadway soil and pavement compaction. For example, California Department of Transportation (Caltrans) uses a combination of nuclear gauge readings and core sampling for pavement QC/QA; however, their draft IC specifications are not used system-wide. Similarly, Minnesota DOT (2016) has created special provisions for IC and has conducted several field demonstrations over the past decade; however, permanent specifications have not been integrated into their standard specifications manual. Texas, Michigan, and Iowa have developed special provisions for soils, but do not include QC/QA parameters for acceptance.

Currently, 18 states, as shown in Fig. 1, have begun adopting IC QC/QA draft specifications and special provisions that may be reviewed for adoption into their standard specification manuals. More states are expected to begin drafting QC/QA specifications as more workshop and field demonstrations are scheduled. Fig. 1 displays the types of QC/QA specifications drafted by states. These draft specifications range from special provisions to comprehensive specifications for statewide roadway construction for soils/aggregates and pavements (The Transtec Group, Inc., 2014a).

The specifications detailed requirements for GPS data, documentation, test sections, and construction QC/QA. The two types of outcomes for the specifications involved reporting compaction value results for QC/QA or providing documentation of IC data for demonstration purposes. For soils, specifications used for QC/QA involved acceptance based on percent difference in measurement values (MVs) between roller passes and/or correlation of IC MVs with in-situ point measurements to establish IC target values. Georgia, Indiana, North Carolina and Vermont required correlations from test trips between in-situ point measurements and MVs. Georgia also required an optimal pass number established when there was a less than five percent change in MVs. The remaining states' IC specifications did not provide more detailed QC/QA specifications for soils (The Transtec Group, Inc., 2014a,b).

For pavements, most states have QC/QA specifications that establish a target number of roller passes by percent difference in MVs followed by establishing target values for MVs based on correlations of nuclear gauge or core samples on a test section. The exceptions to these specifications are Iowa, Nevada, Utah, and Rhode Island, which do not detail a method or requirements for compaction values (The Transtec Group, Inc., 2014a,b).

Despite having field demonstrations, pilot projects, technical training and workshops, and development of specifications and special provisions for IC, results of interviews with industry professions by Kimmel et al. (2016) revealed that these institutional incentives for IC were not the primary drivers for adoption. They examined the assessment and adoption of IC through the application of Kingdon's theory of policy agenda setting. They concluded that the roadblocks to IC and its adoption were related to the conservative culture of individuals whose personal character, ideological affiliations and perception of social obligation inhibit changes. The positive outcomes of the benefit-cost analysis presented in this paper will hope to increase the risk tolerance and perseverance of these professionals who are willing to provide an opportunity for IC adoption and implementation.

Surveys

Surveys of Wyoming professionals and DOTs were developed by the authors to understand the current knowledge of IC among professionals, perceived barriers to implementation of IC, and how IC is being implemented. The Wyoming survey was conducted in March, 2014 for public and private officials attending the Intelligent