TECHBRIEF

U.S. Department of Transportation
Federal Highway Administration

Intelligent Compaction

EXECUTIVE SUMMARY | SUMMER 2013

ABSTRACT

Intelligent compaction uses rollers equipped with an integrated measurement system consisting of a highly accurate Global Positioning System (GPS), accelerometers, onboard computer monitoring/reporting system, and infrared thermometers for HMA/WMA feedback control to:

- Maximize compaction efficiency
- Reduce compaction variability
- Optimize labor deployment and construction time
- Identify non-compactable areas
- Identify weak spots
- Achieve uniform compaction with 100 percent surface coverage

Antonio Nieves
antonio.nieves@dot.gov
(202) 366-4597

Background

Compaction is one of the most critical processes associated with constructing a highway pavement that can provide good long-term performance. The densification of the various layer materials achieved through compaction gives them the strength and stiffness necessary to withstand heavy traffic loading and some of the damaging effects of the environment. The conventional rolling equipment and techniques for achieving the target levels of compaction have worked reasonably well over the years; however, they have not been without their difficulties. The typical problems associated include non-uniformity derived from variability in the materials (particularly in the natural soil), poor control of moisture content in the underlying layers, low or non-uniform temperatures in the hot-mix asphalt (HMA) or warm-mix asphalt (WMA) layer, poorly compacted longitudinal joints, and a lack of tools that provide feedback to the roller operator so that the roller pattern can be continuously achieved.

These problems have, in turn, resulted in lower productivity and higher costs during construction as well as reduced pavement performance, shorter pavement lives, and higher maintenance and rehabilitation costs.
Over the last 10 years, there have been several major innovations in technology for highway pavement construction that will greatly revolutionize pavement construction. One of these innovations, intelligent compaction, is intended to address some of the problems associated with conventional compaction methods.

TECHNOLOGY OVERVIEW

Intelligent compaction (IC) refers to an improved compaction process using rollers equipped with an integrated measurement system that consists of a highly accurate GPS, accelerometers, onboard computer reporting system, and infrared thermometers for HMA/WMA feedback control. By integrating measurement, documentation, and control systems, the use of IC rollers allows for real-time monitoring and corrections in the compaction process. IC rollers also maintain a continuous record of color-coded plots that indicate the number of roller passes, compaction level, temperature measurements (for HMA/WMA applications), and the precise location of the roller drum.

IC equipped vibratory steel roller for HMA/WMA compaction.

The capability of IC technology to improve the compaction process for roadway construction is well documented from projects in Europe, Asia, and the United States. The most significant improvement is in the decrease in variability of measured properties. The more uniform material properties obtained by the IC technology help ensure higher quality pavements that provide the desired performance and intended service life

ADVANTAGES

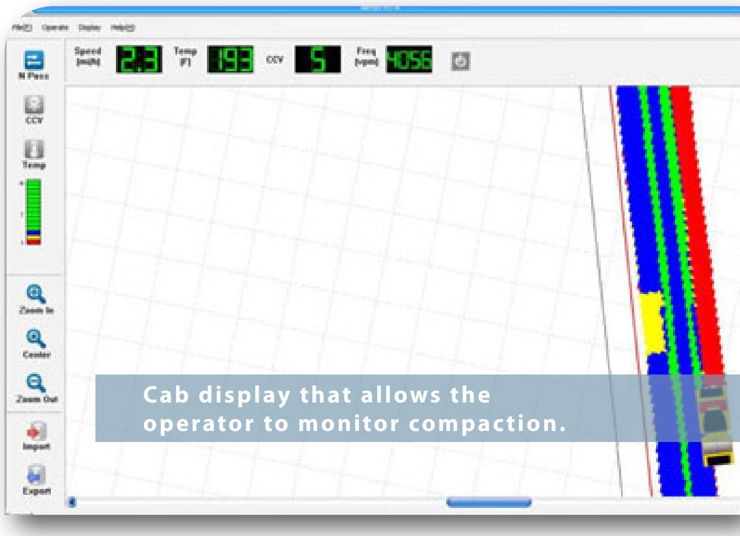
IC techniques provide a number of benefits for roadway construction over the conventional compaction processes. In addition to reducing the compaction variability of road building materials, these include:

- **Optimized labor deployment and construction time** – Contractors can roll the material with the right amount of compactive effort on each pass to help ensure that the proper stiffness is achieved. Both under-rolling and over- rolling can lead to poor performance.
- **Reduced material variability** – IC equipment allows contractors to more closely monitor the stiffness of the material so that there is less variability in the end result. Over the long run, lower variability will result in better pavement performance and reduced maintenance and repair costs.
- **Reduced compaction and maintenance requirements** – The flexibility to make fewer passes to achieve the correct compaction level minimizes fuel use and equipment wear and tear.
- **Identification of non-compactable areas** – Areas that fail to reach the target compaction level can be identified as potential areas for reworking the defective material or removing and replacing it.
- **Ability to make midcourse corrections** – The ability to correct compaction problems in a subsurface layer (before additional layers are placed) ensures that subsurface problems do not affect the entire road surface.
- **Ability to maintain construction records** – Data from IC operation, along with GPS coordinates of compaction activity, can be downloaded into construction quality databases and stored electronically by the contractor for future reference.
- **Ability to generate an IC base map** – Contractors are able to identify weak spots (typically used in pavement rehabilitation projects such as mill and fill).
- **Ability to retrofit existing equipment** – Most existing rollers can be easily converted to an IC roller using a retrofit kit.

IMPLEMENTATION CONSIDERATIONS FOR IC TECHNOLOGY

Before embarking on an implementation, there are several considerations associated with the implementation of IC technology that contractors and highway agencies should take into account:

- **Equipment Cost** – The cost for a new IC-equipped roller for a project is about 3 to 5 percent more than the cost of a conventional roller. The cost of retrofitting an IC integrated measurement system on an existing conventional roller ranges from $50,000 to $75,000, depending on the manufacturer and desired features. These costs are not trivial; however, they can be recuperated within 2 or 3 projects because of the increased efficiency and reduced quantities of rejected material.



Cab display that allows the operator to monitor compaction.

Roller patterns are improved with the use of IC.

- **Roller operator skills** – Some operator and construction supervisor training is required to implement the IC technology. However, the training is not overly complicated or time-consuming and is generally offered by the manufacturer when the equipment is purchased, leased, or rented.
- **Equipment maintenance** – The vibration energy associated with vibratory rollers does increase the need for maintenance and calibration of the IC instrumentation; however, the IC instrumentation is robust.

DETAILED DESCRIPTION

The rollers used for IC are basically the same as their conventional counterparts. The primary difference between the IC and conventional equipment is the instrumentation added to identify roller location, measure/control the process, and display and document the level of compaction. With some differences to account for the type of material being compacted, this instrumentation is basically the same for rollers that are designed to compact unbound/subsurface materials (subgrade soil, subbase, and base) and the pavement surface layers (HMA/WMA binder and wearing courses). The key components of the instrumentation for both types of material compaction equipment include:

- **Location referencing:** The position of the roller is established through GPS. The GPS antenna is mounted on the top of the cab.

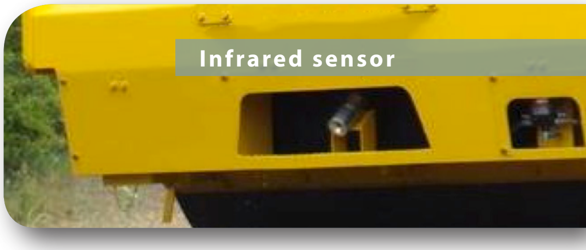
- **Measurement:** An accelerometer is mounted on the frame of the roller near the roller drum. It collects data on the downward acceleration of the roller frame, which, in turn, is used to determine the downward displacement (deflection) of the roller that results from compaction of the underlying materials.

- **Processing:** The downward displacement, roller amplitude, frequency, and speed information are used to determine the level of compaction. As the roller moves, the system generates a continuous, real-time profile of the level of compaction achieved.

- **Display:** A video monitor in the cab of the roller provides a real time display of the compaction information, including a color-coded map that helps the operator identify the number of passes, stiffness, temperature (HWA/WMA), frequencies, amplitude, and roller speed.

- **Documentation:** The system stores a complete record of the compaction effort electronically. The record can be downloaded at any time for analysis and/or printing.

The one additional instrument component found on most IC rollers used for HMA/WMA compaction is an infrared sensor that measures the surface temperature of the HMA/WMA surface. These sensors are mounted on the front and rear of the roller. They are important because they provide a basis for optimizing compactive effort based on the mat temperature.



All IC equipment reports the material's level of compaction in terms of a stiffness value rather than density (the standard measure of compaction used in the highway community for quality acceptance). Stiffness is considered a better measure of compaction because it provides a more direct indicator of the material's ability to resist load-associated bending and tensile stresses. A standard method for characterizing the material's stiffness using IC equipment has not yet been established. Consequently, each IC equipment manufacturer has developed its own measure to go along with its particular IC technology. Collectively, these measures are referred to as intelligent compaction measurement values (or ICMVs) and all are considered representative of the in-situ stiffness of the materials and meaningful indicators of the level of compaction.

IC EQUIPMENT MANUFACTURERS

There are six primary manufacturers of intelligent compaction equipment for soils and subbase materials in the United States. They include Ammann/Case, Bomag, Caterpillar, Dynapac, Hamm-Wirtgen, and Sakai. The U.S. manufacturers of HMA paving equipment are Bomag, HAMM-Wirtgen Caterpillar, and Sakai.

AVAILABLE RESOURCES

The best source of information currently available on IC is the website: www.intelligentcompaction.com. In addition to providing valuable up-to-date information on most IC topics, it also identifies sources of information from previous and currently ongoing research efforts and case studies and provides links to other useful websites.

One valuable resource is the final report on a Transportation Pooled Fund project [TPF-5(128)] involving FHWA and 12 states (California, Georgia, Indiana, Kansas, Maryland, Minnesota, Mississippi, New York, North Dakota, Pennsylvania, Texas, Virginia, and Wisconsin) where IC technologies were demonstrated through 16 field projects and open-house activities, numerous meetings and training for TPF State personnel and local contractors, and assistance on the development of State IC specifications. This report is available for download from the intelligentcompaction.com website.

Accelerated Implementation of Intelligent Compaction Technology for Embankment Subgrade Soils, Aggregate Base, and Asphalt Pavement Materials, Final Report, Publication No. FHWA-IF-12-002, Federal Highway Administration.

Other recent IC studies include:

NCHRP Report 676, Intelligent Soil Compaction Systems, National Cooperative Highway Research Program, Transportation Research Board, National Research Council, Washington, D.C., 2010.

Evaluation of Intelligent Compaction Technology for Densification of Roadway Subgrades and Structural Layers, Draft Final Report, Wisconsin Highway Research Program, WHRP Project ID #0092-08-07, June 2010.

GLOSSARY

Compaction Meter: A device that is mounted on compaction rollers that determines the level of compaction (i.e., stiffness or modulus) achieved using roller displacement information along with roller amplitude, frequency, and speed information.

Continuous Compaction Control (CCC): A technique that uses an instrumented compactor to measure soil or asphalt compaction in real time and adjusts compactive effort accordingly to control the level of compaction.

Global Positioning System (GPS): This refers to the only fully functional global navigation satellite system. Utilizing a constellation of at least 24 medium Earth orbit satellites that transmit precise microwave signals, the system enables a GPS receiver to determine its location, speed, direction, and time.

Infrared Sensor: A device that measures pavement surface temperatures using infrared technology.

Intelligent compaction measurement values (ICMV): A generic term used to describe the compaction measurements obtained from all IC equipment.

Technical Contacts

Antonio Nieves (Team Lead)

antonio.nieves@dot.gov

202) 366-4597

Mike Arasteh (Resource Center Baltimore)

micheal.arasteh@dot.gov

(410) 962-0678

U.S. Department of Transportation
Federal Highway Administration

FHWA-HIF-13-051