

# THE CHANGING FACE OF COMPACTION AND COMPACTION CONTROL FOR ROAD BUILDING – A GLOBAL REVIEW

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The road building industry is not renowned for its fast pace of change, which is often constrained by Department of Transport standards and specifications and limited funds to demonstrate the merits and drawbacks of new methods.

However, somewhat of a revolution is happening in the compaction and compaction control space, led by the Federal Highway Authority (FHWA), the organisation that provides leadership and guidance to State Departments of Transportation in the planning and construction of transportation projects in the USA.

Compaction is one of the most important processes in roadway construction. A uniform sub-base and sub-grade is a key ingredient in maximising pavement performance and the stiffness of the sub-grade is a major contributor to this uniformity, whether it is in pavements, road embankments or bridge abutments.

Professor David White, Head of the Iowa State University Center for Earthworks Engineering Research and a respected authority in the field, concludes:

“I’ve studied where we spend money in the U.S. to fix our infrastructure, and a lot of the cost can be tied directly to the performance of compacted materials underneath our civil infrastructure.”

The same is true in Australia.

## How do you achieve a uniformly compacted sub-grade?

To achieve a uniformly compacted subgrade, one needs to be able to measure it. In the traditional content, the roller operator feels the level of compaction through their seat and makes adjustments according to this.

Every operator has a different learned experience for what is acceptable or not. Verification is typically done using the Nuclear Gauge, using a prescribed random sampling grid pattern. However, there are many issues associated with this conventional density control method, including:

- in-situ spot tests or cores are limited and often conducted at random locations, and thus those tests are not necessarily representative for the entire pavement area;
- there may be weak or unqualified compaction areas unidentified by the limited spot tests; and
- the measured density of top bound layer is limited to indicate the structural capacity of the entire pavement layers.

The result is typically a non-uniformly compacted sub-grade with unidentified weak spots, leading to premature failure and worse long-term life performance.

A new integrated system of compaction and compaction control is well established in Europe, is now widely adopted in the USA and has early adopters in Australia.

It integrates Intelligent Compaction with the measurement of modulus for Quality Control / Quality Assurance (QC / QA) procedures for evaluating compaction of soils and aggregate bases.

## What is Intelligent Compaction?

Intelligent Compaction (IC) is the ability of a soil or asphalt roller to measure the stiffness or solidity of the underlying material and instruct the operator what to do next. IC rollers use vibration and a system to collect, process, and analyse the measurements in real time.

- a stiffness measuring and recording system;
- a GPS-based documentation system that is capable of producing colour-coded mapping of pertinent information during the compaction process;
- a continuous record of color-coded plots records the number of roller passes, compaction measurement values and the precise location of the roller;
- using the onboard computer reporting system, IC roller operators can monitor in real-time, see whether they are

overcompacting (and destroying the material), undercompacting or right on target, and then make corrections to the compaction process;

- as operators make multiple passes with the roller, a computer screen shows which areas need attention;
- some rollers have an automatic feedback system that is capable of varying compactive effort based on measured stiffness;
- roller operators can inspect and verify their own work before turning it over to the owner for verification and payment; and
- calibrated and verified using a compaction control device measuring dynamic modulus e.g. Light Weight Deflectometer (LWD)

## Measuring Compaction: Fundamental Changes from Density to Stiffness/Modulus




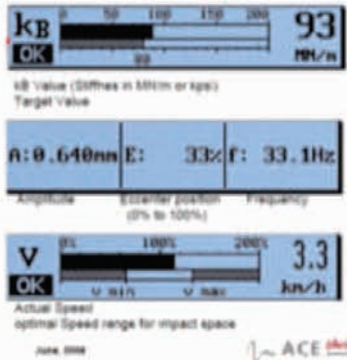

Physical density, typically measured with a Nuclear Gauge, is connected with material properties, but not with stiffness and bearing capacity.

Stiffness is the basis for calculating an even more fundamental material property, “modulus,” which experts agree is the most accurate and independent means for judging deformation and, thus, a material’s level of compaction.

Stiffness is loosely defined as a measure of a material’s ability to resist deformation under load.

The IC rollers have on-board measuring devices that measure stiffness, giving an indication of the level of compaction.

These onboard systems are calibrated at each site using a portable compaction control measurement device such as a Light Weight Deflectometer (LWD), which measures dynamic modulus. Both the IC rollers and the LWD use the same principles of assessing the dynamic mechanical properties of soil or asphalt.

<b>Compaction Control</b>		
Compaction Method	Measurement Unit & When	In-situ test methods
<b>Traditional Method</b> 	<b>Density</b>  After Compaction is Complete  Provides little or no "on the fly" feedback	 <b>Nuclear Gauge</b>
<b>New Method</b>  <b>Intelligent Compaction</b>	<b>Stiffness</b> Ongoing measurement & feedback to operator 	Verified using a compaction control device (inc Light Weight Deflectometer, DCP and GeoGauge) 

Above: Traditional and new Compaction and Compaction Control methods

## Changes to the Standards

As part of the integrated approach, the Department of Transport standards and specifications for contractors against which compaction is evaluated have been updated. In addition, test methods e.g. *ASTM E2835-11* and *ASTM E2583-07 (2011)* have been developed.

## Benefits of integrating Intelligent Compaction with modulus QA/QC verification to evaluate compaction

The integrating IC with modulus acceptance criteria and QA/QC procedures approach is being trumpeted as one of the most significant changes to road building methods for many years. The benefits include:

- Increase the Life of Infrastructure (some

experts say double)

- o European experience, says the Minnesota DOT's research, "clearly demonstrates that greater compaction uniformity increases the useable life of pavement systems, and similar benefits occur with embankment compaction and buried-structure backfill".
- o reduction in highway repair costs.
- Increased Compaction Uniformity
  - o produce more uniform compaction, provided soils are within the moisture-content range necessary to achieve the target compaction;
  - o identification of non-compactable areas;
  - o eliminate over-compaction and under-compaction, applying additional effort only if necessary;
  - o improved density of pavement materials;
- o improved depth of compaction.
- Cut Construction Costs
  - o with more efficient paving processes, production can increase and contractors can construct greater amounts of roadway daily;
  - o cost-benefit analyses indicate that investment in IC will break even within one to two years;
  - o minimising over compaction reduces costs - wasted diesel fuel, construction labour, equipment maintenance, rework etc;
  - o reduce manual spot checks required for confirmation, since the IC roller automatically checks virtually every spot on the jobsite for compaction results (Example: 75% reduction in QA testing (Sweden) - Briaud and Seo, Texas A&M, 2004)

- Better Documentation & Pavement Management
  - o complete documentation for every lift with measurement and recording of materials stiffness values;
  - o full documentation of compaction results may be the basis on which states potentially may award bonuses or assess penalties for compaction-work quality.
- Construction Verification of Design Values
  - o “Comprehensive data on the mechanistic properties of all materials compacted, permitting links between design, construction and performance. For example, the data record produced by the compactor, which covers all areas and all lifts, will be essential to the pavement-management process. Long-term performance may be correlated with the properties produced during construction.”

Continued use and further improvement of IC technology will only produce better quality roadways that help keep motorists safe and allow DOTs to operate more efficiently.

## How did the compaction revolution start?

Back in 2004, the FHWA started their journey from the same base of where Australia is now.

Conventional rollers were used for compaction and density testing using the Nuclear Gauge was the compaction evaluation method.

*“Europeans have over 10 years experience with Intelligent Compaction for soils and asphalt. Once our Scan Team saw it, we knew we wanted it in the US. It was a matter of making our case to DOTs and industry...”*

It started with a 160-page study – “Intelligent Compaction: Strategic Plan” – which detailed the technology and its potential benefits, identified research needs and presented a national implementation plan.

The FHWA’s strategic rationale from 2004 makes compelling reading:

- Improved Roads
  - o higher density and better uniformity;
  - o pavement service life increased;
  - o reduced pavement distress.
- Reduction of Congestion
  - o maintenance and repair activities delayed / eliminated;
  - o less traffic disruption due to construction activity;
- Increased Safety
  - o pavements are smoother and safer;
  - o less construction activity eliminates dangerous road hazards

## What will change the face of compaction and compaction control in Australia?

The Roadmap for Change doesn’t need to be re-invented. The process of evaluation doesn’t need to be re-invented either. Road building contractors who use Intelligent Compaction rollers in Australia are reaping the benefits, delivering a superior pavement in less time and it’s costing them less to do it.

There is healthy appetite for change amongst the pavement design houses, road building contractors and geotechnical companies. The stumbling blocks are the specifications and methods of evaluating compaction mandated by our road authorities in Australia.

How long will it take our road authorities and peak bodies to embrace the integrated approach combining *Intelligent Compaction* with the measurement of *modulus* for evaluating compaction?

A lot of the hard work has been done in the USA and in Europe. We just need to have the courage to learn from overseas experience, allocate resources and try something that’s new to us. The financial rewards of uniformly compacted pavements will be enormous.

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