COMPACTION – THE BUILDING BLOCK OF QUALITY INFRASTRUCTURE

FOR MOST THINGS, THE COSTS OF GETTING SOMETHING RIGHT THE FIRST TIME IS A FRACTION OF THE COST OF BUILDING SOMETHING POORLY AND THEN SUBSEQUENTLY HAVING TO RECTIFY THE PROBLEM.

This is certainly true of compaction: lack of attention to this area leads to high ongoing maintenance costs and ultimately to a premature need for reconstruction. All of these things mean less than ideal road safety; and the need for expenditure that governments are crying poor about.

There have been significant advances in compaction and compaction measurement in the past 20 years – generally led by Europe and followed by the US – but the technology has made limited advances in Australia.

Perhaps one of the reasons is that it is not mandated or written into the specification; and if it not mandated then it is hard for contractors in a competitive bid process to factor in the costs of a technology that competitors may not use.

Oscillatory compaction

Hamm developed oscillatory compaction some 30 years ago, and it is now widely adopted around the world. The drum leaves the ground in traditional vibratory compaction, but this is not the case with oscillatory compaction.

With oscillatory compaction, the amplitude is reduced as the soil rigidity increases. As a result, over-compaction is avoided. The characteristics of oscillatory compaction mean that it can be used close to sensitive infrastructure and over services and bridges, where vibratory rollers could not safely be used. A particular application benefiting from this form of vibration is asphalt compaction and soil compaction in residential areas.

Oscillation rollers can be used on all types of asphalt and soils, and have proven to compact quickly due to their responsiveness to changes in rigidity.

Last year oscillatory compaction became available in the sub-4.5 tonne class for the first time when Hamm released four new oscillatory rollers in the HD CompactLine.

Oscillation rollers are being used to good effect on the WA Gateway project around the Perth Airport, where there is a concentration of existing infrastructure and sections that back onto residential areas. They have also been used on sensitive projects around Australia and the world for a number of years.

Hamm CompactLine oscillation roller

Compaction Meters and Intelligent Compaction

Compaction meters were first discussed at an international conference as long ago as 1980.

Traditional earth compaction used a combination of the number of roller passes and a constant roller speed, amplitude and vibration frequency to control compaction. While this had theoretical correctness, it was virtually impossible to get uniform material properties, moisture content and stiffness of the underlying layer; resulting in a mix of over-compacted, under-compacted and adequately compacted areas.

Spot testing of compaction was undertaken, but the small size of the sample relative to the area compacted meant that the testing could not be regarded as a reliable indication of adequate and uniform compaction across the work area.

A further drawback was the time taken to undertake the testing – sometimes resulting in days lost before work could resume.

Ammann compaction meter display

A Swedish R&D project in the early 1970s looked at whether and how compaction could be measured instantly and continuously, leading to the development of the Compactometer that was the subject of the 1980 paper.[1] An Oscillometer provided compaction metering for oscillating rollers, which were first used in soil compaction in the 1960s.

Since that time other companies have developed compaction meters; so that by now virtually all of the leading compaction equipment manufacturers offer a compaction meter option. The compaction meter produced a number that was meaningless in itself, but it could be calibrated using a traditional compaction test. The meter reading that equated to the target compaction could be used by the operator as the target to achieve on the work site.

Continuous Compaction Control (CCC) developed to combine positional and compaction information; with light displays showing operators the state of compaction across the work area. This could lead to having an "as built" record of compaction as part of a quality management system.

The CCC system has some limitations that need to be borne in mind, but its benefits are sufficient for it to have been written into the national standards of some European countries.

While CCC can be seen as a means of documenting compaction, its most important benefit is in guiding the compaction process to efficiently achieve uniform compaction. An important part of achieving this is that the contractor understands of the application of CCC; and the operator is trained in understanding how to interpret and react to the displayed CCC results.

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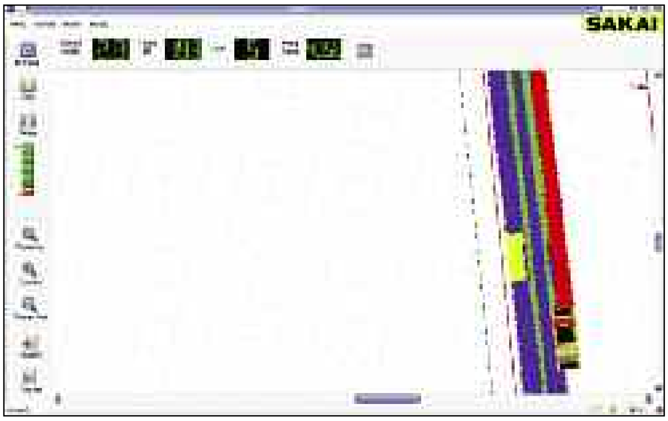
The CCC process requires calibration of the reading to an accepted test method. The Atlas Copco "Compaction, Paving and Milling: Theory and Practice" booklet states, "The CCC values are calibrated to create a correlation to the acceptance control method, typically static plate load tests. Using this correlation a corresponding CCC value is determined and used as the target value for the area."

While Europe has been to the forefront in the development and application of compaction meters and positional information that are key elements of what is termed Intelligent Compaction (IC), the US is well advanced in its application and IC is promoted by the Federal Highways Administration[2] (FHWA).



Sakai Intelligent Compaction display

The FHWA provides leadership and guidance to State Departments of Transportation in the planning and construction of road infrastructure; and provides education and training in appropriate new technologies as part of its role. This is an approach that we could learn from for the Australian environment.

Alternative testing tools

While compaction meters have been around for a while, they still produce numbers that have to be calibrated to accepted benchmarks for measuring compaction. The ease and speed of doing such tests can be an issue, depending on the methods mandated or accepted.

The Nuclear Density Meter (NDM) is a widely accepted Quality Control / Quality Assurance (QC/QA) method in Australia in a prescribed random sampling grid pattern. Robin Power of geotechnical consultants TIC Service Group believes that this method has a number of issues, including:

- Density is an indirect parameter of strength
- Because in-situ spot tests are limited and random, they are not necessarily representative of the entire pavement area. There may be weak or unqualified compaction areas that are not identified by spot tests.

Europe has led the move to an integrated system of compaction and compaction control combining IC with the measurement of modulus for QC/QA procedures when evaluating the compaction of soils and aggregate bases.

Robin explains the difference between density and modulus as, "Physical density, which is typically measured with a Nuclear Gauge, is an indicator of material properties, but not an indicator of stiffness.

"Stiffness is the basis for calculating a more fundamental material property, called modulus. Experts agree this that is the most accurate and independent means of judging deformation, and thus its level of compaction. Stiffness is broadly defined as a measure of a material's ability to resist deformation under load."

IC rollers have on-board devices that measure stiffness, giving an indication of the level of compaction. These are calibrated at each site using a portable compaction control measurement device such as a Light Weight Deflectometer (LWD), which measures dynamic modulus.

Light Weight Deflectometer in use on a stabilisation project

Both the IC rollers and the LWD use the same principles when assessing the dynamic mechanical properties of soil so that there is consistency of correlation between IC and LWD measurements. This has provided the basis for their acceptance in Europe and many parts of the US.

European standards allow an LWD to be used as an alternative to static plate load testing e.g. for sub-base. One static plate load test measuring the static modulus, Ev2, is done at least every 6,000m^2 and then the dynamic modulus, Evd, is measured using the LWD, at least every 600 m^2. For widening work, testing is required at least for every 200 metres of construction.

In the US, the Department of Transport standards and specifications for contractors have been updated, and test methods e.g. ASTM E2835-11 and ASTM E2583-07 (2011) have been developed to reflect the integrated use of IC and LWD.

The Minnesota Department of Transport's research says that the combination of IC and LWD "clearly demonstrates that greater compaction uniformity increases the useable life of pavement systems, and similar benefits occur with embankment compaction and buried-structure backfill."

Cost-benefit analyses indicate that investment in IC will break even within one to two years.

Perhaps the greatest benefit of using LWD in conjunction with IC is the immediacy of the results, so that where there is a problem it can be identified and rectified virtually immediately, rather than being buried by the next layer of material.

Where is Australia at?

There have been some trials of LWD by road authorities in Australia, with Queensland being most advanced. A possible driver for this was the large scale rectification required after successive major floods, bringing a realisation that funding was limited and advanced technology was one way of getting "more bang for the buck" with infrastructure spending.

TIC Service Group itself uses and advocates LWD technology. Its use is simple and fast (3 minutes to get GPS located results which you can use to make on-site decisions):

- Prepare the test area so the plate has full contact with the ground. Use bedding sand if required.
- Perform three settlement drops to settle in the plate.
- Do three more drops to perform the test.
- Review the modulus and deflection results on screen, print them or download the data to your laptop.

While many in the industry see the benefits of IC, some see the way in which contracts are let, and contractors are remunerated, as being an obstacle to its adoption as it does not seem to provide an incentive for new technologies to be adopted that provide a higher quality asset with a lower cost of life. The common 24-month defect rectification period is seen by some as being too short for a problem to be identified in many instances, allowing a calculated gamble to be made when considering compaction technology that is initially more costly.

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TENA SA offers several other key MDP benefits, beyond the productivity improvements.

- MDP proved reliable in clay soils, where an accelerometer-based system would suffer from high variability – and therefore provide questionable readings. Without MDP, TENA SA would not have been able to show target densities were achieved – and the passes would not have been eliminated.
- Quality control was improved by spotting problems early and taking immediate corrective action.

MDP Defined

MDP is a significant change in compaction measurement technology. It is a not a breakthrough in how machines compact. Instead, it evaluates the rolling resistance.

That resistance provides an indication of soil stiffness and load-bearing strength; and whether compaction is adequate to structurally support the road, parking lot, building – or whatever is planned for the site.

The ultimate benefit of MDP, a proprietary technology developed by Caterpillar, might be summed up in one word: uniformity. Is the entire site compacted the same way, or are there areas where structural integrity is compromised?

Historic methods of testing can only provide a snapshot, and are no guarantee of uniformity. Typically only one percent of the jobsite is tested. MDP acts as a proof roller while it works, enabling much faster discovery of inconsistencies across the entire jobsite. It works in any type of soil, and performs whether the compactor is smooth or padfoot, vibrating or static.

The Dam Jobsite

Before the Triantafullia dam project began, authorities set the following requirements to ensure proper compaction:

- A rolling speed of 2km/h
- 12 passes with the roller.

When work started, the authorities tested MDP findings against other on-site measurements. They were impressed with MDP's consistency and their trust grew enough for them to make significant adjustments.

- The number of passes required was reduced from 12 to eight because MDP indicated targets were reached in four fewer passes than originally required.
- Rolling speeds for the remaining passes were increased from 2km/h to 4.5km/h, as MDP showed the desired results were also being achieved at the much higher speed.

"I would recommend others use it because of fast measurement of compaction, accuracy, reliability and increased productivity," Nathanailidis said. □

HAV EXPLAINED

OUR ARTICLE ON WACKER NEUSON DEVELOPMENTS (P. 27) INCLUDED MENTION OF A CONTROL POLE DESIGNED TO REDUCE HAND ARM VIBRATION (HAV).

This topic is not yet widely discussed in Australia but Professor David Edwards, a pioneer of research in this area and driving force in the founding of the Off-highway Plant and Equipment Research Centre (OPERC) in the UK, kindly provided *Earthmover* with his perspective.

***HAV syndrome (HAVS)** is an irreparable condition that impacts upon the neurological, vascular and muscular skeletal symptoms within the human body – if untreated, the condition can lead to debilitating illness; hence the urgent need for individuals and companies to mitigate the risks.*

During the early days, research into this field focused upon the tri-axial measurement of vibration emission from the tool in terms of M/S2 (metres per second squared), which is a form of acceleration measurement.

However the evidence suggests that "vibration is the precise measurement of an imprecise science" because field measurements (to ISO5349 parts 1 and 2) vary greatly even when the variables (temperature, appendage wear, tool wear etc.) are held constant.

As a result, HAV research in the UK has changed to focus more on controlling risk mitigation measures such as operator training and competence, tool maintenance, tool rotation (between operatives) etc. Where a robust health surveillance system is in place, the early symptoms of HAVS can be readily detected and risk mitigating measurements implemented.

My advice to all practitioners is to use practical risk mitigation control measures as stated above and not to spend valuable resource on endless testing of tools: these will afford the greatest protection against HAVS. Training of managers and site supervisors is also most important since they are the very people who must ensure that policies are implemented in practice.

Organisations such as OPERC offer applied work-based distance courses that importantly include theory and practice – try to avoid courses that simply discuss theory and legislation alone as these are ineffective in practice.

Also consider conducting productivity performance studies (or work studies) on key tools (or combinations of tools used) because the management of HAV requires consideration of both productivity performance and the tool's vibration magnitude to measure vibration exposure.

The OPERC HAV vibration magnitude poster may be a good starting point for this and is already being used by the US Department for Defence.

And finally, avoid gimmicks and gadgets like the plague – there is no silver bullet for HAV management except good management and thorough risk control implementation. □

OPERC Link: www.operc.com
Further info: http://patient.info/health/hand-arm-vibration-syndrome-leaflet

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There is an incentive for road authorities to look at mandating IC technology and testing methodology that allows its potential benefits to be fully realised. Todd Mansell (Training Consultant, Caterpillar Paving Products, US) made a relevant observation prior to the planned 10th Australian Road Engineering and Maintenance Conference in Sydney earlier this year when he said, "A pavement only lasts as long as its weakest link. When compaction is not uniform and a weak area fails, it is a failure of the entire road."

Jim Harris is National Sales Manager at Conplant, which represents Ammann rollers and its Ammann Compaction Expert (ACE) system. Jim cautions that for a compaction system to have real value, it must be used in the right application and in the right way.

Jim sees operator training as a further consideration, saying, "A compaction meter is of little benefit unless people are trained in how and when to use them. They have little value in applications such as maintenance compaction, and can be a cost without a commensurate return if their use is not approached correctly."

The US started its concerted approach to adopting Intelligent Compaction in 2004: when will Australia make its start, and will it show the same unity of purpose and proactive approach to education and training that the US does? □

NOTES:
[1] "Continuous Compaction Control, CCC", by Heinz F Thurner & Ake Sandstrom (Geodynamik, AB), presented to the European Workshop "Compaction of Soils and Granular Materials" in Paris on 19 May 2000
[2] View: www.fhwa.dot.gov/construction/ictssc/