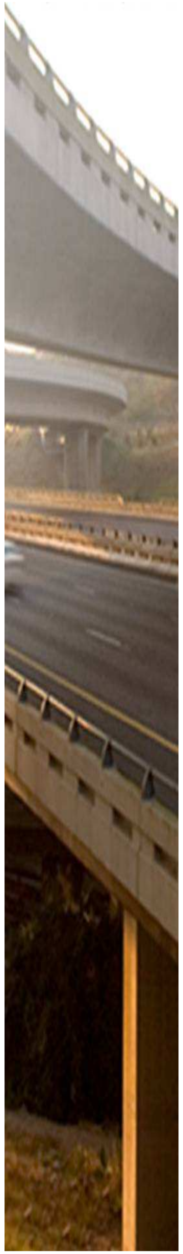
THE SOUTH AFRICAN NATIONAL ROADS AGENCY LTD



Revision of the South African Pavement Design Method

Intelligent Compaction

RPF, Gordon's Bay
10 May 2011
Project SAPDM/E-4

P Paige-Green (& L Kannemeyer)

CSIR
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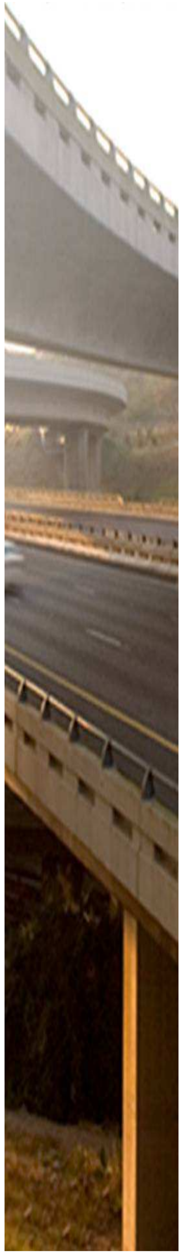
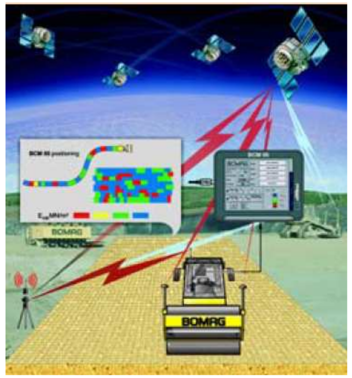
Background

- Intelligent Compaction (IC) is widely used in Europe, Japan & United States
- Seen as the latest big advancement in pavement performance
- Fits into the revision of SAPDM perfectly
- Incorporate into specifications and QC/QA procedures
- Proposed investigation as part of the SAPDM programme

What is IC ?

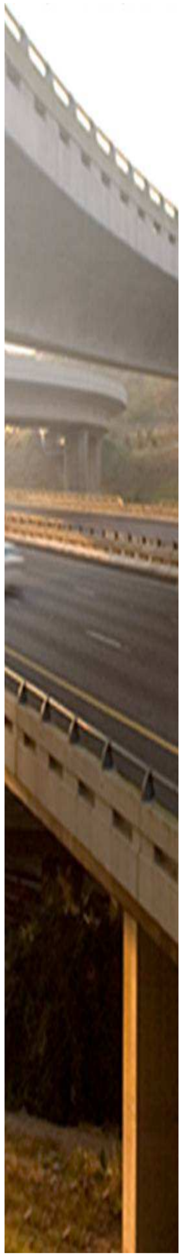


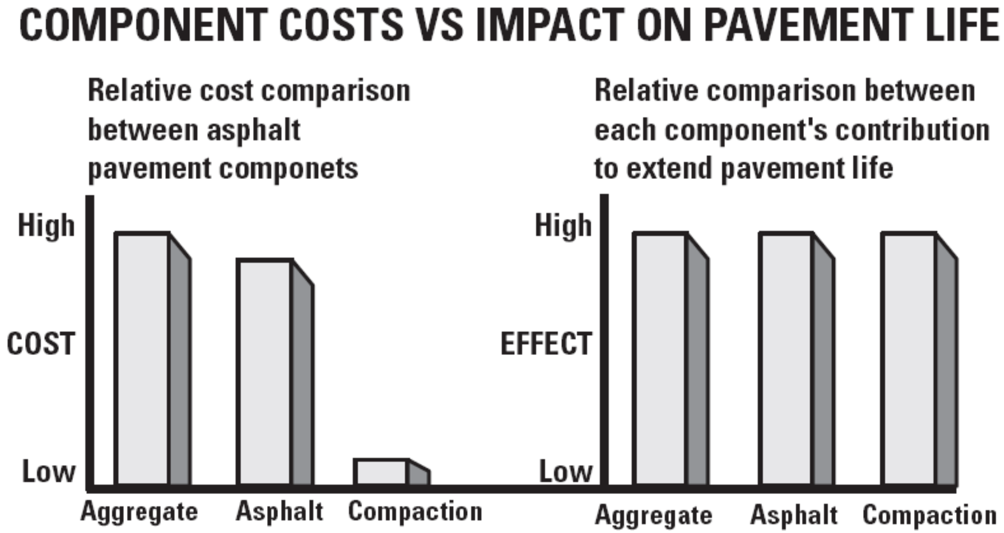
- Compaction of road materials (unbound, treated, asphalt) using rollers equipped with in situ measurement and feedback control
- Linked to GPS
- Automatic documentation of results
- Allows :
  - Real time/instantaneous corrections during compaction process
  - Continuous record of colour coded plots of various parameters, eg
    - Number of roller passes
    - Material stiffness measurements
    - Roller locations

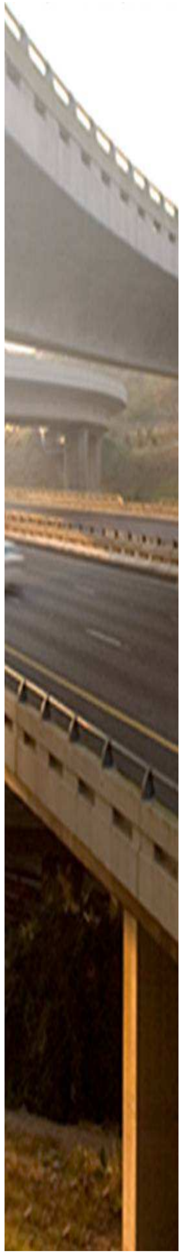


Compaction

- One of most important processes during construction
- Directly affects layer stiffness
- One of the lowest cost operations
- Good return on investment

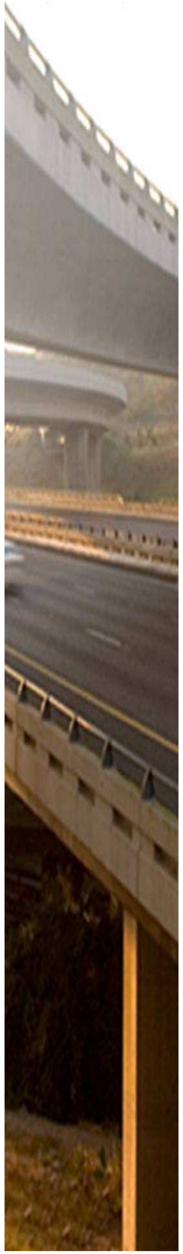






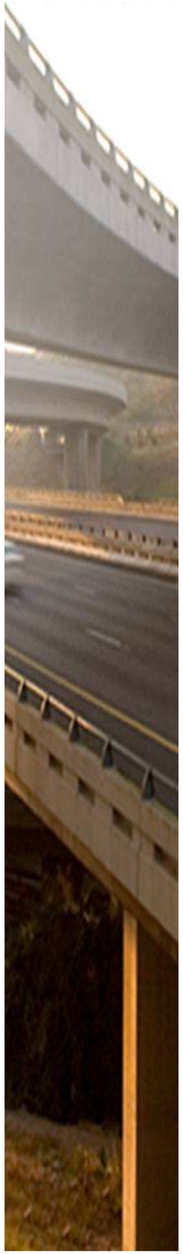
IC principles

- At least 6 vendors trading in IC rollers
- Unsure about comparability of outputs
- Different principles used in most cases
- Need to understand these and be able to compare outputs
- Look at basic differences
- 5 problem areas to be assessed



Problem areas

1. Correlation between Measurement values (MV) of different systems
2. Correlation between MVs of rollers and traditional acceptance tests
3. Correlation between roller MVs and possible future field QC/QA test procedures
4. Statistical evaluation of compaction control and uniformity
5. Development of IC specifications and QC procedures



1. Correlation between Measurement values (MV) of different systems

- Need to assess (for granular, cemented and asphalt materials):
  - What are the fundamental compaction properties measured by each system?
  - Can these be related to one another, if so, how?
  - Can a generic MV be adopted in SA?
  - Is it possible to adopt a standard data output format for the different systems?

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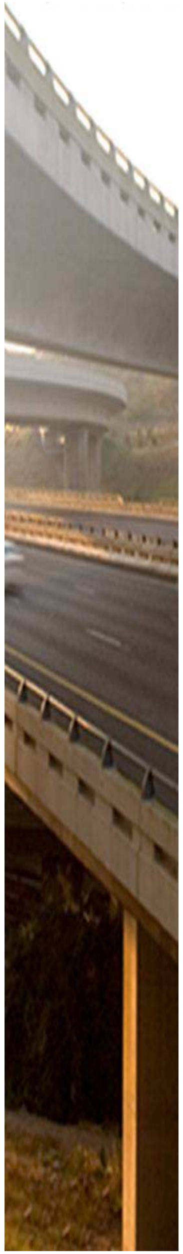
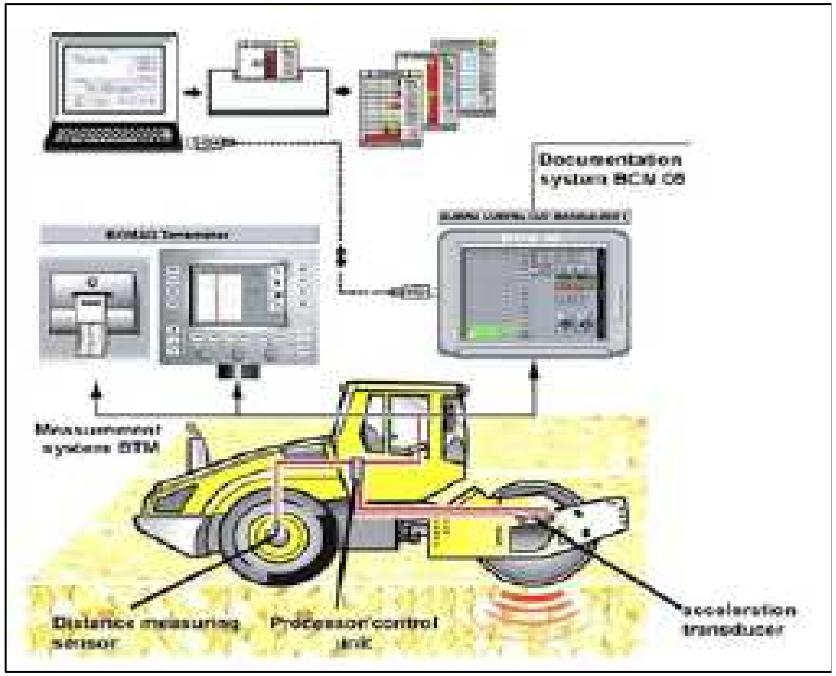
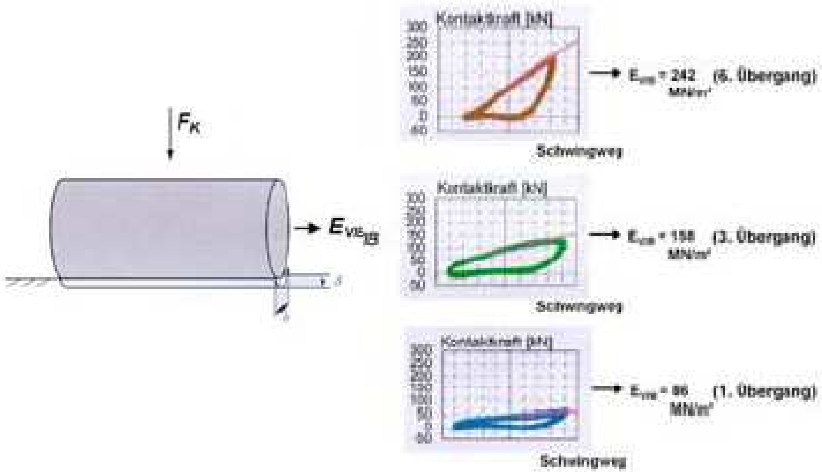
Bomag Soil System

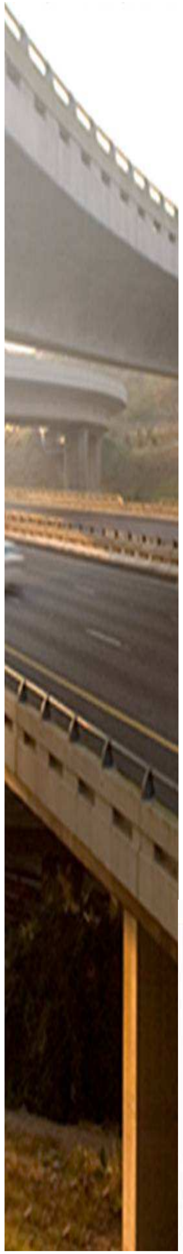


- Variocontrol system
  - 2 acceleration transducers
  - Processor/control unit
  - Distance measurement
  - GPS radio/antenna
  - Bomag operation panel
  - Onboard documentation system
- Measures E_{vib} (MPa) = stiffness
  - Computed from compression paths of contact force vs drum displacement curves
  - Correlates with plate loading tests

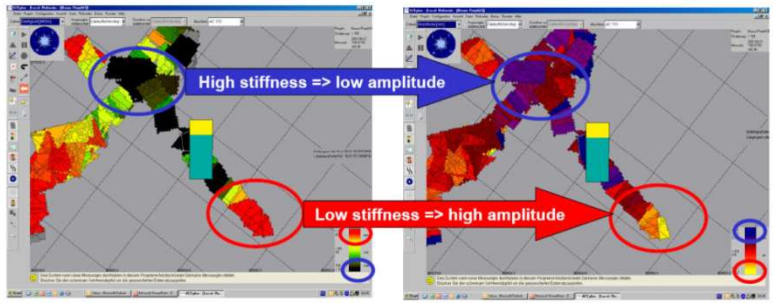




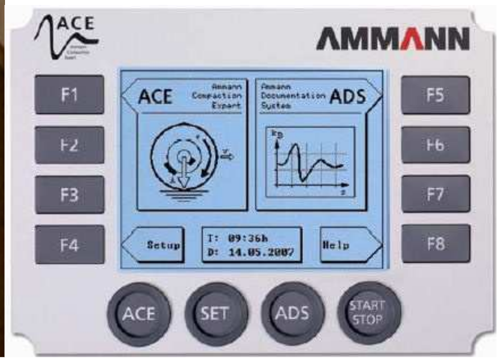
Case/Amman IC system

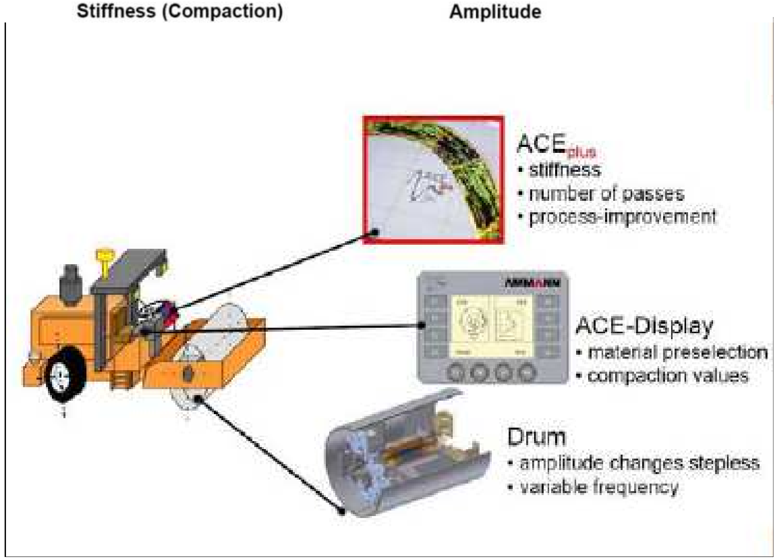


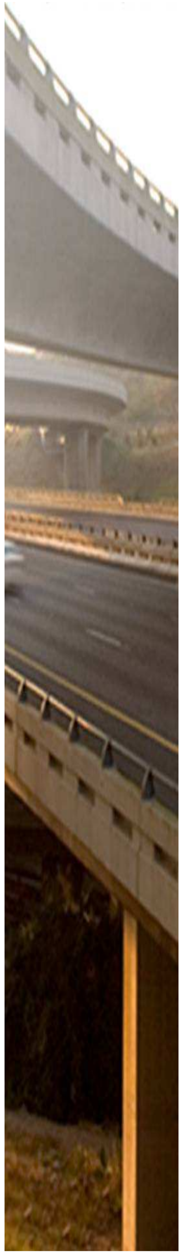
- ACE & feedback drum system
- Combined Amman Compaction Effort (ACE) + continuous compaction control (CCC)
  - Roller integrated stiffness (k_s)
  - Two degrees of freedom springmass-dashpot
  - = Drum/ground system
  - Requires no loss of contact
  - Correlates with plate-load
  - Auto feedback – adjusts f & A



Stiffness (Compaction) Amplitude

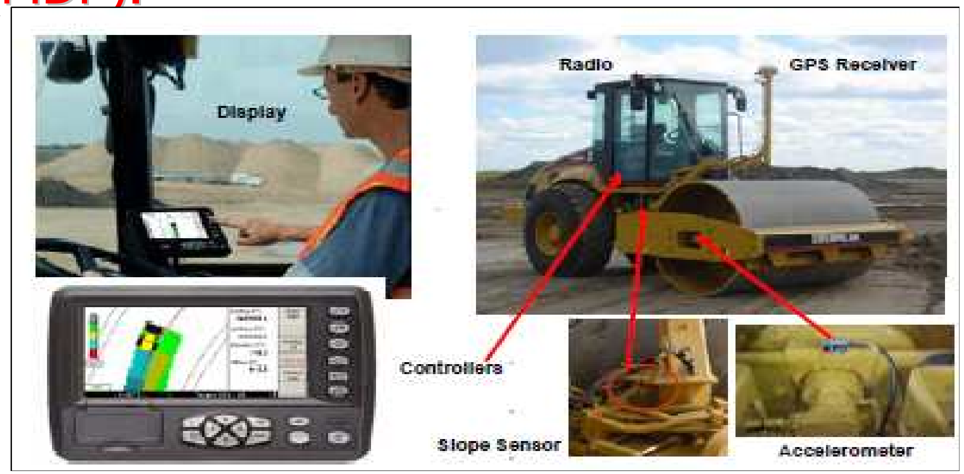


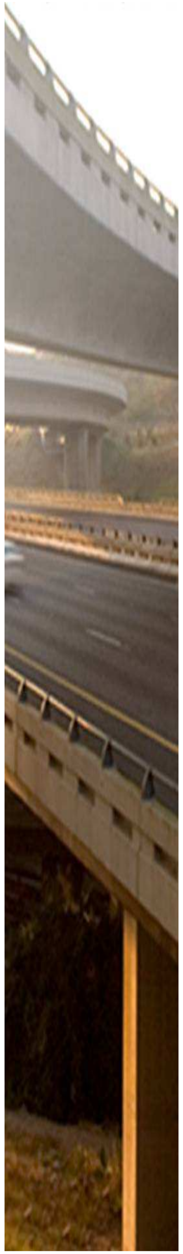




Caterpillar IC system

- The Caterpillar IC system includes:
  - An accelerometer, slope sensor, controllers, communication data radio, Real-time Kinematic (RTK) GPS receiver, an off-board GPS base station, and onboard report system.
  - These components are integrated into the so-called Caterpillar AccuGrade system to provide accurate IC measurements during compaction.
  - Indication of levels of compaction including compaction meter values (CMV), resonance meter values (RMV), and machine drive power (MDP).

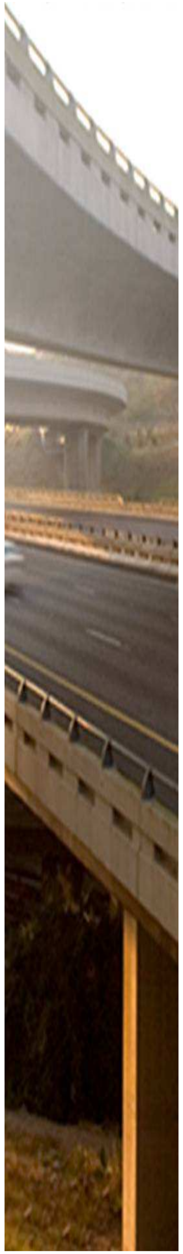




Caterpillar IC system

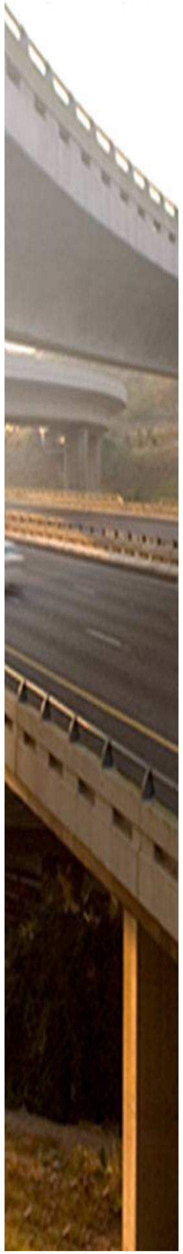
- The CMV is:
  - Defined as a scaled ratio of the second harmonic vs. the first harmonic of the drum vertical acceleration amplitudes based on a spectral analysis.
  - The scaling is made so that CMV values could cover a range of 150 and is reported as average values within two cycles of vibration or typically 0.5 seconds.
  - The CMV is a dimensionless, relative value requiring constant roller parameters such as drum diameter, linear load, frequency, amplitude, speed, etc.
  - The CMV is an integral with contribution from large depths (3 to 6 ft for Caterpillar IC rollers) - the highest weighting is for layers closest to the surface
  - Caution should be taken when comparing CMV with the top layer compaction level measured by other devices such as nuclear gauges or LWD) only.

Dynapac IC system

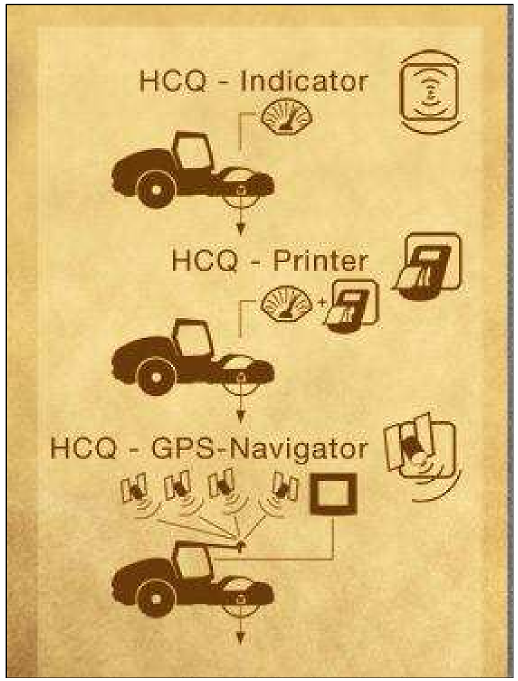


- DCA measures CMV to indicate compaction quality
  - The CMV technology uses accelerometers to measure drum accelerations in response to soil behaviour during compaction operations.
  - The ratio between the amplitudes of the first harmonic and of the fundamental frequency provides an indication of the soil compaction level (CMV).
  - CMV is a dimensionless parameter that depends on roller dimensions (i.e., drum diameter, weight) and roller operation parameters (i.e., frequency, amplitude, and speed).
  - A measurement value (CMV) and bouncing value (BV) is recorded about every 0.5 m at the drum centre along the direction of travel.

Hamm IC system

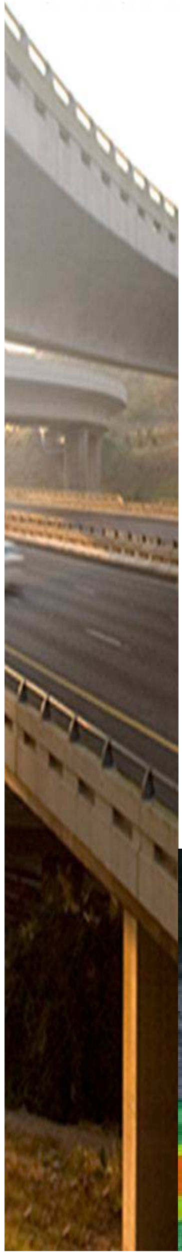


- HCQ – Hamm compaction quality
  - HCQ Indicator measures the stiffness of the soil or asphalt
  - Displays the HMV value in the instrument panel or as the load capacity Ev2.
  - This is the degree of compaction already achieved.
  - Consists of a sensor inside the drum, a processor and a display.
  - The sensor measures the vertical acceleration of the drum.
  - The processor calculates the HMV from the measured signals and displays this value to the driver in the cab.

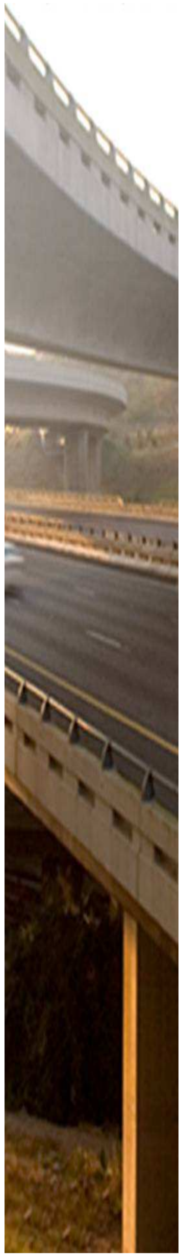


Landpac CRI system

- High Energy Impact Compaction (HIEC)
  - Accelerometer on roller
  - GPS links
- Most suitable for subgrades and removal of potential collapse
- Will use on subgrade in areas of widening
- Possibly also for collapse settlement





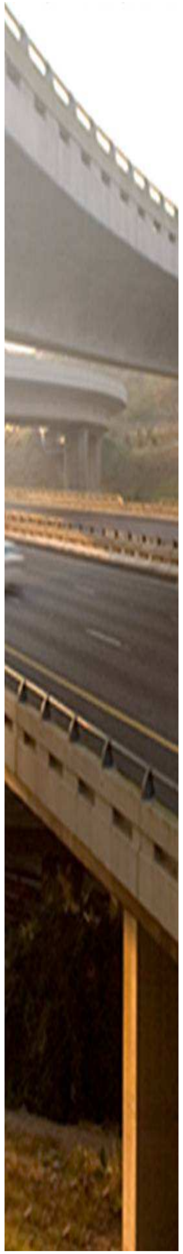


2. Correlation between MVs of different rollers and traditional acceptance tests

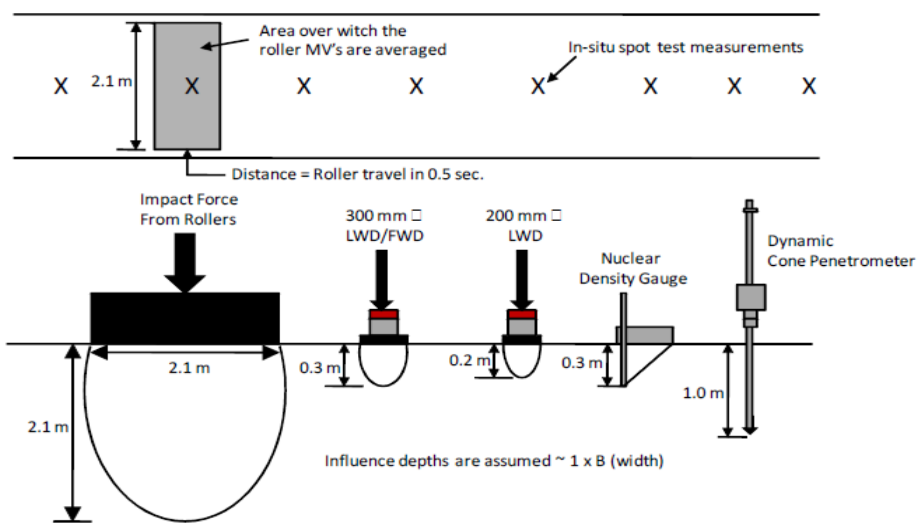
- Look at conventional methods:
  - Calibrated nuclear density meters
  - Sand replacement tests
  - Plate load tests where applicable
  - Lab tests on asphalt cores

- And their relation to:
  - Heterogeneity of support (laterally and vertically)
  - Moisture variations
  - Range of MVs
  - Temperature effects in asphalt
  - Machine operations (amplitude, frequency, speed, etc)
  - Spatial variability of measurements
  - etc

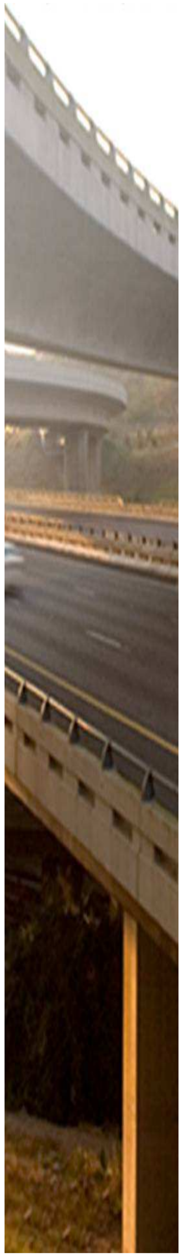
3. Correlation between roller MVs and possible future field QC/QA test procedures



- Expected greater use of NDT methods for control
  - Light weight deflectometer (LWD)
  - PSPA
  - DCP
- Correlate with MV



(Courtesy of Dr. David White)



4. Statistics for evaluation of compaction control and uniformity

- Spatial data from IC outputs allow quantification of uniformity of compaction
- Need statistical assessment
  - Considering Semi-variograms, which together with conventional statistics have been shown to be effective for uniformity of earthworks
    - SV is a plot of the average squared differences between data values as a function of separation distance (common geostatistical technique to describe spatial variation)

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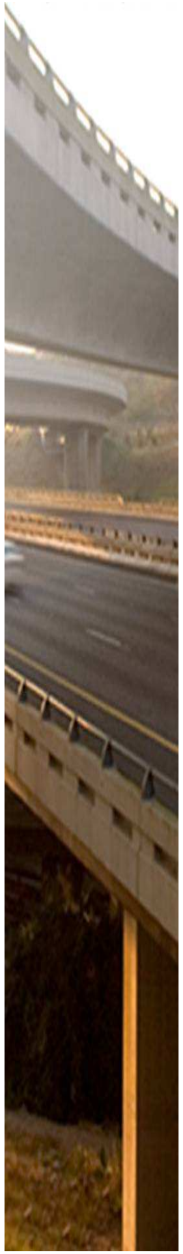
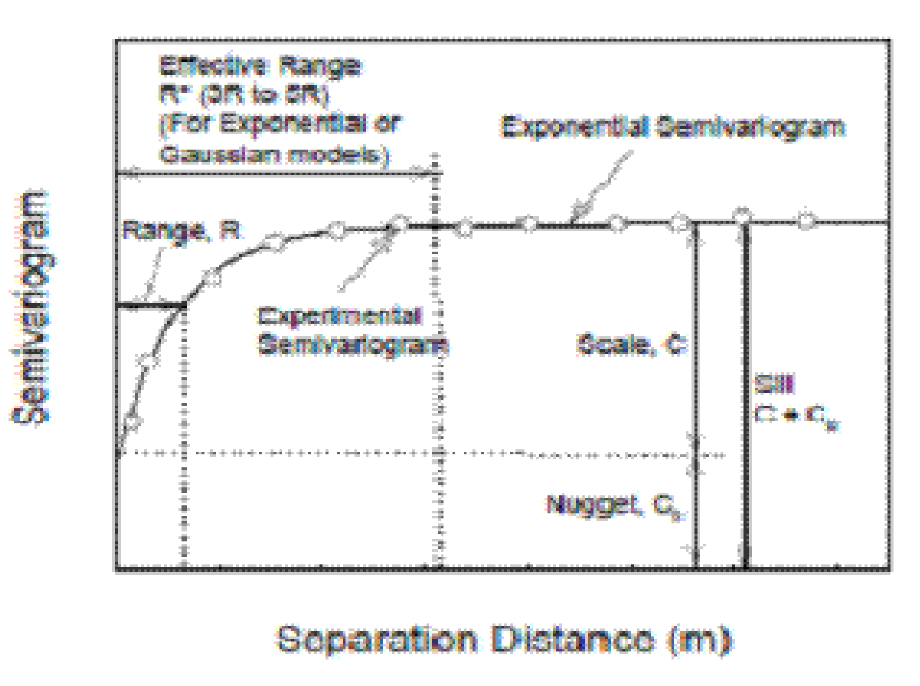
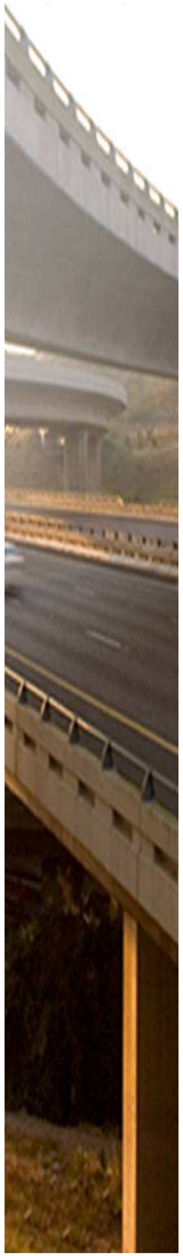
Planned activities



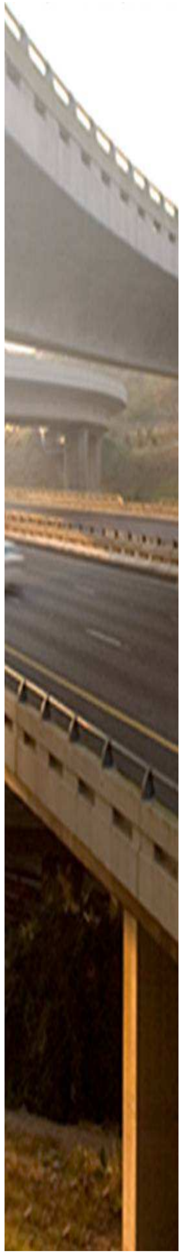
- Range – as separation distance between pairs increases SV will also increase
- Longer range values suggest greater spatial continuity or relatively larger (more spatially coherent) “hot spots”.
- The plateau that the semivariogram reaches at the range is called the sill. A semivariogram generally has a sill that is approximately equal to the variance of the data.





5. Development of IC specifications and QC procedures

- IC is already used in national standards in Austria, Germany and Sweden.
- For local use, new standards would need to be developed
- Investigation will asses these potential standards



Planned activities

- Two road contracts starting shortly
- Will attempt to include a wide range of pavement structures, materials (natural (G1, G4, G5, G6) and different treatments (C3, C4, BSM)) and surfacings (asphalt, double seals, etc)
- Even effect of additives (lime and cement) in foam and bitumen
- Also lift thickness, support conditions, rolling patterns and passes, etc.

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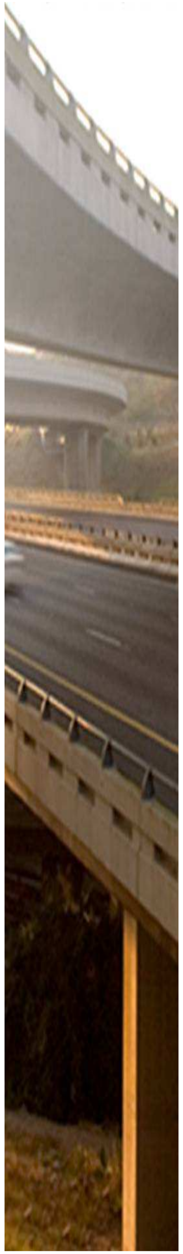
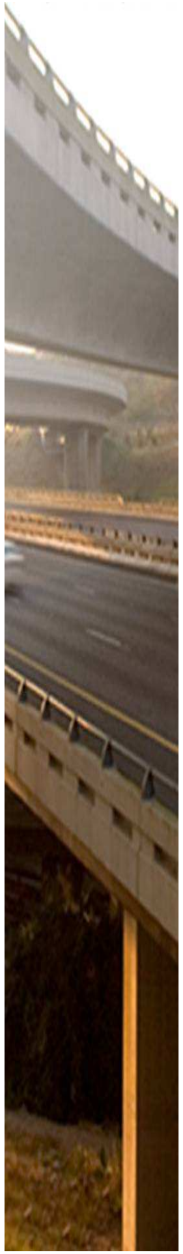


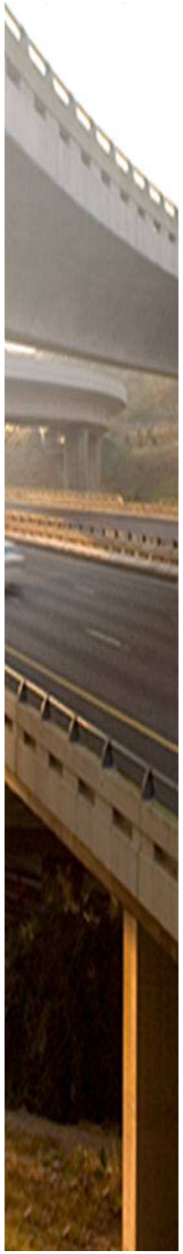
Planned activities

- Use all types of IC systems available (5+1)
- Plan is to use one roller
  - Test after each pass (as many of the tests discussed earlier as possible and practicable)
  - Continue to “end of compaction” as identified by IC
  - Put each of the other rollers over for one pass and monitor their response for comparison
- Change roller sequence on different sections



Planned activities

- One young engineer (with help) on site full time
- Will do the majority of the testing
- Collect all roller data
- First level analysis as work proceeds



Future

- Interesting project
- Should give fascinating results
- Will change QC/QA of the future ?