Defining Intelligent Compaction -

A. *Multiple integrated* compaction measurement technologies
   - GPS Location
   - Pass Count
   - Compaction Reference
   - Temperature
   - Machine Controls

B. Recording Jobsite *Positioning Data* correlated to system measurements

C. Storing and Documenting recorded data for QC Analysis
Benefits from IC — Real Time & Post Analysis Data

**Quality Control** —
- Improved Rolling Pattern,
  - Optimized pass count & coverage
- Improve consistency of Density & Smoothness
  - Better understanding of material conditions
- Documentation
  - Significant of increase in coverage for QC Data
  - Real Time and post-process [Quality control] data analysis

**Process Control** —
- Increased Operator Awareness
  - **Real-time** compaction, temperature (asphalt), pass count data
  - Easier night-time operation
  - Early detection of problem areas, etc.
- **Productivity & Efficiency**
  - Maximized machine utilization with better efficiency
What are contractors doing?

• Learning phase – What is IC? How can it help my operation?

• Finding soft spots

• Trying to establish correlations with density

• Looking at consistent rolling patterns & temperature

• Not sure how to use office software/data analysis
Historic Compaction Measurement

- Nuclear Gauge
- Penetrometer (DCP)
- Deflectometer (LWD)
- Plate Load
With the conventional compaction measurement, what percentage of the surface is actually tested?

Less than 1%
B-Series Soil Compactors
Work Smarter with Optional Compaction Measurement Technology

Cat Compaction Control

• Factory installed, dealer supported; integrated with machine for better protection from theft, vandalism

• Two sensor options available:
  • Machine Drive Power (MDP): exclusive Cat technology, rolling resistance-based
  • Compaction Meter Value (CMV), accelerometer-based

• Mapping/Positioning option

• SBAS GNSS; upgradeable to RTK

• Includes separate display, GNSS antenna
Accelerometer

ROCK
SAND AND GRAVEL
SILT
CLAY

PAVING PRODUCTS
Compaction Meter Value (CMV)

- Accelerometer-based stiffness measurement value
- Unitless number
- Readings are influenced by soil up to a depth of 1 - 2 m (3 - 6 ft)
- Measures the frequency response of the drum with successive roller passes
- Frequency response is correlated with soil stiffness by comparing with conventional point test methods such as nuclear density gauge or dynamic cone penetrometer (DCP)
COMPACTION METER VALUE (CMV)

- CMV Standard
- GNSS Mapping SBAS
- GNSS Mapping RTK
Things to be aware of...

- The soil depth measured by a vibrating drum is greater than that of most all other devices.

- The CMV measurement is a dimensionless unit that is an indicator of soil stiffness.

- Other devices measure density, shear strength, surface level stiffness or bearing strength.

- Devices that measure different soil characteristics will produce different results. Correlation between measurements can be difficult to achieve.

- The IC compactor is its own measuring device.
Energy Based MDP

ROCK   SAND AND GRAVEL   SILT   CLAY

PAVING PRODUCTS
Machine Drive Power

Soft ground condition = hard to push

Firm ground condition = easy to push
MACHINE DRIVE POWER (MDP)

- **Energy-based**
  - Measures rolling resistance
  - Good results on both smooth drum and padfoot rollers
  - Works on granular and cohesive soils
  - Works with vibe system on or off
  - Measures 30-60 cm (1 – 2 ft) deep

- **Benefits of technology:**
  - Measures closer to the depth of the lift you are working
  - Applicable to a wide range of soil types
  - Correlates well with portable measurement devices
## COMPARISON: MDP VS. CMV

<table>
<thead>
<tr>
<th></th>
<th>Machine Drive Power</th>
<th>Compaction Meter Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurement basis</td>
<td>Rolling resistance / Energy</td>
<td>Accelerometer</td>
</tr>
<tr>
<td>Vibe system for measurement</td>
<td>Active or inactive</td>
<td>Active only</td>
</tr>
<tr>
<td>Soil types</td>
<td>Granular or Cohesive</td>
<td>Granular only</td>
</tr>
<tr>
<td>Machine configuration</td>
<td>Smooth drum, Padfoot, Shell kit</td>
<td>Smooth drum only</td>
</tr>
<tr>
<td>Measurement depth*</td>
<td>30 – 60 cm (1-2 feet)</td>
<td>1-2 meters (3 - 6 feet)</td>
</tr>
<tr>
<td>Can add GNSS mapping</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Availability</td>
<td>CAT Dealers only</td>
<td>Several manufacturers including CAT</td>
</tr>
</tbody>
</table>

*Depends on machine weight and soil type / conditions.*
Conventional measurement - asphalt

- Density gauge
- Cores
What does it take to compact asphalt?

Mix Temperature – or nothing else matters…

Machine
- Static Weight
- Vibratory Systems
- Dynamic Forces

Operator – performs the rolling pattern
- Where did I stop on the previous pass?
- Did I go back far enough on the return pass?
- Did I provide enough overlap on the previous pass?
- Is the mat temperature too hot, too cold?
- Night paving?
Equipment Required -

1. GPS –
   - Trimble/Sitech

2. Rollers –
   - Soils – GPS, Compaction Measurement, Data Collection
   - Asphalt – GPS, Compaction Measurement, Temperature, Data Collection

3. Office software
   - VisionLink (Trimble/CAT)
     - Can be imported into VEDA software (FHWA)
GPS MAPPING CAPABILITY

• Utilizes Global Navigation Satellite System (GNSS)

• Correlates measurements to a location
  – Rolling pattern (pass count), frequency, amplitude, temperature

• Choice of GPS accuracy
  – SBAS (1 meter accuracy)
  – RTK (millimeter accuracy)
How GPS Works – the Basics

• Satellite's broadcast where they are
• Satellite's broadcast code (rate = speed of light)
• Receiver measures travel time of signal
• Compute ranges from at least 3 satellites
  – Intersection of all these gives “autonomous” position on earth

**Step 1: Triangulating from Satellites**
- We are somewhere on this sphere
- A second satellite narrows down our location
- A third satellite puts us at either two points
- Two measurements put us somewhere on this circle
- One of these two points is the accurate location
Standalone - How Accurate?

Standalone (Autonomous) GPS: 5–10 m
How SBAS Works

Satellite Based Augmentation System

- Corrections based on ground stations with known positions
- Corrections broadcast via geostationary satellites
SBAS (Satellite Based Augmentation System)  
How does it work?

Regional SBAS Station
SBAS - How Accurate?

- Standalone GPS: 5–10 m
- DGPS: 0.1–3 m
RTK (Real-Time Kinematic)
How does it work?

Local RTK Correction Signal

Local Base Station
RTK – How Accurate?

- Standalone GPS: 5–10 m
- Trimble DGPS: 0.1–3 m
- RTK: 1–3 cm
Intelligent Compaction on Asphalt

Make Every Pass Count

THE ANSWER.
IC Components –
CB44B, CB54B, CD44B, CD54B
CAT COMPACtion CONTROL

- Infrared temperature sensors (front and rear)
  - Keeps operator informed of when optimal temperatures exist for compaction
- Temperature Mapping
  - Record temperatures for data analysis
- Pass-Count Mapping
  - Keeps operator informed of where mat coverage has taken place and the number of passes made
- Accelerometers
  - Provides feedback of vibration energy for a measurement value to be correlated with compaction

This optional feature increases efficiency and productivity while recording data for quality control documentation and future planning.
Positioning Data – required

• Utilizes GPS

• Correlates measurements to a location
  – Compaction, frequency, pass count, temperature, etc.
  – Documents work
  – Can provide picture of overall compaction consistency

• Choice of accuracy
  – SBAS: provides accuracy to 1 meter; this is the standard package
  – RTK – provides millimeter accuracy; this is an upgrade to standard package
Operators Display –

- Provides real-time pass-count and temperature readings
- Operator can see where he/she is on the mat and pass count
- Operator can determine on & off time based on mat temperature

**NOTE** - A warning indicator alerts the operator if the asphalt temperature exceeds or falls below the target temperature
Compactor Data Collection

The Compaction Control system displays and records the following:

- Machine Position (GNSS)
- Machine Pass Count/Coverage
- Compaction Width
- Asphalt Temperature
- Compaction Measurement (soils)
- Vibratory Status (on/off/rear/both)
- Vibratory Frequency
- Machine Speed
- Direction or travel (forward, reverse)
Accelerometer – Front Drum Only
ICMV – Intelligent Compaction Measurement Value

Accelerometer based ICMV is a *composite of the current lift and the layers below it.*

- Current Mat being compacted
- Previous HMA layer
- Sub-base layer
- Portland cement slab/embankment material, etc.
Temperature Mapping –

• Not a direct measure of compaction, rather one data point for process control on asphalt

• Dual infra-red sensors mounted on the front and rear of machine deliver real-time readings

• Keep operator informed of when to begin rolling and when to stop

• Help avoid tender-zones that often occur in the 95º to 115º C (200º to 240º F) temperature range
This illustration provides the pass-count mapping that occurred in the Minneapolis Global Paving parking lot. The colors signify the number of times that the drums hit a specific area.

- **Green** – Target pass-count was met
- **Blue** – Target pass-count not met; 1 more passes needed
- **Red** – Target pass-count not met; 2 more passes needed

*Note: The red slivers within the paved areas indicate that there wasn’t proper drum overlap*
Why is Pass-Count mapping important?

- Perform required number of passes
- Perform uniform and/or established rolling pattern
- Prevent incomplete passes, stopping short or missed
- Eliminate excessive overlap
- Identify and eliminate Roller stops and bumps in the mat
- Better night time visibility & operation
- Efficiency – fuel, machine wear
Mapping Temperature

This illustration provides asphalt temperatures as the roller passed over the fresh mat. The color pattern signifies the different temperature ranges that were present.

- **Green** – Optimum temperature met
- **Blue** – Target temperature met, lower range than green
- **Red** – Temperature below target
Why is temperature important?

Understanding the asphalt temperature helps operators and supervisors determine when the asphalt can be compacted.

- Monitoring material temperature
- Helpful in making adjustments at the plant or in rolling pattern
- Upper temperature limit that permits compaction is normally around 149°C (300°F)
- Lower limit that permits compaction is normally around 80°C (175°F)
- Avoid “tender zones” if one is present
VisionLink® Software

- Compaction module is what we are interested in today

- Web-based only – no ‘standalone’ version

- Data can be uploaded wirelessly from machine

- Must have a paid subscription and user-account and “register” each machine

- Login at www.myvisionlink.com
Data: VisionLink®

- VisionLink – must have an internet connection to view & analyze the data
In-field reporting: Printer option
VisionLink mobile app

- Location: Find Last Known Location of Assets
- Fault Codes: View Fault Codes for Assets
- Service Due: Overdue and Upcoming Service
- Utilization Hours: View Hours of Use
- Fuel Level: View Assets that Need Refueling

THE ANSWER.
Data: VisionLink

- Data can be exported in *.csv (MS Excel) format
Compatible with VEDA software

IC data → Vendor’s software

Point Tests and GPS data → Veda
Compatible with Veda 2.0

- VEDA capable of various analytical tools
  - Histograms of pass count frequency, CMV, temperature, etc.
  - Correlations with nuclear gauge, other correlation tools
Thank you for your attention.
Discussion…
Questions??