Intelligent Compaction for Soils, Aggregate, and HMA

Original: October 20, 2014
Updated: February 16, 2015

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IC 101 video provides a broad overview of the technology – developed by TTICC

By the Technology Transfer Intelligent Compaction Consortium TPF-5(233): CA, GA, IA, KY, MO, MS, OH, PA, UT, VA, and WisDOT

Date Published: 1/31/2014
Statistics
as of 2/16/2015:
No. of views: 2,457
No. of Countries: 70
TTICC website hosts IC101 video, T2 summaries, and a database of IC projects
IC technology presents a paradigm shift in earthwork construction QC/QA

- Traditional QC/QA @ 1:1,000 to 1,000,000 ft$^3$ to 1:1 using IC measurements

Random testing can be a hit and miss proposition in catching “weak” areas during construction.
IC rollers for soils and aggregates

**Caterpillar:**
CMV, RMV, MDP

**Dynapac:**
CMV, BV

**Bomag:** $E_{VIB}$
IC rollers for soils and aggregates

**Sakai:** CCV

**Case/Ammann:** $k_s$

**Volvo:** CMV

**Hamm:** CMV/OMV
IC rollers for HMA

**Caterpillar:**
CMV, Temp, Pass Count

**Bomag:**
$E_{\text{VIB}}$, Temp, Pass Count

**Sakai:**
CCV, Temp, Pass Count

**Hamm:**
CMV, Temp, Pass Count
Overview of different IC measurements for Soils, Aggregate, and HMA

- CMV and OMV Index Values
- $k_s$ or $E_{vib}$ values
- MDP values

Works in both Static and Vibratory Modes
Works in Vibratory Mode
IC measurements provide repeatable measurements

![Graph showing EVIB measurements with passes and strip lengths.](image)
IC measurements are empirically related to:

- Stiffness / Modulus
- Shear Strength
- Moisture content
- Dry Density - in limited scenarios!

IC measurements are influenced by:

- Roller size
- Vibration amplitude & frequency
- Roller speed
- Soil type and stratigraphy
IC measurements have a deeper measurement influence depth than other *in situ* tests

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Notes:

- Influence depths for LWD/FWD are assumed ~ 1 x B (width)
- Influence depth of soil stiffness gauge ~ 0.23 mm (ASTM D6758-08)
- Maximum penetration depth for Nuclear density gauge = 0.3 m

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Vennapusa et al. (2012)
“Weak” areas in subgrade reflect to the surface

- **Clay Subgrade – Subgrade (10-12 inches)**
- **Aggregate Base – Base Layer 2 (6 inches)**
- **Aggregate Base – Base Layer 1 (6 inches)**

Graphs showing EVIB (MPa) vs. Distance (m):

- **Base Layer 2**: EVIB values range from 0 to 180 MPa.
- **Base Layer 1**: EVIB values range from 0 to 180 MPa.
- **Subgrade**: EVIB values range from 0 to 180 MPa.

Legend:
- **EVIB (MPa)**
- **Distance (m)**
- **a = 0.70 mm**

Additional information:
- **Hard subsurface layer reflecting through surface compaction layer**
- **~ 200 ft**
- **~ 40 ft**
IC output on cohesive embankment construction project show soft area with higher moisture content

RC = 92.1%  
w = 16.3%  
RC = 88.5%  
w = 20.3%  
RC = 96.7%  
W = 17.0%

White et al. (2010)
IC measurements over eight passes on lime stabilized subgrade show compaction improvement

White et al. (2008)
IC measurements identified isolated concrete culvert beneath the base layer

White et al. (2010)
IC measurements correlate better with modulus compared to density measurements.

\[ \text{CMV} = 1.62 \exp^{0.05 \text{LWD-Z3}} \]
\[ R^2 = 0.86 \]
\[ n = 104 \]

\[ R^2 = 0.00 \]
\[ n = 85 \]

White et al. (2010)
IC measurements are related to rut measurements and plate load test moduli.
IC measurements are related to rut measurements and plate load test moduli.

White and Vennapusa (2013)
IC data on multiple embankment layers provides the opportunity for 3D visualization of the data

White et al. (2010)
IC roller pass coverage and MDP values on cohesive embankment project
Perspective from contractor after using the IC roller on an earthwork project in Iowa

• “You can add a lot of road life with (road base) uniformity,” Taylor said. “States spend a lot of their transportation money on maintenance. If the base has no weaknesses, you’ll only have to replace a wear course from time to time. That is a huge cost savings at a time when every dime is being watched.”

• “Most of those passes are a waste,” Taylor said. “Many times on jobsites, we could probably get compaction densities with haul trucks. We might not even need rollers. But the specs call for eight passes, so we make them.”

• “You can’t leave technology like this on the shelf,” he said. “You would have better measurements, and better roads, at a lower cost. Those are tough points to argue.”
Subbase layer conditions show influences values on HMA layer

Reflection of hard spots on the HMA layer

HMA Map

Subbase Map

HMA non-wearing course layer map
\(a = 0.6 \text{ mm}, f = 3000 \text{ vpm}\)

Class 5 aggregate subbase layer map,
\(a = 0.6 \text{ mm}, f = 2500 \text{ vpm}\)

Reflection of hard spots on the HMA layer

Reflection of soft spots on the HMA layer

\[ y = 2.45 \ln(x) + 2.3 \]
\[ R^2 = 0.69 \]

White and Vennapusa (2008)
Roller pass coverage can be improved using IC data on HMA pavements

White et al. (2011)
IC measurements correlate better with modulus compared to density

\[ CCV = 8.0 + 0.01 \times (E_{\text{FWD-K3}}) \]
\[ R^2 = 0.80, \quad n = 48 \]

\[ CCV = -63.1 + 0.83 \times (\% \text{ compaction}) \]
\[ R^2 = 0.37, \quad n = 48 \]

Results on HMA project on US218 Overlay Project, Iowa

White et al. (2011)
### Cumulative Number of Projects

<table>
<thead>
<tr>
<th>Year</th>
<th>Projects</th>
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<tr>
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<td>2013</td>
<td>(200+)</td>
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<tr>
<td>2014</td>
<td>(200+)</td>
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### Project Types

- **70+** Research/Demonstration Projects
- **130+** Pilot Projects with IC Specifications
IC Earthwork Projects in US: 63
IC HMA & Earthwork Projects in US: 9
IC CIR Projects in US: 9
All IC Projects in US: 212

Legend
Material Type
- Unknown
- HMA
- Earthwork
- Earthwork and HMA
- CIR

Center for Earthworks Engineering Research
IOWA STATE UNIVERSITY
IC specifications for Soils and HMA in U.S.

<table>
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<th>Developed By</th>
<th>HMA (Year)</th>
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<td>FHWA (Generic Specs)</td>
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IC increases cost as bid item...what’s it worth?

+1.1%

IC Research/Implementation/Educational Element Ratings – TTICC 2008-2012

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White et al. (2014)
IC Research/Implementation/Educational Element Ratings – TTICC 2014 vs. 2013

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Handling data remains the top challenge followed by Education (Knowledge gaps), Correlations, and need to establish ROI.

Voting performed by 30 representatives from agency, industry, and academia.

Picture at TTICC meeting in Harrisburg, PA on September 3-4, 2014
IC implementation challenges

1. Easy to use data management solutions are needed

2. Engineers need proper training on interpreting IC measurements and relevant software's

3. Calibration protocols with correlating IC measurements with design parameters are needed