Intelligent Construction Data Management (ICDM) Guidelines

For use with Veta 4.0+
2. Government Accession No. N/A  
3. Recipient Catalog No. N/A

4. Title and Subtitle  
Intelligent Compaction Data Guidelines – For Use with Veta 4.0+

5. Report Date  
March 2016

6. Performing Organization Code  
N/A

7. Author(s)  
George Chang, Jason Dick, Jennifer Rutledge  
Transtec Group Inc.

N/A

9. Performing Organization Name and Address  
The Transtec Group, Inc.  
6111 Balcones Drive  
Austin TX 78731

10. Work Unit No. (TRAIS)  
N/A

11. Contract or Grant No.  
MnDOT Contracts

12. Sponsoring Agencies  
Minnesota Dept. of Transportation Consultant Services Section, Mail Stop 680  
395 John Ireland Boulevard  
St. Paul, Minnesota 55155  
Federal Highway Administration  
Office of Pavement Technology  
1200 New Jersey Ave., SE  
Washington, DC 20590

13. Type of Report and Period Covered  
Final report

N/A

15. Supplementary Notes

16. Abstract  
Intelligent compaction (IC) is an emerging technology, and for some applications it is mature enough for implementation in field compaction of pavement materials. IC data are often massive and new to DOTs and industries. Thus, it requires practical guidelines and protocol to assist DOTs and industries to properly manage the IC data in order to provide support for decision-making and quality control (QC) and acceptance. Therefore, there is an immediate need to develop IC Data Guidelines to fulfill these needs, and on a local level, to assist with Minnesota's current IC implementation efforts. This document also includes paver-mounted profilers.  
This document is to provide guidelines for IC data viewing and export in order to make use of a third party, independent IC data management tool, Veta. This document is compatible with Veta 4.0+

17. Key words  
Compaction, intelligent compaction, roller, data, viewing, export, analysis, pavement performance.

18. Distribution Statement  
No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)  
Unclassified

20. Security Classif. (of this page)  
Unclassified

21. No. of Pages  
22. Price
## SI* (MODERN METRIC) CONVERSION FACTORS

### APPROXIMATE CONVERSIONS TO SI UNITS

<table>
<thead>
<tr>
<th>Symbol</th>
<th>When You Know</th>
<th>Multiply By</th>
<th>To Find</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LENGTH</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>in</td>
<td>inches</td>
<td>25.4</td>
<td>millimeters</td>
<td>mm</td>
</tr>
<tr>
<td>ft</td>
<td>feet</td>
<td>0.305</td>
<td>meters</td>
<td>m</td>
</tr>
<tr>
<td>yd</td>
<td>yards</td>
<td>0.914</td>
<td>meters</td>
<td>m</td>
</tr>
<tr>
<td>mi</td>
<td>miles</td>
<td>1.61</td>
<td>kilometers</td>
<td>km</td>
</tr>
<tr>
<td>in²</td>
<td>square inches</td>
<td>645.2</td>
<td>square millimeters</td>
<td>mm²</td>
</tr>
<tr>
<td>ft²</td>
<td>square feet</td>
<td>0.093</td>
<td>square meters</td>
<td>m²</td>
</tr>
<tr>
<td>yd²</td>
<td>square yard</td>
<td>0.836</td>
<td>square meters</td>
<td>m²</td>
</tr>
<tr>
<td>ac</td>
<td>acres</td>
<td>0.405</td>
<td>hectares</td>
<td>ha</td>
</tr>
<tr>
<td>m²</td>
<td>square miles</td>
<td>2.59</td>
<td>square kilometers</td>
<td>km²</td>
</tr>
<tr>
<td><strong>VOLUME</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>fl oz</td>
<td>fluid ounces</td>
<td>29.57</td>
<td>milliliters</td>
<td>mL</td>
</tr>
<tr>
<td>gal</td>
<td>gallons</td>
<td>3.785</td>
<td>liters</td>
<td>L</td>
</tr>
<tr>
<td>ft³</td>
<td>cubic feet</td>
<td>0.028</td>
<td>cubic meters</td>
<td>m³</td>
</tr>
<tr>
<td>yd³</td>
<td>cubic yards</td>
<td>0.765</td>
<td>cubic meters</td>
<td>m³</td>
</tr>
</tbody>
</table>

**NOTE:** volumes greater than 1000 L shall be shown in m³.

| **MASS** | | | | |
| oz | ounces | 28.35 | grams | g |
| lb | pounds | 0.454 | kilograms | kg |
| T | short tons (2000 lb) | 0.907 | megagrams (or "metric ton") | Mg (or "t") |

| **TEMPERATURE (exact degrees)** | | | | |
| °F | Fahrenheit | 5 (F-32)/9 | Celsius | °C |
| | or (F-32)/1.8 |

| **ILLUMINATION** | | | | |
| fc | foot-candles | 10.76 | lux | lx |
| fl | foot-Lamberts | 3.426 | candela/m² | cd/m² |

| **FORCE and PRESSURE or STRESS** | | | | |
| lbf | poundforce | 4.45 | newtons | N |
| lbf/in² | poundforce per square inch | 6.89 | kilopascals | kPa |

### APPROXIMATE CONVERSIONS FROM SI UNITS

<table>
<thead>
<tr>
<th>Symbol</th>
<th>When You Know</th>
<th>Multiply By</th>
<th>To Find</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LENGTH</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mm</td>
<td>millimeters</td>
<td>0.039</td>
<td>inches</td>
<td>in</td>
</tr>
<tr>
<td>m</td>
<td>meters</td>
<td>3.28</td>
<td>feet</td>
<td>ft</td>
</tr>
<tr>
<td>m</td>
<td>meters</td>
<td>1.09</td>
<td>yards</td>
<td>yd</td>
</tr>
<tr>
<td>km</td>
<td>kilometers</td>
<td>0.621</td>
<td>miles</td>
<td>mi</td>
</tr>
<tr>
<td>mm²</td>
<td>square millimeters</td>
<td>0.0016</td>
<td>square inches</td>
<td>in²</td>
</tr>
<tr>
<td>m²</td>
<td>square meters</td>
<td>10.764</td>
<td>square feet</td>
<td>ft²</td>
</tr>
<tr>
<td>m³</td>
<td>cubic meters</td>
<td>1.195</td>
<td>cubic yards</td>
<td>yd³</td>
</tr>
<tr>
<td>ha</td>
<td>hectares</td>
<td>2.47</td>
<td>acres</td>
<td>ac</td>
</tr>
<tr>
<td>km²</td>
<td>square kilometers</td>
<td>0.386</td>
<td>square miles</td>
<td>mi²</td>
</tr>
<tr>
<td>mL</td>
<td>milliliters</td>
<td>0.034</td>
<td>fluid ounces</td>
<td>fl oz</td>
</tr>
<tr>
<td>L</td>
<td>liters</td>
<td>0.264</td>
<td>gallons</td>
<td>gal</td>
</tr>
<tr>
<td>m³</td>
<td>cubic meters</td>
<td>35.314</td>
<td>cubic feet</td>
<td>ft³</td>
</tr>
<tr>
<td>m³</td>
<td>cubic meters</td>
<td>1.307</td>
<td>cubic yards</td>
<td>yd³</td>
</tr>
<tr>
<td>g</td>
<td>grams</td>
<td>0.035</td>
<td>ounces</td>
<td>oz</td>
</tr>
<tr>
<td>kg</td>
<td>kilograms</td>
<td>2.202</td>
<td>pounds</td>
<td>lb</td>
</tr>
<tr>
<td>Mg (or &quot;t&quot;)</td>
<td>megagrams (or &quot;metric ton&quot;)</td>
<td>1.103</td>
<td>short tons (2000 lb)</td>
<td>T</td>
</tr>
</tbody>
</table>

| **TEMPERATURE (exact degrees)** | | | | |
| °C | Celsius | 1.8C+32 | Fahrenheit | °F |

| **ILLUMINATION** | | | | |
| lx | lux | 0.0929 | foot-candles | fc |
| cd/m² | candela/m² | 0.2919 | foot-Lamberts | fl |

| **FORCE and PRESSURE or STRESS** | | | | |
| N | newtons | 0.225 | poundforce | lbf |
| kPa | kilopascals | 0.145 | poundforce per square inch | lbf/in² |

*Si is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)
Intelligent Compaction Data Guidelines

For Use with Veta 4.0+

Prepared by:
George Chang, Jason Dick, Jennifer Rutledge, and Sabrina Garber
The Transtec Group, Inc.
6111 Balcones Dr. Austin, TX 78731

For

Minnesota Department of Transportation
Office of Materials and Road Research
395 John Ireland Blvd, St. Paul, MN 55155

This report represents the results of research conducted by the authors and does not necessarily represent the views or policies of the Minnesota Department of Transportation. This report does not contain a standard or specified technique.
The authors and the Minnesota Department of Transportation do not endorse products or manufacturers. Trade or manufacturers’ names appear herein solely because they are considered essential to this report.
TABLE OF CONTENTS

Acknowledgement .................................................................................................................. 8
Introduction 9
Terminology 10
  Terms ................................................................................................................................. 10
  Acronym ........................................................................................................................... 10
IC Data Basics11
  IC Roller Systems ............................................................................................................. 11
  How IC Rollers Work ......................................................................................................... 12
  Single Drum IC Rollers ...................................................................................................... 14
  Double Drum IC Rollers .................................................................................................... 18
  Positioning Requirements ................................................................................................. 22
Universal IC Data Elements................................................................................................. 28
  IC Data Types .................................................................................................................... 28
  IC Data Contents ............................................................................................................. 32
Ammann/Case IC Data ........................................................................................................ 35
  System Summary ............................................................................................................. 35
  Viewing Program .............................................................................................................. 36
  Data Organization ........................................................................................................... 36
  Data Export Procedures ................................................................................................. 36
Atlas Copco/Dynapac IC Data ............................................................................................ 37
  System Summary ............................................................................................................. 37
  Viewing Program .............................................................................................................. 38
  Data Organization ........................................................................................................... 38
  Data Export Procedures ................................................................................................. 38
Bomag IC Data ...................................................................................................................... 40
  System Summary ............................................................................................................. 40
  Viewing Program .............................................................................................................. 41
  Data Organization ........................................................................................................... 42
  Data Export Procedures ................................................................................................. 42
Caterpillar IC Data ............................................................................................................... 44
  System Summary ............................................................................................................. 44
  Viewing Programs ............................................................................................................ 45
  Data Management ........................................................................................................... 45
  Data Export Procedures ................................................................................................. 47
Hammer/Wirtgen IC Data ..................................................................................................... 50
  System Summary ............................................................................................................. 50
  Viewing Program .............................................................................................................. 50
  Data Organization ........................................................................................................... 51
  Data Export Procedures ................................................................................................. 51
Sakai IC Data 54
  System Summary ............................................................................................................. 54
  Viewing Program .............................................................................................................. 55
  Data Export Procedures ................................................................................................. 56
Trimble IC Data .................................................................................................................... 59
  System Summary ............................................................................................................. 59
  Viewing Programs ............................................................................................................ 60
  Data Management ........................................................................................................... 60
  Data Export Procedures ................................................................................................. 62
TOPCON IC Data ................................................................................................................ 65
System Summary ................................................................. 65
Viewing Program .................................................................... 66
Data Export Procedures .......................................................... 67
VOLVO IC Data ........................................................................ 71
System Summary ...................................................................... 71
Viewing Program ...................................................................... 72
Data Export Procedures .......................................................... 73
MOBA PAVE-IR Thermal Profiler Data ......................................... 75
System Summary ...................................................................... 75
Viewing Programs ..................................................................... 76
Data Management ..................................................................... 76
Data Export Procedures .......................................................... 76

LIST OF TABLES
Table 1. Summary Table for Single-Drum Soils IC Rollers .................. 16
Table 2. Summary Table for Asphalt IC Rollers ................................ 20
Table 3. Essential IC Data Header ............................................... 32
Table 4. Essential Elements for Each IC Data Block ......................... 33

LIST OF FIGURES
Figure 1. Bomag VarioControl System ........................................ 11
Figure 2. Case/Ammann auto-feedback system ............................ 12
Figure 3. Calibration test – with compaction growth curves vs. pass count for Case/Ammann ICMV (kSPD) and in-situ point measurements (ICPF TXDOT demo) ......................... 13
Figure 4. Infrared temperature sensor on a Sakai IC roller ............... 13
Figure 5. Single smooth drum soils IC rollers ............................... 14
Figure 6. Trimble IC retrofit for single drum rollers ....................... 15
Figure 7. TOPCON IC retrofit for single drum rollers ................... 15
Figure 8. Double drum asphalt IC rollers ..................................... 18
Figure 9. Trimble IC retrofit for double drum rollers ..................... 19
Figure 10. TOPCON IC retrofit for double drum rollers ................ 19
Figure 11. Base Station for Ground-based RTK GPS ..................... 22
Figure 12. Network Type of RTK GPS ........................................ 22
Figure 13. RTK GPS receiver and antenna on a Sakai roller (ICPF MnDOT demo) .................. 23
Figure 14. Offsets from antenna for a Sakai roller ......................... 23
Figure 15. An example of network type RTK GPS - OmniSTAR ......... 24
Figure 16. UTM Zones in the US ............................................... 24
Figure 17. UTM Zones in the World .......................................... 25
Figure 18. US State Plane Coordinate (SPC) Zones ....................... 25
Figure 19. A Trimble GPS base station (ICPF MnDOT demo) ............ 26
Figure 20. Validation of roller mounted GPS with a hand-held rover at a marked location on the ground. .................................................. 26
Figure 21. Raw data vs. gridded data .......................................... 28
Figure 22. All passes data vs. final coverage data ............................ 29
Figure 23. An example of pass count map of final coverage data ......... 30
Figure 24. An example of progress of pass count maps of all-passes data ............................................. 31
Figure 25. An example of statistics of final coverage data ................ 34
Figure 26. An example of compaction curves and correlation based on all passes data .............................. 34
Figure 27. Ammann/Case IC rollers and IC system ....................... 35
Figure 28. Dynapac IC system ................................................................. 37
Figure 29. Dynapac Dyn@lzer IC Display ............................................... 38
Figure 30. Bomag IC roller and IC system ............................................... 40
Figure 31. Bomag IC onboard BCM documentation system and control panel in the roller cabinet ...... 41
Figure 32. Hierarchical structure of Bomag IC data ........................................ 42
Figure 33. Caterpillar IC System .............................................................. 44
Figure 34. View data in VisionLink .......................................................... 46
Figure 35. Hamm IC system ................................................................. 50
Figure 36. HAMM HCQ software – Folder structure ...................................... 51
Figure 37. HAMM HCQ software – Open project dialogue ................................ 52
Figure 38. HAMM HCQ software – Export menu ........................................ 53
Figure 39. HAMM HCQ software – IC Export all data .................................... 53
Figure 40. Sakai IC system ................................................................. 54
Figure 41. TopCon sitelink3D web solution .............................................. 55
Figure 42. Trimble retrofit IC System ....................................................... 59
Figure 43. View data in VisionLink .......................................................... 61
Figure 44. TOPCON IC Retrofit system ..................................................... 65
Figure 45. TopCon sitelink3D web solution ............................................... 66
Figure 46. VOLVO IC Retrofit system ...................................................... 71
Figure 47. VOLVO IC Display ............................................................... 72
Figure 48. MOBA PAVE-IR Paver-Mounted thermal profile system ...................... 75
Figure 49. MOBA Pave-IR PPM Software ............................................... 76
Acknowledgement

The authors would like to acknowledge the funding from MNDOT (for version 1.0 and 2.0+) and FHWA (for version 1.0) to support the development of this critical and essential document for implementing intelligent compaction. Future development of Veta will be steered and sponsored by the Transportation Pooled Fund Study to be formed by the Solicitation no. 1831 “Enhancement to the Intelligent Construction Data Management System (Veda) and Implementation”.

The authors would also like to specifically acknowledge the following individuals for their contribution to this document:

- Mn/DOT: Curt Turgeon, Glenn Engstrom, Terry Beaudry, Rebecca Embacher, and Greg Johnson.
- FHWA: Victor (Lee) Gallivan (retired, now Gallivan Consultant).
- Ammann/Case: George Whitaker (Case Construction Equipment, USA); Kuno Kaufmann (Ammann Compaction Ltd. Switzerland).
- BOMAG: Bert Erdmann, Dave Dennison (USA); Hans-Josef Kloubert, Peter Decker, and Hans-Jurgen Wagner (Germany).
- Caterpillar: Bryan Downing, Todd Mansell, Dave King, Allen DeClerk, Kevin Adams, Mark Tarvin, Nick Oetken.
- HAMM/Wirtgen: Richard Evans, Tim Kowalski, Josh Weston (USA); Patrick Gärtnner, Sebastian Villwock, Jens Ruprecht and Axel Romer (Germany).
- Atlas Copco/Dynapac: Tim Hoffman, Vijayakumar Palanisamy, Matt Nelson and Gert Hannson (USA); Fredrik Akesson (Sweden).
- Sakai: Denver Weinstiger, Josh Steele, Done Jones (USA); Yuki Tsukimoto, and Kei Uchiyama (Japan).
- Trimble: Kevin Garcia, Jeff Drake, Chris Wheeler, Tim McClannahan, Pete Kaz, Bruce Hanes (USA); Russell Moffat, Jeff Tait, and Grant Higgins (New Zealand).
- TOPCON: Jan Mennink, Peter Painter, Jim Preston.
- Volvo: Mark Eckert, Bill Laing, Dan Weaver, Fares Beainy.
- MOBA: Paul Angerhofer, James Iano, David Shelsad (USA); Mirko Marx (Germany).
Introduction

This document provides a guideline for intelligent compaction (IC) data and thermal profiling (TP) data viewing and export for systems from Ammann/Case, Bomag, Caterpillar, Atlas Copco/Dynapac, HAMM/Wirtgen, Sakai, and Trimble. This document contains detailed steps for the above operations. This document also includes paver-mounted thermal profilers and scanners from MOBA PAVE-IR.

The goal of this document is to assist users to export IC data files from a vendor-specific program. Therefore, these exported files can be imported to third party, independent software tool for standardized analyses and reporting. To address this need, FHWA and MNDOT have been funded a software tool, Veta, to view and analyze IC and associated geospatial data (such as in-situ test data and test rolling data) for implementation of IC.

This document includes detailed IC data viewing and export procedures to convert IC data files in vendor-specific native formats to ASCII or text files. Specific options and settings for export procedures are mandated in order to obtain consistent file formats.

This report consists of the following chapters:

- IC basics – fundamental of IC technology
- Universal IC data elements – Essential IC data for data exchange
- IC data comparisons – IC data among various vendors
- IC data exports –
  Viewing program, data organization, and data export procedures for the following IC systems:
  - Ammann/Case
  - Bomag
  - Caterpillar
  - Dynapac
  - Hamm/Wirtgen
  - Sakai
  - Trimble
  - TOPCON
  - VOLVO
  - MOBA PAVE-IR (thermal profiler)

Further information regarding Veta is available at www.IntelligentCompaction.com/veta/
## Terminology

### Terms

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>All passes data</td>
<td>Gridded IC data that contain measurements from all passes</td>
</tr>
<tr>
<td>Drum passes</td>
<td>Pass count based on drums</td>
</tr>
<tr>
<td>Final coverage data</td>
<td>Gridded IC data that contain the last pass measurements</td>
</tr>
<tr>
<td>Gridded data</td>
<td>Processed data after mesh refinement</td>
</tr>
<tr>
<td>Machine passes</td>
<td>Pass count based on machines</td>
</tr>
<tr>
<td>Pass Count</td>
<td>Number of roller passes for a given gridded data mesh</td>
</tr>
<tr>
<td>Raw data</td>
<td>Ungridded raw IC data recorded during compaction operations</td>
</tr>
</tbody>
</table>

### Acronym

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACEplus</td>
<td>Ammann Compaction Expert – Plus DCA – S software</td>
</tr>
<tr>
<td>BCM</td>
<td>Bomag Compaction Manager software</td>
</tr>
<tr>
<td>CCV</td>
<td>Compaction Control Value from the Sakai IC system</td>
</tr>
<tr>
<td>CIS</td>
<td>Sakai Compaction Information System</td>
</tr>
<tr>
<td>CMV</td>
<td>Compaction Meter Value from the Caterpillar and Dynapac IC system</td>
</tr>
<tr>
<td>DCA</td>
<td>Dynapac Dynamic Compaction Analyzer software</td>
</tr>
<tr>
<td>EDV</td>
<td>Estimated density values from VOLVO</td>
</tr>
<tr>
<td>Evib</td>
<td>Vibration modulus from the Bomag IC system</td>
</tr>
<tr>
<td>HCQ</td>
<td>HAMM Compaction Quality software</td>
</tr>
<tr>
<td>HMV</td>
<td>HAMM Measurement Value (similar to CMV).</td>
</tr>
<tr>
<td>ICMV</td>
<td>Generic term for Intelligent Compaction Measurement Value</td>
</tr>
<tr>
<td>Kb</td>
<td>Stiffness value from the Ammann/Case IC system (also known as Ks)</td>
</tr>
<tr>
<td>MDP</td>
<td>Machine Drive Power value from the Caterpillar IC system</td>
</tr>
<tr>
<td>VL</td>
<td>Trimble VisionLink web solution</td>
</tr>
<tr>
<td>PPM</td>
<td>MOBA Pave-IR pave project manager software</td>
</tr>
</tbody>
</table>
IC Data Basics

IC Roller Systems

Intelligent Compaction refers to the compaction of road materials, such as soils, aggregate bases, or asphalt pavement materials, using modern vibratory rollers equipped with an in-situ measurement system and feedback control. Global Positioning System (GPS) based mapping is included, as well as software that automates documentation of the results. By integrating measurement, documentation, and control systems, the IC rollers allow for real-time monitoring and correction of the compaction process. IC rollers also maintain a continuous record of (nominally) color-coded plots that indicate the number of roller passes, roller-generated material stiffness measurements, and precise location of the roller. The sampling frequency is normally between 5 to 10 Hz, i.e., once every second or 2 seconds. An example of such an IC roller system is illustrated in Figure 1.

Figure 1. Bomag VarioControl System

(Courtesy of Bomag)

To understand IC data, it is important to understand how IC rollers work first.
How IC Rollers Work

IC rollers utilize the framework of a vibratory roller to provide monitoring of IC measurements as a real-time “visual feedback” to roller operators. IC rollers, if outfitted with “auto-feedback systems”, would automatically adjust roller vibration amplitudes and/or frequencies to optimize compaction. An example of such IC auto-feedback systems is illustrated in Figure 2.

Figure 2. Case/Ammann auto-feedback system.

The precise location of the roller, speed, and number of passes over a given location are mapped using GPS. These systems are commonly used to establish grade and to control other pieces of equipment.

Compaction meters or accelerometers are mounted in or about the drum to monitor applied compaction effort, frequency, and response from the material being compacted. The readings from this instrumentation determine the effectiveness of the compaction process. The methodology to calculate material response to compaction is often proprietary resulting in various types of intelligent compaction measurement values (ICMV).

A calibration procedure is often used to correlate the ICMV to a material modulus or density measured by other (in-situ) test devices. Compaction curves from ICMVs and in-situ test results can be established to indicate the target ICMV and optimum roller passes (see an example in Figure 3).
For asphalt IC rollers, additional temperature instrumentation is used to monitor the surface temperature of the asphalt pavement material. This is critical as vibratory compaction within certain temperature ranges (such as too-cold-to-compact temperatures or tender zones for Superpave mixtures) can have adverse effects. An example of IC temperature instrumentation is illustrated in Figure 4 to measure asphalt surface temperatures by using an infra-red sensor.
Single Drum IC Rollers

IC rollers which compact natural subgrade and aggregate materials use a single drum, as shown in Figure 5 for the participating vendors under this study. The drums can be smooth or fitted with a padfoot shell kit. The Sakai single drum IC roller system, instead, is a padfoot with smooth drum shell kit. Being a more straightforward form of IC, there is currently more experience, available rollers, and construction history for soil and aggregate IC.

Figure 5. Single smooth drum soils IC rollers.
Figure 6. Trimble IC retrofit for single drum rollers.

Figure 7. TOPCON IC retrofit for single drum rollers.
A summary of single drum IC rollers for soil materials is presented below in Table 1:

**Table 1. Summary Table for Single-Drum Soils IC Rollers**

<table>
<thead>
<tr>
<th>Vendor</th>
<th>Model</th>
<th>Model No.</th>
<th>ICMV</th>
<th>Software</th>
<th>Contacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammann/Case</td>
<td>ACEplus</td>
<td>SV212, SV212(PD)</td>
<td>Kb (MN/m)</td>
<td>ACEplus</td>
<td>George Whitaker</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(262) 636-4959</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><a href="mailto:george.whitaker@cnh.com">george.whitaker@cnh.com</a></td>
</tr>
<tr>
<td>BOMAG</td>
<td>VarioControl</td>
<td>BW213-4BVC</td>
<td>Evib (MN/m²)</td>
<td>BCM05</td>
<td>Bert Erdmann</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(309) 883-2989</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><a href="mailto:bert.erdmann@bomag.com">bert.erdmann@bomag.com</a></td>
</tr>
<tr>
<td>Caterpillar</td>
<td>CAT Compaction</td>
<td>CS44-CS78, CP54-CP74</td>
<td>CMV</td>
<td>VisionLink</td>
<td>Todd Mansell</td>
</tr>
<tr>
<td></td>
<td>AccuGrade</td>
<td></td>
<td></td>
<td></td>
<td>(763) 315-5518</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><a href="mailto:Mansell_Todd_W@cat.com">Mansell_Todd_W@cat.com</a></td>
</tr>
<tr>
<td>Dynapac/Atlas Copco</td>
<td>DCA-S</td>
<td>CA1500-CA6500</td>
<td>CMV</td>
<td>DCA-S</td>
<td>Tim Hoffman</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(303) 248-9029</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><a href="mailto:tim.hoffman@us.atlascopco.com">tim.hoffman@us.atlascopco.com</a></td>
</tr>
<tr>
<td>HAMM(Wirtgen Group)</td>
<td>HCQ</td>
<td>All 3000 series</td>
<td>HMV</td>
<td>HCQ</td>
<td>Tim Kowalski</td>
</tr>
<tr>
<td></td>
<td></td>
<td>rollers</td>
<td></td>
<td></td>
<td>(615) 594-4604</td>
</tr>
<tr>
<td></td>
<td></td>
<td>All new H series</td>
<td></td>
<td></td>
<td><a href="mailto:tkowalski@Wirtgenamerica.com">tkowalski@Wirtgenamerica.com</a></td>
</tr>
<tr>
<td>Sakai</td>
<td>CIS</td>
<td>SV640 series, SV540 series</td>
<td>CCV</td>
<td>Sitelink3D</td>
<td>Josh Steele</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(770) 773-6133</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><a href="mailto:j-steele@sakaiamerica.com">j-steele@sakaiamerica.com</a></td>
</tr>
<tr>
<td>Volvo</td>
<td>Trimble retrofit</td>
<td>SD70D, SD77DX, SD75, SD100D, SD105DX, SD115, SD160DX, SD200DX</td>
<td>CMV</td>
<td>VisionLink</td>
<td>Mark Eckert</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(717) 372-9762</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><a href="mailto:mark.eckert@volvo.com">mark.eckert@volvo.com</a></td>
</tr>
<tr>
<td>TOPCON*</td>
<td>TOPCON</td>
<td>TOPCON retrofit</td>
<td>CMV</td>
<td>Sitelink3D</td>
<td>Jan Mennink</td>
</tr>
</tbody>
</table>

16
<table>
<thead>
<tr>
<th>Vendor</th>
<th>Model</th>
<th>Model No.</th>
<th>ICMV</th>
<th>Software</th>
<th>Contacts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>retrofit</td>
<td></td>
<td></td>
<td></td>
<td>(925) 245-8438 <a href="mailto:jmennink@topcon.com">jmennink@topcon.com</a></td>
</tr>
<tr>
<td>Trimble*</td>
<td>Trimble retrofit</td>
<td>CCSFlex for soils compactors</td>
<td>CMV</td>
<td>VisionLink</td>
<td>Jeff Drake (720) 587-4569 <a href="mailto:jeff_drake@trimble.com">jeff_drake@trimble.com</a></td>
</tr>
</tbody>
</table>

Notes:
- ICMV: Intelligent compaction measurement values; a generic term for all IC measurements
- ACEplus: Ammann Compaction Expert – Plus DCA – S
- GPS: Global Positioning System
- Evib: Vibration Modulus
- CMV: Caterpillar and Dynapac Compaction Meter Value
- MDP: Caterpillar Machine Drive Power
- CIS: Sakai Compaction Information System
- CCV: Sakai Compaction Control Value
- DCA: Dynamic Compaction Analyzer
- HCQ: HAMM Compaction Quality
- HMV: HAMM Measurement Value

For further information: Contact Dr. George Chang: US (512) 451-6233 ext. 227, gkchang@thetranstecgroup.com
Double Drum IC Rollers

IC rollers used to compact asphalt pavement materials use a dual-drum configuration, as shown in Figure 8 for the participating vendors under this study. Monitoring and automating feedback controls for two vibratory drums add complexity to the IC process for asphalt pavement materials. In addition, timing of rolling and mat temperature is critical when compacting asphalt pavement materials. For this reason, additional instrumentation and considerations are necessary when utilizing IC technology for these materials.

Figure 8. Double drum asphalt IC rollers.
Figure 9. Trimble IC retrofit for double drum rollers.

Figure 10. TOPCON IC retrofit for double drum rollers.
A summary of IC rollers for asphalt materials is presented below in Table 2:

**Table 2. Summary Table for Asphalt IC Rollers**

<table>
<thead>
<tr>
<th>Vendor</th>
<th>Model</th>
<th>Model No.</th>
<th>ICMV</th>
<th>Software</th>
<th>Contacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOMAG</td>
<td>AsphaltManager</td>
<td>BW190AD-4AM, BW278AD-AM</td>
<td>Evib</td>
<td>BCM05</td>
<td>Bert Erdmann (309) 883-2989</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(MN/m²)</td>
<td></td>
<td><a href="mailto:bert.erdmann@bomag.com">bert.erdmann@bomag.com</a></td>
</tr>
<tr>
<td>Caterpillar</td>
<td>CAT Compaction</td>
<td>CB44B, CB54B, CD44B, CD54B, CB54, CB54XW, CB64, CB64B, CB66B, CB68B</td>
<td>CMV</td>
<td>VisionLink</td>
<td>Bryan Downing (763) 315-5546</td>
</tr>
<tr>
<td></td>
<td>Control and AccuGrade</td>
<td></td>
<td></td>
<td></td>
<td><a href="mailto:Downing_Bryan_J@cat.com">Downing_Bryan_J@cat.com</a></td>
</tr>
<tr>
<td>HAMM(Wirtgen Group)</td>
<td>HCQ</td>
<td>HD+90 - HD+140 (90, 110, 120, 140), HD+70i - HD+140i (70, 80, 90, 110, 120, 140), HD+120, HD+140</td>
<td>HMV</td>
<td>HCQ</td>
<td>Tim Kowalski (615) 594-4604</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><a href="mailto:tkowalski@Wirtgenamerica.com">tkowalski@Wirtgenamerica.com</a></td>
</tr>
<tr>
<td>Sakai</td>
<td>CIS</td>
<td>SW880-1, SW990-1, SW850-II, SW770HF, SW652-1</td>
<td>CCV</td>
<td>SiteLink3D</td>
<td>Josh Steele (770) 773-6133</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><a href="mailto:j-steele@sakaiamerica.com">j-steele@sakaiamerica.com</a></td>
</tr>
<tr>
<td>Volvo</td>
<td>Trimble retrofit</td>
<td>DD112HF, DD118HF, DD118HFA, DD132HF, DD138HF, DD138HFA, DD110B, DD120B, DD140B</td>
<td>CMV</td>
<td>VisionLink</td>
<td>Mark Eckert (717) 372-9762</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><a href="mailto:mark.eckert@volvo.com">mark.eckert@volvo.com</a></td>
</tr>
<tr>
<td>Vendor</td>
<td>Model</td>
<td>Model No.</td>
<td>ICMV</td>
<td>Software</td>
<td>Contacts</td>
</tr>
<tr>
<td>----------</td>
<td>------------------</td>
<td>-----------</td>
<td>------</td>
<td>-------------</td>
<td>------------------------------------</td>
</tr>
<tr>
<td>TOPCON*</td>
<td>TOPCON retrofit</td>
<td>TOPCON retrofit</td>
<td>CMV</td>
<td>Sitelink3D</td>
<td>Jan Mennink</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(925) 245-8438 <a href="mailto:jmennink@topcon.com">jmennink@topcon.com</a></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trimble*</td>
<td>Trimble retrofit</td>
<td>CCSFlex and CCS900</td>
<td>CMV</td>
<td>VisionLink</td>
<td>Kevin Garcia</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(303) 635-8834 <a href="mailto:kevin_garcia@trimble.com">kevin_garcia@trimble.com</a></td>
</tr>
</tbody>
</table>

Notes:
- IC-MV: Intelligent compaction measurement values; a generic term for all IC measurements
- Evib: Vibration modulus
- CMV: Caterpillar and Dynapac Compaction Meter Value
- Sakai CIS: Sakai Compaction Information System
- Sakai CCV: Sakai Compaction Control Value
- HCQ: HAMM Compaction Quality
- HMV: HAMM Measurement Value

For further information: Contact Dr. George Chang: US (512) 451-6233 ext. 227, gkchang@thetranstecgroup.com
Positioning Requirements

High precision positioning data collection is the most critical element in IC implementation. To ensure accurate and consistent data collection, the following capabilities for the roller positioning systems are required:

- RTK-GPS (Real Time Kinematic-GPS) systems or equivalent on IC rollers with either ground-based GPS base station or network type of reference system.
- Recommended positioning system reports and records values in Northing/Easting or longitude/latitude in UTM coordinates or state plane coordinates for the project site.
- If an offset is necessary between GPS antenna and the ICMV measuring drum(s), it must be input and validated.
- Hand-held rovers are required for both validation tests and point measurements at locations where in-situ tests are performed using conventional methods.

![Figure 11. Base Station for Ground-based RTK GPS.](image1)

![Figure 12. Network Type of RTK GPS.](image2)
Figure 13. RTK GPS receiver and antenna on a Sakai roller (ICPF MnDOT demo).

Figure 14. Offsets from antenna for a Sakai roller.
The UTM (Universal Transverse Mercator) coordinate system zone is designated when the UTM grids are produced based on the geodetic GPS data, longitudes and latitudes. The conversion is based on The World Geodetic System 84 (WGS84). US State plane is also allowable which is based on North American Datum of 1983 (NAD83). See Figure 16 for the UTM zones in the US and Figure 17 in the world. Users can normally select the desired UTM zone in the settings of vendors IC field software program.

**Figure 15. An example of network type RTK GPS - OmniSTAR.**

**Figure 16. UTM Zones in the US.**
Figure 17. UTM Zones in the World.

Figure 18. US State Plane Coordinate (SPC) Zones.
Technical assistance by roller vendors or GPS equipment manufacturers is often recommended:

- On-site staff with sufficient technical knowledge to set up roller mounted GPS equipment and provide input for equipment operation during the first day of the field operation.
- Contact information for personnel with sufficient technical knowledge to assist the authors with technical questions during field testing when on-site technical assistance is not available.

Use of a GPS base station radio operating at 900MHz or higher is recommended (see Figure 19). Many GPS vendors offer solutions such as Trimble, TopCon, Leica, and etc. In addition to setting up GPS base stations, there can also be other options such as virtual reference station (VRS) and internet-based correction signals. Prior to the beginning of IC data collection during the compaction operation, the GPS setup must be validated using a survey grade hand-held GPS “rover” unit to ensure that the roller-mounted GPS is providing accurate positioning data. (Figure 20).

**Figure 19. A Trimble GPS base station (ICPF MnDOT demo).**

**Figure 20. Validation of roller mounted GPS with a hand-held rover at a marked location on the ground.**
The GPS setup and verification can be summarized in the following steps:

1. Select a Coordinate System
2. Select Location(s) for GPS Base Station
3. Set up a GPS Base Station (Initialization takes 30 to 60 seconds, and re-initialization when machine first powers up and loss-of-lock)
4. Set up Hand-held GPS Receiver (rover)
5. Set up GPS Receiver on IC Roller
6. Verify GPS Measurements
   - Move the IC roller around until the GPS header computation is initialized.
   - Move the IC roller and park at a selected location. Record the GPS measurements from the IC roller ensuring the distance offsets are applied so that the GPS coordinate is at the center or at left/right edges of the front drum.
   - Mark two locations on the ground adjacent to the right and left edges of the front drum contact patch. Move the IC roller from the marked locations.
   - Use a hand-held rover to measure at the marked locations.
   - Average the rover GPS measurements if the roller GPS measurement is at the center of the front drum.
   - The differences between the roller GPS and rover measurements shall be within ±12 inches (±300 mm) for northing and easting.
**Universal IC Data Elements**

**IC Data Types**

IC data are generally in two forms: *Raw Data* and *Gridded Data*.

- **Raw Data**: Raw data are recorded during compaction operations prior to the gridding process. Raw data consists of one data point for a roller drum at approximately 10 Hz or 1 ft. interval. Therefore, the data mesh or data foot print is about the drum width by 1 ft. Both vibratory and non-vibratory data are normally recorded.

- **Gridded Data**: Gridded data are processed from raw data by refining the data mesh. Raw measurement data are duplicated over the meshes for the entire drum width (i.e., multiple data points cover the drum width). The refined data mesh size is generally 1 ft. by 1 ft. in horizontal directions. One of the purposes of this process is to track partial drum overlaps among passes. It is anticipated that the gridding rule will be included in a future standard.

The raw data and gridded data are illustrated in Figure 21.

![Figure 21. Raw data vs. gridded data.](image-url)
The **gridded data** are in two sub-forms:

- **All-Passes Data**: All-passes data include all measurements within a given mesh. All passes are generally used to build compaction curves in order to establish rolling patterns.

- **Final Coverage Data**: Final coverage data contain measurements from the last passes within a given mesh. Final coverage data can be used to assess the end results of compaction.

Gridded all-passes data and final coverage data are illustrated in Figure 22.

![Gridded All-Passes Data vs. Gridded Final Coverage Data](image)

**Figure 22. All passes data vs. final coverage data.**

**Starting Veta 4.0+, only All-Passes Data is required to import to Veta** as the Final Coverage Data will be automatically generated based on the All-Passes Data.

**It is anticipated Only Raw Data will be required to import to Veta in the future.**
Figure 23. An example of pass count map of final coverage data.
Figure 24. An example of progress of pass count maps of all-passes data.
IC Data Contents

The following requirements are consistent with those in the AASHTO PP 81-14 Standard Practice for Intelligent Compaction Technology for Embankment and Asphalt Pavement Applications.

For the purpose of effective data exchange, the IC data files need to include essential IC data header and essential data blocks. Data header consists of information regarding the measurement data in the data blocks (Table 3). Data blocks consist of all measurement data while each measurement point or block includes all essential elements (Table 4).

Table 3. Essential IC Data Header

<table>
<thead>
<tr>
<th>No.</th>
<th>Field Name/Definition/Unit</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Section title</td>
<td>I-95 NB S1</td>
</tr>
<tr>
<td>2</td>
<td>Layer number</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Machine trade name</td>
<td>My Brand</td>
</tr>
<tr>
<td>4</td>
<td>Machine ID (serial number)</td>
<td>Machine1234</td>
</tr>
<tr>
<td>5</td>
<td>Drum configuration (1: single drum; 2: double-drum)</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>Drum width (m)</td>
<td>2.007</td>
</tr>
<tr>
<td>7</td>
<td>Drum diameter (m)</td>
<td>1.2</td>
</tr>
<tr>
<td>8</td>
<td>Machine weight (metric ton)</td>
<td>14.0</td>
</tr>
<tr>
<td>9</td>
<td>Data reporting interval in the direction 90 degrees to the roller moving direction (mm)</td>
<td>30</td>
</tr>
<tr>
<td>10</td>
<td>Data reporting interval in the roller moving direction (mm)</td>
<td>30</td>
</tr>
<tr>
<td>11</td>
<td>EPSG coordinate system code (0 for non-EPSG coordinate system)</td>
<td>3745</td>
</tr>
<tr>
<td>12</td>
<td>Non-EPSG coordinate system zone name</td>
<td>NA</td>
</tr>
<tr>
<td>13</td>
<td>Name index of ICMV (1: Kb, 2: Evib, 3: CMV, 4: HMV, 5: CCV, 6: MDP, 7: Other)</td>
<td>1</td>
</tr>
<tr>
<td>14</td>
<td>IC Data type (1: Raw data, 2: Gridded all–passes data, 3: Gridded final coverage data)</td>
<td>3</td>
</tr>
<tr>
<td>15</td>
<td>Number of IC data points</td>
<td>100000</td>
</tr>
</tbody>
</table>

Notes:
- Item 2: A layer is a construction layer that may consist of one or more lifts.
- Item 3: The machine trade name is for the host roller regardless whether it is a retrofit system or not.
- Item 4: Machine ID is required to filter data if a project file consists of data from multiple machines.
- Items 6 to 8: Machine weight, drum width, and drum diameter are used to compute the Nijboer number to assess the risk of ground or asphalt buckling or cracking during compaction.
- Items 9 and 10: Data reporting intervals are applied to both raw and gridded IC data.
- Item 11: The European Petroleum Survey Group (EPSG) geodetic parameter dataset is a structured dataset of coordinate reference systems and coordinate transformations. EPSG code covers GPS, UTM, State plane NAD 1983, and others. For example, EPSG 3745 represents UTM 15N.
- Item 12: An example of non-EPSG is Minnesota Dodge county coordinate system that can be parsed and recognized by Veta.
- Item 13: ICMV can be either from OEM or a retrofit system. ICMV for a retrofit system can be from a different manufacturer than the one for the machine.
Table 4. Essential Elements for Each IC Data Block.

<table>
<thead>
<tr>
<th>No.</th>
<th>Data Field Name/Definition/Unit</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Date Stamp (YYYYMMDD)</td>
<td>20080701</td>
</tr>
<tr>
<td>2</td>
<td>Time Stamp (HHMMSS.SSS)</td>
<td>090504.001</td>
</tr>
<tr>
<td>3</td>
<td>Longitude (decimal degrees) or Easting (m)</td>
<td>94.85920403</td>
</tr>
<tr>
<td>4</td>
<td>Latitude (decimal degrees) or Northing (m)</td>
<td>45.22777335</td>
</tr>
<tr>
<td>5</td>
<td>Height of ground above WGS84 geoid (m)</td>
<td>339.945</td>
</tr>
<tr>
<td>6</td>
<td>GPS flag (1: valid, 2: invalid)</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>Construction lift number</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>Current compaction mode (1: steel vibration drum; 2: steel oscillation drum, 3: static drum; 4: pneumatic tire)</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>Current pass number</td>
<td>5</td>
</tr>
<tr>
<td>10</td>
<td>Direction index (1: forward, 2: reverse)</td>
<td>1</td>
</tr>
<tr>
<td>11</td>
<td>Roller speed (km/h)</td>
<td>4.0</td>
</tr>
<tr>
<td>12</td>
<td>Vibration frequency (vpm)</td>
<td>3500.0</td>
</tr>
<tr>
<td>13</td>
<td>Vibration amplitude (mm)</td>
<td>0.6</td>
</tr>
<tr>
<td>14</td>
<td>Temperature flag (1: valid, 2: invalid)</td>
<td>1</td>
</tr>
<tr>
<td>15</td>
<td>Temperature (°C)</td>
<td>120.0</td>
</tr>
<tr>
<td>16</td>
<td>ICMV flag (1: valid, 2: invalid)</td>
<td>1</td>
</tr>
<tr>
<td>17</td>
<td>ICMV for the last vibratory pass</td>
<td>20.0</td>
</tr>
</tbody>
</table>

Notes:

- Items 1 and 2: The date/time need to be recorded as local time.
- Item 2: The resolution of 0.001 second is required to differentiate data points during post processing for viewing and analysis.
- Items 3 to 4: The storage can be either GPS or coordinates, but the numbers need to be precise within 1cm. For example, at least 8 decimal places are needed for GPS.
- Item 6: GPS flag is invalid when the status is at non-RTK mode caused by losing GPS correction signals or others.
- Item 7: Construction lift number is required even when there is only one lift for a specific layer. Both layer and lift numbers are counted in consecutive sequence from the bottom up.
- Item 9: Current roller pass number is the counts of roller machine passes, instead of individual drum passes, within a given mesh for a construction lift. It is an accumulated value of passes of all compaction modes. For example, a total passes of 5 consists of 3 vibratory passes and 2 static passes.
- Item 11: Direction index is referenced to machine configuration/movement instead of traffic directions.
- Item 16: Temperature flag is invalid when temperature sensors or recording is faulty.
- Item 17: ICMV flag is invalid when starting/stopping a machine or when sensors are faulty or absent.
- Item 18: The unit of ICMV should be either unitless or in SI. That is Kb [MN/m] and Evib [MN/m²].
- Accumulated vibratory passes will be needed in the future for using all passes data to produce a compaction curve (i.e., ICMV vs. pass counts) and for using final coverage data to access the end results of ICMV.
Figure 25. An example of statistics of final coverage data.

Figure 26. An example of compaction curves and correlation based on all passes data.
Ammann/Case IC Data

The import of the Ammann IC data to Veta is not available.

System Summary

The Ammann/Case IC system can be summarized in Figure 27.

![Ammann/Case IC rollers and IC system.](image)
**Viewing Program**

With positioning information and a graphical representation of the measurement data, ACEplus enables a fast, simple interpretation of the compaction work performed. Users are encouraged to use the Ammann ACEPlus software to view the data and confirm the desired data as a part of the data QA process. ACEplus allows users to “replay” the IC data. Consult the Ammann vendor for detailed software operation as there is currently no users’ manual available.

**Data Organization**

Ammann IC data can be downloaded from the onboard display unit using a USB flash drive. Ammann data are contained under a folder for a specific project. The files include a text file (*.log), XML file, and a subfolder for “cache.” The *.log file consists of IC data while the XML contain header information.

**Data Export Procedures**

Unlike other IC data, the above Ammann IC data files are ready for import and there is no need for using the Ammann IC software or requiring additional data export steps.

Veta currently does not import Ammann IC data.
Atlas Copco/Dynapac IC Data

System Summary

The Dynapac IC system is summarized in Figure 28.

Figure 28. Dynapac IC system.
Viewing Program

The Dyn@lyzer IC system displays and stores ICMV (CMV, Evib1, or Evib2) and temperature (for asphalt) data along with number of roller passes, vibration amplitude, vibration frequency, roller speed, etc.

![Dynapac Dyn@lyzer IC Display](image)

Figure 29. Dynapac Dyn@lyzer IC Display

Data Organization

The Dyn@lyzer IC data is stored in a database under Project/Object/Layer. The original file can be exported to text files.

The Dyn@lyzer IC system allows users to prepare a new project with different objects, layers and sections prior to the field work. A grid system can selected to be used for positioning including UTM coordinates. Other grid systems can also be used based on transformation from WGS 84 to the desired local grid systems.

The Dyn@lyzer documentation structure can be transferred to the roller computer using a USB memory stick after the data are recorded. Further objects, layers and sections can be added in the roller on-board computer if needed.

Data Export Procedures

Once the data is recorded, it can be viewed and analysed on the roller on-board computer. Users are strongly recommended to transfer the data to the office computer using a USB memory stick.

To export from database to text files:
1. Open a project in Dyn@lyzer software and select a desired Project/Object/Layer.

2. Connect USB-stick

3. Click “Export Text File”

The exported text data can be imported to Veta for further analysis.
Bomag IC Data

System Summary

The Bomag IC system is summarized in Figure 30.

Roller

![Double drum roller](image1.png) ![Single smooth drum roller](image2.png)

double drum  single smooth drum

Control Panel

![Control panel](image3.png)

Documentation

![Documentation](image4.png)

BCM-05 Office 4

Figure 30. Bomag IC roller and IC system.
The Bomag IC onboard documentation system is called BCM system (currently Version 4.0.2623 +). The system is designed to accurately record and store continuous compaction data (Evib, type of roller, frequency, amplitude, and operating speed) and the corresponding roller locations from GPS signals. The tracking of the roller is achieved with a mobile GPS receiver on the roller. If higher GPS accuracy is needed, a stationary reference receiver or a GPS reference service (base station) can be used. Depending on the available onsite GPS, the accuracy of locations can be within 2 inches. The BCM system offers convenient measurement data management and extensive documentation and evaluation possibilities. After data has been transferred to a computer via USB memory sticks, BCM Office software can then be used to perform further analysis (see Figure 31).

Figure 31. Bomag IC onboard BCM documentation system and control panel in the roller cabinet.
**Data Organization**

The Bomag IC data are organized in a hierarchical data structure: project, lot, layer, and field. The data management structure needs to be setup prior to the compaction and data collection. An example of the hierarchical data structure is shown on the BCM Open dialogue in Figure 32.

![Hierarchical structure of Bomag IC data](image)

**Figure 32. Hierarchical structure of Bomag IC data.**

**Data Export Procedures**

Bomag IC data can be downloaded from the onboard display unit using a USB flash drive. Users should be cautious about how to setup BCM prior to data collection during compaction following a hierarchical project structure: Project/Lot/Layer/Field. The downloaded files need to be restored to a computer by using the BCM Office software prior to the export process. Consult the BCM Office users’ manual for further details.

*View the restored data using the BCM Office software:*

1. Use File/Open, and select a specific Project/Lot/Layer/Field.
2. Inspect the data by using various viewing options.
Export Bomag IC data to CSV files using the BCM Office software:

1. Select File/Export/CSV from the software menu.

2. Under the “Values available for export”, select all items and click the double-arrow button pointing to the right.

3. Select “Export data over complete width (grid data)”. 

4. Select the default “,” as Delimiter.

5. Select “All passes”.

6. Click the folder icon and rename the export file as “*.csva” (CSV files for all passes data).

7. Click Export to export to the csva file.

8. Select Last Pass and repeat the process to export final coverage data and save as *.csvp file.

9. Both the *.csva and *.csvp files can be readily imported to Veda 4.0+. 

---

![Image of BCM Office Version 4.0 interface with Export and CSV options highlighted]
Caterpillar IC Data

System Summary

The summary of the Caterpillar IC system is presented as follows.

Rollers

Single smooth drum

Single drum pad foot

Double drum

Onboard Display

Documentation

VisionLink

Figure 33. Caterpillar IC System.
Viewing Programs

The Caterpillar IC system uses the Trimble CCS 900 as an onboard, in-cab, three dimensional (3D) display. The display is equipped with a keypad that allows the operator to interface with the system using push buttons and a color monitor. The operator can then view real-time information, such as machine location and speed, drum amplitude, vibration frequency, and number of passes, relative to the design plan. This system uses 3D design files that are stored on a CompactFlash data card and inserted into a slot next to the keypad.

Figure 32. CS900 onboard display.

VisionLink is a web-based solution that includes IC data management for the Trimble retrofit IC system. IC data can be wirelessly transmitting IC data to the VisionLink at a 5-10 min. interval when cellular coverage is available. Manual upload to VisionLink will be needed if cellular coverage is unavailable. In this case, users need to transfer the *.tag files from the CS900 unit, use the Trimble Business Center to generate a DC file, then logon to VisionLink to create an appropriate project and upload the files. Contact Caterpillar/Trimble/SITECH for further details.

Data Management

The Caterpillar IC data are managed with the VisionLink.

Very Important: Prior to any compaction for a given lift of a section, a specific “On Machine Design” needs to be set. Then, select the desired “Design” under the Project Data Filters prior to the data export. This would bypass current issues with time stamps and layers/lifts. Note that Veta current analyzes one lift at a time.
Figure 34. View data in VisionLink.
Data Export Procedures


2. Make sure the desired “Design” under the Project Data Filters is selected prior to the data export.

3. Ensure the No Lift Filter is selected.

4. Select Administration/Export from the menu.
5. Within the “Management Exports/Export Type” dialog, select the Export to Veta, Coordinates (Latitude/Longitude), and Output (All Passes) to export the all passes data. Click “Next – Details”

6. Within the “Management Exports/Details” dialogue, click “Next – Summary”

7. Within the “Management Exports/Summary” dialog, click “Export”
8. Select a target folder to save the exported zip file.

9. Click “Back – Details”, then “Back – Export Type” and Repeat the above steps for “Final Coverage”

10. Unzip both the last pass and all passes files to csv files. These csv files are ready to be imported to Veta.
Hamm/Wirtgen IC Data

System Summary

The Hamm/Wirtgen IC system is summarized in Figure 35.

Rollers

| Double drum | Single smooth drum |

Onboard Display

Documentation

Figure 35. Hamm IC system.

Viewing Program

The HCQ-GPS Navigator software allows convenient data archival and evaluation:
- Logging of diverse data during the compaction process, e.g. DGPS position, compaction value, driving speed, frequency, amplitude, roller type.
- Geolines or graphics can be additionally provided in the project for orientation.
- Filtering of data based on dates/time, vibration status, temperature, and heights.
- Calibration against plate loading tests.
- Convenient data archival with data transfer via USB interface.
- Creation of result logs in digital format or as printouts.
- Export data for Veta analysis.
**Data Organization**

Hamm IC data need to transferred and stored locally under the following folder.
"C:\Users\Public\HammHcqData\Project"

Hamm IC data are stored in a folder that contains 7 sub-folders: Calibration, Dictionary, ErrorData, Export, PlanningData, Project, and Settings. The raw IC data are under the “Project” folder. The export files, once done, are in the Export subfolder.

![Folder Structure Image]

**Figure 36.** HAMM HCQ software – Folder structure.

**Data Export Procedures**

HAMM IC data can be downloaded from the onboard display unit using a USB flash drive. Native Hamm IC data are organized in folders for any given project. The raw IC data are stored in binary files with the “hcq” extension under the “Project” subfolder. No naming convention is required.  

*View Hamm *.hcq data using the HCQ software:*

1. Select File/Open Project from the menu.
2. Under the “Open project” dialogue, select the Project and Section and load the data.
3. Adjust the view setting to view desired IC maps. Note that HCQ allows split screens to view two types of data maps at the same time.
4. Use the Analysis/Filter setup to filter and view desired data.
Figure 37. HAMM HCQ software – Open project dialogue.

Export HAMM *.hcq data to text files using the HCQ software:

1. Select File/IC Export All Data to export all-passes data.
2. A “File > IC Export Dialogue” would appear and show progress bars. Click the OK button once the Export is finished.
3. Use Windows’ file explorer to navigate to "C:\Users\Public\HammHcqData\Project" and select the current project name and its Export subfolder.
4. The exported data will be saved under the Export subfolder with *_amd.vexp as filename extension. Use only the front drum data to import to Veta. Normally the file name would consist of date stamp and “F” instead of “R” (e.g. Mainline Surface_IC_2070045F(2)_1_amd.vexp).
Figure 38. HAMM HCQ software – Export menu.

Figure 39. HAMM HCQ software – IC Export all data.
The Sakai IC system is summarized in Figure 40.

**Roller**

![Double drum roller](image1)

![Single drum pad foot](image2)

**Control Panel**

![Control panel](image3)

**Documentation**

![TopCon SiteLink web service with the ability to export files to Veta](image4)

*Figure 40. Sakai IC system.*
**Viewing Program**

The Sakai IC documentation system is TopCon SiteLink web service with the ability to export files to Veta.

![Sign In page of TopCon sitelink3D web solution](image)

*Figure 41. TopCon sitelink3D web solution.*
Data Export Procedures

1. Select “Reports” from the Menu.

2. Click “New Report” on the REPORTS screen.

3. Select “Pln Report”
4. Provide report Description, select a region, select As Build Layer, select PLN format (all-passes), Set start/end Date/time, then click Generate Report.
5. The Report Generation is under progress with notes “Running (started a few seconds ago)”

6. Once it is complete, a report range would appear.

7. Click the gear wheel symbol and select Email.

8. Enter the email address for receiving a download link for the PLN report.

9. Download the report.zip and unzip the PLN file to your local computer. Rename the report.pln file to a more descriptive file name. The PLN file can then be readily imported to Veta.
Trimble IC Data

System Summary

The summary of the Trimble IC retrofit system is presented as follows.

Rollers

for double drum rollers

for single drum rollers

Onboard Display

Documentation

VisionLink

Figure 42. Trimble retrofit IC System.
**Viewing Programs**

Trimble retrofit IC systems use the Trimble CCS 900 as an onboard, in-cab, three dimensional (3D) display. The display is equipped with a keypad that allows the operator to interface with the system using push buttons and a color monitor. The operator can then view real-time information, such as machine location and speed, drum amplitude, vibration frequency, and number of passes, relative to the design plan. This system uses 3D design files that are stored on a CompactFlash data card and inserted into a slot next to the keypad.

![Figure 32. CS900 onboard display.](image)

VisionLink is a web-based solution that includes IC data management for the Trimble retrofit IC system. IC data can be wirelessly transmitting IC data to the VisionLink at a 5-10 min. interval when cellular coverage is available. Manual upload to VisionLink will be needed if cellular coverage is unavailable. In this case, uses need to transfer the *.tag files from the CS900 unit, use the Trimble Business Center to generate a DC file, then logon to VisionLink to create an appropriate project and upload the files. Contact Caterpillar/Trimble/SITECH for further details.

**Data Management**

The Caterpillar IC data are managed with the VisionLink.

**Very Important**: Prior to any compaction for a given lift of a section, a specific “On Machine Design” needs to set. Then, select the desired “Design” under the Project Data Filters prior to the data export. This would bypass current issues with time stamps and layers/lifts. Note that Veta current analyzes one lift at a time.
Figure 43. View data in VisionLink.
Data Export Procedures


2. Make sure the desired “Design” under the Project Data Filters is selected prior to the data export.

3. Ensure the No Lift Filter is selected.

4. Select Administration/Export from the menu.
5. Within the “Management Exports/Export Type” dialog, select the Export to Veta, Coordinates (Latitude/Longitude), and Output (All Passes) to export the all passes data. Click “Next – Details”

6. Within the “Management Exports/Details” dialogue, click “Next – Summary”

7. Within the “Management Exports/Summary” dialog, click “Export”
8. Select a target folder to save the exported zip file.

9. Click “Back – Details”, then “Back – Export Type” and Repeat the above steps for “Final Coverage”

10. Unzip both the last pass and all passes files to csv files. These csv files are ready to be imported to Veta.
TOPCON IC Data

System Summary

The TOPCON IC retrofit system is summarized in Figure 40.

Roller

IC retrofit can be mounted on selected roller models.

Onboard Display

Documentation

TopCon SiteLink web service with the ability to export files to Veta

Figure 44. TOPCON IC Retrofit system.
Viewing Program

The TOPCON IC documentation system is SiteLink3D web service with the ability to export files to Veta.

Figure 45. TopCon sitelink3D web solution.
**Data Export Procedures**

1. Select “Reports” from the Menu.

2. Click “New Report” on the REPORTS screen.

3. Select “Pln Report”
4. Provide report Description, select a region, select As Build Layer, select PLN format (all-passes), Set start/end Date/time, then click Generate Report.
5. The Report Generation is under progress with notes “Running (started a few seconds ago)”

6. Once it is complete, a report range would appear.

7. Click the gear wheel symbol and select Email.

8. Enter the email address for receiving a download link for
the PLN report.

9. Download the report.zip and unzip the PLN file to your local computer. Rename the report.pln file to a more descriptive file name. The PLN file can then be readily imported to Veta.
VOLVO IC Data

System Summary

The VOLVO IC retrofit system is summarized in Figure 40.

Roller

Onboard Display

Documentation

Volvo proprietary IC software

Figure 46. VOLVO IC Retrofit system.
**Viewing Program**

The VOLVO IC system makes use of Android–based tablets. The system can display the pass count map, temperature map, and estimated density map as follows.

![Pass Count](image1.png) ![Temperature](image2.png) ![Estimated Density](image3.png)

*Figure 47. VOLVO IC Display.*
Data Export Procedures

The VOLVO IC tablets can export IC data in csv format directly to an USB drive. The csv files can then be imported to Veta.

1. Select Project

2. Select USB
3. Remove USB and download to PC.

4. Make sure USB stick is inserted in back of display.
   Select OK

5. Remove USB and download to PC.

There are two data files in each zipped project file: all-passes data and final coverage data.
The file name convention is: Lift number + UTM zone + Date + Time.
“_final_coverage” denotes the final coverage data.
MOBA PAVE-IR Thermal Profiler Data

System Summary

The summary of the MOBA PAVE-IR paver-mounted thermal profile system is presented as follows.

<table>
<thead>
<tr>
<th>Hardware</th>
<th>MOBA PAVE-IR paver-mounted thermal profile system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Onboard Display</td>
<td><img src="image" alt="Onboard Display" /></td>
</tr>
<tr>
<td>Documentation</td>
<td><img src="image" alt="Documentation" /></td>
</tr>
</tbody>
</table>

Figure 48. MOBA PAVE-IR Paver-Mounted thermal profile system.
Viewing Programs

The viewing program is called MOBA Pave-IR PPM (Pave Project Manager). Thermal profile is displayed a color-coded maps vs. distance. Other charts include: Time (paver stops) and Speed.

![MOBA Pave-IR PPM Software](image)

Figure 49. MOBA Pave-IR PPM Software.

Data Management

The thermal profile data are stored in either *.log (older format) or *.paveproj formats.

Data Export Procedures

All MOBA thermal profile data (*.log or *.paveproj) can be imported directly to Veta. There is no need for data export.
Contact Information

Rebecca A. Embacher
Advanced Materials and Technology Engineer
MnDOT Office Of Materials & Road Research
1400 Gervais Avenue, M.S. 645
Maplewood, MN  55109-2044
T: 1+ (651).366.5525
Rebecca.Embacher@state.mn.us

George K. Chang, PhD, PE (NJ)
The Transtec Group, Inc
6111 Balcones Dr. Austin, TX 78731
T: 1+ (512) 451-6233
GKChang@TheTranstecGroup.com

Report Prepared by

George K. Chang, PhD, PE (NJ)
Jason Dick
Jennifer Rutledge
Sabrina Garber
The Transtec Group, Inc.