Chapter 3 – Construction Technologies and Procedures

Advanced Materials and Technology Manual
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3.0  INTRODUCTION

This chapter provides details related to project selection (i.e., project selection criteria used to determine whether a project will require use of a given technology), MnCORS, background and alignment files, lot establishments and best practices related to technologies such as intelligent compaction and paver mounted thermal profiling.
3.1 PROJECT SELECTION

3.1.1 Intelligent Compaction (IC) and Paver Mounted Thermal Profile (PMTP) Methods

Chapter 8, of the Pavement Design Manual, outlines the recommended site conditions used to assist with determination as to whether (2016) Quality Management – Paver Mounted Thermal Profile Method and/or (2016) Quality Management Special – Intelligent Compaction Method should be included on a given project. The link to this chapter is available on the MnDOT Pavement Design Manual website at:

http://www.dot.state.mn.us/materials/pvmtdesign/manual.html

3.1.2 Automated Machine Guidance (AMG) – Excavation

Automated Machine Guidance – Excavation is required on all muck and pond excavation activities where there is adequate satellite coverage within the excavation areas.
3.2 MNCORS / RTRN GNSS NETWORK

The Continuously Operating Reference Station Network is a cooperative effort between MnDOT, other state agencies and institutions, counties, cities and private enterprises with the goal of providing Global Navigation Satellite System (GNSS) corrections state-wide. Using signals from all available GNSS satellites, and receivers at over 130 known positions, MnCORS is able to continuously provide survey grade positioning corrections. See Figure 3.1 for the network map / station locations. More detailed information regarding each station and an update on the network status can be found at:

http://www.dot.state.mn.us/surveying/cors/mncors_contacts.html.

FIGURE 3.1 – Image of the CORS/VRS Network Map.
Access the MnCORS GNSS Network website at the link below to receive a free account to access this network.

http://www.dot.state.mn.us/surveying/cors/index.html

This system is stable and has been successfully used by many individuals. Figure 3.2 illustrates the number of users of the MnCORS network since fiscal year 2002 through 2017. There were nearly 4,500 users connecting to the network in FY2017.

FIGURE 3.2 – The number and type of MnCORS users over time.
3.3 BACKGROUND AND ALIGNMENT FILES

3.3.1 Intelligent Compaction Method

A background and alignment file is required for projects requiring the use of intelligent compaction method. See Chapter 7 of the Design Scene for the background and alignment file requirements and how to create complex shapes. The link for this chapter is available on the Design Scene and Guidance website:

http://www.dot.state.mn.us/pre-letting/scene/

The background and alignment files are imported into Veta to allow for more detailed analyses with respect to given locations within the project limits and to allow for removal of miscellaneous data that is not associated with the given compaction efforts (see figure 3.3). Additionally, these background or alignment files are loaded onto the on-board display of each intelligent compaction roller to allow the roller operator to visually see the line-work of the production area(s) with respect to compaction efforts. This real-time view helps ensure that adequate and uniform compaction efforts occur across the production area.

FIGURE 3.3 – Use of complex shapes within alignment file to trim intelligent compaction data.

The intelligent compaction system currently requires a GNSS accuracy of ± 2 in (50 mm) in the horizontal direction. This level of accuracy is required to help ensure that adequate compaction is achieved across the entire lot. Pavement performance issues are often associated with improper compaction near longitudinal joints and the outer limits of the road core (shoulder PIs). Consequently, a horizontal accuracy of at least ± 2 in is required for the line work within the alignment files.

The MnDOT Advanced Materials and Technology YouTube Channel provides video examples on how to create a background closed complex shape and how to convert to b-spline. A link to this channel can be found on the Advanced Materials and Technology Website under the Manuals, Guides & Videos tab:

http://www.dot.state.mn.us/materials/amt/index.html
3.3.2 Paver Mounted Thermal Profile Method

A background and alignment file is required for projects requiring the use of the paver mounted thermal profile method. See Chapter 7 of the Design Scene for the background and alignment file requirements. The link for this chapter is available on the Advanced Materials and Technology website under the Manuals, Guides & Videos tab:


Alignment files are not currently loaded onto the on-board data acquisition systems of the thermal profiling systems, but are imported into Veta to allow for spatial viewing of the surface temperature measurements with respect to the centerline alignment and to provide assistance with the filtering process.

The paver mounted thermal profile system currently requires a GNSS accuracy of ± 4 ft (1.2 m) in the horizontal direction. Consequently, a highly accurate horizontal accuracy, as that required with the intelligent compaction technology, is not required for the line work within these alignment files.
3.4 LOT ESTABLISHMENTS

3.4.1 Examples of Lot Establishments for the IC and PMTP Methods

An immense amount of data is collected from the instrumented rollers and thermal profiling systems during daily compaction and paving efforts, respectively. Consequently, appropriate establishment of standardized naming of lots are needed to properly filter the data and to reduce the number of filter operations required in Veta during data analyses and summaries. Improper lot designations may result in incorrect grouping of data, which can adversely affect monetary price adjustments. It is important that operators use the correct lot designations during all compaction and paving efforts. The naming convention of each lot is standardized per the following special provision tables:

Paver Mounted Thermal Profile Method: Tables 2016-4 (PMTP) and 2016-5 (PMTP)

Intelligent Compaction: Tables 2016-6 (IC) and 2016-7 (IC)

The following subsections outline examples of the standardized lot naming convention for a few different construction operations.

EXAMPLE 1 – DIVIDED HIGHWAY, ASPHALT PAVING

The following outlines general information about the example 1 project (4-lane divided highway with asphalt paving). Figure 3.4 presents a map illustrating the divided highway and lot locations. Table 3.1 lists the standardized naming convention for each lot. For this case, the paving width is 12-ft in each traffic lane.

- Divided Highway
- 2 West Bound Traffic Lanes; 2 East Bound Traffic Lanes
- Hot Mixed Asphalt Paving Operation
- 12-ft Paving Operation
- Two (2) Lifts of Hot Mix Asphalt

FIGURE 3.4 – Example 1: Map of a divided highway for lot standardized naming convention.
TABLE 3.1 – Example 1: Standardized names of lots for divided highway.

<table>
<thead>
<tr>
<th>Lot Location (Note 1)</th>
<th>Lift</th>
<th>Lot Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>TH12-HMA-L1-12L-CL-WB</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>TH12-HMA-L2-12L-CL-WB</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>TH12-HMA-L1-CL-12R-WB</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>TH12-HMA-L2-CL-12R-WB</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>TH12-HMA-L1-12L-CL-EB</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>TH12-HMA-L2-12L-CL-EB</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>TH12-HMA-L1-CL-12R-EB</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>TH12-HMA-L2-CL-12R-EB</td>
</tr>
</tbody>
</table>

Note 1: The referenced lot location is the number in bold and parenthesis presented in Figure 3.1.

EXAMPLE 2 – 4-LANE UNDIVIDED HIGHWAY, ASPHALT PAVING

The following outlines general information about the example 2 project (4-lane undivided highway with asphalt paving). Figure 3.5 presents a map illustrating the undivided highway and lot locations. Table 3.2 lists the standardized naming convention for each lot. For this case, the paving width is 12-ft in each traffic lane.

- Undivided Highway
- 2 West Bound Traffic Lanes; 2 East Bound Traffic Lanes
- Hot Mixed Asphalt Paving Operation
- 12-ft Paving Operation
- Two (2) Lifts of Hot Mix Asphalt

FIGURE 3.5 – Example 2: Map of an undivided highway for lot standardized naming convention.
EXAMPLE 3 – UNDIVIDED HIGHWAY, ASPHALT PAVING WITH AUXILIARY LANE

The following outlines general information about the example 3 project (3-lane undivided highway and asphalt paving). Figure 3.6 presents a map illustrating the undivided highway and centerline offsets. Table 3.3 lists the standardized naming convention for each lot. For this case, the paving width is 1.5 lanes (18-ft).

- Undivided Highway
- (3, 12-ft lanes) 1 West Bound Traffic Lane; 1 East Bound Traffic Lane; 1 Auxiliary Lane
- Hot Mix Asphalt Paving Operation
- 18-ft Paving Operation
- Two (2) Lifts of Hot Mix Asphalt

FIGURE 3.6 – Example 3: Map of an undivided highway (with auxiliary lane) for lot standardized naming convention.

<table>
<thead>
<tr>
<th>Lot Location (Note 1)</th>
<th>Lift</th>
<th>Lot Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>TH12-HMA-L1-18L-18L-CL</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>TH12-HMA-L2-18L-18L-CL</td>
</tr>
</tbody>
</table>

Note 1: The referenced lot location is the number in bold and parenthesis presented in Figure 3.2.
<table>
<thead>
<tr>
<th>2</th>
<th>1</th>
<th>HMA-L1-CL-18R</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2</td>
<td>HMA-L2-CL-18R</td>
</tr>
</tbody>
</table>

Note 1: The referenced lot location is the number in bold and parenthesis presented in Figure 3.3.
### 3.5 INTELLIGENT COMPACTION (IC) METHOD

This method consists of using the intelligent compaction systems to continually monitor compaction efforts during grading and/or asphalt paving operations.

#### 3.5.1 Typical Process for Data Transfer

Figure 3.7 presents an illustration showing the transfer of intelligent compaction and paver mounted thermal profile data from the instrumented systems to Veta. Details pertaining to each figure within this illustration are outlined below using the corresponding numeric number.

**FIGURE 3.7 – Illustration of intelligent compaction and thermal profiling data flow.**

(Images courtesy of The Transtec Group, Inc.)

1. The intelligent compaction and paver mounted thermal profiling technology must store the data internally at least every 5 minutes and transfer the data directly from the device to the cloud storage within 15-minute intervals, or at least once per day when there is limited cellular coverage.

2. The data is transferred from the Instrumented Roller/Thermal Profiling System and stored in Cloud Storage (remote server). The Cloud Storage and associated user names and passwords are provided to the Contractor by the vendor/distributor of the system. Both the Contractor and Agency can gain access to the real-time data using the provided login information. It is recommended that...
the Contractor provides the agency with a different user name and password that are associated with limited user privileges.

(3) The data is then transferred from the cloud storage to the cloud computing mapping/analysis software. The cloud computing mapping/analysis software allows the users view the near, real-time data through the internet and/or a portable electronic device application (e.g., iPAD, iPhone, Android, etc.). The cloud computing and associated user names and passwords are provided to the Contractor by the vendor/distributor of the system. Both the Contractor and Department can gain access to the real-time mapping/analysis using the provided login information. It is recommended that the Contractor provides the Department with a different user name and password that are associated with limited user privileges.

Please note that some vendors are working towards a solution to send data directly from the cloud storage to Veta, and therefore, step (4) would not be necessary.

(4) Users should export the data listed below from the cloud computing following the instructions provided by the vendor/distributor.

(a) Intelligent Compaction Method: Gridded All Passes Data
(b) Paver Mounted Thermal Profile Method: Surface Temperature Measurements

(5) Quality Control/Quality Assurance data (spot test data), with associated GNSS coordinates for the location of the given test, can be loaded into Veta for correlation analyses or to assist with troubleshooting construction activities. Please note that this data cannot be loaded into Veta without coordinate information.

(6) Final analyses and reporting of intelligent compaction and paver mounted thermal profiling data, to meet contract requirements, will be completed using Veta.

### 3.5.2 Training of Contractor’s Personnel

It is recommended that the Contractor’s personnel obtain training per Table 3.4, at least one time per calendar year, prior to use of instrumented rollers. Table 3.5 provides a check list for content that is recommended for inclusion in training of both the IC Supervisors and Onsite IC Support. Table 3.6 provides a check list for content that is recommended for inclusion in the training of the Operators of the instrumented rollers.

<table>
<thead>
<tr>
<th>Personnel</th>
<th>Training By</th>
<th>Training Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intelligent Compaction Supervisors</td>
<td>• Vendor or Manufacturer</td>
<td>See Table 3.5</td>
</tr>
</tbody>
</table>
| Onsite IC Support              | • Vendor or Manufacturer, or
|                                | • Intelligent Compaction Supervisor, or
|                                | • Onsite IC Support                             |                           |
| Operator(s) of the Instrumented Rollers | • Vendor or Manufacturer, or
|                                | • Intelligent Compaction Supervisor, or
|                                | • Onsite IC Support                             | See Table 3.6             |
### TABLE 3.5 – Recommended training content for IC supervisors and onsite IC support.

<table>
<thead>
<tr>
<th>Training Completed</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐</td>
<td>Provided Administrator/Manager rights for system troubleshooting and training on how to use complete troubleshooting.</td>
</tr>
<tr>
<td>☐</td>
<td>Process to contact Vendor / Sales Representative with further issues after troubleshooting.</td>
</tr>
<tr>
<td>☐</td>
<td>Educated on the training necessary for new or returning operators of instrumented rollers.</td>
</tr>
<tr>
<td>☐</td>
<td>Setup and operation of the IC system.</td>
</tr>
<tr>
<td>☐</td>
<td>Setup and operation of Rover. Including coordinate export.</td>
</tr>
<tr>
<td>☐</td>
<td>Site Setup and Calibration (includes setup of local, ground-based base station, Rovers, MnDOT’s MnCORS/RTRN)</td>
</tr>
<tr>
<td>☐</td>
<td>Verification of complete radio coverage for site.</td>
</tr>
<tr>
<td>☐</td>
<td>Verification of cellular coverage for site (needed when accessing MnDOT’s MnCORS/RTRN).</td>
</tr>
<tr>
<td>☐</td>
<td>Uploading alignment and site calibration files to instrumented rollers.</td>
</tr>
<tr>
<td>☐</td>
<td>Verification of accuracy of instrumented roller (includes: accelerometer range, GNSS Accuracy, pavement surface temperature, digital data recording correctly)</td>
</tr>
<tr>
<td>☐</td>
<td>Daily checks to ensure that the IC system is mapping (working) correctly.</td>
</tr>
<tr>
<td>☐</td>
<td>Daily verification of GNSS Coordinates or temperature, or both.</td>
</tr>
<tr>
<td>☐</td>
<td>Manual and wireless transfer of Data Files.</td>
</tr>
<tr>
<td>☐</td>
<td>Creation and setup of folders for different projects in cloud storage.</td>
</tr>
<tr>
<td>☐</td>
<td>Creation and use of standardized lot naming convention.</td>
</tr>
<tr>
<td>☐</td>
<td>Use of Manufacturers cloud storage and cloud computing.</td>
</tr>
<tr>
<td>☐</td>
<td>Certification of Veta Software Operator.</td>
</tr>
</tbody>
</table>

### TABLE 3.6 – Recommended training content for the operators of the instrumented rollers.

<table>
<thead>
<tr>
<th>Training Completed</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐</td>
<td>Daily setup and operation of instrumented roller.</td>
</tr>
<tr>
<td>☐</td>
<td>Basic troubleshooting of instrumented roller system.</td>
</tr>
<tr>
<td>☐</td>
<td>When to contact onsite IC support (e.g., screen not painting, intermittent GNSS signal).</td>
</tr>
<tr>
<td>☐</td>
<td>Manual and wireless transfer of data files.</td>
</tr>
<tr>
<td>☐</td>
<td>Creation and use of lot names. Understanding of importance of lot names for data management, correct map visualization by other staff and calculations of monetary price adjustments.</td>
</tr>
</tbody>
</table>
TABLE 3.6 – Recommended training content for the operators of the instrumented rollers.

<table>
<thead>
<tr>
<th>Training Completed</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐</td>
<td>Reading of X and Y Coordinates or temperature, or both (on the Onboard Documentation System) for verification of GNSS and Temperature Measurements</td>
</tr>
</tbody>
</table>

3.5.3 Recommended Intelligent Compaction System Checks

It is recommended that the Contractor perform an independent equipment demonstration to ensure that the IC system is working correctly before the start of compaction efforts on each project. The parameters outlined in Table 3.7 provide general guidance for items to be reviewed during the system check. Form IC-103 “Approval of Instrumented Roller for Use” provides a check list for items that are recommended for verification during the system demonstration. This form is available on the Advanced Materials and Technology website under the Forms & Worksheets tab:


TABLE 3.7 – Recommended intelligent compaction system checks.

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Demonstration</th>
<th>Testing Location</th>
<th>No. of Passes</th>
<th>Measurement Area</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Width</td>
</tr>
<tr>
<td>Verification of Adequate Sensor Range</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Soft Material (Note 1)</td>
<td>Project Site or Offsite Location</td>
<td>1</td>
<td>≥ 7 ft (2 m)</td>
</tr>
<tr>
<td>2</td>
<td>Stiff Material (Note 1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Verification of Data Contained within Measurement pass files</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Data Quality (Note 2)</td>
<td>Project Site</td>
<td>2</td>
<td>≥ 7 ft (2 m)</td>
</tr>
</tbody>
</table>

Note 1: Verify that the ICMVs can identify differences between weak and strong materials.

Note 2: Verify that all measurements are recorded and meet the requirements of 2016 Quality Management Special – Intelligent Compaction Method.

As part of the checks, it is recommended that the GNSS and temperature measurements are calibrated. The following subsections outline these procedures.

CALIBRATION OF GNSS ACCURACY

Step 1. Verify that the rover(s) are calibrated to the correct coordinate system, using control points, within the project limits. Complete this verification prior to checking the intelligent compaction system’s GNSS.

Step 2. Mark a spot on the ground next to the drum location being recorded and displayed by the onboard documentation system (e.g., center [or left or right edge] of a steel roller drum or the outside edge of a pneumatic roller tire). See Figure 3.8.
NOTE—For pneumatic rollers, ensure that the outside edge of a pneumatic roller tire is used, as not all pneumatic rollers have a wide-track width.

**FIGURE 3.8 – Photo of marking spot on the ground next to the roller drum.**

---

Step 3. Collect and compare the coordinates from the rover and the instrumented roller (see figure 3.9). The coordinates should compare within 0.5 ft (150 mm) of each other in the horizontal direction (X and Y direction). It is recommended that a digital photo (or snapshot using the on-board display) is used to capture the coordinates of the instrumented roller on the onboard display (see figure 3.10). This helps mitigate translation errors when recording the measurements on the form.

**FIGURE 3.9 – Photo of collection of coordinate using rover.**
CALIBRATION OF THE INSTRUMENTED ROLLER TEMPERATURE ACCURACY

Step 1: Power on the IC temperature sensors, a minimum of 10 minutes, before verifying measurements.

Step 2: Collect and compare the temperature measurements from an independent device and the temperature sensor(s) of the instrumented roller (see figure 3.11). The temperatures should compare within 5°F (2.8°C).

FIGURE 3.11 – Photo of the infrared sensor mounted on an instrumented roller.
3.6 PAVER MOUNTED THERMAL PROFILE (PMTP) METHOD

This method consists in using a paver mounted thermal profiling system to continually monitor the surface temperature of the mat immediately behind the paver screed during placement operations.

3.6.1 Typical Process for Data Transfer

See section 3.5.1 for details related to the transfer of paver mounted thermal profile data from the system to Veta.

3.6.2 Recommended PMTP System Checks

It is recommended that the Contractor perform an independent equipment check to ensure that the PMTP system is working correctly before the start of paving efforts on each project.

CALIBRATION OF GNSS ACCURACY

Collect and compare the coordinates from the PMTP system with an independent measuring device such as a rover.

Verify that the rover(s) are setup to the correct coordinate system. Complete this verification prior to checking the PMTP system’s GNSS.

Collect and compare the coordinates from the rover and the PMTP system. The coordinates should compare within 4 ft (1.2 m) of each other in the horizontal direction (XY direction).

CALIBRATION OF TEMPERATURE ACCURACY

Collect and compare the temperature measurements from an independent device and the temperature sensor(s) of the paver mounted thermal profile system. The temperatures should compare within 5°F (2.8°C).

CALIBRATION OF DMI ACCURACY

If a distance measuring instrument (DMI) is utilized with the PMTP system, verify that the correct correction factor is set for accurate stationing per the manufacturer’s procedures.

3.6.3 Field Review of Surface Temperature Measurements

It is recommended that the Engineer views the surface temperature readings and/or thermal summary on the PMTP system display within the first 100 tons of production and at about 1,000 ton intervals thereafter, for each day of production. This periodic review is intended to assist with ensuring that there are no problems with the system and/or with production efforts.