Accelerated Implementation of Intelligent Compaction Technology for Embankment Subgrade Soils, Aggregate Base, and Asphalt Pavement Materials

Soil IC Experiment Plan
FM 156, Fort Worth, TX
Texas Department of Transportation

The Transtec Group, Inc.
15 July 2008
# Accelerated Implementation Of Intelligent Compaction Technology For Embankment Subgrade Soils, Aggregate Base, And Asphalt Pavement Materials - Specific Experiment Plan for the TxDOT Soil IC Demonstration

**Abstract**

Intelligent compaction (IC) is an emerging technology, and for some applications it is mature enough for implementation for field compaction of pavement materials. The intent of this project is to realize the blueprint in the FHWA IC strategic plan. This study was initiated under the Transportation Pooled Fund (TPF) Solicitation No. 954, which includes 13 participating state department of transportation (DOTs): Georgia, Indiana, Iowa, Kansas, Maryland, Minnesota, Mississippi, North Dakota, New York, Pennsylvania, Texas, and Virginia, and Wisconsin.

This document is to provide a detailed site-specific experiment plan for the TxDOT Soil IC field demonstration.

**Key words**

Compaction, intelligent compaction, roller, soils, subgrade, aggregate, embankment, stabilized base, asphalt, HMA, pavement performance.
# SI* (MODERN METRIC) CONVERSION FACTORS
## APPROXIMATE CONVERSIONS TO SI UNITS

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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") |

| TEMPÉRATURE (exact degrees) | | | | |
| °F | Fahrenheit | 5 (F-32)/9 | Celsius | °C |

| **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

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<td>g</td>
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<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>
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</table>

| **TEMPÉRATURE (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)
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Introduction

The intelligent compaction (IC) field demonstrations are a major part of the FHWA Transportation Pooled Fund (TPF) research project effort, “Accelerated Implementation of Intelligent Compaction Technology for Embankment Subgrade Soils, Aggregate Base, and Asphalt Pavement Materials.” The IC field demonstrations are anticipated to be conducted in each of the 13 participating state departments of transportation (DOTs), including: Georgia, Indiana, Iowa, Kansas, Maryland, Minnesota, Mississippi, North Dakota, New York, Pennsylvania, Texas, Virginia, and Wisconsin between 2008 and 2010. To facilitate this project, a Technical Working Group (TWG) was formed to include the FHWA Contracting Officer’s Technical Representative (COTR) and IC-associated team members, IC project team, IC facilitator, IC pooled fund State representatives, and IC roller vendor representatives. The IC project team and IC facilitator are referred to collectively as ICPF team.

The purpose of this site-specific and roller-specific experimental plan is to provide details of the soil IC field demonstration to be conducted in July 2008 for the Texas Department of Transportation (TxDOT). This is the second IC demonstration under this TPF IC study. Key attributes for this field demonstration will be on-site training, comparison of IC roller technologies to traditional compaction equipment and practices, correlating IC roller measurements to in-situ spot test measurements, mapping two or more layers of compacted material to understand the influence of underlying layer support, selecting the appropriate machine operation parameters (e.g., speed, amplitude, frequency, etc.), and managing and analyzing the IC and in-situ test data.

This document includes: specific goals of this demonstration project, timelines and test site description, description of the selected rollers, logistics, schedule and details of field demonstration activities, and data analysis and reporting.
Goals

The goals of this demonstration project are to:

- Demonstrate IC technology to TxDOT personnel, contractors, and the highway community at large,
- Help TxDOT’s accelerate the development of IC quality control (QC) specifications for subgrade soils, aggregate bases, and HMA pavement materials,
- Develop an experienced and knowledgeable IC expertise base within TxDOT, and
- Identify and prioritize needed improvements and research for IC equipment.

The objectives of this demonstration project are short-term goals for introducing soil IC technology to TxDOT and contractors who may not have prior experience with IC, in order to demonstrate the benefits of IC for improving the compaction process by achieving more uniform density/modulus of the soil and stabilized base material and providing roller operators (and superintendents) better feedback tools to make right decisions, and ultimately real-time quality control.

Timeline and Test Site Description

Timeline of Activities

The demonstration site and material of interest (including Type II cohesive subgrade soil and Type V stabilized base material), were selected by TxDOT and a planning meeting was conducted with TxDOT and the ICPF Team on June 26, 2008. The field IC demonstration (which may last 5 to 6 days) will be performed during the week of July 20, 2008.

Location of Test Site – FM 156

The project is to relocate the highway to accommodate Alliance Airport's runway extension on the north end. The FHWA and FAA are paying for the entire project. TxDOT is handling the construction portion.

The CSJ is 0718-01-047 with project name HP 2007 (522), etc. It is a "pasture" project so it will not have live traffic on it. This project begins at the STA 97+30.54 (southern end) and ends at the STA 13+53.47 (northern end) – note that the STA transits at STA 266+84.32(BK)=STA 10+00.00.

The project preconstruction meeting was on Feb. 19, 2008 with construction to start March 3, 2008. There are 4 culverts to be built first with an anticipated 30 working days to completion. Work on the embankment delivery and installation should begin in earnest about May 1, 2008. With 200,000+ CY of borrow material to come into the project, the embankment work will probably last more than a year. They have 100,000+ CY to do in a 1000' - 2000' section, 2 lanes wide, and 0'-15' in height.

The lower layers will be normal embankment with the top 18" lime treated. Then 14" of flex base, 4" Type B HMAC, and topped with 2" Type D HMAC.

Therefore, the target material for IC compaction may be either: (1) existing soil embankment, (2) lime treated base, or (3) flex base.
Figure 2. Map of the test site (FM 156)
Figure 3. Site plan of the project site (FM 156)

Soil Properties of Test Site – FM 156

Table 1. Plasticity Indexes (PI) of the soils onsite.

<table>
<thead>
<tr>
<th>Location</th>
<th>Material</th>
<th>P.I.</th>
</tr>
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<tbody>
<tr>
<td>E. side of J.C. Penny, Sight A @ 4'</td>
<td>Light Brown Clay w/Rock</td>
<td>35</td>
</tr>
<tr>
<td>E. side of J.C. Penny, Sight B @ 1' to 2'</td>
<td>Dark Brown Clay</td>
<td>34</td>
</tr>
<tr>
<td>E. side of J.C. Penny, Sight B @ 4'</td>
<td>Light Tan Clay w/Rock</td>
<td>29</td>
</tr>
<tr>
<td>S.W. side of J.C. Penny, Stockpile</td>
<td>Light Tan Clay</td>
<td>28</td>
</tr>
<tr>
<td>S.W. side of J.C. Penny, Stockpile</td>
<td>Dark Brown Sandy Clay</td>
<td>40</td>
</tr>
<tr>
<td>S.W. side of J.C. Penny, Stockpile</td>
<td>Light Tan Clay</td>
<td>25</td>
</tr>
<tr>
<td>N. side of J.C. Penny, Berm #1-A @ 2' to 4'</td>
<td>Dark Brown Clay</td>
<td>49</td>
</tr>
<tr>
<td>N. side of J.C. Penny, Berm #1-A @ 5' to 7'</td>
<td>Dark Brown Clay</td>
<td>41</td>
</tr>
<tr>
<td>N. side of J.C. Penny, Berm #1-A @ 8'</td>
<td>Tan Sandy Clay</td>
<td>36</td>
</tr>
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<td>N. side of J.C. Penny, Berm #1-B @ 2' to 4'</td>
<td>Dark Tan Clay</td>
<td>38</td>
</tr>
<tr>
<td>N. side of J.C. Penny, Berm #1-B @ 8'</td>
<td>Tan Clay</td>
<td>32</td>
</tr>
<tr>
<td>N. side of J.C. Penny, Berm #2 @ 8'</td>
<td>Light Brown Clay</td>
<td>40</td>
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</table>
Description of the Selected IC Rollers

The Texana/Ammann/Case single drum IC rollers (one pad foot and one smooth drum) and the Dynapac pad foot single drum roller will be used for this demonstration project. All the above IC rollers are equipped with a global position system (GPS), a roller response measurement system, and a document system.

Table 2. Features of the Soil IC Rollers.

<table>
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<tr>
<th>Manufacturer/Vendor</th>
<th>Ammann/Case/Texana</th>
<th>Dynapac</th>
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<tr>
<td>Model</td>
<td>Ammann Compaction Expert-Plus (ACEplus)</td>
<td>Dynamic Compaction Analyzer for Soil with GPS DCA-S (GPS)</td>
</tr>
<tr>
<td>Model Number</td>
<td>SV</td>
<td>CA 362D</td>
</tr>
<tr>
<td>Drum Size</td>
<td>86” wide</td>
<td>84” wide</td>
</tr>
<tr>
<td>Machine Weight</td>
<td>16,000 lbs</td>
<td>30,000 lbs</td>
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<td>Amplitude Settings</td>
<td>0 to 0.08”</td>
<td>0 to 0.08”</td>
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<td>Frequency Setting/Range</td>
<td>1380 to 2100 rpm</td>
<td>Fixed at 1680 rpm</td>
</tr>
<tr>
<td>Auto-Feedback</td>
<td>Y (both frequency and amplitude)</td>
<td>Y (amplitude) DCO for CA362</td>
</tr>
<tr>
<td>With measurement System</td>
<td>Y</td>
<td>Y</td>
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<tr>
<td>Measurement Value</td>
<td>Kb - Ground bearing capacity</td>
<td>Compaction Meter Value (CMV)</td>
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<td>Measurement Unit</td>
<td>MN/m</td>
<td>Unitless</td>
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<tr>
<td>GPS Capability</td>
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<td>Documentation System</td>
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Figure 4. Ammann/Case/Texana Soil IC Roller
Logistics

Team Members and Responsibilities

The primary parties that will be involved with planning and conducting the demonstration projects will be the ICPF project team, TxDOT personnel, the roller manufacturers, and the paving contractor. The ICPF project team for this demonstration includes Lee Gallivan, George Chang, Dave Merritt, Bob Horan, and David White. Mr. Horan is the main coordinator of this demonstration. Dr. Chang and Dr. White are main contacts of the research team during the demonstration. Mr. Richard Williamee is the main contact for TxDOT. The contact information of the team members are listed below:
Table 3. Team Members for the TxDOT IC Demonstration Project

<table>
<thead>
<tr>
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<th>First name</th>
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<tr>
<td>Chang</td>
<td>George</td>
<td>Transtec Group, Inc. (main contact)</td>
<td>512-451-6233</td>
<td><a href="mailto:gkchang@thetranstecgroup.com">gkchang@thetranstecgroup.com</a></td>
</tr>
<tr>
<td>Horan</td>
<td>Bob</td>
<td>Asphalt Institute</td>
<td>C 804-539-3036</td>
<td><a href="mailto:bhoran@AsphaltInstitute.org">bhoran@AsphaltInstitute.org</a></td>
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<tr>
<td>Merritt</td>
<td>Dave</td>
<td>Transtec Group, Inc.</td>
<td>512-451-6233</td>
<td><a href="mailto:dmerritt@thetranstecgroup.com">dmerritt@thetranstecgroup.com</a></td>
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<tr>
<td>White</td>
<td>David</td>
<td>ISU</td>
<td>C 515-290-1080</td>
<td><a href="mailto:djwhite@iastate.edu">djwhite@iastate.edu</a></td>
</tr>
<tr>
<td>Gallivan</td>
<td>Lee</td>
<td>FHWA</td>
<td>317-226-7493</td>
<td><a href="mailto:Victor.Gallivan@fhwa.dot.gov">Victor.Gallivan@fhwa.dot.gov</a></td>
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<tr>
<td>Williamee</td>
<td>Richard</td>
<td>TxDOT – Fort Worth (Main Contact)</td>
<td>817-370-6675</td>
<td><a href="mailto:RWILLIA@dot.state.tx.us">RWILLIA@dot.state.tx.us</a></td>
</tr>
<tr>
<td>Si</td>
<td>Zhiming</td>
<td>TxDOT – HQ – TPF rep</td>
<td>512-506-5901</td>
<td><a href="mailto:ZSI@dot.state.tx.us">ZSI@dot.state.tx.us</a></td>
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<tr>
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<td>Kirby</td>
<td>Texana/Ammann</td>
<td>210-333-8000</td>
<td><a href="mailto:t-mansell@sakaiamerica.com">t-mansell@sakaiamerica.com</a></td>
</tr>
<tr>
<td>Prichard</td>
<td>Mike</td>
<td>Dynapac</td>
<td>210-860-1720</td>
<td><a href="mailto:Mike.Prichard@dynapac.com">Mike.Prichard@dynapac.com</a></td>
</tr>
<tr>
<td>Allen</td>
<td>Stan</td>
<td>Ed Bell Construction Co.</td>
<td>214-358-6581</td>
<td><a href="mailto:sallen@ebcc.com">sallen@ebcc.com</a></td>
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A separate field summary sheets will be updated and distributed during the demonstration.

While all the parties will work together and coordinate efforts, each will have primary responsibility for different aspects of the project both in the planning phase and during the actual project, as delineated below.

ICPF Project Team Responsibilities:

- Coordination among all parties,
- Assisting in the project selection,
- Scheduling and arrangements for IC roller,
- Coordination with IC roller manufacturers and other equipment suppliers,
- Assisting with correlation testing,
- Data collection/management,
- Cost of agreed upon fees associated with mobilization of IC roller, and
- Cost of ISU geotechnical mobile lab.

State DOT (TxDOT) Responsibilities:

- Project selection (with assistance from the project team),
- Project contractual arrangements (if required),
- Coordination with contractors,
• Providing storage locations for IC rollers,
• Providing test equipment and manpower for in-situ testing (using standard equipment and practices for acceptance, but possibly at a higher frequency than normal),
• Providing or coordinating traffic control (when necessary),
• Facilitating the Open House, and
• Project delta costs for contractors.

Roller Manufacturer (Texana_Ammann/Dyanpac) Responsibilities:

• Coordinating with the project team, TxDOT, and contractor concerning shipping the IC roller in a timely manner,
• Providing the project team a copy of their software to view the information obtained from their IC roller,
• Arranging for necessary GPS base station setup,
• Training the operator, DOT representative, and project team on proper roller operation,
• Participating in the roller demonstrations in a limited capacity, and
• Providing technical support in a timely manner throughout the project (e.g., via phone) including equipment maintenance and repair, if needed.

Paving/Earthwork Contractor Responsibilities:

• Coordination of paving/rolling activities and cooperation with the above parties during the course of field demonstration, and
• Providing conventional roller operation for the control sections.

Three special provision specification by TxDOT (reformatted based on the ICPF generic version for lime treatment road-mixed, flexible base, and embankment – see Appendix C for details) were provided to contractor as a part of the paving contract. Costs resulting from field delays, including adverse weather conditions and machine malfunctioning will be shared by the project team and TxDOT.

Schedule and Details of Field Demonstration Activities

This soil IC demonstration project will be scheduled for a 5 to 6 consecutive day period. A summary of day-to-day activities for this asphalt IC field demonstration is described in Table 4.
Table 4. Summary of Activities for the Soil IC Field Demonstration

<table>
<thead>
<tr>
<th>Date</th>
<th>Tasks</th>
<th>Detailed Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sun., July 20</td>
<td>Setup rollers</td>
<td>(ISU) Set up the IC machine(s) and GPS base station system.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>(Dynapac/Texana)</em> Conduct trial runs to verify the machine is operating and communicating with the GPS base station.</td>
</tr>
<tr>
<td>Mon., July 21 (Day 1)</td>
<td>Training &amp; Calibration/Production/Mapping</td>
<td><em>(Research Team)</em> Initial training of TxDOT and contractor personnel in machine operations, data collection, data management, and in-situ testing strategies.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>(Research Team/Dynapac)</em> Calibration, production and mapping rolling with the pad foot IC roller.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>(Research Team/ISU/TxDOT)</em> A variety of in-situ testing measurements.</td>
</tr>
<tr>
<td>Tue. July 22 (Day 2)</td>
<td>Calibration/Production/Mapping</td>
<td><em>(Research Team/Texana)</em> Calibration, production and mapping rolling with the pad foot IC roller.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>(Research Team/ISU/TxDOT)</em> A variety of in-situ testing measurements.</td>
</tr>
<tr>
<td>Wed. July 23 (Day 3)</td>
<td>Calibration/Production/Mapping</td>
<td><em>(Research Team/Dynapac/Texana)</em> Calibration, production and mapping rolling with the Dynapac and Texana pad foot IC rollers and Texana/Ammann smooth drum roller.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>(Research Team/ISU/TxDOT)</em> A variety of in-situ testing measurements.</td>
</tr>
<tr>
<td>Thu. July 24 (Day 4)</td>
<td>Calibration/Production/Mapping/Open House</td>
<td><em>(Research Team/Texana)</em> Calibration, production and mapping rolling with the Texana/Ammann smooth drum roller.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>(Research Team/ISU/TxDOT)</em> A variety of in-situ testing measurements.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>(Research Team)</em> Analyze and report the IC and in-situ results, generating a preliminary report and presentation of results.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>(TXDOT)</em> 2-4PM conduct a two-hour Open House to discuss the results and lessons learned followed by a field tour.</td>
</tr>
<tr>
<td>Fri. July 24 (Day 5)</td>
<td>Calibration/Production/Mapping</td>
<td><em>(Research Team/Texana)</em> Calibration, production and mapping rolling.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>(Research Team/ISU/TxDOT)</em> A variety of in-situ testing measurements.</td>
</tr>
</tbody>
</table>

During the field demonstration, the following tasks will be conducted:

1. **Roller and GPS Setup**
2. **Initial Training**
3. **Correlation Test**
4. **Mapping of Existing Layer**
5. Production Compaction  
6. Preliminary Analysis and Report  
7. Open House  

Roller and GPS Setup

While the setup and correlation of the roller will be necessary in all cases, the basic steps in the correlation will vary depending on the capabilities of the specific IC roller to be used on the project. A GPS base station will be established on the project and the contractor must demonstrate that the mapping is working properly, is accurate, and can be used to identify a designated spot on the pavement surface within 4 inches before work can progress. Detailed field notes will be taken during the course of the demonstration project.

Since each IC system is unique, the project team will require IC data to be submitted in a standard format. The data submission process will require exporting data from the roller vendor field program and post processing, if necessary, with a naming convention specified by the project team. (data requirements and data format definition is described in a separate document.)

Initial Training

Initial training will consist of on-site hands-on training with IC machine and GPS system setup, conducting reproducibility testing with the IC machine for varying operating conditions, managing and analyzing the data, performing in-situ testing in a timely and effective manner, and establishing a plan for comparing results to tradition compaction.

The State DOT lead and ICPF project team lead will also brief all parties on the plan and answer any questions about roles and responsibilities. The roller manufacturer’s representative will be available at this meeting to discuss roller operation and capabilities. The roller manufacturer’s representative will be responsible for providing training for the designated roller operator(s).

The initial training will take place before any field operation and accommodate 1 to 2 DOT personnel and 1 to 2 contractor personnel at each site. Selective aspects of the field demonstration will be video recorded to document the project and contribute to future presentation/technology transfer tools.

Correlation Tests

Since the IC rollers have drum measuring systems, correlation tests will be conducted in order to compare in-situ measurements or coring (when mandated by States) of the material being compacted with the drum measurement values from the IC system. The test locations will need to be tied with the corresponding IC roller MVs using GPS.

The recommended correlation tests are:

- Falling weight deflectometer (FWD)
- Light Weight Deflectometer (LWD)
- Dynamic Cone Penetrometer (DCP)
- Nuclear density gauges
- Moisture test
- Dynamic Seismic Pavement Analyzer (DSPA)
However, it is particularly important to stress that when interpreting IC data as the measurement influence depth normally exceeds the compaction layer thickness, as demonstrated in Figure 6. Therefore, caution should be taken when correlate the results from the above correlation test results with the IC measurement values.

**Figure 6.** Comparison of IC measurement influence depth compared to traditional in situ spot test measurements.

The schematic of the calibration strips is illustrated in Figure 6 where the areas of calibration strips will be selected based on IC-Map from pass one. The in-situ measurement data will be compiled in a standard format (specified by the project team) to facilitate correlation analysis with the IC data.
Mapping Existing Layer

Results from IC compaction are best interpreted with knowledge of the underlying layer support conditions. Figure 8 shows IC measurements for a base layer overlying a variable support layer. Hard and soft underlying conditions tend to reflect through the upper layers affecting surface compaction. This aspect has not been addressed very well in IC specifications and in interpreting IC measurements to date. The same tandem drum vibratory roller with a measurement system can be used for mapping of existing in-place layers.
Figure 8. IC measurement values for successive lifts of aggregate base over cohesive subgrade, showing hard and soft areas reflecting through the surface compaction layer.

**Production Compaction**

Production compaction, including IC and conventional compaction, will follow patterns established in a specific plan for either soil/aggregate IC or HMA IC. Final data submission (exported IC data from the IC vendors’ field programs with appropriate post processing, compiled spot test data associated with both the IC and conventional compaction) will comply with the data requirements specified by the IC project team.

The test schedule and settings are summarized as follows:
ISU meet TxDOT at 6:30pm. ISU mobile move from maintenance shop to project site. All parties meet at Sleep Inn at 7:30pm.

Near the end of the demonstration project, an evaluation (including an interview with the roller operator) will be conducted to judge any differences in the effectiveness and efficiency of the compaction operation. The results of the evaluation and interview will be published as part of the project report.
Preliminary Analysis and Report

IC roller data and other associated in-situ testing data will be managed, analyzed, and issued in a concise summary report for each demonstration project. One of the challenging aspects of implementing IC technologies is learning to use the manufacturer’s software, extracting the data from the machine, organizing data files, filtering the data to evaluate selected areas, analyzing the data to develop correlations and comparisons to in-situ spot measurements, and documenting the roller operations. As such, a significant effort will occur daily to download and process the results. Projects will not be successful without daily analysis of the data to learn about compaction quality and factors affecting the IC measurement values. By analyzing the data daily, changes in operations can be made to optimize the process. Therefore, standardized formats for both IC data and in-situ measurement data are crucial to make the analysis and report process successful.

Open House

TxDOT will conduct an Open House for this demonstration. The open house will be informal and invitations would be limited to those directly involved with the project and pooled fund states. Tentatively, it will include a one-hour presentation at the Sleep Inn & Suite Speedway followed by a site visit. See the field summary sheets for the most updated information.

Data Analysis and Reporting

The final report will be produced by refining the preliminary analysis and report approximately three weeks after the completion of the field demonstration. The report will include the following elements:

- Executive Summary of field operations and conditions,
- Test methods employed during the demonstration,
- Laboratory material classification and compaction characteristics,
- Analysis of the IC measurements (color-coded maps, probability density distribution, semi-variogram, etc.),
- Correlation analyses,
- Effectiveness of the IC technology to meet the TxDOT specification,
- Efficiency of the operations, comparison to traditional compaction operations,
- Summary of feedback/interviews from contractor and TxDOT personnel, and
- Conclusions that relate to the overall goals/objectives of the study.

All detailed data and analysis results will be included in appendixes. A final draft report will be distributed to all TWG members within 15 days after the completion of the field demonstration and finalized one week after that.

Deliverables

Deliverables from the demonstration projects will include the following:

- Project report with summary of project conditions, specifications, material classification and compaction characteristics, IC measurements values, in-situ spot test measurements, correlation analysis, production compaction analysis, and conclusions.
• Digital documentary from each demonstration project with photos and video of field operations and selected interviews.
• Updated website with project results.

**Anticipated Benefits**

• Pavement Designers can use the knowledge gained from this project to improve pavement designs to minimize both initial and life-cycle costs due to reduced variability of compaction of the constructed pavement layers.
• QC/QA Personnel will be able to use IC data to increase the amount of available information related to the quality of construction and possibly reduce the amount of conventional QA testing.
• Contractors can optimize their construction practice and QC processes to better achieve compliance with compaction specifications.
• Materials Suppliers can integrate the results from this study into their materials selection and proportioning procedures.
• Specification Developers can determine what variables should be controlled to optimize construction quality and long-term performance, thus minimizing life-cycle costs.
Appendix A. Interview and Sample Questions

Interview Strategy

Reason for interview process?

Interviews will be conducted to capture the experiences, impressions and suggestions of key project personnel concerning the use of Intelligent Compaction to improve the compaction process and for use as a Quality Assurance/Quality Control tool. A series of standard questions will be asked during each ICPF project. The interviews will be conducted on all ICPF projects and the interview results and important comments will be captured in project, annual and final reports. The interviews will be used to improve the process of planning, training and conducting the ICPF projects. In addition, the interviews will allow the research team to do a better job of developing specifications and making recommendations for the next steps in the study and implementation of IC technology in the United States.

Who to interview?

The interviews will be conducted with a minimum of four key personnel from the roller manufacturer, the state DOT and the paving contractor. The “interviewers” (those conducting the interviews) will be members of the ICPF research team that are on-site. The “interviewees” will be as follows:

- The ICPF state DOT representative
- The state DOT project manager or other field personnel
- The lead person for the roller manufacturer
- The contractor’s roller operator (if applicable)
- A representative of the contractor’s management personnel (paving foreman, project manager)

When to interview?

Interviews will generally be conducted before and after the ICPF project. Some of the interview questions will be the same and some will be different for before and after interviews. The interview questions may vary somewhat different depending on the person being interviewed due to that persons roles and perspectives.
Sample Questions - Contractor's Roller Operator (if applicable)

Initial Interview (beginning or early in ICPF project)
1. What is your name and who do you work for?
2. Please describe your experience as a roller operator?
3. Briefly describe your role in the process of placing the pavement material?
4. What are the biggest challenges that you face as a roller operator?
5. What do you know or have you heard about intelligent compaction, if any?
6. How do you think IC can improve your effectiveness as a roller operator, if any?
7. What type of training and how long was the training you received on the IC roller?

Final interview (end of ICPF project)
1. How long did you work with the IC roller on this project?
2. What features of the IC roller (other than just standard features) did you use on this project? e.g. color-coded mapping display, roller pattern mapping, temperature mapping, roller measurement value mapping, displays of RMV, temperature reading from thermal gauge, etc.
3. What was your general impression of the IC roller and its ability to make you job easier? In what way?
4. Please rate the amount of improvement that IC technology, as you experienced it on this project, can have on making your job easier: 1. Large improvement 2. Some improvement 3. No difference 4. Made my job harder
5. What was your general impression of the IC roller’s capability to improve the compaction process? In what way?
6. Please rate the amount of improvement that IC technology, as you experienced it on this project, can have on the compaction process: 1. Large improvement 2. Some improvement 3. No difference 4. Worse than conventional compaction
7. In your opinion, was the initial training you received adequate to allow you to operate and effectively use the IC technology?
8. What suggestions do you have to improve the training the roller operator is given?
9. If given the opportunity, would you prefer to use a roller equipped with IC technology or a standard roller with no IC technology in the future?
10. Any final thoughts / suggestions?
Appendix B. ISU Intelligent Construction Geo-Mobile Lab

Capabilities

GPS rover and base station, satellite communication, video projector and conference room, water, diesel power plant, climate control, weather station, four wheel mule truck, 10,000 lb reaction for plate load tests, hydraulic tube sampler, and video camera with wireless microphone.

Additional Testing Equipment

<table>
<thead>
<tr>
<th>Soils/Aggregate</th>
<th>Laboratory: Automated Standard/modified Proctor, Resilient Modulus, Vibratory Compaction, Static Compaction, Kneading Compaction, grain-size distribution, index properties</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Field: Light weight deflectometers (LWD), dynamic cone penetrometers (DCP), nuclear density gauge, (NG), drive core, sand cone, Shelby tube sampler and hydraulic pusher, static/repetitive plate load test (PLT)</td>
</tr>
</tbody>
</table>
Appendix C. TxDOT Special Provision Documents
SPECIAL PROVISION
132---003
Embankment

For this project, Item 132, “Embankment,” of the Standard Specifications, is hereby amended with respect to the clauses cited below, and no other clauses or requirements of this Item are waived or changed hereby.

Article 132.1. Description. is supplemented by the following:

Furnish additional materials, equipment, and operators if needed to support the Intelligent Compaction Pooled Fund Research Study “Accelerated Implementation of Intelligent Compaction Technology for Embankment Subgrade Soils, Aggregate Base and Asphalt Pavement Materials”, Subgrade Soils (Type II) to be conducted during placement and compaction of subgrade soils. The purpose of the research study is to demonstrate Intelligent Compaction (IC) technology, to evaluate the benefits of IC technology for compaction of untreated and/or treated subgrade soils compared to conventional compaction equipment/practices, to accelerate the development of IC specifications, and to identify/prioritize needed improvements and research in IC equipment. The IC test results will not be used for approval or rejection of the materials but only for support of the research study.

The research study will be performed for a period of 8 to 10 consecutive working days during normal construction of the project. The research team will provide the IC roller(s) and operators plus all related testing for the research work at no charge. Provide embankment material as specified elsewhere in the plans, equipment and operator(s) to prepare "test beds" and “compaction sections” of uncompacted untreated and/or treated subgrade soils materials for testing by the research team at various locations on the project. The research team will provide testing for the “test beds” and “compaction sections” through Iowa State University (ISU), TxDOT, or a combination of both entities.

Article 132.3.A. Earth Embankments. is supplemented by the following:

Test beds are defined as 100-200 ft long, 20-30 ft wide specially prepared sections away from mainline earthwork construction. Compaction sections are existing 1000-2000 ft long, full earthwork width (e.g., 30 ft or more) areas where production compaction is taking place. Compaction sections are prepared to meet normal construction requirements. Coordinate with the research team during placement of the test beds to ensure that material types, percentage and uniformity of moisture content and lift thickness are satisfactory. Details of the test bed and compaction section preparation are described below.
1. Test Bed Preparation

The approximate number and location of the test beds will be established at a preconstruction meeting at least two weeks prior to the beginning of the research activities. Attend and participate in the preconstruction meeting when scheduled. Test bed locations will be selected away from normal operations. The work will be scheduled at times that are convenient for the Contractor and the research team.

The research team will place instrumentation in the ground prior to the placement of the test bed material.

During test bed preparation, approximately 2-3 hours per day, use equipment to include but not limited to sufficient haul trucks, water truck, grader and disc to place the materials, introduce and blend sufficient water into the materials to obtain uniform moisture content, and level the materials in uniform lifts at the thickness designated by the research team. The team will work with contractor personnel to verify the material type, measure lift depth, and determine the percentage and uniformity of moisture content in a timely manner. Various moisture contents will be specified by the research team between optimum – 4% and optimum + 4%. The tolerances on specified mixing depths and moisture contents are ± 2 inch and ± 2%, respectively. Use the same equipment on the research test beds as used on the remainder of the project. The team will approve the test bed placement before the equipment is removed from the test bed location. The team will completely compact the test bed materials.

At the completion of the research study, the test beds may be left in place at the discretion of the Contractor and TxDOT. The research team is not responsible for any of the specified project material, density, or moisture content requirements.

2. Compaction Section Preparation

Three sections will be considered for compaction. The location of the sections will be established at the preconstruction meeting. Compaction section locations will be selected within normal operation areas. The work will be scheduled at times that are convenient for the Contractor and the research team.

Construct the compaction sections with the same equipment, personnel, and methods used on the project and conforming to the other applicable parts of this specification.

The research team will perform normal compaction operations on three sections of selected untreated and/or treated subgrade soils using the IC rollers. Place and moisture condition the material to meet the specification requirements. For each section, the team will perform IC roller calibration within a 100 ft long area followed by compaction of the remainder. The team will perform tests on 10-20 points for moisture, density and other spot testing in the 100 ft long calibration area and 10-20 additional points in the larger section. The team might compact multiple lifts of subgrade courses. Perform Quality Control tests or review and accept the research team’s data. The team, however, will not be responsible for meeting any of the specified project material, density or moisture content requirements.
Article 132.3.D. Compaction Methods. is supplemented by the following:

3. Time Frame
The research team will be conducting experiments for approximately 8 to 10 consecutive working days, not including days affected by weather conditions.

4. Equipment
The research team will provide the IC roller(s) and roller operator(s) at no cost to TxDOT or to the Contractor. Provide up to 100 gallons of diesel fuel for the operation of the rollers. Provide roller operators for the compaction sections that are qualified, skilled individuals familiar with the operation of the equipment assigned to them.

5. Communication with Research Team (Project Manager)
Meet with the research team at least daily to plan and coordinate the support work. At the time of the meeting, the research team will provide clear instructions on the location, material types, desired moisture content, lift thickness and other details of the preparation of the test beds, compaction sections and/or other types of preparation.

Article 132.3.G. ISU Mobile Testing Laboratory. is added by the following:

Most lab testing will be performed in a mobile field laboratory owned by Iowa State University (ISU). The trailer will be moved onto the project and set up in a convenient location prior to the beginning of the research work. The lab trailer will remain in that location for the duration of the research activities. Provide a suitable location with a solid platform approximately 100 feet long and 50 feet wide for the mobile laboratory location. The exact location will be selected during the preconstruction meeting. The research team will also have several support vehicles on the project and will park them in the same area as the mobile lab.

Article 132.4. Measurement. is supplemented by the following:

This work will be measured and paid for at the contract unit price on providing assistance for the implementation of the research project.

Article 132.3. Payment. is supplemented by the following:

This work will be paid at the unit bid price based on providing assistance for the implementation of the research project. Payment will be full compensation for materials, equipment, and operators, any delay during the testing program, site preparation, use of a GPS system, water tank, discing to control moisture content or any other services required for progress of the Intelligent Compaction research program.
SPECIAL PROVISION

247---031

Flexible Base

For this project, Item 247, “Flexible Base,” of the Standard Specifications, is hereby amended with respect to the clauses cited below, and no other clauses or requirements of this Item are waived or changed hereby.

**Article 132.1. Description.** is supplemented by the following:

Furnish additional materials, equipment, and operators if needed to support the Intelligent Compaction Pooled Fund Research Study “Accelerated Implementation of Intelligent Compaction Technology for Embankment Subgrade Soils, Aggregate Base and Asphalt Pavement Materials”, Aggregate Base Materials (Type III) to be conducted during placement and compaction of flexible base layers. The purpose of the research study is to demonstrate Intelligent Compaction (IC) technology, to evaluate the benefits of IC technology for compaction of flexible base layers compared to conventional compaction equipment/practices, to accelerate the development of IC specifications, and to identify/prioritize needed improvements and research in IC equipment. The IC test results will only be used for support of the research study.

The research study will be performed for a period of 8 to 10 consecutive working days, not including days affected by weather conditions, during normal construction of the project. The research team will provide the IC roller(s) and operators plus all related testing for the research work at no charge. Provide flexible base material as specified elsewhere in the plans, equipment, and operator(s) to prepare "test beds" and “compaction sections” of uncompacted flexible base for testing by the research team at various locations on the project. The research team will provide testing for the “test beds” and “compaction sections” through Iowa State University (ISU), TxDOT, or a combination of both entities.

**Article 132.3.A. Earth Embankments.** is supplemented by the following:

Test beds are defined as 100-200 ft long, 20-30 ft wide specially prepared sections away from mainline earthwork construction. Compaction sections are existing 1000-2000 ft long, full earthwork width (e.g., 30 ft or more) areas where production compaction is taking place. Compaction sections are prepared to meet normal construction requirements. Coordinate with the research team during placement of the test beds to ensure that material types, percentage and uniformity of moisture content and lift thickness are satisfactory. Details of the test bed and compaction section preparation are described below.
1. Test Bed Preparation
The approximate number and location of the test beds will be established at a preconstruction meeting at least two weeks prior to the beginning of the research activities. Attend and participate in the preconstruction meeting when scheduled. Test bed locations will be selected away from normal operations. The work will be scheduled at times that are convenient for the Contractor and the research team.

The research team will place instrumentation in the ground prior to the placement of the test bed material.

During test bed preparation, use equipment to include, but not be limited to sufficient haul trucks, water truck, grader and mixer to place the materials, introduce and blend sufficient water into the materials to obtain uniform moisture content, and level the materials in uniform lifts at the thickness designated by the research team. The research team will work with contractor personnel to verify the material type, measure lift depth, and determine the percentage and uniformity of moisture content in a timely manner. Various moisture contents will be specified by the research team between optimum – 4% and optimum + 4%. The tolerances on specified mixing depths and moisture contents are ± 2 inch and ± 2%, respectively. Use the same equipment on the test beds as used on the remainder of the project. The research team will approve the test bed placement before the equipment is removed from the test bed location. The research team will completely compact the test bed materials.

At the completion of the research study, the test beds may be left in place at the discretion of the Contractor and TxDOT. The research team is not responsible for any of the specified project material, density, or moisture content requirements.

2. Compaction Section Preparation
Three sections will be considered for compaction. The location of the sections will be established at the preconstruction meeting. Compaction section locations will be selected within normal operation areas. The work will be scheduled at times that are convenient for the Contractor and the research team.

Construct the compaction sections with the same equipment, personnel, and methods used on the project and conforming to the other applicable parts of this specification.

The research team will perform normal compaction operations on three sections of selected flexible base layers using the IC rollers. Place and moisture condition the material to meet the specification requirements. For each section, the research team will perform IC roller calibration within a 100 ft long area followed by compaction of the remainder. The research team will perform tests on 10-20 points for moisture, density and other spot testing in the 100 ft long calibration area and 10-20 additional points in the larger section. The research team might compact multiple lifts of base courses. Perform Quality Control tests or review and accept the research team’s data. The research team will not be responsible for meeting any of the specified project material, density or moisture content requirements.
Article 132.3.D. Compaction Methods. is supplemented by the following:

3. Equipment
The research team will provide the IC roller(s) and roller operator(s) at no cost to TxDOT or to the Contractor. Provide up to 100 gallons of diesel fuel for the operation of the rollers. Provide roller operators for the compaction sections that are qualified, skilled individuals familiar with the operation of the equipment assigned to them.

4. Communication with Research Team (Project Manager)
Meet with the research team at least daily to plan and coordinate the support work. At the time of the meeting, the research team will provide clear instructions on the location, material types, desired moisture content, lift thickness and other details of the preparation of the test beds, compaction sections and/or other types of preparation.

Article 132.3.G. ISU Mobile Testing Laboratory. is added by the following:

Most lab testing will be performed in a mobile field laboratory owned by Iowa State University (ISU). The trailer will be moved onto the project and set up in a convenient location prior to the beginning of the research work. The lab trailer will remain in that location for the duration of the research activities. Provide a suitable location with a solid platform approximately 100 feet long and 50 feet wide for the mobile laboratory location. The exact location will be selected during the preconstruction meeting. The research team will also have several support vehicles on the project and will park them in the same area as the mobile lab.

Article 132.4. Measurement. is supplemented by the following:

This work will be measured and paid for at the contract unit price on providing assistance for the implementation of the research project.

Article 132.3. Payment. is supplemented by the following:

This work will be paid at the unit bid price based on providing assistance for the implementation of the research project. Payment will be full compensation for materials, equipment, and operators, any delay during the testing program, site preparation, use of a GPS system, water tank, mixer to control moisture content or any other services required for progress of the Intelligent Compaction research program.
SPECIAL PROVISION

260---002

Lime Treatment (Road-Mixed)

For this project, Item 260, “Lime Treatment (Road –Mixed),” of the Standard Specifications, is hereby amended with respect to the clauses cited below, and no other clauses or requirements of this Item are waived or changed hereby.

**Article 132.1. Description.** is supplemented by the following:

Furnish additional materials, equipment, and operators if needed to support the Intelligent Compaction Pooled Fund Research Study “Accelerated Implementation of Intelligent Compaction Technology for Embankment Subgrade Soils, Aggregate Base and Asphalt Pavement Materials”, Subgrade Soils (Type II) to be conducted during placement and compaction of lime treated subgrade soils. The purpose of the research study is to demonstrate Intelligent Compaction (IC) technology, to evaluate the benefits of IC technology for compaction of lime treated subgrade soils compared to conventional compaction equipment/practices, to accelerate the development of IC specifications, and to identify/prioritize needed improvements and research in IC equipment. The IC test results will only be used for support of the research study.

The research study will be performed for a period of 8 to 10 consecutive working days, not including days affected by weather conditions, during normal construction of the project. The research team will provide the IC roller(s) and operators plus all related testing for the research work at no charge. Provide lime treated material as specified elsewhere in the plans, equipment, and operator(s) to prepare "test beds" and “compaction sections” of uncompacted subgrade soil for testing by the research team at various locations on the project. The research team will provide testing for the “test beds” and “compaction sections” through Iowa State University (ISU), TxDOT, or a combination of both entities.

**Article 132.3.A. Earth Embankments.** is supplemented by the following:

Test beds are defined as 100-200 ft long, 20-30 ft wide specially prepared sections away from mainline earthwork construction. Compaction sections are existing 1000-2000 ft long, full earthwork width (e.g., 30 ft or more) areas where production compaction is taking place. Compaction sections are prepared to meet normal construction requirements. Coordinate with the research team during placement of the test beds to ensure that material types, percentage and uniformity of moisture content and lift thickness are satisfactory. Details of the test bed and compaction section preparation are described below.
1. **Test Bed Preparation**
   The approximate number and location of the test beds will be established at a preconstruction meeting at least two weeks prior to the beginning of the research activities. Attend and participate in the preconstruction meeting when scheduled. Test bed locations will be selected away from normal operations. The work will be scheduled at times that are convenient for the Contractor and the research team.

   The research team will place instrumentation in the ground prior to the placement of the test bed material.

   During test bed preparation, use equipment to include, but not be limited to sufficient haul trucks, water truck, grader and mixer to place the materials, introduce and blend sufficient water into the materials to obtain uniform moisture content, and level the materials in uniform lifts at the thickness designated by the research team. The research team will work with contractor personnel to verify the material type, measure lift depth, and determine the percentage and uniformity of moisture content in a timely manner. Various moisture contents will be specified by the research team between optimum – 4% and optimum + 4%. The tolerances on specified mixing depths and moisture contents are ± 2 inch and ± 2%, respectively. Use the same equipment on the test beds as used on the remainder of the project. The research team will approve the test bed placement before the equipment is removed from the test bed location. The research team will completely compact the test bed materials.

   At the completion of the research study, the test beds may be left in place at the discretion of the Contractor and TxDOT. The research team is not responsible for any of the specified project material, density, or moisture content requirements.

2. **Compaction Section Preparation**
   Three sections will be considered for compaction. The location of the sections will be established at the preconstruction meeting. Compaction section locations will be selected within normal operation areas. The work will be scheduled at times that are convenient for the Contractor and the research team.

   Construct the compaction sections with the same equipment, personnel, and methods used on the project and conforming to the other applicable parts of this specification.

   The research team will perform normal compaction operations on three sections of selected lime treated subgrade soils using the IC rollers. Place and moisture condition the material to meet the specification requirements. For each section, the research team will perform IC roller calibration within a 100 ft long area followed by compaction of the remainder. The research team will perform tests on 10-20 points for moisture, density and other spot testing in the 100 ft long calibration area and 10-20 additional points in the larger section. The research team might compact multiple lifts of subgrade courses. Perform Quality Control tests or review and accept the research team’s data. The research team will not be responsible for meeting any of the specified project material, density or moisture content requirements.
Article 132.3.D. Compaction Methods. is supplemented by the following:

3. Equipment
The research team will provide the IC roller(s) and roller operator(s) at no cost to TxDOT or to the Contractor. Provide up to 100 gallons of diesel fuel for the operation of the rollers. Provide roller operators for the compaction sections that are qualified, skilled individuals familiar with the operation of the equipment assigned to them.

4. Communication with Research Team (Project Manager)
Meet with the research team at least daily to plan and coordinate the support work. At the time of the meeting, the research team will provide clear instructions on the location, material types, desired moisture content, lift thickness and other details of the preparation of the test beds, compaction sections and/or other types of preparation.

Article 132.3.G. ISU Mobile Testing Laboratory. is added by the following:

Most lab testing will be performed in a mobile field laboratory owned by Iowa State University (ISU). The trailer will be moved onto the project and set up in a convenient location prior to the beginning of the research work. The lab trailer will remain in that location for the duration of the research activities. Provide a suitable location with a solid platform approximately 100 feet long and 50 feet wide for the mobile laboratory location. The exact location will be selected during the preconstruction meeting. The research team will also have several support vehicles on the project and will park them in the same area as the mobile lab.

Article 132.4. Measurement. is supplemented by the following:

This work will be measured and paid for at the contract unit price on providing assistance for the implementation of the research project.

Article 132.3. Payment. is supplemented by the following:

This work will be paid at the unit bid price based on providing assistance for the implementation of the research project. Payment will be full compensation for materials, equipment, and operators, any delay during the testing program, site preparation, use of a GPS system, water tank, mixer to control moisture content or any other services required for progress of the Intelligent Compaction research program.
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