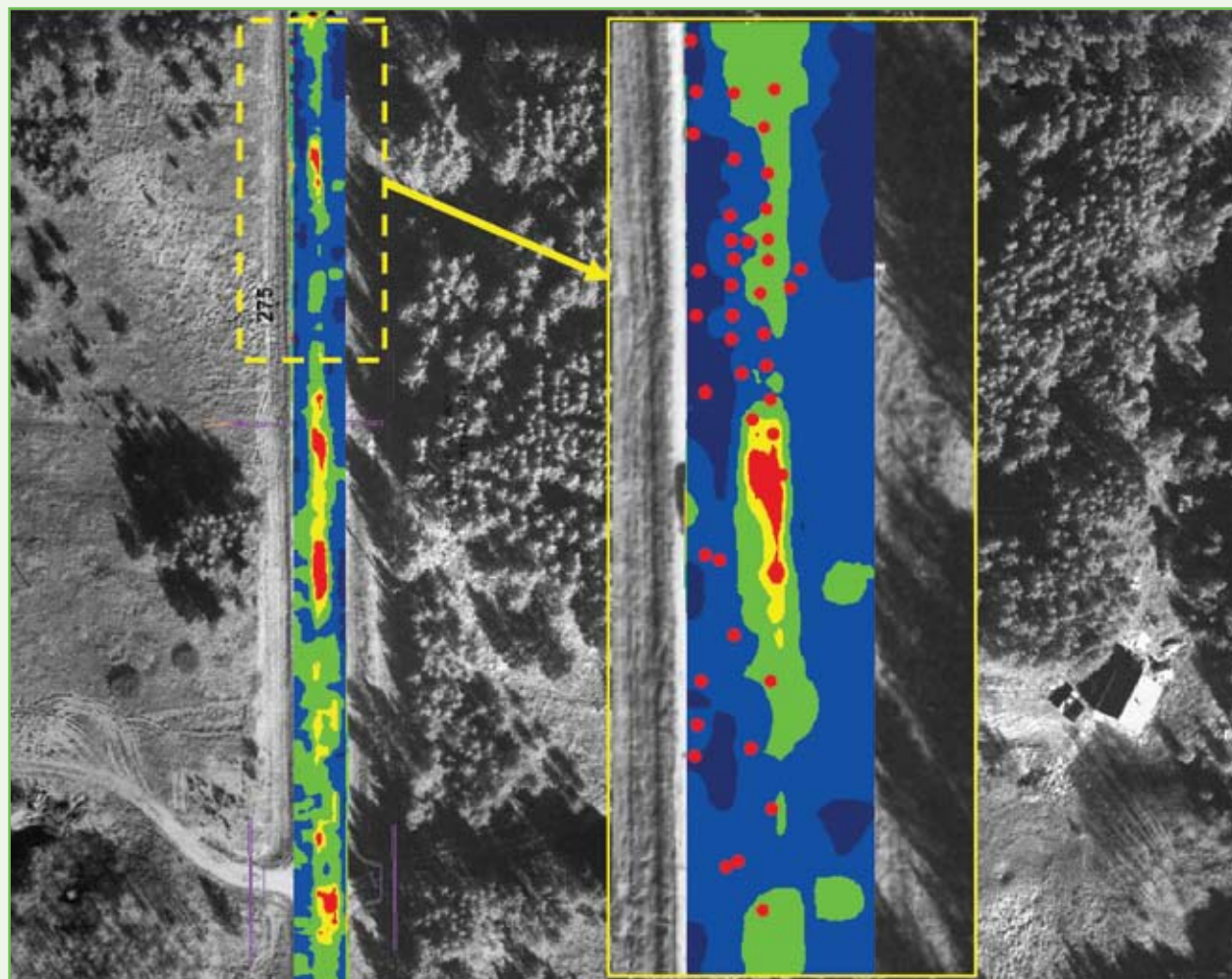


Report of the Webinar Workshop on Intelligent Compaction for Earthworks and HMA

ER10-02

March 1–2, 2010



Report of the Webinar Workshop on Intelligent Compaction for Earthworks and HMA

March 1–2, 2010

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**Sponsored by the Iowa Department of Transportation
and the Earthworks Engineering Research Center at Iowa State University**

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Preface

This document summarizes the discussion and findings of the Webinar Workshop on Intelligent Compaction for Earthworks and Hot Mix Asphalt (HMA), held March 1–2, 2010. This workshop represents the third annual meeting organized jointly by the Iowa Department of Transportation and the Earthworks Engineering Research Center at Iowa State University. The objective of the workshop was to generate a focused discussion to identify the research, education, and implementation goals necessary for advancing intelligent compaction for earthworks and HMA. Technical presentations, a discussion of developmental specifications, a vote to prioritize needs, and a discussion about organizing the Technology Transfer Intelligent Compaction Consortium comprised the workshop. About 165 attendees representing state departments of transportation, Federal Highway Administration, the National Cooperative Highway Research Program, trade organizations, contractors, equipment manufacturers, and researchers participated in the webinar.

Acknowledgments

The Earthworks Engineering Research Center (EERC) at Iowa State University of Science and Technology gratefully acknowledges the Iowa Department of Transportation for sponsoring the webinar. Denise Wagner of the EERC provided administrative support in organizing and executing the webinar.

The EERC also sincerely thanks the following individuals for their support of this workshop:

Planning Committee

Sandra Larson (co-chair), Iowa Department of Transportation
 David White (co-chair), Earthworks Engineering Research Center, Iowa State University
 Steve Megivern, Iowa Department of Transportation
 Mark Dunn, Iowa Department of Transportation
 Sharon Prochnow, Institute for Transportation, Iowa State University
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Presenters/Moderators

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 Pavana Vennapusa, Earthworks Engineering Research Center, Iowa State University
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 David Jared, Georgia Department of Transportation
 Brett Dening, New York State Department of Transportation
 Zhiming Si, Texas Department of Transportation
 Rebecca Embacher, Minnesota Department of Transportation
 Greg Johnson, Minnesota Department of Transportation
 Steve Adamsky, Minnesota Department of Transportation
 Mark Dunn, Iowa Department of Transportation
 Fredrik Åkesson, Dynapac AB
 Chris Connolly, BOMAG Americas, Inc.
 Dean Potts, Caterpillar, Inc.
 Derrick Darby, Trimble Navigation Ltd.
 William Stone, Missouri Department of Transportation
 Riyad Wahab, Illinois Department of Transportation

Executive Summary

A Webinar Workshop on Intelligent Compaction for Earthworks and Hot Mix Asphalt (HMA) was held March 1–2, 2010, to consider ways of implementing intelligent compaction (IC) and continuous compaction control (CCC) technologies in earthwork and HMA practice. The objectives were to facilitate collaboration and information exchange, update the IC/CCC roadmap of key research and training areas, establish a Technology Transfer Intelligent Compaction Consortium (TTICC) special task force to develop widely accepted specifications, and evaluate the webinar format for future workshops.

Webinar sessions were held over two days and were organized as follows:

- Day 1: Review of the 2009 workshop proceedings; technical presentations about demonstration projects and FHWA pooled fund research; briefings from participating state departments of transportation (DOTs); review of state DOTs' existing IC/CCC developmental specifications
- Day 2: Presentations from industry/equipment manufacturers; additional state DOT briefings; a discussion of the proposed problem statement for the TTICC pooled fund study; closing remarks/comments by DOTs, manufacturers, and contractors

Additionally, webinar participants were surveyed to update the IC Road Map, a list of key research, implementation, and training areas developed from the 2008 and 2009 workshops. Participants were given the 2009 IC Road Map and were asked to rank the items and provide comments regarding topics that should be removed, adjusted, or added. The 2010 IC Road Map, based on participant voting, is presented in Table 5 of the report and replicated below.

The starred (*) items in Table 5 denote the two new elements added this year. The numbers in the parentheses indicate the number of votes each topic area received.

Table 5. Prioritized IC technology research/implementation needs – 2010 workshop

Prioritized IC/CCC Technology Research/Implementation Needs

1. Intelligent Compaction and In Situ Correlations (91)
2. Intelligent Compaction Specifications/Guidance (46)
3. In Situ Testing Advancements and New Mechanistic Based QC/QA (43)
4. Intelligent Compaction Technology Advancements and Innovations (21)
5. Project Scale Demonstration and Case Histories (19)
6. Understanding Impact of Non-Uniformity of Performance (18)
7. Data management and Analysis (17)
8. Standardization of roller output and output format files* (13)
9. Understanding Roller Measurement Influence Depth (11)
10. Education Program/Certification Program (6)
11. Intelligent Compaction Research Database (6)
12. Standardization of Roller Sensor Calibration Protocols* (4)

Important outcomes from the 2010 workshop included providing a forum that facilitated information exchange and collaboration, updating and prioritizing the IC/CCC road map, connecting people interested in implementing IC/CCC into earthwork and HMA construction practice, and developing plans for further workshops and other activities. Based on the information derived from the webinar sessions, as well as the authors' perspective, Table 7 presents a proposed action plan for advancing IC/CCC technologies.

Table 7. Action plan for advancing IC technologies into earthwork and HMA practices

Action Plan for Advancing IC/CCC Technologies into Earthwork and HMA

1. Establish a Technology Transfer Intelligent Compaction Consortium (TTICC) to identify research gaps and implementation needs, develop problem statements for needed research, identify key partners, and form a national-level Specifications Technical Working Group to coordinate efforts.
2. Explore the possibility of conducting a National Highway Institute course or a one-day training course at conferences on IC/CCC technologies.
3. Develop several case histories (technical briefs) to demonstrate the technical aspects and benefits of the technologies.
4. Plan future webinar workshop meetings to facilitate technology transfer.

Introduction

The Challenge

Participation in this year's Webinar Workshop on Intelligent Compaction for Earthworks and Hot Mix Asphalt (HMA), held March 1–2, 2010, exceeded the previous two years' attendance and emphatically indicated that there is growing interest in understanding how to effectively incorporate intelligent compaction (IC) or continuous compaction control (CCC) technologies into earthwork and hot mix asphalt (HMA) pavement construction practice. However, the key implementation obstacles identified in the previous years' workshops^{1,2} largely remain. These obstacles include

- Lack of adequate knowledge about technical aspects,
- No widely accepted specifications or standards,
- Limited number of well-documented case histories demonstrating the benefits of IC/CCC, and
- Inadequate education/training materials.

Improvements to earthwork and HMA construction using IC/CCC can offer a significant return on capital investments and can enhance the abilities of state and federal agencies and contractors to construct infrastructure projects better, more quickly, more safely, and more cheaply. These benefits will not be maximized without addressing the implementation obstacles noted above.

Workshop Objectives and Agenda

The following were the key objectives of this workshop webinar:

- Facilitate a collaborative exchange of information that accelerates effective implementation of IC/CCC technologies.
- Update the IC/CCC 2010 roadmap for identifying key research and training focal areas (via an email voting process).
- Establish a collaborative task force by founding the Technology Transfer Intelligent Compaction Consortium (TTICC) with specific tasks and a schedule to develop widely accepted and technology-independent specifications.
- Evaluate the webinar delivery format for future workshops in light of travel restrictions for many participants.

¹ White D.J. (2008). *Report of the Workshop on Intelligent Compaction for Soils and HMA*. ER08-01, Workshop Organized by the Earthworks Engineering Research Center at Iowa State University and the Iowa Department of Transportation, April 2–4, West Des Moines, Iowa.

² White D.J., and Vennapusa, P. (2009). *Report of the Workshop on Intelligent Construction for Earthworks*. ER09-02, Workshop Organized by the Earthworks Engineering Research Center at Iowa State University and the Iowa Department of Transportation, April 14–16, West Des Moines, Iowa.

The webinar sessions were held over two days (four hours each day) and were attended by about 165 participants from 20 state departments of transportations (DOTs), 8 industry/manufacturing companies, 8 contractors/consultants, 5 academic research facilities, the National Cooperative Highway Research Program, Federal Highway Administration (FHWA), Iowa American General Contractors (AGC), and the Asphalt Paving Association of Iowa (APAI).

The first day involved a review of the 2009 workshop proceedings and the webinar agenda, technical presentations about Iowa Department of Transportation (Iowa DOT) 2009 IC demonstration projects and FHWA pooled fund studies in areas of subgrade/subbase research, three participating state department of transportation (DOT) briefings (Georgia Department of Transportation [GDOT], New York State Department of Transportation [NYSDOT], and Texas Department of Transportation [TxDOT]), and a review of the IC/CCC developmental specifications produced by DOTs in Minnesota, Iowa, and Texas.

The second day involved industry/equipment manufacturer presentations, two participating state DOT briefings (Missouri Department of Transportation [MoDOT] and Illinois Department of Transportation [IDOT]), a discussion of the proposed problem statement for the Technology Transfer for Intelligent Compaction Consortium (TTICC) pooled fund study, results from the 2010 prioritized roadmap voting, and closing remarks/comments by DOTs, manufacturers, and contractors.

The complete workshop agenda, list of workshop attendees, Iowa DOT and TxDOT developmental specifications, and webinar evaluation summary results are presented in Appendices A through E, respectively. As background information, the remainder of this introduction presents a brief review of previous workshop proceedings, a review of the key outcomes and action items identified in the 2009 workshop, and the details of the TTICC problem statement. More background information regarding IC/CCC technologies and key references are provided in the 2008/2009 workshop proceedings ^{1,2}.

Background

Overview of the 2008 and 2009 IC Workshops

The 2008 and 2009 workshops were each attended by about 100 participants, with representatives from several state DOTs, FHWA, industry/manufacturers, contractors, and universities. The workshops featured several technical presentations, breakout sessions, panel discussions, and group exercises to identify and prioritize implementation strategies. The 2008 workshop focused on IC technologies, while the 2009 workshop focused on IC and automated machine guidance (AMG) technologies. One of the key outcomes from both workshops was that a follow-up annual event was highly encouraged to identify opportunities to advance/accelerate implementation of IC/CCC/AMG technologies into earthwork and HMA construction. Proceedings for the workshop sessions that summarize the workshop events and outcomes have been developed and are available online at www.eerc.iastate.edu/publications.cfm ^{1,2} (Figure 1).

Key Outcomes and Action Items of 2009 Workshop

The 2009 workshop offered a platform for researchers, practitioners, and policy makers to exchange ideas and provide input on the current state of IC and AMG practice/technology.

Some of the significant outcomes of the 2009 workshop included identifying (a) a prioritized top 10 list of IC technology research/implementation needs, or the IC Road Map (Table 1), and (b) action items for advancing the IC Road Map (Table 2 and Table 3). A panel discussion involving representatives from state DOTs, FHWA, and manufacturer representatives was conducted to identify action items, challenges, and strategies for moving forward. Key outcomes from the panel discussion are presented in Table 2. Participants during the workshop identified that although the road map is a good starting point, effective and accelerated implementation of IC technologies will require “champions” to create opportunities.



Figure 1. Reports for the 2008 and 2009 workshops (www.eerc.iastate.edu/publications.cfm)

Table 1. Prioritized IC technology research/implementation needs – 2009 workshop

Prioritized Top 10 IC Technology Research/Implementation Needs	
1.	Intelligent Compaction Specifications/Guidance (41)
2.	Intelligent Compaction and In Situ Correlations (25)
3.	In Situ Testing Advancements and New Mechanistic-Based QC/QA (20)
4.	Understanding Impact of Non-Uniformity of Performance (16)
5.	Data Management and Analysis (16)
6.	Project Scale Demonstration and Case Histories (13)
7.	Understanding Roller Measurement Influence Depth (13)
8.	Intelligent Compaction Technology Advancements and Innovations (9)
9.	Education Program/Certification Program (8)
10.	Intelligent Compaction Research Database (8)

Table 2. Summary of panel discussion – 2009 workshop

Key Outcomes from Panel Discussion	
1.	Need “champions” to create opportunities for implementation—using the technology for QC by contractor and performing independent QA by DOT is a good strategy to further implementation.
2.	Need demonstration/pilot projects to improve confidence, create evidence that it reduces costs/improves efficiency to contractors, create training opportunities, and implement pilot specifications.
3.	Need more research on identifying “gold standard” QA method for correlations with IC measurements.
4.	Need more refinement in the technologies with respect to more user-friendly on-board interfaces for data analysis and visualization and retrofitting capabilities.

Table 3. Action items for advancing IC road map and AMG road map – 2009 workshop

Action Items for Advancing IC Road Map and AMG Road Map	
1.	Develop six case histories (technical briefs) to demonstrate the benefits of the technologies
2.	Conduct six webinars to facilitate training and technology transfer
3.	Create a Specifications Technical Working Group to coordinate efforts
4.	Regularly update the Earthworks Engineering Research Center web site (www.eerc.iastate.edu)
5.	Explore the possibility of conducting a National Highway Institute course on IC and AMG technologies
6.	Identify current research gaps, develop problem statements for needed research, and identify key research partners

Proposed Technology Transfer Intelligent Compaction Consortium (TTICC)

To help accelerate effective implementation of the IC/CCC technologies, experts from state DOTs, FHWA, academia, and industry must collaborate and communicate. For this purpose, the Iowa DOT proposed a draft pooled fund problem statement for a TTICC to be discussed during the 2010 workshop. The draft TTICC problem statement is provided in Appendix F. The main goals of the TTICC are to

- Identify needed research projects,
- Develop pooled fund initiatives,
- Plan and conduct an annual workshop on intelligent compaction for soils and HMA,
- Provide a forum for technology exchange between participants,
- Develop and fund technology transfer materials, and
- Provide ongoing communication of state agencies’ research needs to the FHWA, states, industry, and the Earthworks Engineering Research Center (EERC).

It is anticipated that the TTICC would become the national forum for involving states in the technical exchange necessary for collaboration and new initiatives, as well as a forum for advancing the applications and benefits of IC/CCC technologies for soils, bases, and asphalt pavements. State participation in this process will be through a pooled fund. FHWA, industry, and other organizations will be invited to participate in the project discussions and activities.

Presentations

The following is a list of the presentations delivered at the workshop. The presentation slides are provided on the following pages.

1. Intelligent Compaction for Earthworks and HMA—Sandra Larson and David White
2. Iowa DOT Demonstration Projects 2009—David White, Pavana Vennapusa, and Heath Gieselman
3. FHWA Pooled Fund Study Update —David White, Pavana Vennapusa, and Heath Gieselman
4. Intelligent Compaction for Hot Mix Asphalt: GDOT Demonstration Results—David Jared
5. Overview and Status Update: Intelligent Construction in New York—Brett Denning
6. Texas Department of Transportation Status Update—Zhiming Si
7. Mn/DOT Specification Development for Use of CCC on Non-Granular and Granular Materials—Rebecca Embacher
8. Mn/DOT Priorities and Specification Development for Use of IC on HMA—Greg Johnson
9. Mn/DOT Specification Development for Use of IC on Emulsion Stabilized FDR—Steve Adamsky
10. Manufacturer Updates
 - a. Dynapac C³—Fredrik Åkesson, Dynapac
 - b. Intelligent Compaction and the Greenroads Rating System—Dean Potts, Caterpillar
 - c. Trimble Connected Community for Compaction—Derrick Darby, Trimble/XYZ
 - d. New Actions of Sakai in TPF's IC Projects—Todd Mansell, Sakai
11. Update on MoDOT's Intelligent Compaction Efforts—William Stone
12. Illinois DOT Experience and Concerns with IC—Riyad Wahab

Intelligent Compaction for Earthworks and HMA

Sandra Larson and David White



Acknowledgments

- Mark Dunn, Ed Engle, Stephen Megivern – Iowa DOT
- Dr. Pavana Vennapusa, Assist. Research Prof., EERC
- Heath Gieselman, M.S. Assoc. Scientist, EERC
- Several ISU students
- Denise Wagner, CP Tech Center, InTrans
- All of you for participating

Registered Participants - 115

- State DOTs/FHWA: CT, GA, IA, IL, KS, MD, MI, MN, NC, ND, NJ, NY, OH, UT, VA, WA, and WI = 82 participants
- Contractors/Consultants: 18 participants
 - Norris Asphalt
 - Stenger Construction
 - Fort Dodge Asphalt
 - CMA Consulting Engineers
 - Dynamic Force Solutions
 - Kiewit
- Industry: 9 participants
 - Sauer-Danfoss
 - Bomag
 - Caterpillar
 - Dynapac
 - Volvo
 - Sakai
- Trade Organizations: 2 participants
 - APWA
 - Iowa AGC
- Academia: 5 participants
- Others ??? (Please register by emailing Denise Wagner(dfwagner@iastate.edu))

States Involved with IC Projects



Intelligent Compaction for Earthworks and HMA

Sandra Larson and David White

"Ground" Rules

1. Please keep phone on MUTE!
2. Use chat function and submit to "QUESTIONS/COMMENTS"
3. For each session, the moderator will summarize key QUESTIONS and COMMENTS and presenters will provide feedback
4. Please request to make a verbal comment, the moderator will initiate.
5. Presenters Options: (1) you run slides from your computer; (2) request we run them; or (3) we run them and present them!

FTP Site

- Documents referenced during this workshop will be posted at:

<ftp://www.intrans.iastate.edu/IC%20Workshop%202010/>

username: intransftp
password: ftpintrans

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Review Agenda



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www.ccee.engineering.iastate.edu

Previous Workshop Results



- 2.5 day events in Des Moines, IA
 - April 2-4, 2008
 - April 14-16, 2009
- ~100 participants (State DOTs, FHWA, Contractors, Equipment Manufacturers, Academics)
- \$\$\$ provided for State DOTs
- Technical Session, Breakout Working Sessions, Panel Discussion, Group Exercise
- Funded by Iowa DOT

<http://www.eerc.iastate.edu/publications.cfm>

2009 IC Roadmap

Table 3. Prioritized IC technology research/implementation needs

Prioritized Top 10 IC Technology Research/Implementation Needs

1. Intelligent Compaction Specifications/Guidance (41)
2. Intelligent Compaction and In Situ Correlations (25)
3. In Situ Testing Advancements and New Mechanistic-Based QC/QA (20)
4. Understanding Impact of Non-Uniformity of Performance (16)
5. Data Management and Analysis (16)
6. Project Scale Demonstration and Case Histories (13)
7. Understanding Roller Measurement Influence Depth (13)
8. Intelligent Compaction Technology Advancements and Innovations (9)
9. Education Program/Certification Program (8)
10. Intelligent Compaction Research Database (8)

2009 Key Outcomes

Table 6. Summary of panel discussion

Key Outcomes from Panel Discussion

1. Need "champions" to create opportunities for implementation—using the technology for QC by contractor and performing independent QA by DOT is a good strategy to further implementation.
2. Need demonstration/pilot projects to improve confidence, create evidence that it reduces costs/improves efficiency to contractors, create training opportunities, and implement pilot specifications.
3. Need more research on identifying "gold standard" QA method for correlations with IC measurements.
4. Need more refinement in the technologies with respect to more user-friendly on-board interfaces for data analysis and visualization and retrofitting capabilities.

Intelligent Compaction for Earthworks and HMA

Sandra Larson and David White

2009 Key Outcomes

Table 9. Action items for advancing IC road map and AMG road map

Action Items for Advancing IC Road Map and AMG Road Map

1. Develop six case histories (technical briefs) to demonstrate the benefits of the technologies
2. Conduct six webinars to facilitate training and technology transfer
3. Create a Specifications Technical Working Group to coordinate efforts
4. Regularly update the Earthworks Engineering Research Center web site (www.eerc.iastate.edu)
5. Explore the possibility of conducting a National Highway Institute course on IC and AMG technologies
6. Identify current research gaps, develop problem statements for needed research, and identify key research partners

2010 Workshop Goals/Opportunities

1. Provide a collaborative exchange of information that accelerates effective implementation of IC technologies.
2. Update roadmap for identifying key research and training focal areas (via email voting process).
3. Establish collaborative task force with specific task and schedule to develop widely accepted and technology independent specifications.

Iowa DOT Demonstration Projects 2009

David White, Pavana Vennapusa,
and Heath Gieselmann

IOWA STATE UNIVERSITY
Civil, Construction & Environmental Engineering



Iowa DOT Demonstration Projects 2009

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Heath Gieselmann, M.S.
Assistant Scientist III, EERC

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March 1-2, 2010

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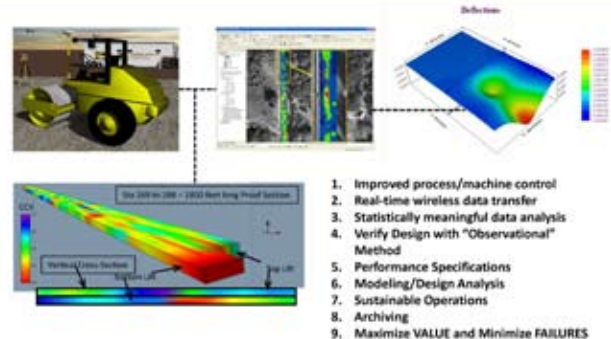
Iowa Program to Implement IC Technology

- Develop Research Work Plan 2009
 - Three demonstration projects
 - I-29 (Subbase/Pavement Foundation)
 - Hwy 30 (Subgrade)
 - Hwy 218 (Hot Mix Asphalt - Overlay)
- Develop 2010 Special Provision for IC
 - HMA – three projects (two specifications completed)
 - Subgrade – one project (in progress)
 - Subbase/Pavement Foundation – two projects (in-progress)


Why is this Important?

- **Improve construction process control**
 - Fix “bad” stops before its too late
 - Manage construction equipment during compaction operations efficiently
- **Improved QC/QA operations**
 - Reduce field personnel time and testing?
 - Reduce spatially variability
- **Impacts**
 - Cost, performance, safety, sustainable...

Future Goal – Improved Risk Assessment



IOWA STATE UNIVERSITY
GEOTECHNICAL MOBILE LAB
Advancing Intelligent Construction

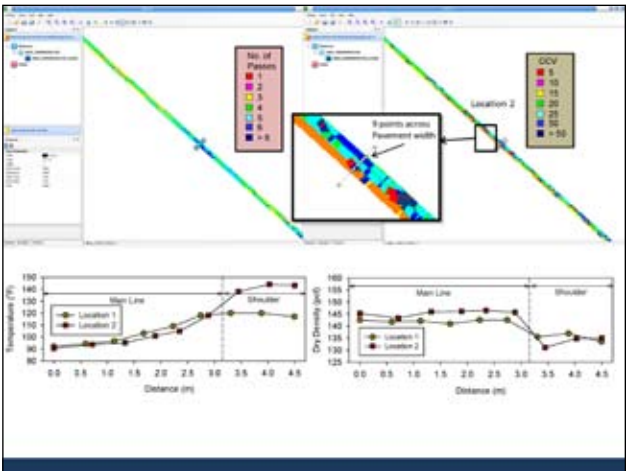
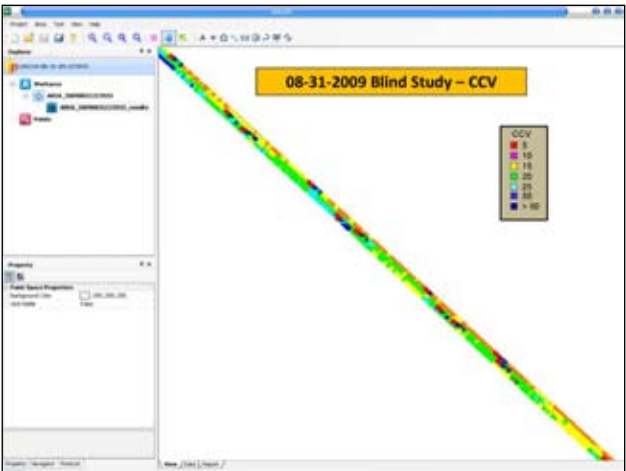
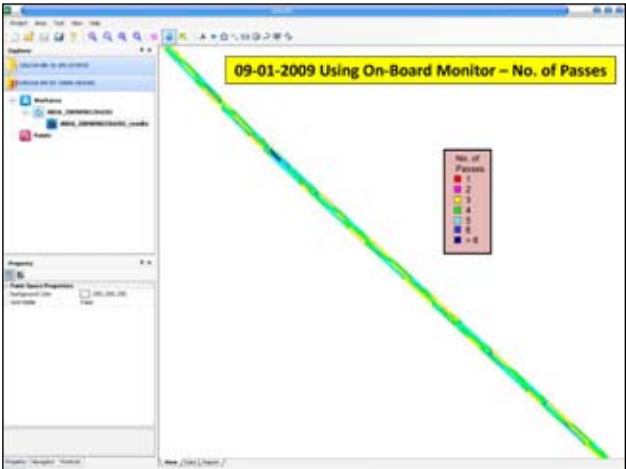
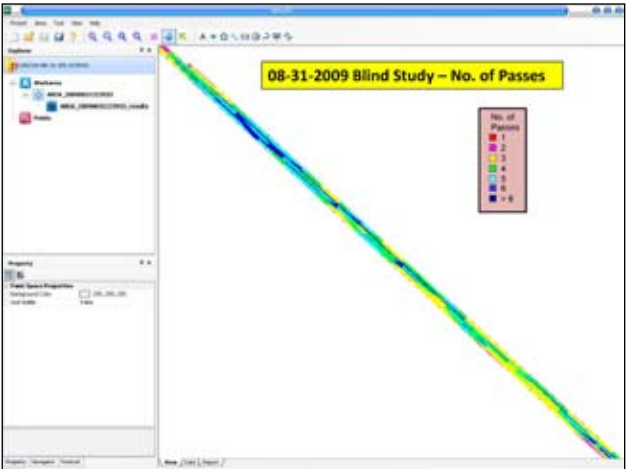



Correlations - In-Situ Testing Equipment



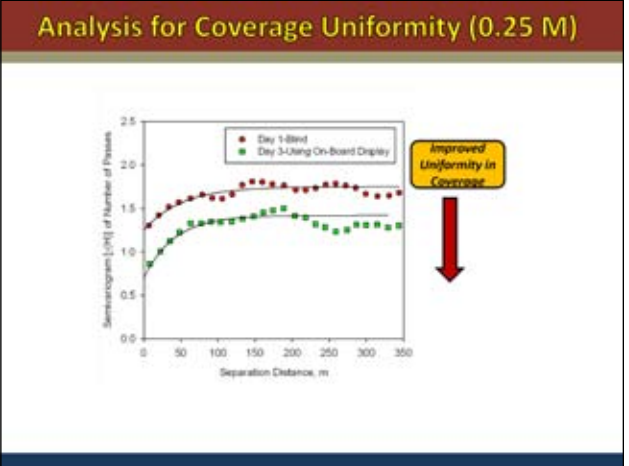
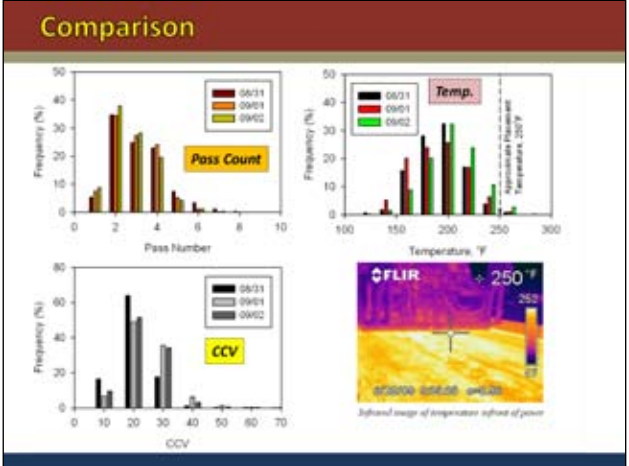
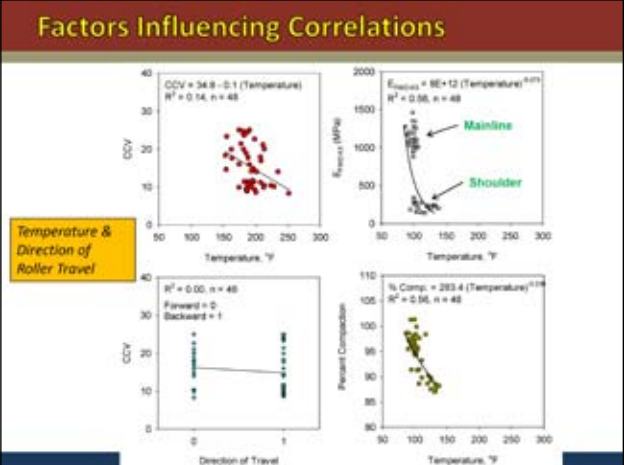
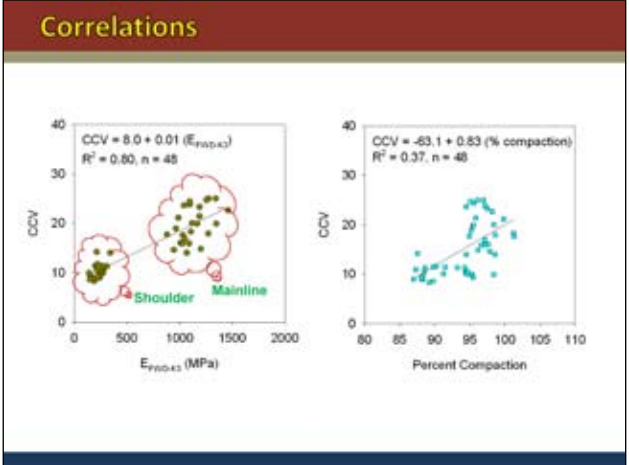
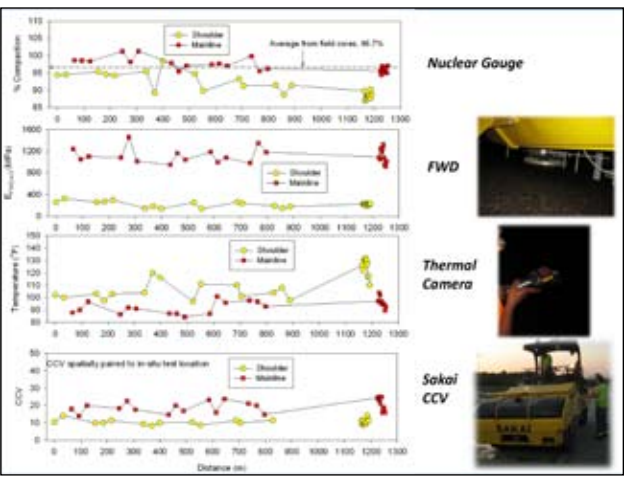
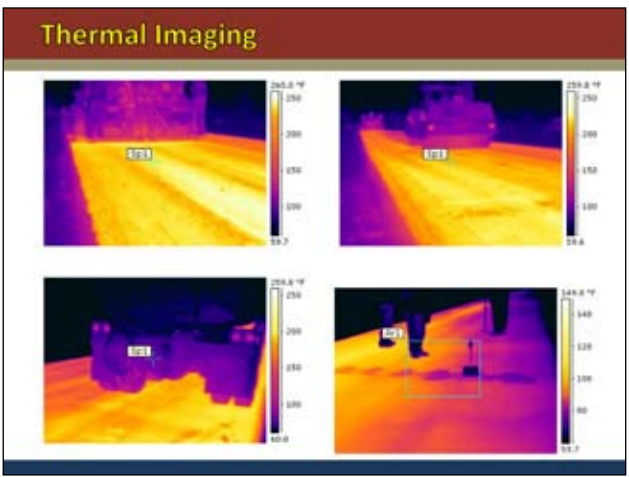
Iowa DOT Demonstration Projects 2009

David White, Pavana Vennapusa,
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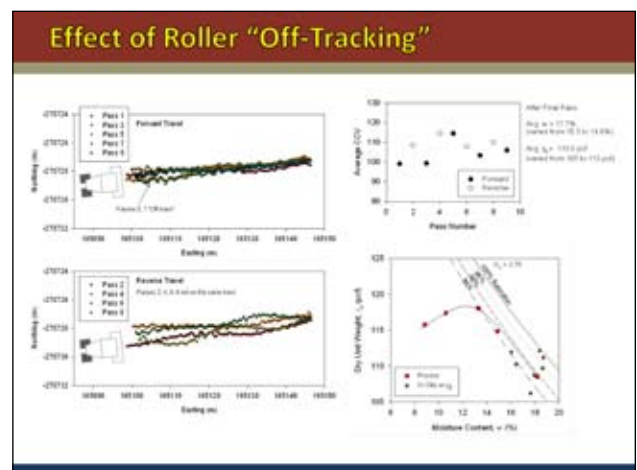
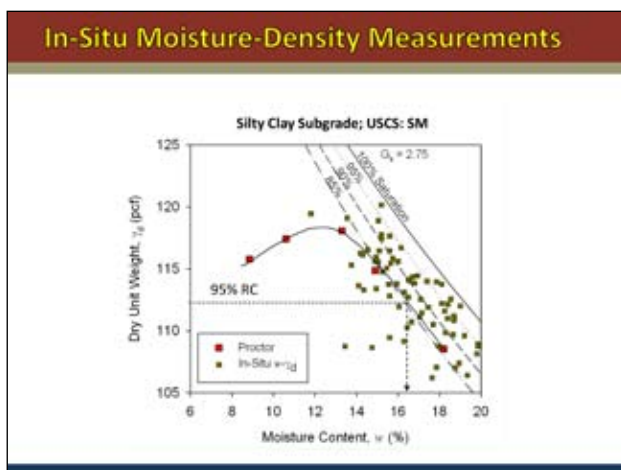
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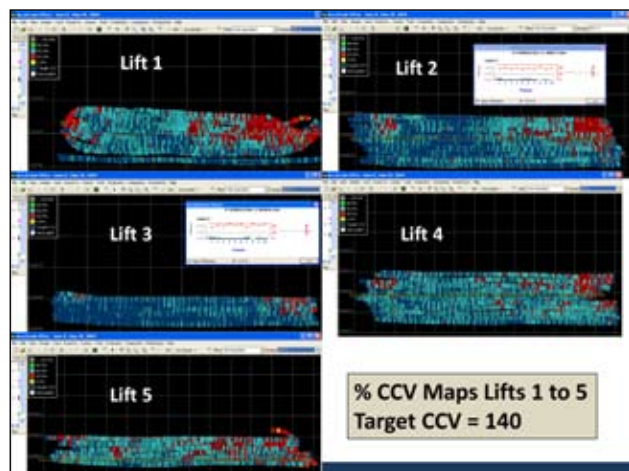
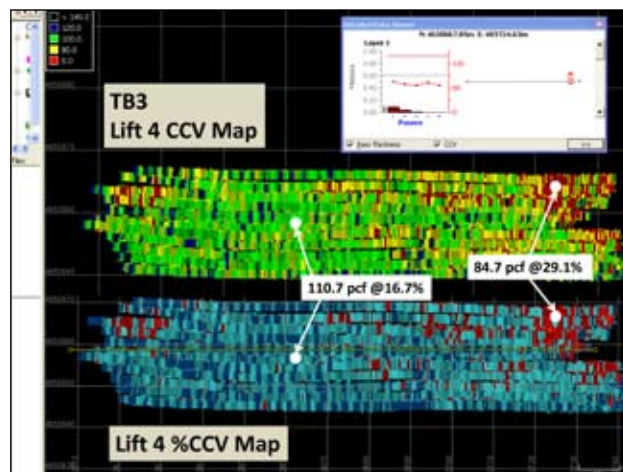
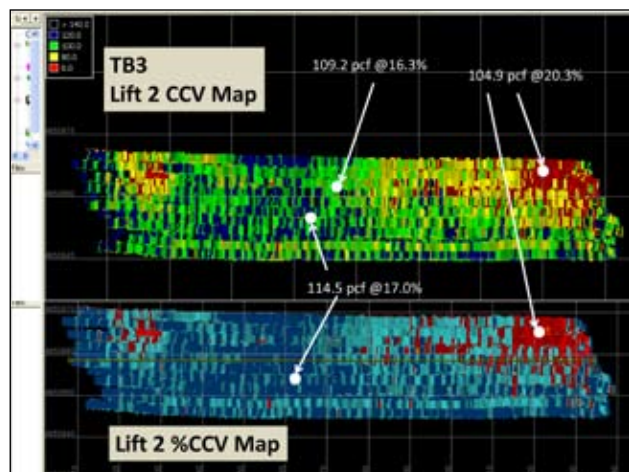
Iowa DOT Demonstration Projects 2009

David White, Pavana Vennapusa,
and Heath Gieselman



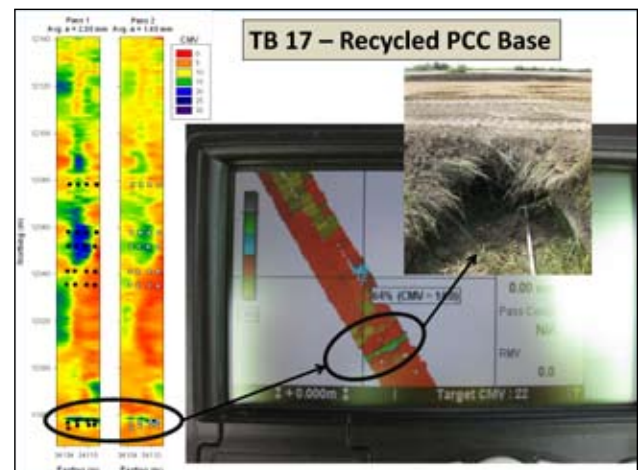
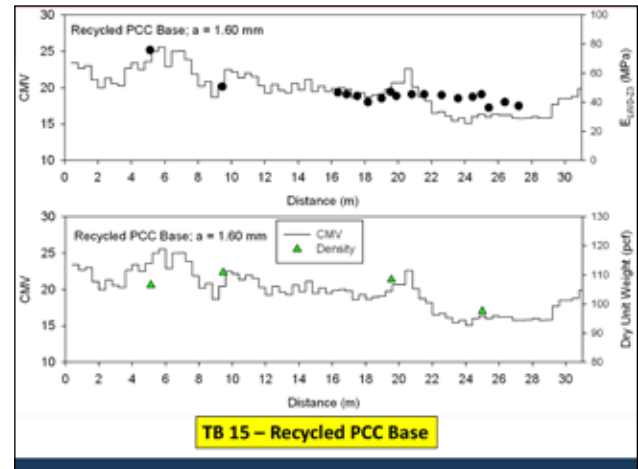
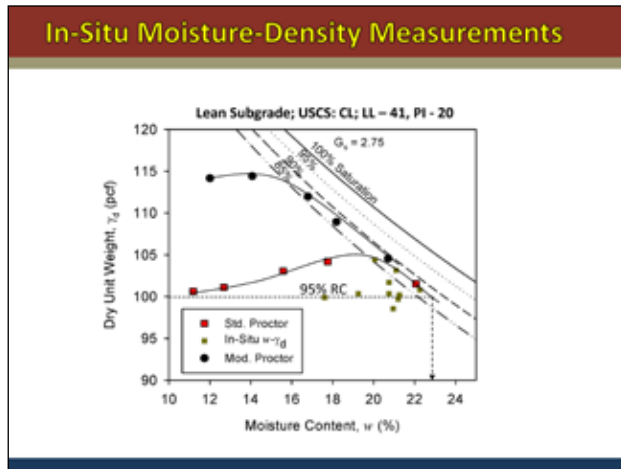
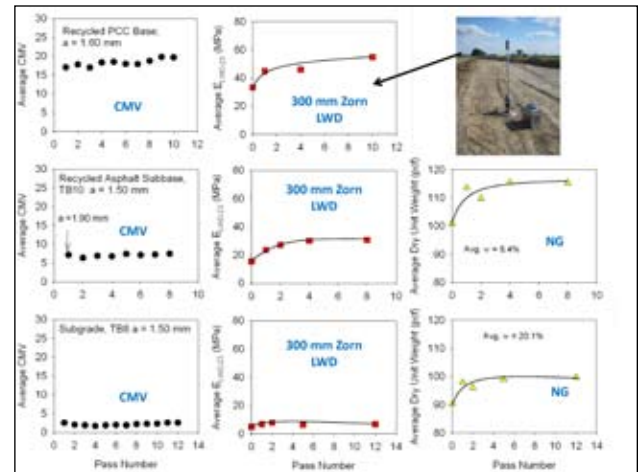
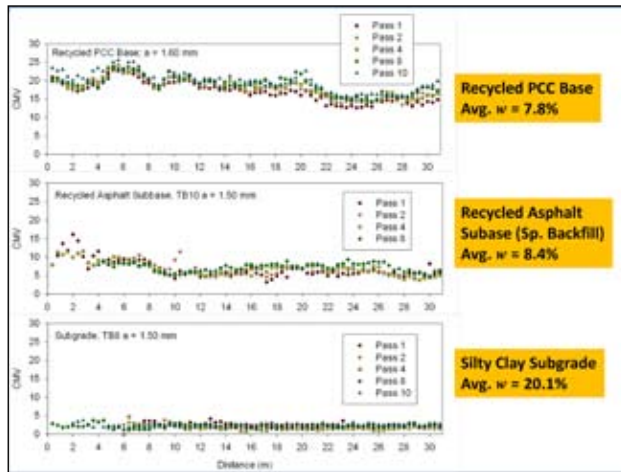
Iowa DOT Demonstration Projects 2009

David White, Pavana Vennapusa,
and Heath Gieselman



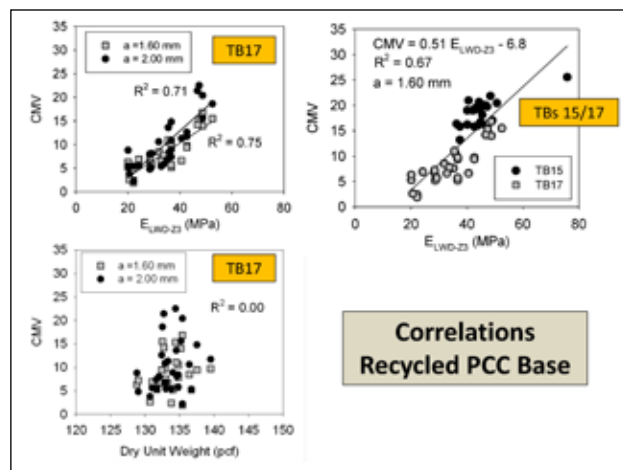
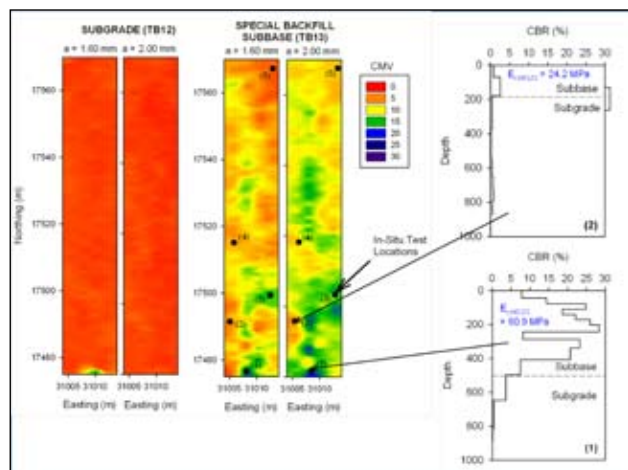
Iowa DOT Demonstration Projects 2009

David White, Pavana Vennapusa, and Heath Gieselmann



Iowa DOT Demonstration Projects 2009

David White, Pavana Vennapusa,
and Heath Gieselman

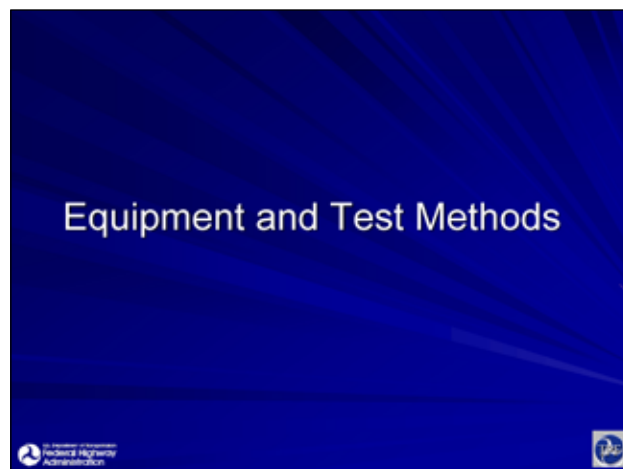


What's Next? - 2010 Pilot Specifications

- Specifications require IC technologies, mapping of compacted fill, QA spot test locations based on maps for research purposes.
- For this year traditional acceptance still used.
- Results will be evaluated to make specification changes for future that use the IC data as part of the QC and possibly QA process.

FHWA Pooled Fund Study Update

David White, Pavana Vennapusa,
and Heath Gieselman



FHWA Pooled Fund Study Update

David White, Pavana Vennapusa,
and Heath Gieselman

In-Situ Testing Methods

FWD, DCP, LWD, PLT, NG, GG, ST, CH, DSPA

Laboratory Test Methods

Proctor, Relative Density, Gradation, Atterberg Limits, Resilient Modulus, Moisture content, Gyrotray/PDA Compaction

Laboratory Test Methods

Proctor, Relative Density, Gradation, Atterberg Limits, Resilient Modulus, Moisture content, Gyrotray/PDA Compaction

Factors Affecting IC-MVs

- Heterogeneity in underlying layer support conditions
- Moisture content variation
- Range of measurement values
- Machine operations (amplitude, frequency, speed) and roller "jumping"
- Non-uniform drum/soil contact
- Limited number of in-situ measurements for correlation
- Uncertainty in spatial pairing of point measurements and roller MVs
- Not enough information to interpret the results
- Measurement errors associated with the roller MVs and in-situ point test measurements

Project Goals

1. Document impact of variable feedback control on compaction uniformity
2. Document machine vibration amplitude influence on compaction efficiency
3. Evaluate impact of lift thickness on IC roller values and compaction efficiency
4. Develop correlations b/w IC roller values to traditional measurements
5. Study IC roller measurement influence depth
6. Compare IC results to tradition compaction operations
7. Study IC roller measurement values in production compaction operations

FM 156 Project Fort Worth, Texas

FHWA Pooled Fund Study Update

David White, Pavana Vennapusa,
and Heath Gieselman

FM 156 Project Fort Worth, Texas



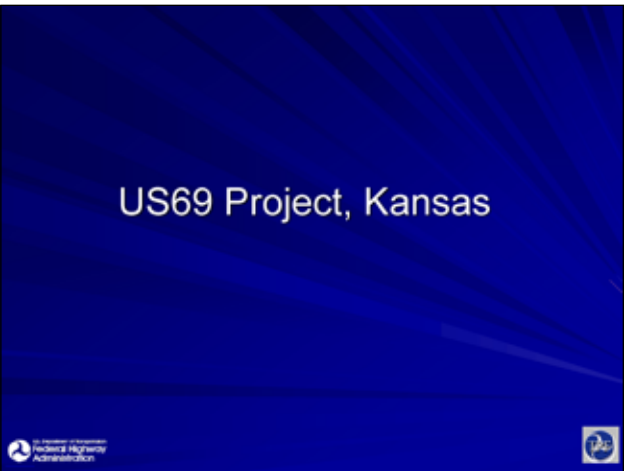
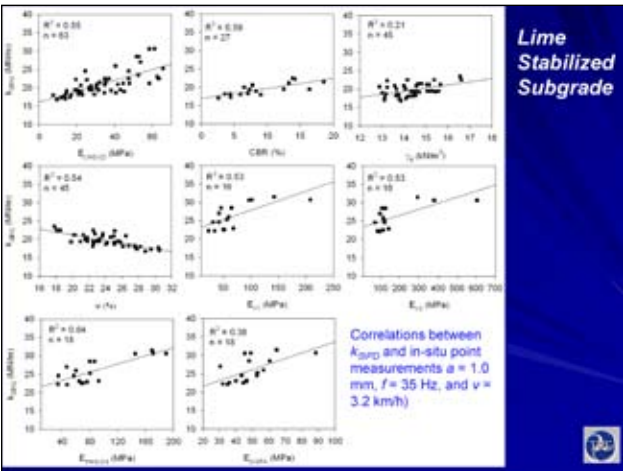
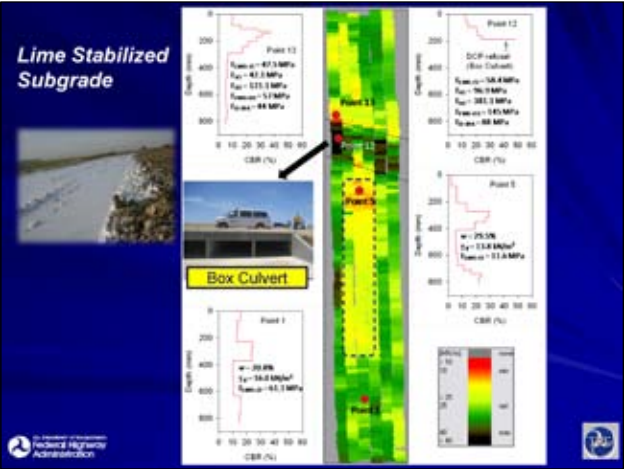
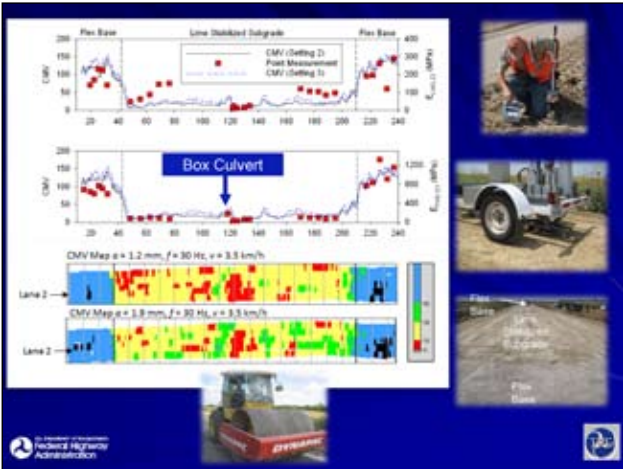
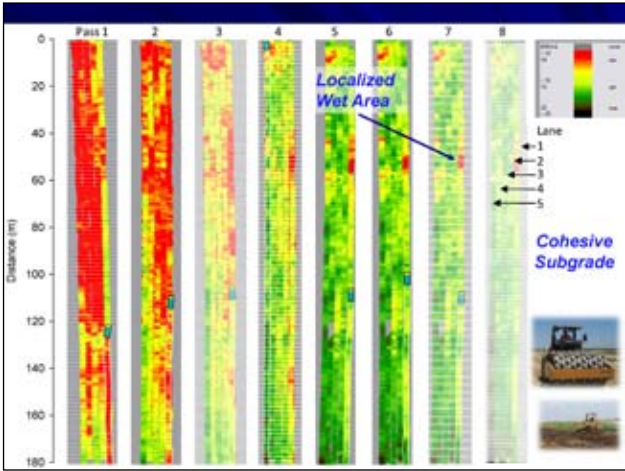
Parameter	Subgrade	Lime Stabilized Subgrade	Flex Base
Material Description (USCS)	Lean clay	Silty sand with gravel	Poorly graded gravel to silty gravel with sand
Gravel Content (%)	3	17	69
Sand Content (%)	10	80	21
Silt Content (%)	50	19	7
Clay Content (%)	37	4	3
Liquid Limit, LL (%)	41	47	-
Plasticity Index, PI	29	12	-
AASHTO	A-7-6(24)	A-3-7	A-1-a
USCS	CL	SM	GP-GM





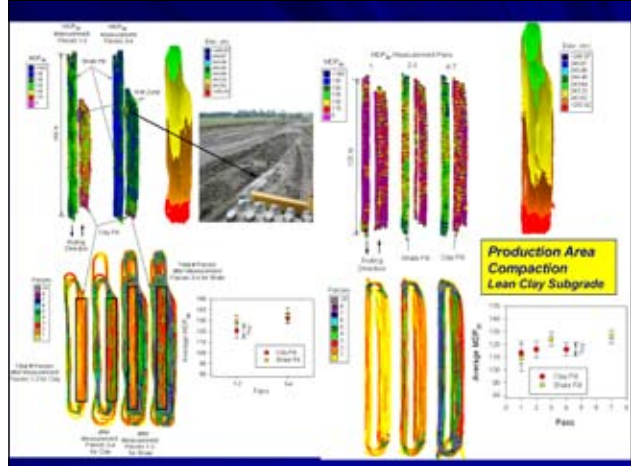
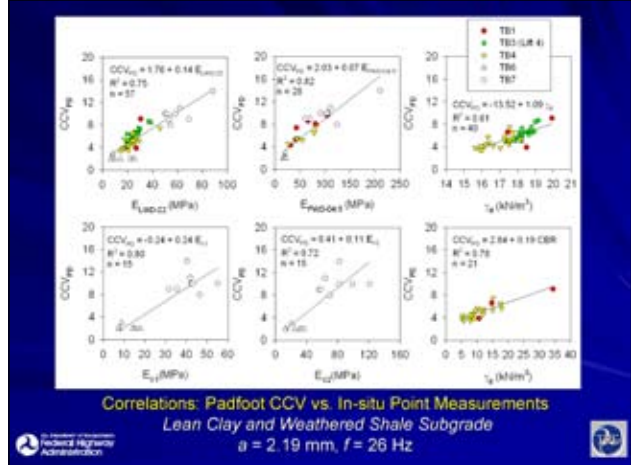
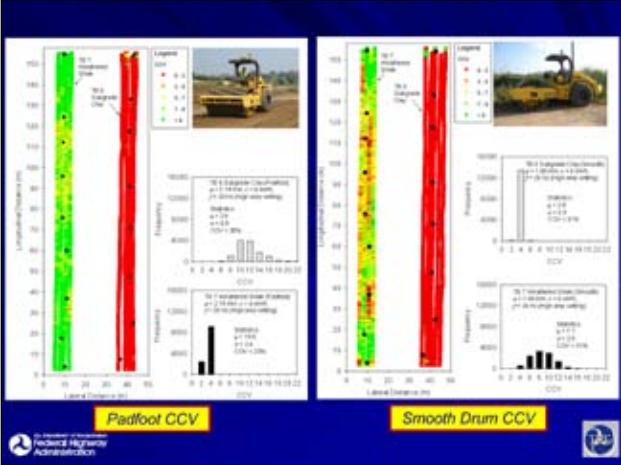
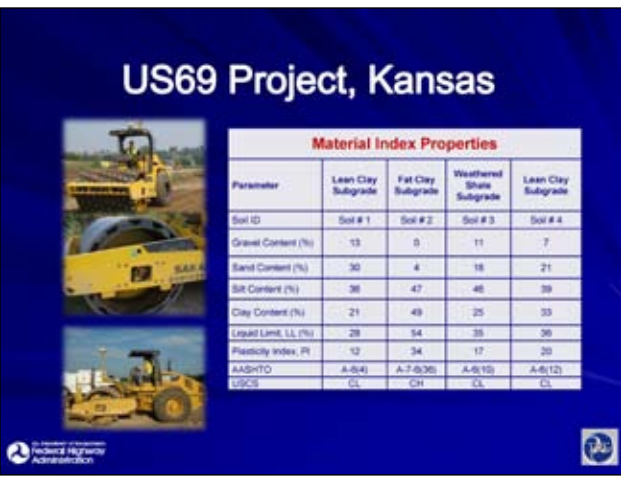
FHWA Pooled Fund Study Update

David White, Pavana Vennapusa,
and Heath Gieselman



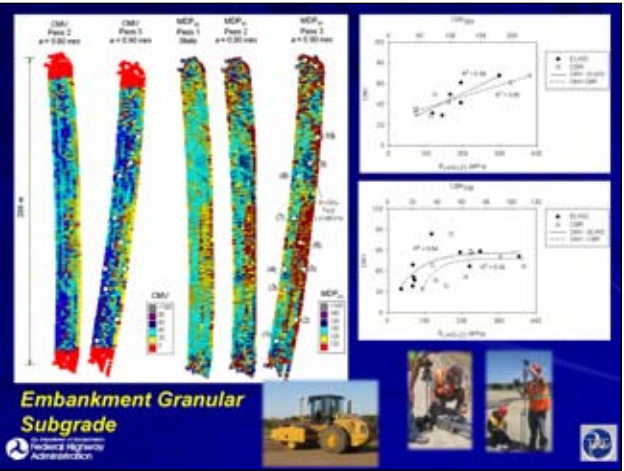
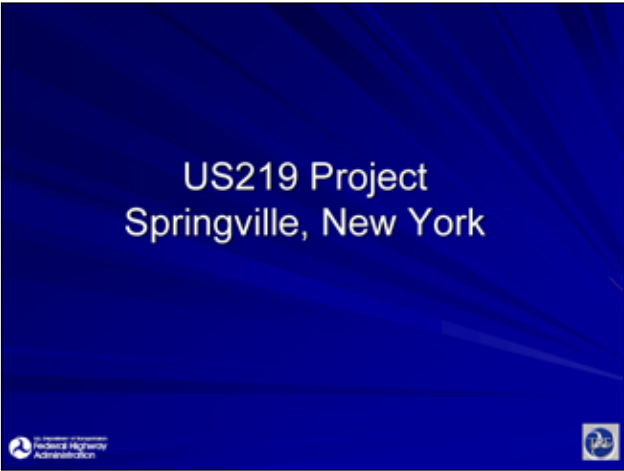
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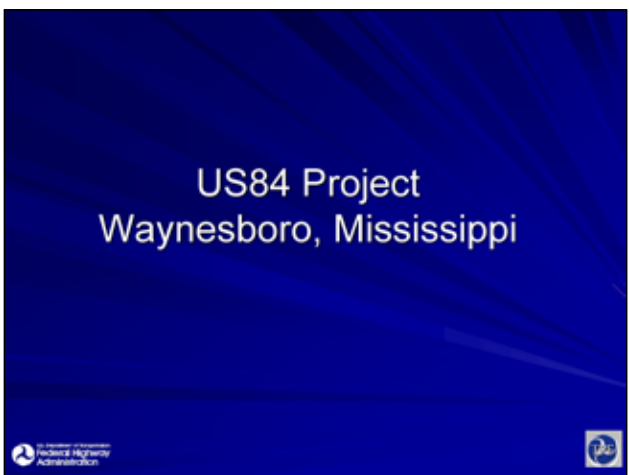
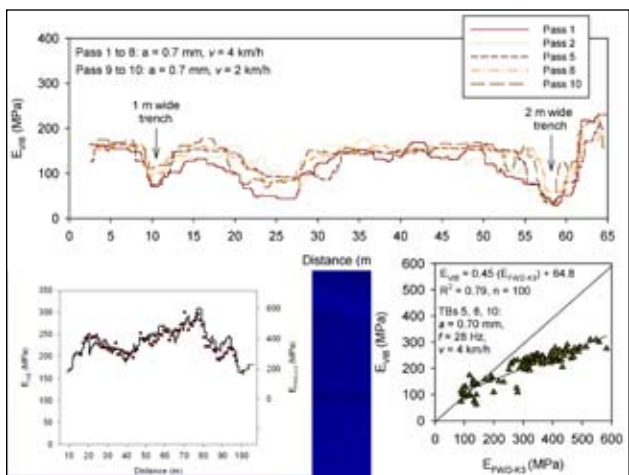
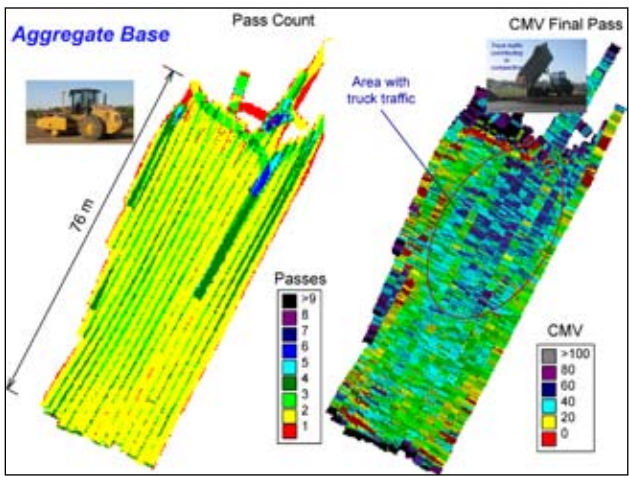
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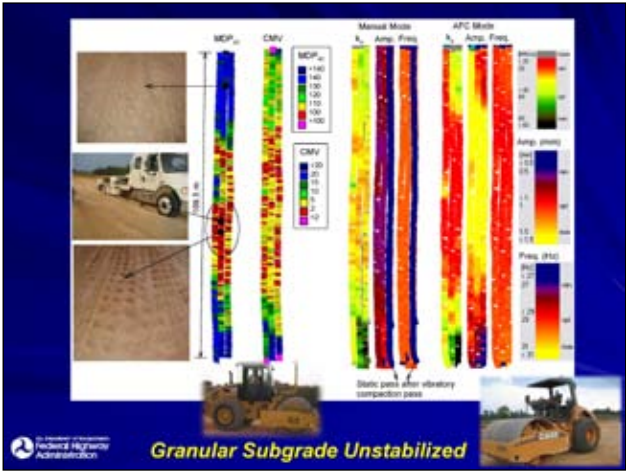
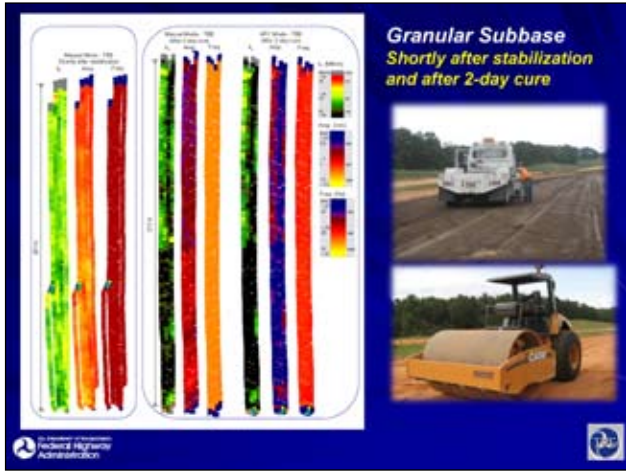
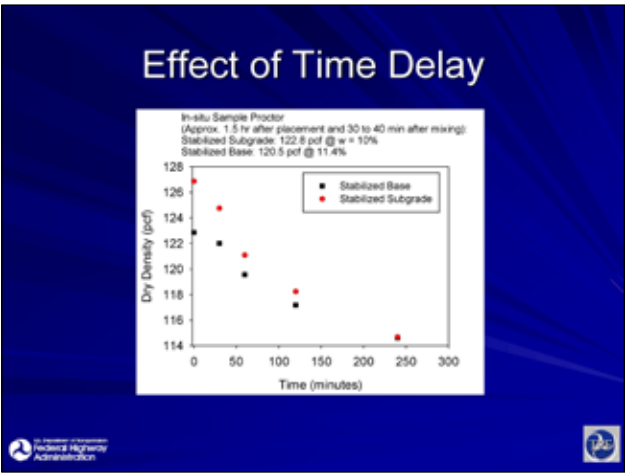
FHWA Pooled Fund Study Update

David White, Pavana Vennapusa,
and Heath Gieselman



FHWA Pooled Fund Study Update

David White, Pavana Vennapusa,
and Heath Gieselman



Summary Comments

- ### Key Findings
- Construction process-control greatly improved
 - IC-MVs correlate to various in-situ point measurements
 - Measurement influence depth varies depending on technology and site conditions
 - Machine operation parameters influence MVs

2010 Projects - Suggestions

- Evaluate Implementation Approaches:
 - (1) Use IC-MVs as part of "intelligent QC/QA";
 - (2) Link IC-MVs to mechanistic QA parameters in top 1 – 3 m
- Statistical analysis tools/protocols – need to better understand link to performance!
 - Need to start planning some long-term case studies
 - Organize committee to review analysis approach



Thank you



Intelligent Compaction for Hot Mix Asphalt: GDOT Demonstration Results

—David Jared

Intelligent Compaction for Hot Mix Asphalt: GDOT Demonstration Results

David M. Jared, P.E., GDOT
FHWA/TPF IC Team



Talking Points

- Pooled-fund study overview
- Georgia demo objectives & scope
- Construction issues & observations
- Mapping & testing results
- Summary
- Questions

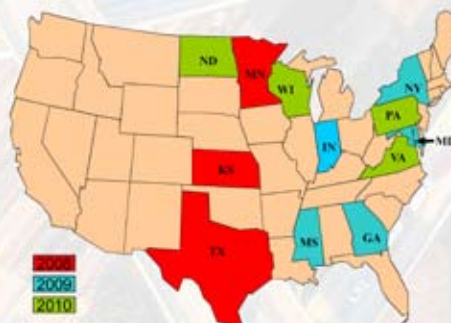


Pooled-fund Study Overview

- Goal: gain knowledge needed to develop credible and productive IC specifications for future projects



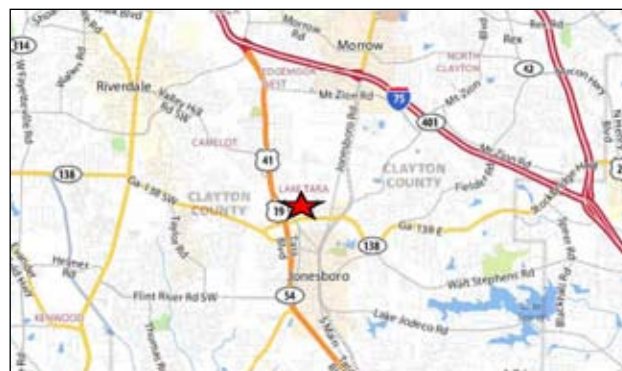
TPF State Demo Projects



Georgia HMA IC Demo

- Park & Ride, Clayton County, GA
- September 14-18, 2009
- Mapping graded aggregate base (GAB)
- New HMA construction

Sakai Double-drum
IC Roller



Intelligent Compaction for Hot Mix Asphalt: GDOT Demonstration Results

David Jared

Objectives

- Demonstrate HMA IC technology to GDOT personnel, contractors, et al.
- Correlate IC roller measurements with GDOT's current in-situ density & stiffness measurements
- Identify and prioritize needed improvements and further research for IC equipment



Scope: Test Beds



Scope: In-Situ Tests

- GAB stiffness: Falling weight deflectometer (FWD)
- GAB density: Nuclear density gauge (NDG)
- HMA density: NDG & coring
- HMA stiffness: Lightweight deflectometer (LWD)



Testing Summary

Test Bed	Material/Layer	Date	Amplitude	In-situ Tests
01	GAB/Base	9/14	0.3-mm, 3000 vpm, 3 kmh	FWD, NDG
02	"	"	"	FWD
03	"	"	"	FWD
04	"	"	"	—
05	"	"	"	FWD
01	HMA/Intermediate	9/16	0.6-mm, 3000 vpm, 3 kmh	LWD, Cores
02	"	9/17	0.3-mm, 3000 vpm, 3 kmh	—
03	"	"	"	—
05	"	9/15-9/16	"	—
05	HMA/Surface	9/17	"	LWD



Construction Issues & Observations

- Subgrade preparation
- GAB grading
- GAB moisture
- Roller size
- Pass number, HMA surface temperature, CCV

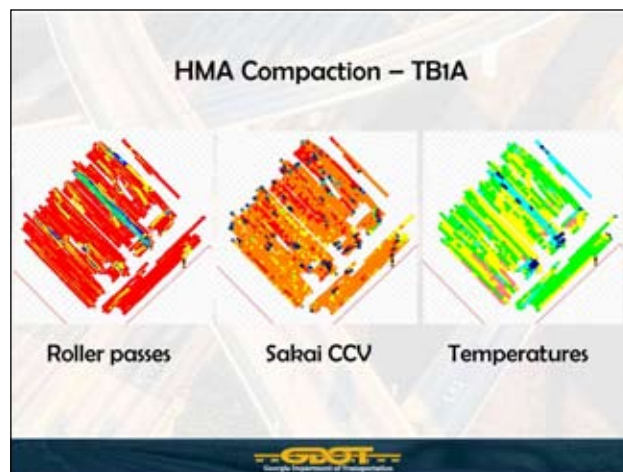


Mapping & Testing Results



Intelligent Compaction for Hot Mix Asphalt: GDOT Demonstration Results

David Jared

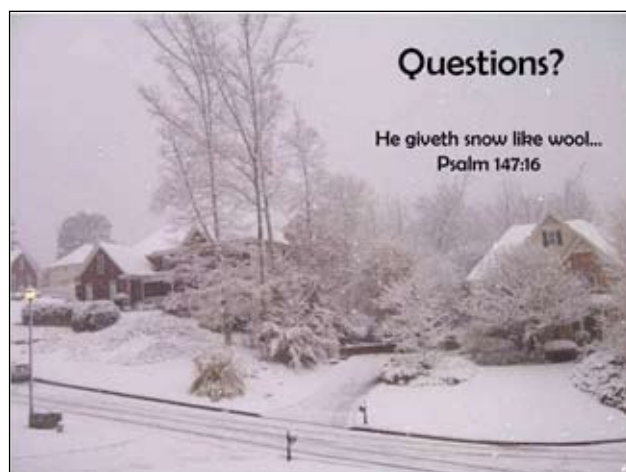


Correlation of IC Roller Measurements & In-situ Density Measurements

Testing Method	Material	Linear Rel. w/CCV	Best Correlation	Comment
Falling Weight Deflectometer	GAB	Partial	0.41	Some results linear, some not
Lightweight Deflectometer	HMA	Yes	0.25	Lowest overall correlation
Nuclear Density Gauge	GAB	Yes	0.55	Best overall correlation
Core Density	HMA	Yes	0.42	Reverse trend

The GDOT logo is at the bottom.

- Summary**
- HMA IC technology provides valid data and is a good QC tool
 - Proper subgrade preparation & GAB stability critical for proper CCV
 - Generally low correlations between IC roller and in-situ density measurements (for GDOT demo)
 - Standardization of IC data collection, storage, and processing strongly encouraged
- The GDOT logo is at the bottom.



Overview and Status Update: Intelligent Construction in New York

Brett Denning



Study Objectives

- Demonstrate soil IC technology to NYSDOT personnel, contractors, etc.
- Evaluate the benefits and effectiveness of IC Rollers vs. conventional rollers.
- Assist NYSDOT to accelerate the development of IC quality control (QC) specifications for soil pavement materials.
- Prioritize needed improvements and identify further research for IC equipment.

Considerations

- Are IC compaction results improved over conventional compaction?
- Is IC compaction more efficient than conventional compaction?
- Does the IC measurement value correlate with other independent testing (QA testing)?

Overview and Status Update: Intelligent Construction in New York

Brett Denning



Project experiences

- Correlation of IC measurement value with in-situ testing still uncertain.
- IC rollers can be an excellent QC tool, but QA is still essential.
- Low spots that are bridged by the drum may detect as "good".
- Proper use of testing device critical to obtaining meaningful data
- The experiments appeared to contain many variables and the data is still being evaluated.

Project experiences

- It appears that the IC rollers are capable of determining uniformity.
- Proper calibration and use of these devices may allow us to eliminate proof rolling.
- Data obtained can help us determine locations for QA testing.
- At this stage, density determination (be it sand cone, NDG, EDG, LWD or SDG) can't be eliminated from the soil compaction QC/QA process.
- Final results not yet published**



Electrical Density Gauge (EDG)

Measures and displays:

- Wet and Dry Density*
- % Moisture*
- % Compaction*
- *Soil Model Required
- Total test time = 3 – 5 minutes

This image shows the Electrical Density Gauge (EDG) device, which is a handheld unit with a digital display and various cables attached.

Overview and Status Update: Intelligent Construction in New York

Brett Denning

Electrical Density Gauge (EDG)

Measures and displays:

- Wet and Dry Density*
- % Moisture*
- % Compaction*
- *Soil Model Required

- Total test time = 3 – 5 minutes



- 'Soil Models' are established through laboratory and field testing:
 - Existing Density and Moisture Content (Sand Cone or Nuclear Density Gauge).
 - Moisture-Density Relationship (Laboratory Proctor test).

Electrical Density Gauge (EDG)

Summary

- Cons:
 - Unit is somewhat cumbersome with many parts and could use improvements.
 - Building 'Soil Model' involves significant amount of initial time and effort.
 - Initial cost more than nuclear gauge.

Electrical Density Gauge (EDG)

Summary

- Cons:
 - Unit is somewhat cumbersome with many parts and could use improvements.
 - Building 'Soil Model' involves significant amount of initial time and effort.
 - Initial cost more than nuclear gauge.
 - Pros:
 - Field testing time is comparable to NDG.
 - No certification or training courses required.
 - Unit is light and easy to transport.
- EDG is still being developed, therefore potential for widespread use still uncertain.

Soil Density Gauge (SDG)

Measures and displays:

- Wet and Dry Density*
- % Moisture*
- % Compaction*
- *Soil Model Required

- Total test time >2 minutes



Soil Density Gauge (SDG)

Measures and displays:

- Wet and Dry Density*
- % Moisture*
- % Compaction*
- *Soil Model Required

- Total test time >2 minutes



- Soil Model required for each job site: Gradation, Maximum Dry Density, Optimum Moisture Content, Liquid Limit, Plastic Limit, Coefficient of Uniformity and Curvature.

Soil Density Gauge (SDG)

Summary

- Cons:
 - Soil parameters needed prior to testing.
 - May not be accurate on material placed more than a few days prior (according to manufacture).
 - Moisture Content accuracy unreliable.
 - Initial cost more than NDG.

Overview and Status Update: Intelligent Construction in New York

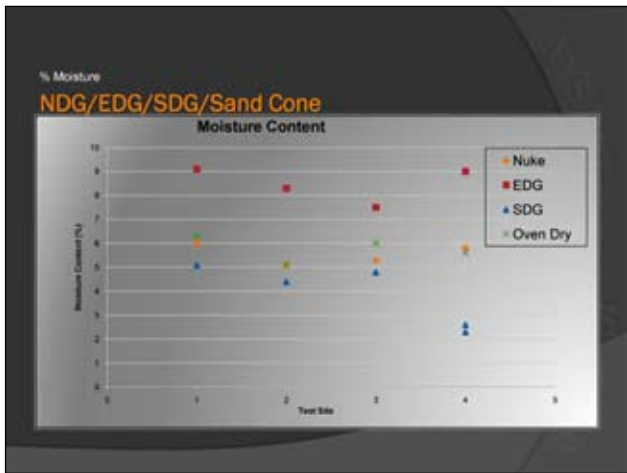
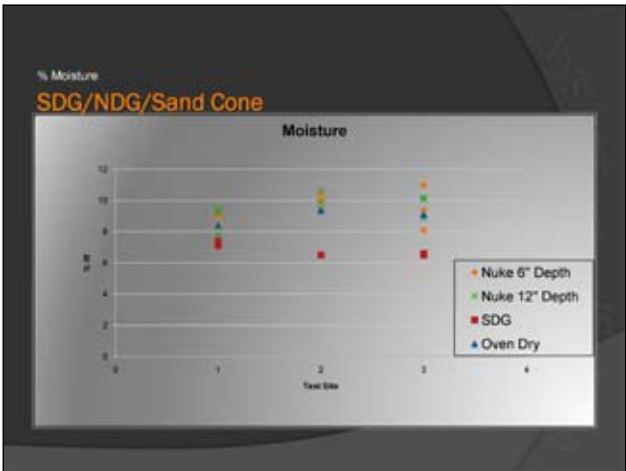
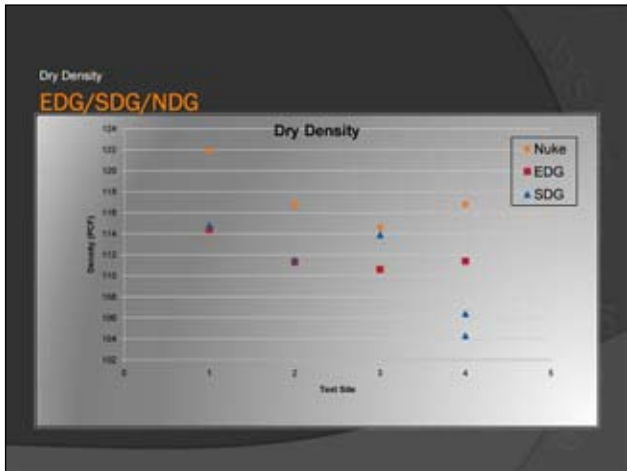
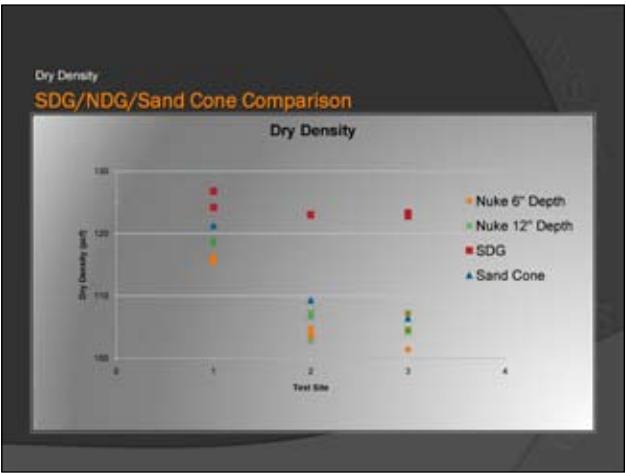
Brett Denning

Soil Density Gauge (SDG)

Summary

- Cons:**
 - Soil parameters needed prior to testing.
 - May not be accurate on material placed more than a few days prior (according to manufacture).
 - Moisture Content accuracy unreliable.
 - Initial cost more than NDG.
- Pros:**
 - Field testing time is quicker than NDG.
 - No certification or training courses required.
 - Unit is light and easy to transport.
 - New York State-based company.

TransTech's Pavement Quality Indicator (PQI) is already an accepted alternative to the NDG for density readings on asphalt, providing some credibility (and hope) for this new design.



Light Weight Deflectometer (LWD)

- Measures soil movement to an applied load and calculates stiffness (E_{st})
- Total test time >1 minutes
- Target Value developed for each job site / material

Overview and Status Update: Intelligent Construction in New York

Brett Denning

Light Weight Deflectometer

Summary

- Cons:
 - No history with stiffness measurements
 - Target value developed at each job site
 - Heavy (~70 lbs)
 - Accuracy unknown
 - Calibration required by out of country manufacturer \$\$\$

Light Weight Deflectometer

Summary

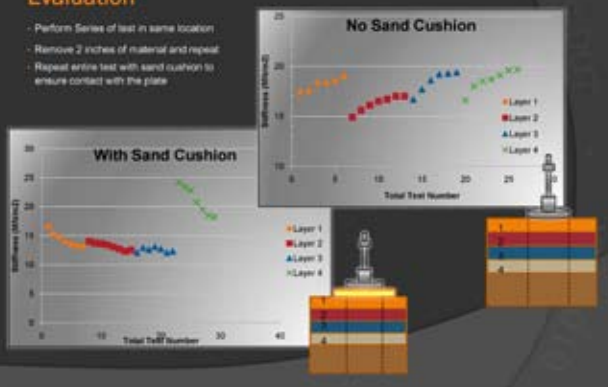
- Cons:
 - No history with stiffness measurements
 - Target value developed at each job site
 - Heavy (~70 lbs)
 - Accuracy unknown
 - Calibration required by out of country manufacturer \$\$\$
- Pros:
 - Fast field testing time
 - No certification or training courses required
 - Cost comparable to nuke gauge

NYSDOT owns and is evaluating the LWD

Light Weight Deflectometer (LWD)

Evaluation

- Perform Series of test in same location
- Remove 2 inches of material and repeat
- Repeat entire test with sand cushion to ensure contact with the plate



Texas Department of Transportation Status Update

Zhiming Si

Texas Department of Transportation Zhiming Si

Materials and Pavements Engineer
Materials & Pavements Section
Construction Division

125 E. 11th Street
Austin, TX 78701-2483
Ph: (512) 506-5901
Fax: (512) 506-5865
Email: zsi@dot.state.tx.us

IC Project Updates

- Developed a one-time use special specification for IC rollers
- FM 1938 - Federal aid project (Project # - STP 2009 (880) MM, CSJ: 1978-01-048)
 - Tarrant County, Fort Worth District has been let using the retrofit IC system.
 - It will start in late March or Early April.
- US 287 - Federal aid project (Project # - STP 2010 (629) MM, CSJ: 0172-09-031)
 - Tarrant County, Fort Worth District
 - It will be let in March using IC rollers



Mn/DOT Specification Development for Use of CCC on Non-Granular and Granular Materials

Rebecca Embacher

Mn/DOT Specification Development for use of CCC on Non-Granular and Granular Materials

Intelligent Compaction For Earthworks and HMA
Webinar
March 1 - 2, 2010

Rebecca A. Embacher, Mn/DOT

Your Destination... Our Priority

Outline

- Our Goals
- More Comprehensive Inspection
- Specification Development
 - Equipment Requirements
 - Contractor's QC
 - CMV Requirements
 - Production
 - Submittals
 - Measurement & Payment
- 2010 CCC Projects

Our Goals

- More Comprehensive Inspection
- More Efficient Construction
- Develop a Link to Design
- Improve Pavement Performance
- Improve Safety

MORE COMPREHENSIVE INSPECTION

Continuous Coverage

IS VALID
Valid
Invalid
Compaction attempted

No data

Mn/ROAD Cell 20: Clay

Compaction
0 - 130
130 - 135
135 - 140
140 - 145
145 - 150

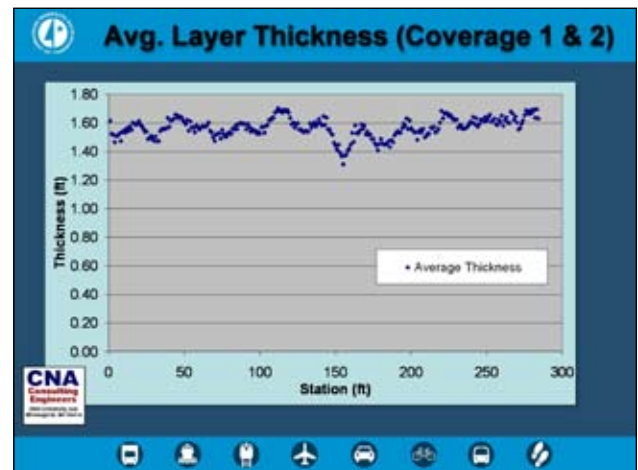
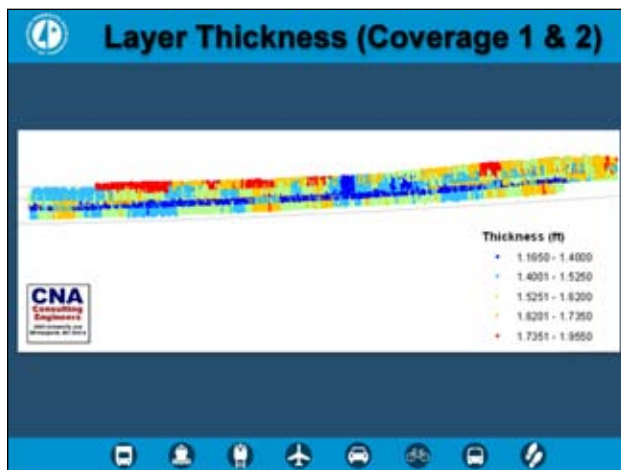
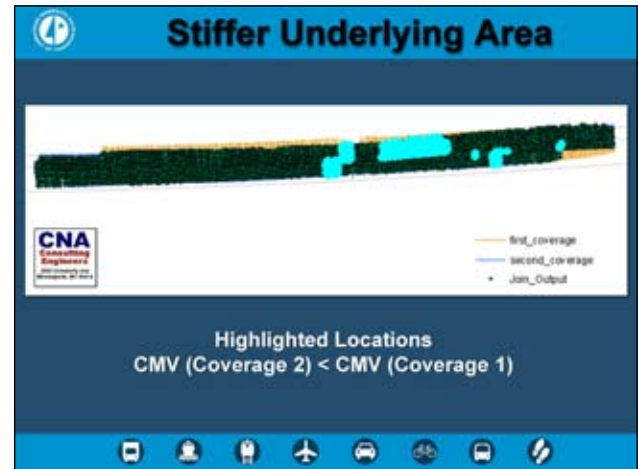
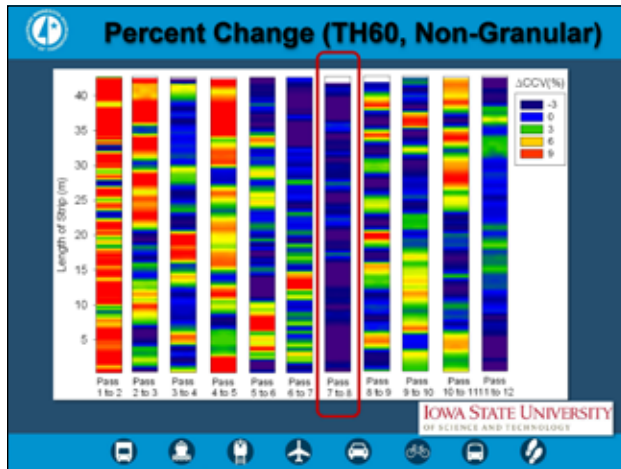
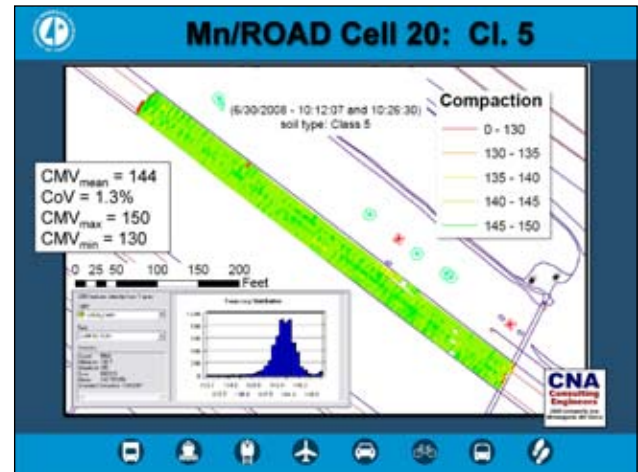
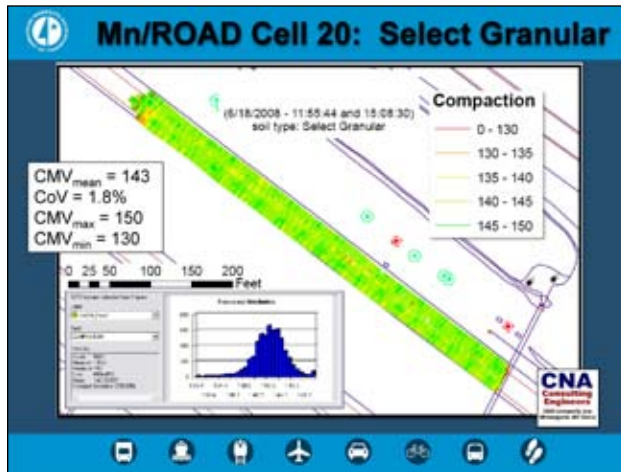
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CoV = 2.1%
CMV_max = 150
CMV_min = 130

Frequency Distribution

CNA Consulting Engineers

Mn/DOT Specification Development for Use of CCC on Non-Granular and Granular Materials

Rebecca Embacher



Mn/DOT Specification Development for Use of CCC on Non-Granular and Granular Materials

Rebecca Embacher



Specification Development

EQUIPMENT REQUIREMENTS

(MN/DOT 2123.30)

Equipment Requirements

Requirements

- Self propelled, vibratory soil compactor
- Weight $\geq 22,000$ lb
- Instrumented
 - Accelerometer-Based System
 - Global Position System
 - Onboard Display
 - Compactor Measurement Value (MV) Output
 - Display of 2-D Design

Equipment Requirements


Accuracy

Operating Parameter	Accuracy
Global Positioning System	± 150 mm (6 in) in the X and Y Direction
Rolling Speed	± 0.5 km/h (0.3 mph)
Frequency	± 2 Hz
Amplitude	± 0.2 mm (0.0008 in)



Measurement Pass ASCII Files

Machine Model	GPS Mode
Machine Type	Travel Direction
Drum Width	Rolling Speed
Drum Diameter	Vibration
Machine Weight	Frequency
File Name	Peak Vertical Amplitude
Date Stamp	Indicator of Double Jumping
Time Stamp	Compactor Measurement Value
XYZ Coordinates	Automatic Feedback Control



Specification Development

CONTRACTOR'S QC

Operating Settings

Definition:

Are compactor settings used during operation, which include forward speed, forward direction, vibration frequency and peak vertical force amplitude.

Mn/DOT Specification Development for Use of CCC on Non-Granular and Granular Materials

Rebecca Embacher

Pre-Approval of Compactor

Demonstration

- Schedule 14-Calendar Days in Advance
- Attain approval of Operating Settings
- Meets Equipment Requirements
- Range of Measuring System

Pre-Approval of Compactor

Demonstration (Cont.)

- Provide Documentation
 - Manufacturer's recommended compactor operating settings
 - Manufacturer's Users Manual
 - Demonstration Data
 - ASCII File(s)
 - Data Files Downloaded directly from Compactor

Moisture Requirements

- Determine Target Moisture Content
 - Standard Proctor
 - 1-Point Proctor
 - EOMC Form (for Granular Only)
- Maintain between 65 to 95% of Target Moisture Content




CMV REQUIREMENTS (CONTRACTOR'S QC [CONT])



Specification Development

Design Intent



1 to 2 m

Measurement Pass

Definition:

Is a pass where the compactor measurement values and machine position are recorded over the Measurement Pass Layer.

Operating Settings must be held within the specified limits.

Mn/DOT Specification Development for Use of CCC on Non-Granular and Granular Materials

Rebecca Embacher

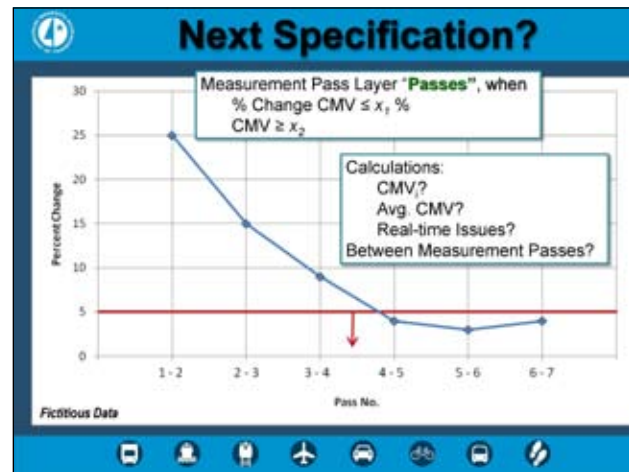
Measurement Pass Layer

Is a predetermined layer that requires QC measurements to ensure compliance with this specification.

Grading Slope > 5%

Measurement Passes capture the design intent: Stiffness

Measurement Pass captures Base Mat



Measurement Pass Layers

Locations (cont).

- Slope gradients > 5% → obtain approval
- Ensure > 4 ft above water table
- Provide locations 24-hrs prior to starting measurements

Measurement Pass Layers

- Operate within Approved Operating Settings
- All passes → Forward Direction
- Roller Track Overlap ≤ 10% of drum width

Photo Courtesy of Dr. David White (USD 1000)

Measurement Pass Layers

Complete 3 Measurement Passes

Case No.	Embankment Thickness	Layer Number		
		1 (Note 1)	2	3
1	< 600 mm (2 ft)	0 ft		
2	≥ 600 mm (2 ft) and < 2 m (6 ft)	0 ft	(Note 2)	
3	≥ 1.8 m (6 ft) and ≤ 2.4 m (8 ft)	0 ft	4 ft	(Note 2)
4	> 2.4 m (8 ft)	0 ft	4 ft	8 ft

Note 1: Complete test rolling immediately after completion of final measurement pass.

Note 2: Bottom of Fill Section: Complete 3 measurement passes on bottom of fill section prior to construction of fill.

Measurement Pass Layers

- Over-Compaction → Contact Engineer
- Corrected Areas → Complete 1 Meas. Pass
- Allow Engr. Immediate viewing of Measurement Pass data

Mn/DOT Specification Development for Use of CCC on Non-Granular and Granular Materials

Rebecca Embacher

Production Usage

Operate compactor continuously at locations selected by Contractor.



Submittals

Submit QC data daily

- Measurement Pass and Production Data Files
 - ASCII Files
 - Data files downloaded directly from compactor


Measurement and Payment

- **Method of Measurement**
 - Compactor will be supplied for x weeks.
- **Basis of Payment**
 - Instrumented Compactor week
- **Unauthorized Work (Mn/DOT 1512)**
 - Embankment mat'ls are unauthorized when supporting QC data is not submitted.

2010 CCC PROJECTS


2010 CCC Projects

- SAP 55-610-22 CSAH 10
 - 8.142 miles
 - Non-Granular – Si / SiL / SiCL (using CCC)
 - 6" Modified Cl. 5 Aggregate Base (CCC undecided)
 - Concrete Surfacing



2010 CCC Projects


- SP3408-15 (TH23)
 - 6 Sections
 - Granular (S to SL)



Case No.	Fill Thickness	Section Length	No. of Sections
1	≥ 600 mm (2 feet) and < 2 m (6 feet)	≥ 300 m (1000 feet)	2
2	≥ 1.8 m (6 feet) and ≤ 2.4 m (8 feet)		
3	> 2.4 m (8 feet)		


Mn/DOT Specification Development for Use of CCC on Non-Granular and Granular Materials









Rebecca Embacher




2010 CCC Projects

- SP2771-38 (TH610) – Design Build
- Granular (S)
- 2.5 miles
- Use is unknown
 - CCC Design Packet not currently available





















Thank you
for your attention, time and
support!


Your Destination...Our Priority








Mn/DOT Priorities and Specification Development for Intelligent Compaction on HMA

Greg Johnson





Mn/DOT Priorities & Specification Development for Intelligent Compaction on HMA





Greg Johnson, PE
Assistant Bituminous Engr.
(651) 366-5464
gjohnson@state.mn.us



Your Destination...Our Priority

Mn/DOT HMA IC Priorities







1. GPS & Display on all rollers in train
2. Visualization of compaction data (desktop)
3. Infrared temperature bar on paver
4. Real time display of roller passes on all rollers
5. Integrate #3 & #4
6. Mat temperature
7. Roller/Pavement characteristics (compaction value)





Potential 2010 HMA IC Projects

- TH 27 (Onamia)
- TH 96 (St. Paul suburb)
- Others?



2010 HMA IC Objectives

- All rollers have GPS & display for operator
 - Breakdown
 - Intermediate
 - Finish
- Compaction Uniformity
- Collect roller characteristics
 - GPS coordinates
 - Speed
 - Temperature
- Infrared Temperature Bar


Draft Specification

- Data is collected for information purposes only
- Must provide roller output data
- Payment
 - Lump sum?
 - Days of functional use?
- State innovative research money is available


Benefits

- Complete documentation record
- Decrease QC/QA density cores


Mn/DOT Priorities and Specification Development for Intelligent Compaction on HMA


Greg Johnson





Drawbacks

- Equipment availability
- Current cost of equipment
- Need Retro-fit GPS & display for existing rollers










Thank You

Your Destination...Our Priority



Mn/DOT Specification Development for Use of IC on Emulsion Stabilized FDR

Steve Adamsky




Mn/DOT Specification Development for use of IC on Emulsion Stabilized FDR

Your Destination...Our Priority





Where we are:

- * Developing use of stabilized reclamation as a rehab for roads
- * Past practice indicates density of reclaimed material is the most important property





- * How do we measure density on reclamation?
- * No experience with any standard tests that MnDOT has
- * Nuke tests might be the only option as a QA tool, with IC as a QC tool



- * 2010 will be an educational year for us with IC!
- * Discussion?

Steven.adamsky@state.mn.us



Dynapac C³

Fredrik Åkesson, Dynapac

Dynapac C³



Dynapac CompLogger

- Based on the existing compaction meter with added wireless communication
- Shares office software with the Compaction Analyzer for Soil (DCA-S)
- Hardware:
 - Rugged PDA
 - Wireless serial adapter
- Software: DCA office
- Relative positioning with distance sensor and manual track changes



Continuous Compaction Control Systems



System components



Components, DCA

- Computer and software
 - DCA-S
 - DCA-A
- GPS-receiver
 - Min. DGPS for Soil
 - Min. Omnistar HP for Asphalt
- Accessories differ
 - Compaction Meter (DCA-S)
 - Temperature sensors (DCA-A)

Compaction documentation

- Register the number of passes (static/vibratory)
- Relative stiffness reading (DCA-S only)
- Measure and register the surface temperature (calculate core temperature.) (DCA-A only)
- Graphic display of the temperature/CMV and the number of passes (real time in the roller)
- Documentation of the compaction process
- Background material for the quality analysis
- Support for continuous improvements of the paving process, rolling patterns and overall compaction results

Dynapac C³

Fredrik Åkesson, Dynapac

Positioning options

- Any brand GPS receiver with suitable accuracy can be used
- Standard NMEA messages are used
 - Transformation to UTM coordinates included in the software
 - Other grids can be used with build in coordinate conversion module
- Brand specific NMEA messages for RTK position in local grids from TOPCON, Leica and Trimble can also be used.
- Positioning relative to a digital road alignment file (reference line) provides real time station and offset reading to the operator. User defined reference line format can be used.
- Operation without a reference line provides local grid coordinates to the operator.

DYNAPAC
Part of the Wirtgen Group

Dynapac Compaction Optimizer



(Nominal amplitudes applicable on CA 302/362/432)

DYNAPAC
Part of the Wirtgen Group

Summary

Documentation systems

- Positioning: Relative to 1" accuracy (GNSS). Not brand specific. Free range or reference line. Any grid.
- CMV/passes or Temp/passes
- Real time operator information for process control

CompLogger, Compaction
Analyzer-Soil and Asphalt

Feed-back roller (Soil)

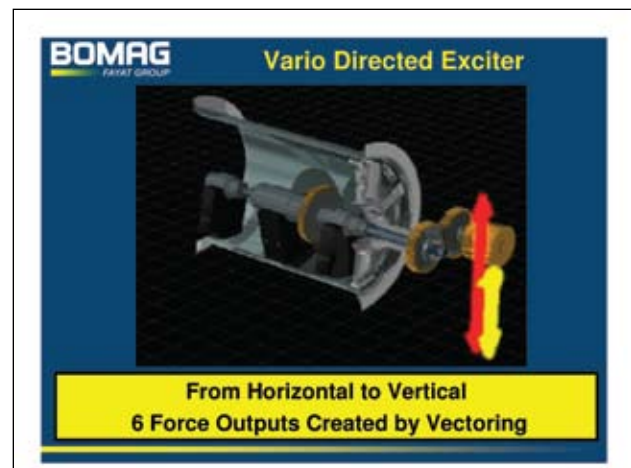
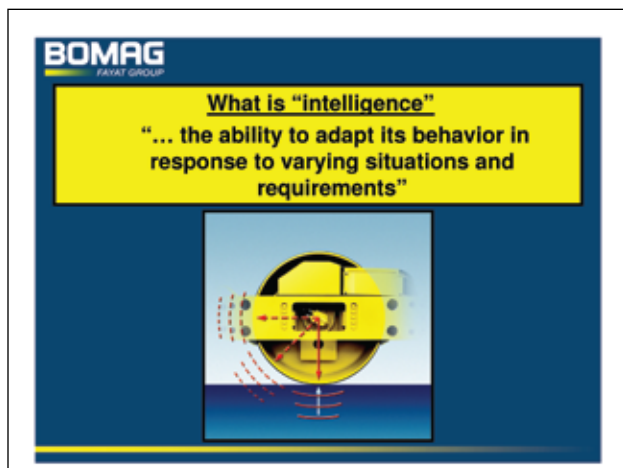
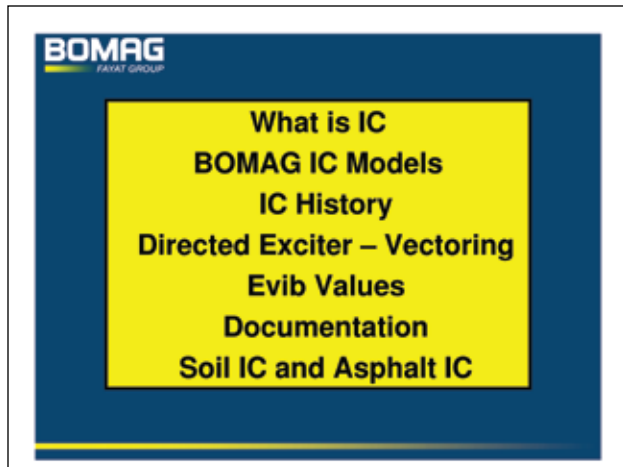
- Stiffness feedback controls amplitude
- True amplitude adjustment, circular vibration
- Automatic mode or manual with 6 amplitude settings. (Max 0,078")

Compaction Optimizer (Soil)

DYNAPAC
Part of the Wirtgen Group

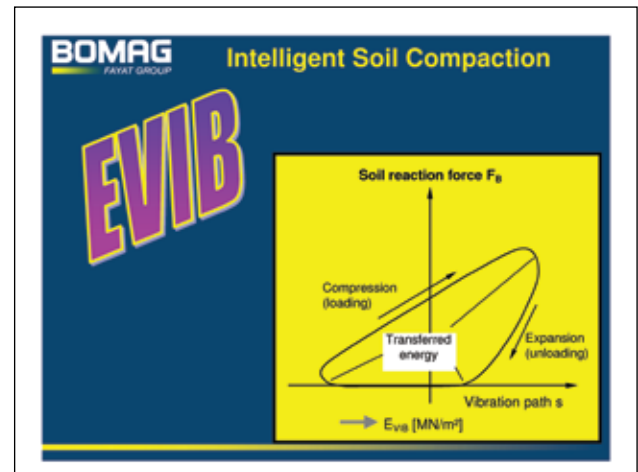
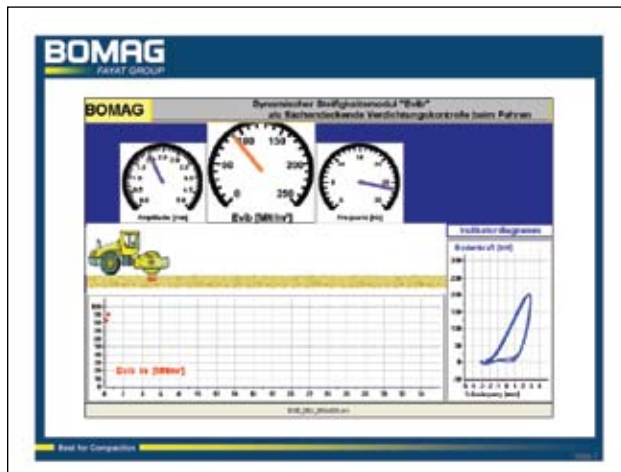
BOMAG Intelligent Compaction Products

Chris Connolly, BOMAG



BOMAG Intelligent Compaction Products

Chris Connolly, BOMAG



Complete Line of IC Models

15 Current Models Worldwide

- BW 177 DH-4 BVC
- BW 213 DH-4 BVC
- BW 226 DH-4 BVC
- BW 141 AD-4 AM
- BW 151 AD-4 AM
- BW 151 AC-4 AM
- BW 154 AD-4 AM
- BW 154 AC-4 AM
- BW 154 AP-4 AM
- BW 170 AP AM
- BW 174 AP AM
- BW 174 ACP AM
- BW 190 AD-4 AM
- BW 203 AD-4 AM
- BW 278 AD-4 AM

History

Key steps for development of the BOMAG IC Technology

- 1983 First compaction measurement system for soil compaction (Terrameter BTM 01)
- 1996 Compaction Management (BCM 03) Variomatic for asphalt rollers
- 1998 Variocontrol
- 2000 Evib Technology – Measurement for stiffness
- 2001 Asphalt Manager for Heavy Tandem Rollers and BCM05
- 2005 German DOT (BAST) research project with GPS
- 2006 European High Speed Rail Projects
- 2009 European IC spec for soils and asphalt
- Ongoing – IC Studies with Local Contractors and Dealer Network, State DOT's, NCHRP, and ICPF Projects

The Traditional Way of Compacting

- High or Low Amplitude Choices
- Pre-defined number of passes – or Experience
- No real time information on load bearing capacity or progress on achieved stiffness
- Potentially Low Efficiency
- Potentially Low Effectiveness
- Contractor loses time and money
- Material can be crushed
- Roller potentially damaged
- Compaction quality compromised

IC Vario Benefits – Why IC ???

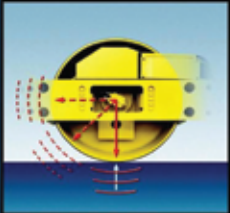
- Enhances Quality Control
- Consistent Rolling Patterns
- Exceptional Compaction Performance
- Real Time Data Display
- Wide Range of Adaptability
- Reduced Shock Loads to Surroundings
- Increased Depth Effect
- Proof Rolling to identify soft spots
- Under Compaction is avoided
- Over Compaction is avoided
- Unnecessary Passes are avoided
- Yields Fuel and Labor Savings
- Reduces In-Situ Measurements / Cost
- Reduces Highway Maintenance / Repair
- Provides Clear Documentation

BOMAG Intelligent Compaction Products

Chris Connolly, BOMAG

BOMAG FAYAT GROUP **Data Collection / Real Time Display**

- Evib Stiffness
- Pass Count
- GPS Position
- Asphalt Mat Temperature
- Time and Date
- Roller Operator ID



BOMAG FAYAT GROUP **Exciter Method Variations**

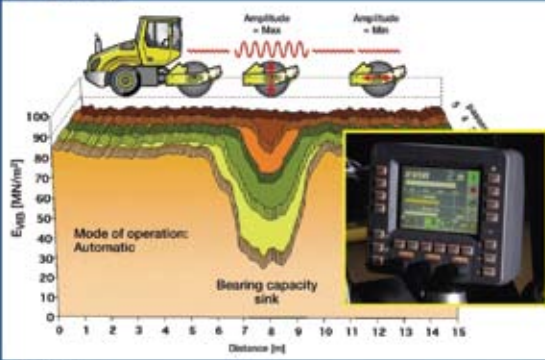
Rotary exciter Oscillation Directed exciter

BOMAG FAYAT GROUP **BOP Screen**



EVIB
TEMP

BOMAG FAYAT GROUP **IC BVC Performance**



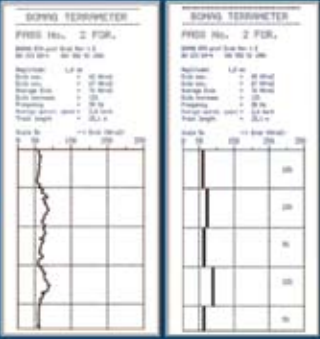
Amplitude = Max
Amplitude = Min

Mode of operation: Automatic

Bearing capacity sink

BOMAG FAYAT GROUP **Basic Printed Documentation**

- Number of Passes
- Temperature
- Evibe Min and Max
- Evibe Average
- Frequency
- Average Speed
- Track Length

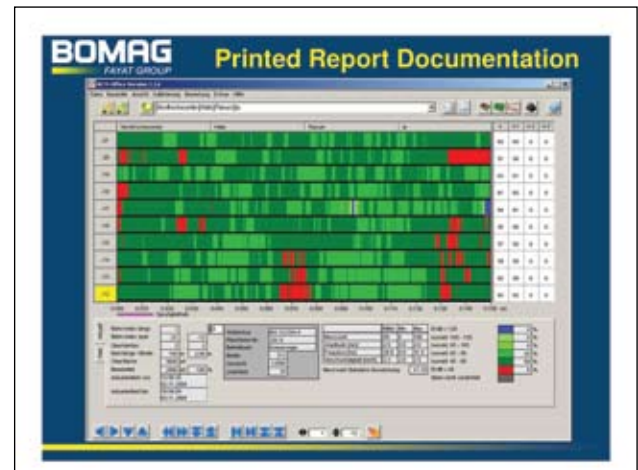


BOMAG FAYAT GROUP **On Board Printer**



BOMAG Intelligent Compaction Products

Chris Connolly, BOMAG



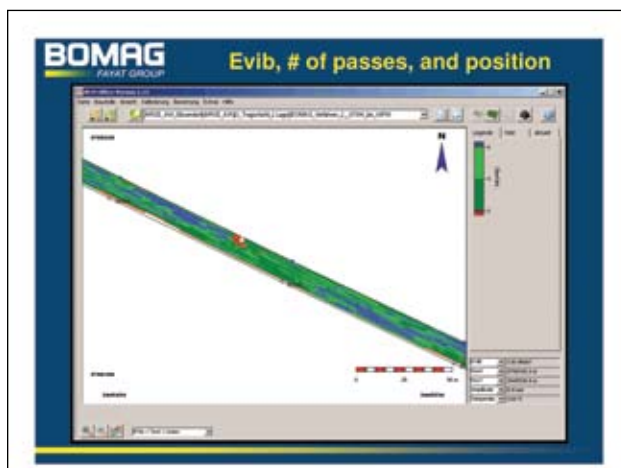
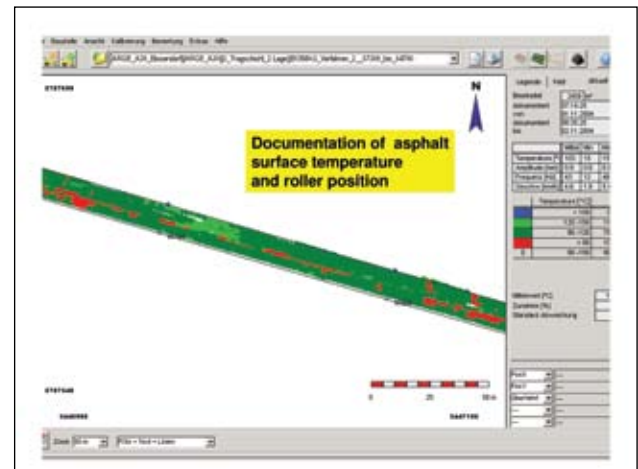
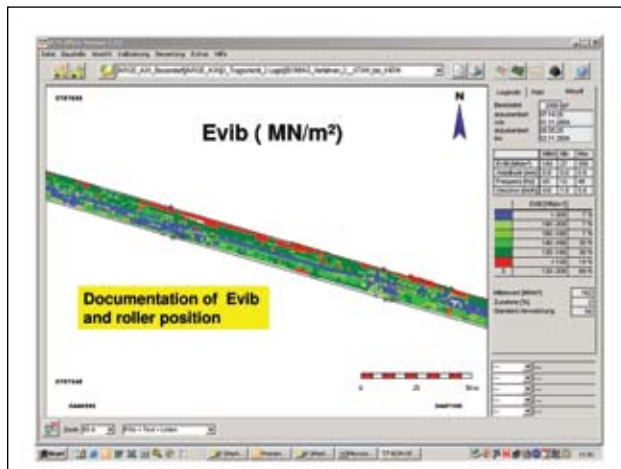
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Chris Connolly, BOMAG



Intelligent Compaction and the Greenroads Rating System

Dean Potts, Caterpillar

Intelligent Compaction and the




Rating System

A majority of the presentation information is taken from the source listed below and other presentations found on the (WWW.GREENROADS.US) Website. Used with permission of S.T. Muench.

Muench, S.T., Anderson, J.L., Hatfield, J.P., Koester, J.R., & Soderlund, M. et al. (2010) *Greenroads Rating System v1.0*. (J.L. Anderson and S.T. Muench, Eds.) Seattle, WA: University of Washington.

Iowa State 2010 IC Conference
Dean Potts – Caterpillar Research

Agenda

- What is the  rating system?
- Greenroads sustainability and how it is defined.
- Who is developing & sponsoring the Greenroads sustainability performance metric?
- What is the rating system and how does it work?
- Does Intelligent Compaction apply to Greenroads?
- Potential of Intelligent Compaction to impact sustainability metrics.

Note: In the interest of conservation, this presentation is purposely devoid of a lot of color which causes additional environmental impact when the presentation is printed.

What is ?

INTRODUCTION

Greenroads is a sustainability performance metric for roadways that awards points for more sustainable practices.

Fundamentally, Greenroads is a metric that helps quantify the sustainable attributes of a roadway project. This quantification can be used to:

- ☐ Define what project attributes contribute to roadway **sustainability**.
- ☐ Provide a **sustainability** accounting tool for roadway projects.
- ☐ Communicate **sustainable** project attributes to stakeholders.
- ☐ Manage and improve roadway **sustainability**.
- ☐ Grant "certification" based on achieving a minimum number of points.

Muench, S.T., Anderson, J.L., Hatfield, J.P., Koester, J.R., & Soderlund, M. et al. (2010) *Greenroads Rating System v1.0*. (J.L. Anderson and S.T. Muench, Eds.) Seattle, WA: University of Washington.

What is ?

WHAT IS A GREENROAD?

A Greenroad is defined as roadway project that has been designed and constructed to a level of **sustainability that is substantially higher than current common practice.**

Greenroads **Sustainability** and how it is defined.

Sustainability is a system characteristic which refers to the system's capacity to support **natural laws** and **human values**.

Natural laws = Ecology

Rule: Don't break the earth

Human values = equity and economy

Equity rule: Seek quality of life for all

Economy rule: Manage resources wisely

Resources = human, natural, manufactured and financial capital

Who is **developing** the Greenroads sustainability performance metric?

- University of Washington
 - Martina Sölderlund, Master's Thesis – *Sustainable Roadway Design: a Model for an Environmental Rating System* (2007)
 - Dr. Stephen Muench, Jeralee L. Anderson, + 11 others.
- CH2M HILL, Inc. (An engineering and project management company with offices world wide that specializes in sustainable development.)
 - Various Individuals (19 people listed on authors section)

Intelligent Compaction and the Greenroads Rating System

Dean Potts, Caterpillar

Who is **sponsoring** the Greenroads sustainability performance metric?

- Transportation Northwest (TransNow)
- State Pavement Technology Consortium (SPTC)
- Western Federal Lands Highway Division
- Oregon Department of Transportation (ODOT)

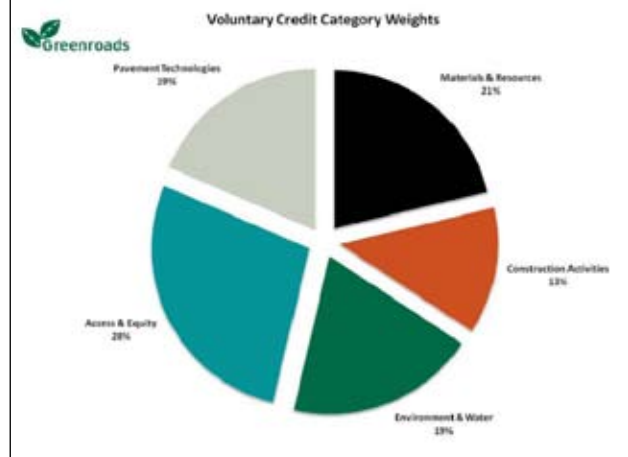
What is the Rating System and how does it work?

Category points	Description	Req
Project Requirements	Minimum requirements for a Greenroad	Req
Environment & Water	Stormwater, habitat, vegetation	21
Access & Equity	Modal access, culture, aesthetics, safety	30
Pavement Technology	Pavement design, material use, function	20
Construction Activities	Construction equipment, quality, use	14
Materials & Resources	Material extraction, processing, transport	23
108	Total Voluntary Credit Points	
Custom Credits	Write your own credit for approval	
10	Current Manual at v.1.0 is 442 pages long.	
	Grand Total	

What is the Rating System and how does it work?



- ☐ Certified: All Project Requirements + 32-42 Voluntary Credit points (30-40% of total)
- ☐ Silver: All Project Requirements + 43-53 Voluntary Credit points (40-50% of total)
- ☐ Gold: All Project Requirements + 54-63 Voluntary Credit points (50-60% of total)
- ☐ Evergreen: All Project Requirements + 64+ Voluntary Credit points (>60% of total)



CREDIT CHECKLIST

Note: This checklist is two pages.

No.	Title	Pts.	Brief Description
Project Requirements (PR)			
PR-1	Environmental Review Process	Req	Complete an environmental review process
PR-2	Lifecycle Cost Analysis (LCCA)	Req	Perform LCCA for pavement section
PR-3	Lifecycle Inventory (LCI)	Req	Perform LCI of pavement section with software tool
PR-4	Quality Control Plan	Req	Have a formal contractor quality control plan
PR-5	Noise Mitigation Plan	Req	Have a noise mitigation plan
PR-6	Waste Management Plan	Req	Have a formal plan to divert C&D waste from landfill
PR-7	Pollution Prevention Plan	Req	Have a TESC/S&PPP
PR-8	Low-Impact Development (LID)	Req	Feasibility study for LID techniques for stormwater
PR-9	Pavement Management System	Req	Have a pavement preservation system
PR-10	Site Maintenance Plan	Req	Have a maintenance plan for environment, utilities
PR-11	Educational Outreach	Req	Publishize sustainability information for project
PR Subtotal:		22	
Environment & Water (EW)			
EW-1	Environmental Management System	2	Obtain ISO 14001 certification for general contractor
EW-2	Runoff Flow Control	3	Reduce runoff quantity
EW-3	Runoff Quality	3	Treat stormwater on-site
EW-4	Stormwater Cost Analysis	1	Conduct an LCCA for stormwater BMP/LID selection
EW-5	Site Vegetation	3	Use native species water vegetation
EW-6	Habitat Restoration	3	Create new habitat beyond what is required
EW-7	Ecological Connectivity	3	Connect habitat across roadways
EW-8	Light Pollution	3	Discourage light pollution
EW Subtotal:		21	

Access & Equity (AE)

<input type="checkbox"/> AE-1	Safety Audit	2	Perform roadway safety audit
<input type="checkbox"/> AE-2	Intelligent Transportation Systems	5	Implement ITS solutions
<input type="checkbox"/> AE-3	Context Sensitive Solutions	5	Plan for context sensitive solutions
<input type="checkbox"/> AE-4	Traffic Emissions Reduction	5	Systematically reduce air emissions
<input type="checkbox"/> AE-5	Pedestrian Access	2	Provide/improve pedestrian accessibility
<input type="checkbox"/> AE-6	Bicycle Access	2	Provide/improve bicycle accessibility
<input type="checkbox"/> AE-7	Transit & HOV Access	5	Provide/improve transit accessibility
<input type="checkbox"/> AE-8	Scenic Views	2	Provide views of scenery or vistas
<input type="checkbox"/> AE-9	Cultural Outreach	2	Promote art/culture/community values on roadway
AE Subtotal:		30	

Construction Activities (CA)

<input type="checkbox"/> CA-1	Quality Management System (QMS)	2	Obtain ISO 9001 certification for general contractor
<input type="checkbox"/> CA-2	Environmental Training	1	Provide environmental and safety training
<input type="checkbox"/> CA-3	Site Recycling Plan	1	Provide plan for on-site recycling and trash
<input type="checkbox"/> CA-4	Fossil Fuel Reduction	2	Use alternative fuels in construction equipment
<input type="checkbox"/> CA-5	Equipment Emission Reduction	2	Meet EPA Tier 4 standards for non-road equipment
<input type="checkbox"/> CA-6	Paving Emission Reduction	1	Use pavers that meet NIOSH requirements
<input type="checkbox"/> CA-7	Water Use Tracking	2	Develop data on water use in construction
<input type="checkbox"/> CA-8	Contractor Warranty	3	Offer an extended warranty on pavement
CA Subtotal:		14	

Intelligent Compaction and the Greenroads Rating System

Dean Potts, Caterpillar

Materials & Resources (MR)			
<input type="checkbox"/>	MR-1	Lifecycle Assessment (LCA)	2
<input type="checkbox"/>	MR-2	Pavement Reuse	5
<input type="checkbox"/>	MR-3	Earthwork Balance	1
<input type="checkbox"/>	MR-4	Recycled Materials	5
<input type="checkbox"/>	MR-5	Regional Materials	5
<input type="checkbox"/>	MR-6	Energy Efficiency	5
MR Subtotal:			23
Pavement Technologies (PT)			
<input type="checkbox"/>	PT-1	Long-Life Pavement	5
<input type="checkbox"/>	PT-2	Permeable Pavement	3
<input type="checkbox"/>	PT-3	Warm Mix Asphalt	3
<input type="checkbox"/>	PT-4	Cool Pavement	5
<input type="checkbox"/>	PT-5	Quiet Pavement	3
<input type="checkbox"/>	PT-6	Pavement Performance Tracking	1
PT Subtotal:			20
Custom Credit (CC)			
<input type="checkbox"/>	CC-1	Custom Credit Title	10
CC Subtotal:			10
Greenroads Total:			118

Does Intelligent Compaction apply to Greenroads?

- Not specifically
 - There are no points in scorecard awarded for using Intelligent Compaction.
 - No long term history/studies to prove that IC has substantial benefits that are rated under Greenroads metrics.
 - But...It is possible for user to claim points by making a case and putting them in 'Custom Credits'.

Potential of IC to Impact Sustainability Metrics.			
No.	Title	Pts.	Brief Description
Project Requirements (PR)			
<input type="checkbox"/>	PR-1	Environmental Review Process	Req. Complete an environmental review process
<input checked="" type="checkbox"/>	PR-2	Lifecycle Cost Analysis (LCCA)	Req. Perform LCCA for pavement section
<input checked="" type="checkbox"/>	PR-3	Lifecycle Inventory (LCI)	Req. Perform LCI of pavement section with software tool
<input checked="" type="checkbox"/>	PR-4	Quality Control Plan	Req. Have a formal contractor quality control plan
<input type="checkbox"/>	PR-5	Noise Mitigation Plan	Req. Have a noise mitigation plan
<input type="checkbox"/>	PR-6	Waste Management Plan	Req. Have a formal plan to divert C&D waste from landfill
<input type="checkbox"/>	PR-7	Pollution Prevention Plan	Req. Have a TSC/SPPPP
<input type="checkbox"/>	PR-8	Low-Impact Development (LID)	Req. Feasibility study for LID techniques for stormwater
<input type="checkbox"/>	PR-9	Pavement Management System	Req. Have a pavement preservation system
<input type="checkbox"/>	PR-10	Site Maintenance Plan	Req. Have a maintenance plan for environment, utilities
<input type="checkbox"/>	PR-11	Educational Outreach	Req. Publicize sustainability information for project
PR Subtotal:			11
Environment & Water (EW)			
<input type="checkbox"/>	EW-1	Environmental Management System	2
<input type="checkbox"/>	EW-2	Runoff Flow Control	3
<input type="checkbox"/>	EW-3	Runoff Quality	3
<input type="checkbox"/>	EW-4	Stormwater Cost Analysis	1
<input type="checkbox"/>	EW-5	Site Vegetation	3
<input type="checkbox"/>	EW-6	Habitat Restoration	3
<input type="checkbox"/>	EW-7	Ecological Connectivity	3
<input type="checkbox"/>	EW-8	Light Pollution	3
EW Subtotal:			21

Access & Equity (AE)			
<input type="checkbox"/>	AE-1	Safety Audit	2
<input type="checkbox"/>	AE-2	Intelligent Transportation Systems	5
<input type="checkbox"/>	AE-3	Context Sensitive Solutions	5
<input type="checkbox"/>	AE-4	Traffic Emissions Reduction	5
<input type="checkbox"/>	AE-5	Pedestrian Access	2
<input type="checkbox"/>	AE-6	Bicycle Access	2
<input type="checkbox"/>	AE-7	Transit & HOV Access	5
<input type="checkbox"/>	AE-8	Scenic Views	2
<input type="checkbox"/>	AE-9	Cultural Outreach	3
AE Subtotal:			30
Construction Activities (CA)			
<input checked="" type="checkbox"/>	CA-1	Quality Management System (QMS)	2
<input type="checkbox"/>	CA-2	Environmental Training	1
<input type="checkbox"/>	CA-3	Site Recycling Plan	1
<input checked="" type="checkbox"/>	CA-4	Fossil Fuel Reduction	2
<input checked="" type="checkbox"/>	CA-5	Equipment Emission Reduction	2
<input type="checkbox"/>	CA-6	Paving Emission Reduction	2
<input checked="" type="checkbox"/>	CA-7	Water Use Tracking	2
<input checked="" type="checkbox"/>	CA-8	Contractor Warranty	3
CA Subtotal:			14

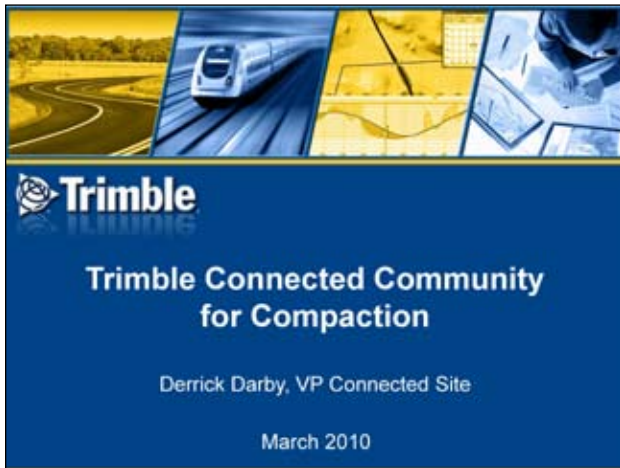
Materials & Resources (MR)			
<input checked="" type="checkbox"/>	MR-1	Lifecycle Assessment (LCA)	2
<input checked="" type="checkbox"/>	MR-2	Pavement Reuse	5
<input checked="" type="checkbox"/>	MR-3	Earthwork Balance	1
<input checked="" type="checkbox"/>	MR-4	Recycled Materials	5
<input checked="" type="checkbox"/>	MR-5	Regional Materials	5
<input checked="" type="checkbox"/>	MR-6	Energy Efficiency	5
MR Subtotal:			23
Pavement Technologies (PT)			
<input checked="" type="checkbox"/>	PT-1	Long-Life Pavement	5
<input checked="" type="checkbox"/>	PT-2	Permeable Pavement	3
<input type="checkbox"/>	PT-3	Warm Mix Asphalt	3
<input type="checkbox"/>	PT-4	Cool Pavement	5
<input type="checkbox"/>	PT-5	Quiet Pavement	3
<input checked="" type="checkbox"/>	PT-6	Pavement Performance Tracking	1
PT Subtotal:			20
Custom Credit (CC)			
<input checked="" type="checkbox"/>	CC-1	Custom Credit Title	10
CC Subtotal:			10
Greenroads Total:			118

Conclusions

- Intelligent Compaction is currently not a specific factor in Greenroads rating.
- With some imagination and published IC studies, various types of IC could impact 18 of 49 Greenroads metrics.
- On a points basis, IC could have some impact on 55 of 118 points in the rating.

Trimble Connected Community for Compaction

Derrick Darby , Trimble/XYZ



Trimble

Trimble Connected Community for Compaction

Derrick Darby, VP Connected Site

March 2010



Agenda

- Trimble's Connected Site Concept
- Trimble Connected Community
- Live Demonstration



Trimble Connected Site Concept




Objectives of the Connected Site

- To answer the question, "How are we doing?" requires that we fuse Production Information, Schedule and Budget
- We want to allow our customers to visit any jobsite without getting in a car or getting on an airplane
- Trimble's goal is to provide our customers with Any Data, Anywhere, Anytime
- Real-time Quality Control / Quality Assurance



Impacts and Potential Improvement

Impacts	Potential Improvements
<ul style="list-style-type: none"> – Errors – Delays – Lack of awareness – Re-work – Cost overruns – Downtime 	<ul style="list-style-type: none"> – Speed – Accuracy – Information availability – Enterprise awareness – Better decision making – Lower costs – Project profitability – Safety – Quality – Operational Excellence

Trimble Connected Community for Compaction

Derrick Darby, Trimble/XYZ



Benefits of the Connected Site

- Provide a Common Operating Picture to the operations of our customers
- Create the experience of the team working together even though they may be hundreds of miles apart
- Cheaper, quicker faster.
Maximize Return On Investment
- Provide a growth path, upgradability, scalability
- We provide visibility to the data to our customers to allow them to analyze operations and make better real-time decisions positively impacting project profitability
- Post-Construction Documentation




Trimble Connected Community

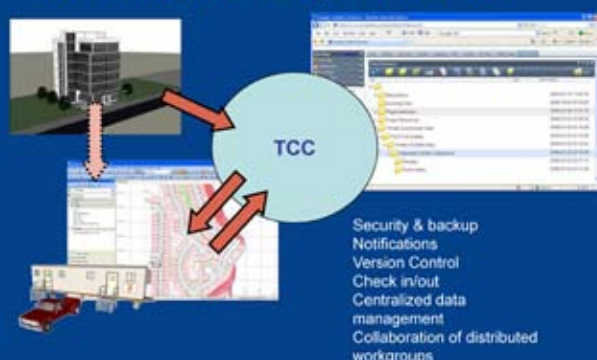


Trimble Connected Community

All of your site information in one place.

Trimble Connected Community for Construction



Security & backup
Notifications
Version Control
Check in/out
Centralized data management
Collaboration of distributed workgroups



Integrated Workflows




Trimble Connected Community Aggregates Workflows and Connects User Communities





Benefits of the Connected Community

- **Benefits:**
 - Foundation for the Connected Site
 - Connects people and assets
 - Creates organizational transparency
 - Facilitates collaboration with partners
 - Centralizes information
 - Reduces travel time, fuel costs and emissions
 - Reduces errors and re-work
 - Provides security, backup and recovery
 - Provides sophisticated administration tools
 - Is easy to deploy and use
 - Safety is improved and can be monitored
 - Post Construction Documentation and Archival

Live Demonstration

Derrick Darby
cell: (678) 427-5974
derrick_darby@trimble.com

New Actions of Sakai in TPF's IC Projects

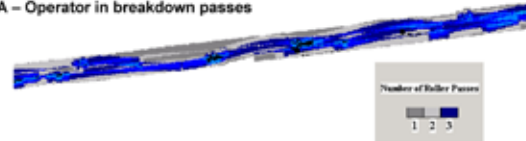
Todd Mansell, Sakai

New Actions of SAKAI in TPF's IC PROJECTS

Sakai America, Inc.
Todd Mansell
Technical Marketing Manager

OLD Business by SAKAI; Real World of Rolling Process

A – Operator in breakdown passes



B – Operator in finish passes

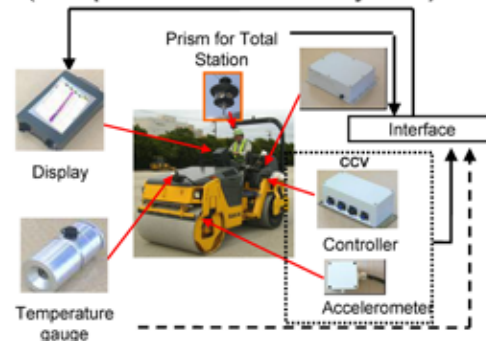


New Business; SAKAI IC Actions '08-'09



Year	State	IC Rollers used for tests		Soil		Pavement layers			
		Make	Model	Subgrade	Subbase/ Base	Binder	Surface		
08	MN	Sakai	SW800	—	X	X	—	X	
	TX	Ammann	SV212	X	—	—	—	—	
	KS	CAT	CP56	X	—	—	—	—	
		Sakai	SV010T-TP	X	—	—	—	—	
09	NY	CAT	CS-400E	X	X	—	—	—	
		Boring	BW213D-4BVD	X	X	—	—	—	
	MS	Sakai	SW800	—	—	X	—	—	
		Ammann	SV212	—	X	—	—	—	
		CAT	CS-400E	—	X	—	—	—	
	MD	Sakai	SW800	—	X	X	—	—	
		Boring	BW276AD-4	—	—	—	—	X	
	GA	Sakai	SW800	—	—	X	X	X	
		Boring	BW276AD-4	—	—	—	X	X	
09	IN	Sakai	SW800	—	—	—	X	X	

SAKAI's CIS (Compaction Information System)



CIS with Total Station (TS) For Tighter Site with Higher Accuracy in elevation



SAKAI 8000 lb Combination Roller,
TW502-1



Software Capabilities of CIS Easy Data Creation from 3D-CAD

1) Aithon "CAD" version:

Select points surrounding the working area directly on 3D-CAD drawing. Coordinates in x, y and z axis of those points can be selected automatically.

2) Aithon "Stand Alone" version:

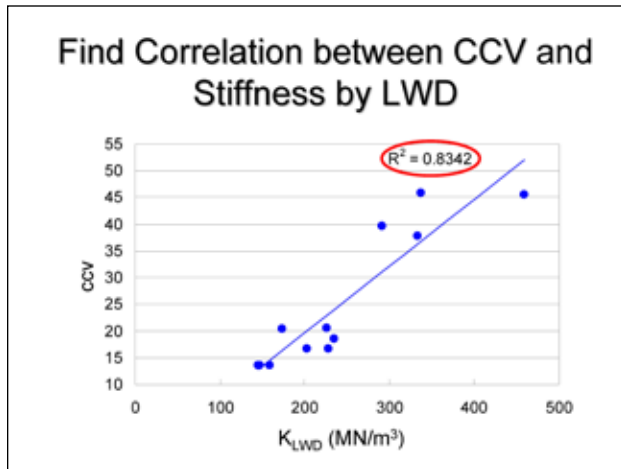
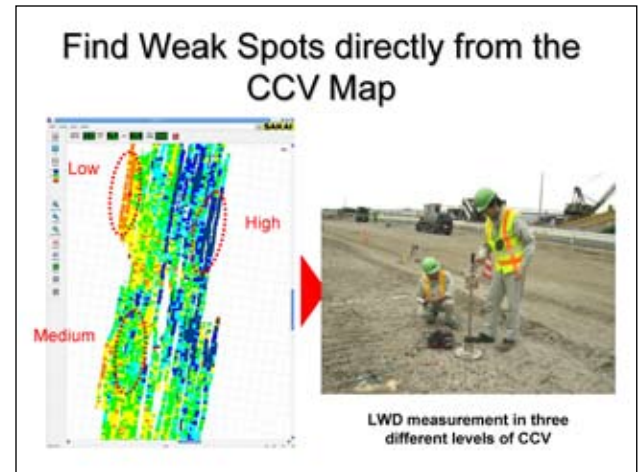
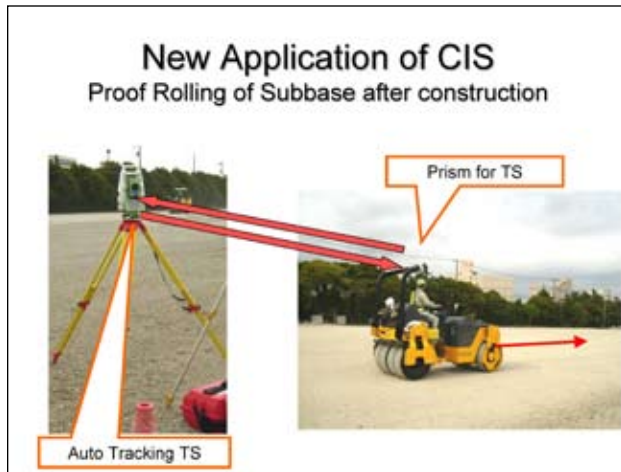
(a) Select points surrounding working area directly on design DXF file, if is available.

(b) Input all coordinates of the working zone, which were measured in the jobsite.



New Actions of Sakai in TPF's IC Projects

Todd Mansell, Sakai



- What's need next?**
- Wireless communication and data transmission
 - Real-time data to "the office"
 - GPS tie in to State-run permanent base stations (eliminate portable base station)
 - How many states already have a network?
 - Standardization of data reporting
 - Who will lead this effort?

Thank you for your attention!

Update on MoDOT's Intelligent Compaction Efforts

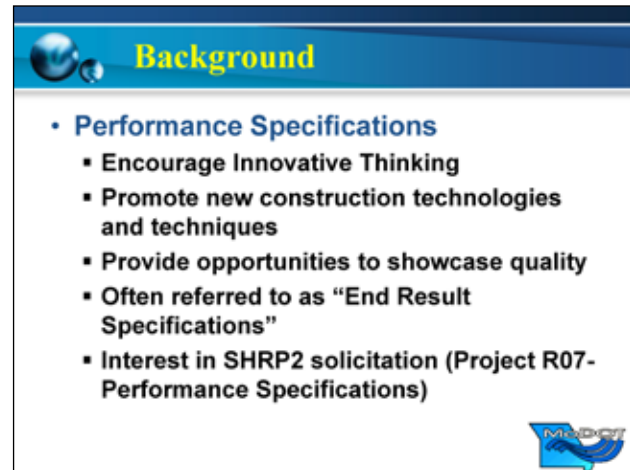
William Stone



**Update on MoDOT's
Intelligent Compaction Efforts**

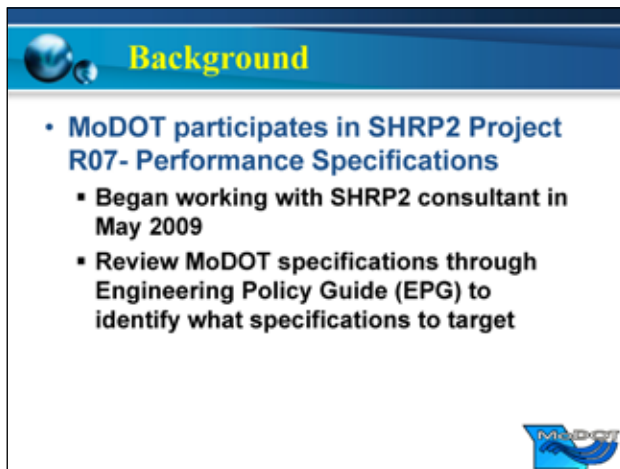
Missouri Department Of Transportation

March 2010



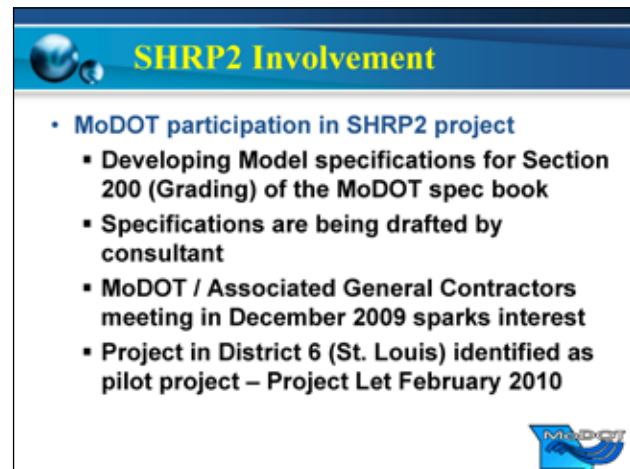
Background

- **Performance Specifications**
 - Encourage Innovative Thinking
 - Promote new construction technologies and techniques
 - Provide opportunities to showcase quality
 - Often referred to as "End Result Specifications"
 - Interest in SHRP2 solicitation (Project R07- Performance Specifications)



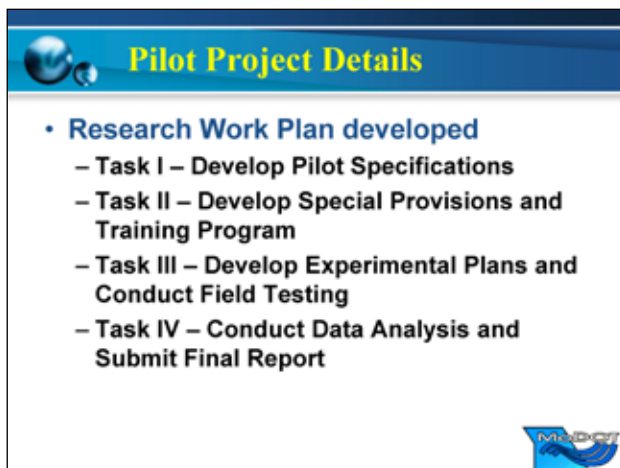
Background

- **MoDOT participates in SHRP2 Project R07- Performance Specifications**
 - Began working with SHRP2 consultant in May 2009
 - Review MoDOT specifications through Engineering Policy Guide (EPG) to identify what specifications to target



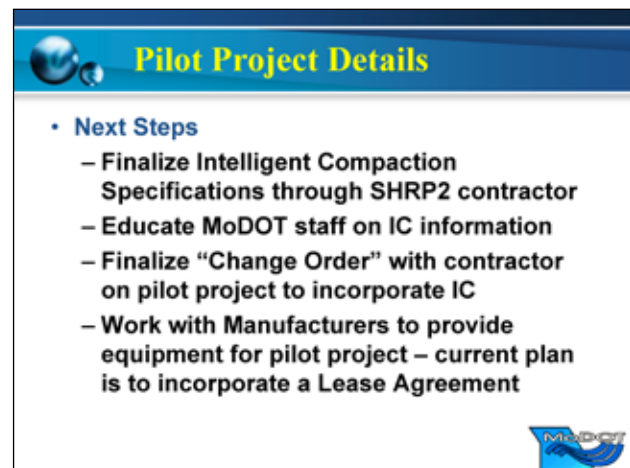
SHRP2 Involvement

- **MoDOT participation in SHRP2 project**
 - Developing Model specifications for Section 200 (Grading) of the MoDOT spec book
 - Specifications are being drafted by consultant
 - MoDOT / Associated General Contractors meeting in December 2009 sparks interest
 - Project in District 6 (St. Louis) identified as pilot project – Project Let February 2010



Pilot Project Details

- **Research Work Plan developed**
 - Task I – Develop Pilot Specifications
 - Task II – Develop Special Provisions and Training Program
 - Task III – Develop Experimental Plans and Conduct Field Testing
 - Task IV – Conduct Data Analysis and Submit Final Report

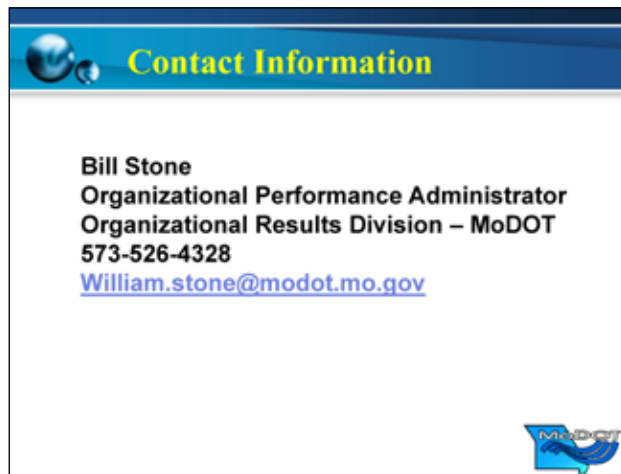


Pilot Project Details

- **Next Steps**
 - Finalize Intelligent Compaction Specifications through SHRP2 contractor
 - Educate MoDOT staff on IC information
 - Finalize "Change Order" with contractor on pilot project to incorporate IC
 - Work with Manufacturers to provide equipment for pilot project – current plan is to incorporate a Lease Agreement

Update on MoDOT's Intelligent Compaction Efforts

William Stone



Illinois DOT Experience and Concerns with IC

Riyad Wahab

Illinois DOT Experience and Concerns with I.C.

Riyad Wahab, PhD, PE

State Geotechnical Engineer
Foundations & Geotechnical Unit
Bureau of Bridge & Structures
riyad.wahab@illinois.gov
217-782-2704

IL DOT's Experience

- ❖ 2002-2004 Experimented with GeoGauge
- ❖ 2008 Sent one of our District Geotech. Engrs to attend Iowa's IC Workshop. (no longer with IDOT)
- ❖ 2009 State Foundations & Geotech Engr attended Iowa's Workshop
- ❖ 2010 Proposed IC research with UIUC/Caterpillar (Rejected by Districts)
- ❖ 2010 State Geotech Engr attending IC webinar

CONCERNS

- ❖ GeoGauge Study (by ILDOT & 25 other DOTs) did not provide definite conclusions, especially in silty soils, thus keeping faith in current practice
- ❖ ILDOT Cost for disposing nuc gauges, training staff on new technology & purchasing new equipment, if any
- ❖ Strong opposition by industry – Contractors not willing to purchase new compaction machinery due to major expense, but may accept retrofitting

Future of I.C. in IL.

- ❖ Dependant on results of current research (by others) .
- ❖ Need to establish comfort level with any new procedures.
- ❖ Cost of implementation (to both ILDOT & Industry) will need to be justified by the benefits of using IC.
 - Although IL-DOT spends a lot on earthwork, subgrades, and HMA, we do not yet see the benefits that justify the costs.
- ❖ Going forward, I have been appointed as the lead contact for IL-DOT's continued evaluation and any implementation of I.C. technology.

Thanks,

↓ Questions, Comments or Suggestions?

Questions/Comments and Responses

The following is a log for each presentation of the questions/comments from the participants and responses from the presenters.

Day 1

Iowa DOT 2009 Demonstration Projects Presentation

Question: How is the CCV value being calculated?

Response: The Sakai CCV (Continuous Compaction Value) is calculated using the drum harmonic response during vibratory drum operations.

Question: When were the CCV values recorded on 218?

Response: The CCV values on Hwy 218 were recorded between 8 pm and 5 am.

Question: Is the CCV measuring only density of the HMA or the ground below it?

Response: Roller measurement values are generally influenced by stiffness of the layers underlying the HMA layer.

Question: Just needed a brief definition of CCV and CMV? Thanks.

Response: Both CMV (Compaction Meter Value) and CCV (Continuous Compaction Value) are calculated using the drum harmonic responses during vibration. Caterpillar also reports CCV (Caterpillar Compaction Value) which in the case of US30 demonstration project is a machine drive power based technology. Please see 2008 and 2009 Workshop Reports for further details on different measurement technologies. (<http://www.eerc.iastate.edu/publications.cfm>)

Georgia DOT Status Update Presentation

Question: How was the sakai roller chosen? Why not another mfg?

Response: Sakai was selected because they were participants in the pooled fund study and had equipment available at the time of construction.

Question: what is prime?

Response: prime in the old days was used to stabilize agg base.

Question: How did you compensate the contractor for extra equipment on the project?

Question: If the rollers are measuring 4' deep, shouldn't the HMA IC projects be done on bases built consistently with IC control?

Response: Subgrade will be rolled prior to the HMA placement because the rollers measurement is influenced by deeper conditions.

Texas DOT Status Update and Developmental Specifications Presentation

Question: Who is the retrofit system from?

Response: TTI (Texas Transportation Institute) developed a retrofit system.

Question: How is this an Approved List without discriminators from the Department?

Response: The list is developed based on the emails received from the manufacturers.

Iowa DOT Developmental Specifications Discussion

Question: Electronic equipment reliability on a vibratory roller could be an issue. How would you address one going down in a three roller train? This would be a case by case basis. The IC component may not be paid during that time or the operation may be halted until equipment is repaired. While the information is not required for acceptance it is.

Question: We talked about the 80% coverage, but we felt the contractor would have too many opportunities to skirt the intent of the specs

Response: The 80% coverage is specified as a starting point to get contractors some experience with the technology. This number is anticipated to change based on lessons learned during 2009 projects.

Question: How much is being paid to have the contractor show up with an IC roller?

Average bid price?

Response: The bid prices were 5k, 40-50k, 130k-140k in Iowa.

Response: Contractor with 40-50k range bid price was selected.

Comment: I don't think the manufacturers currently do not feel comfortable in the reliability of their equipment to cover 80%.

Comment: As an owner we feel less than 100% coverage does not provide the value/data we need to ensure a quality project.

Comment: As a contractor I question that also.

Question: How are you ever going to get 100% with satellites?

Response: Exactly. GPS is where the 100% is hard to reach.

Comment: One can install a repeater on a project to extend the base stations coverage

General Questions/Comments

Comment: Please note that KSE can now calibrate the Zorn LWD in the U.S.

Question: Have there been any demo projects on WMA?

Response: Yes, MD tested WMA a few years ago with IC.

Question: Are the software licenses going to be returned to the contractor after the project?

Comment: Commented on the issue of roller measuring mechanistic properties as well as the approaches to evaluation using mechanistic performance criteria. We need to look forward to the future and how IC can bring a benefit to this type of approach.

Comment: Good point. GDOT wonders if modulus is more appropriate for going forward.

Comment: Tried IC on one project, showed inconsistent results when compared to Nuclear Gauges, existing material varied, took additional passes for IC equipment to show passing after nuclear gauge showed passing results. Does IC work with soils with plastic properties? Does IC measure too deep for the layer being placed? Perhaps correlating IC with gauges is an issue? On-site manufacturer told Contractor that this was the wrong application for IC technology.

Comment: Commented on the cost for adding vibe rollers for soil compaction, they use pulled sheepfoot for most soil.

Question: Back to software, does the State, the Engineer, and/or ISU want to keep the software for future use?

Question: Does IC measure to deep for the layer being placed?

Response: IC measurement influence depth can be deeper than the compaction layer depth.

Day 2

Manufacturer Update Presentations

Note: Due to time limitations and to provide the equipment manufacturers an opportunity to provide a written response, a separate questionnaire was emailed to the equipment manufacturers. Their responses are included in Table 4.

Dynapac

Question: Can the Dynapac system measure CMV, temp, and pass counts at the same time?

Question: Is there any feedback when not in vibratory mode?

Bomag

Question: Do you have a pneumatic tired roller available equipped with IC technology? We meant with respect to roller passes, location, and temp

Question: Is the Evib measured at the middle of roller or average of whole roller width?

Response: The Evib value is measured as an average over the drum width.

Question: Any effort to correlate Evib to FWD modulus?

Question: Following the logic that cooling asphalt can't be compacted and IC can't measure stiffness then has anyone tried IC on cold/freezing soil?

Response: It is a good concept. Not tried before.

Question: Does the Evib work for the padfoot roller?

Question: Was the temperature plot shown during a specific roller pass? Of average of several passes?

Illinois DOT Update Presentation

Question: Has anyone tried correlating Geogauge measurements with IC measurements?

Response: We looked at it several years ago and had no conclusive results

Response: We also tried it, with similar results, and consequently, starting putting energies toward the lwd.

General Questions/Comments/Responses

Question: Is there IC retro fit kits for all existing rollers?

Response: Trimble does retrofits of compaction control systems on existing compactors of all brands and model types.

Response: The retrofit kit that TTI developed can fit any regular roller, but it does not alter both amplitude and frequency. It is just for mapping.

Response: Dynapac can retrofit documentation systems on Dynapac rollers (soil and tandem) dating back to 1998. Adjustable amplitude feed-back systems cannot be retro fitted

Questions: The following are our general questions: 1. For HMA, we want to instrument the

entire rolling train. We want temperature, pass count and locations on the breakdown, pneumatic and static/finishing rollers. We have money. Who can come take our money and give us this! We currently have 2 projects queued in, but are willing to complete this on 5 during 2010. Who can provide this to us this year? What will it cost to have this technology on all the compactors? 2. We have had mixed feedback on the availability of compactors for both soils and HMA. What is the current status of availability of these rollers? 3. Who can provide portable, retrofit instrumentation to install on existing fleets of rollers (i.e., on all rollers...both HMA and soils...old and new).

Response: I would have to direct you to our US organization for correct pricing. I talked to Anderson Construction during WoA and they showed great interest for our system. Who should I ask our US organization to contact?

Question: We may need to include the retrofit IC as one of research topic. What do ya'll think?

Response: absolutely. There is a huge demand for retrofits

Response: We think that would be excellent.

Response: Ditto!

Question: As I understand, your retrofit system only works for Dynapac rollers, is that right?

Response: TxDOT, yes. Our (Dynapac) systems are specifically for Dynapac Rollers.

Comment: We look forward to discuss your retrofit needs for all machine brands.

Comment: This should be an incentive to other manufacturers to develop their own retro systems

Question: Can you modify it to fit in other type of rollers, too?

Question: Not all contractors use Dynapac rollers?

Comment: We will have a project using the retrofit kit. If anyone is interested, I would like to share the info when it comes. Please contact me (TxDOT) after this workshop.

Question: Is there a IC system that is easily moved from one machine to another? (ie. State owned and contractor rented for their machine)

Response: That is what we (TxDOT) are working on

Question: where can one find info on that? (if possible)

Response: Like I said, shoot me (TxDOT) an email after this.

Comment: We are also wondering about equipment availability and whether demand on upcoming projects throughout the country can be met.

Question: Storage??

Question: What are the data storage needs and availability?

Question: Do we need to buy the software? How much is it?

Question: To all manufacturers: what are the maintenance and calibration needs for the IC equipment?

Comment: If manufacturers have validated the IC test result with any of in-situ devices, please provide information which of these in situ device best correlate with the IC equipment.

Response: Our experience is that the CMV corresponds best to the LWD and static plate load tests.

Question: What about FWD?

Response: Static plate load tests have given us the best results when looking into a stiffness value

Response: Some university research has been done about this correlation and indeed the static plate load came out best. I don't think it differs that much between manufacturers.

Comment: It would be great to get all group questions answered, since this is a great forum to do so. We noticed that not all of the manufacturers provided comments. Could you (ISU) provide a summary table of what manufacturer's can provide. For instance, details on who can provide retrofits for use on HMA, what machines can the retrofits be installed on, etc. What is the inventory out there? We are told there are machines available, however when it comes down to it, we call (or our Contractors call) and have been frequently unable to obtain instrumented compactors for both HMA & Soils. Are the compactors available for rental, lease or only sale with respect to each manufacturer? We have been trying now for a few years to instrument an HMA compaction train (with money available to provide compensation for rental/leasing of equipment), but cannot get any interest from manufacturers.

Comment: NYDOT has been told the same

Question: To all manufacturers: what is needed for the setup, maintenance and calibration needs for the IC equipment?

Comment: All accelerometers require calibration after a given period of time. These sensors have been used in other tests and are typically run through calibration testing

Question: How do you tell when the equipment is out of calibration?

Comment: Dave, I'm uncertain as to how one could currently determine when an accelerometer, when within the drum, requires calibration. One could tell when it is completely out of calibration if the stiff and soft range of values appears to be unreasonable, when there are no other software problems. With other test equipment, one would typically use another sensor to check the calibration when the sensor cannot be immediately removed. Please note whether there is a current method for calibration of accelerometers, which the regional FWD centers currently use, since an accelerometer is used to verify the geophones.

Question: Is there or will there be any IC equipment available on hand/walk-behind equipment?

Question: Is it Iowa's intent to pay for the Contractor's QC as a permanent course of action, or just until IC catches on?

Comment: It's Mn/DOT's intent to pay only until IC catches on or until we develop incentive/ decenterives table.

Comment: I can't see a standard roller output until the states pick one and then let the manufacturers figure out how to convert their values

Manufacturer Responses to General Questions

Following are some of the responses received from the manufacturers during the webinar. A follow-up response was received from some of the manufacturers and is included in Table 4 below.

Bomag

- The dealers have been trained.
- The equipment is in stock and is ready for use.
- Regarding question on setup/maintenance/calibration: This has been done in the past on pooled fund study projects.

Caterpillar

- We currently have a number of asphalt and soil machines that are available
- Can work with Trimble to get add-on systems for paving train coverage
- Adding on paving train: so far the developments have been only on compaction side and need some advancement in this area.
- GPS has issues during certain times of the days and locations under bridges, etc., It's beyond our control.
- Regarding question on dealer support and their experience: Dealers have been well trained. Factory has given an option for training to all dealers.
- Regarding question on setup/maintenance/calibration: Setup is fairly easy and has done in the past. No special calibration is required other than calibration from test strips with traditional test methods.

Trimble

- We offer solutions on soil compactors, currently working on asphalt compactors
- We can setup GPS and temperature sensors on any rollers
- No issues are anticipated on the quality of the data
- Data has good reliability
- GPS issues – need good line of sight to sky for good GPS single. Breaks in data should be expected in areas under bridges or poor line of sight to sky, etc.
- Regarding question on dealer support and their experience: Dealers are well experienced and available to provide support. They are well used to these types of technologies.
- Regarding question on setup/maintenance/calibration: On-site calibration is required by construction of test strips and correlations with traditional compaction methods.

Discussion on Proposed Problem Statement for TTICC

Question: Don't pooled fund projects have to request proposals from many bidders rather than just name one?

Response: We are certainly interested in bringing in contributors that can make contributions

to this effort. The development of this problem statement has been with input from the EERC and ISU and we envision their involvement in the project if it moves forward, but again welcome others that would be able to contribute.

Question: When does this pool fund study start?

Response: I anticipate submitting the problem statement to FHWA by mid March. It may take 4 to 6 weeks for processing.

Question: Will you have a formal letter describing the proposed pooled fund that we can give to our DOT?

Response: Yes.

Contacts for State DOT Developmental Specifications

Mn/DOT: contact Greg Johnson for HMA and Rebecca Embacher (soils)

Iowa DOT: Mark Dunn can be the initial contact for the Iowa DOT specification information. Also contact David White at the EERC.

TxDOT: Contact Zhiming Si

Table 4. Equipment manufacturers' responses

Product overview							
Description	Bomag	Case/Ammann	Caterpillar*	Dynapac	Sakai	Trimble	Volvo*
Soil Roller models with IC/CCC systems	BW 177 DH-4 BVC, BW 213 DH-4 BVC, BW 226 DH-4 BVC [all are SD]	SV212 [SD]		CA 152, 182, 252, 262, 302, 362, 402, 512, 602, and 702 [SD with Cab]	Sakai SV 505, SV 510, SV 610 (all 84" wide drums). [SD, PD, PD with SD shell kit]	Retrofit system (CCS900). Works best with SD on granular soils.	
Asphalt Roller models with IC/CCC systems	BW 141 AD-4 AM, BW 151 AD-4 AM, BW 151 AC-4 AM, BW 154 AD-4 AM, BW 154 AC-4 AM, BW 154 AP-4 AM, BW 170 AP AM, BW 174 AP AM, BW 174 ACP AM, BW 190 AD-4 AM, BW 203 AD-4 AM, BW 278 AD-4 AM	None		CC 224, 234, 324, 334, 424, 524, and 624.	SW 850, 880, 900, 990, 800-2, and GW750-2.	Retrofit system (CCS900).	
Retrofit System Capability	No	No		Yes ^a	Yes ^b	Yes	
Equipment Availability for Rent	Yes	Yes		Negotiable	Yes for a minimum 3-months.	Yes. Contact Trimble for rent/lease/sale options.	
Equipment Availability for Lease							
Equipment Availability for Sale				Yes	Yes		
HMA/WMA compaction train documentation	No	—		No solution offered ^c	Yes ^d	Yes ^e	

Equipment Manufacturer Contact Information:

BOMAG Americas: Chris Connolly, BOMAG Americas, 2000 Kentville Road, Kewanee, IL 61443, Ph: 301-529-8477, Email: Chris.connolly@bomag.com

Case Construction: George Whitaker, Case Construction Equipment, Ph: 262-636-4959, Email: George.whitaker@casece.com.

Dynapac: Fredrik Åkesson, Head of Dynapac Competence Center, Karlskrona, Sweden. Ph: +46 455 306095/ +46 705 769981. Email: fredrik.akesson@dynapac.com; Mike Prichard, VP Sales and Marketing, Dynapac USA, Office: 210-474-5771, Mobile: 210-241-7463, Email: mike.prichard@us.atlascopco.com.

Sakai: Todd Mansell, Technical Marketing Manager, Sakai America, Inc., 90 International Parkway, Adairsville, GA 30103, Ph: 770-877-9433 x-223, t-mansell@sakaiamerica.com. Any local Sakai dealer. For more information see www.sakaiamerica.com.

Trimble: Jeff Drake - Soil Compaction, Ph: 720 587 4569, Email: Jeff_Drake@Trimble.com; Jeroen Snoeck – Asphalt Compaction, Ph: 720 587 4414, Email: Jeroen_Snoeck@Trimble.com; Eric Crim – All Compaction, Ph: 720 587 4695, Email: Eric_Crim@trimble.com.

Requirements/recommendations for maintenance and/or calibration of the roller measurement sensors, GPS, data logging systems, etc.?

- Case: Standard scheduled maintenance is required. No specific daily or unique maintenance is required.
- Dynapac: No real calibration needed. CMV can be correlated to acceptance testing, however this is in relation to the job site conditions, not the hardware on the roller.
- Sakai: The CCV sensor (accelerometer) should be calibrated every two years.
- Trimble: GPS is continuously calibrated using the local RTK reference station. We also offer a CCS900 version guided by the robotic total station for mm accuracy. The robotic total station is set-up by shooting to the reference points on site. Compaction sensor needs to be calibrated with traditional equipment like the nuclear densometer. The dimensions of the machine are calibrated at installation only.

Table 4. Equipment manufacturers' responses (continued)

Measurements included in the current documentation system (Soil/Aggregate Rollers)?

Output	Bomag	Case/Ammann	Caterpillar*	Dynapac	Sakai	Trimble	Volvo*
Date/Time	Yes	Yes		Yes	Yes	Yes	
GPS X,Y,Z	Yes	Yes		Yes	Yes	Yes	
Travel Direction	Yes	Yes		Yes	Yes	Yes	
Speed	Yes	Yes		Yes	Yes ^f	Yes	
Pass Count	Yes	Yes		Yes	Yes	Yes	
Vibration Amplitude	Yes	Yes		Yes	No	Yes	
Vibration Frequency	Yes	Yes		Yes	Yes	Yes	
Vibration Settings (On or Off)	Yes	Yes		Yes	Yes	Yes	
IC Measurement Value	Yes	Yes		Yes	Yes	Yes	
Roller Jump Indication Value	Yes	Yes		Yes	No ^g	Yes	
Other?	Vector of the eccentric output	—		—	—	—	

Measurements included in the current documentation system (Asphalt Rollers)?

Output	Bomag	Case/Ammann	Caterpillar*	Dynapac	Sakai	Trimble	Volvo*
Date/Time	Yes	Yes		Yes	Yes	Yes	
GPS X,Y,Z	Yes	Yes		Yes	Yes	Yes	
Travel Direction	Yes	Yes		Yes	Yes	Yes	
Speed	Yes	Yes		Yes	Yes ^f	Yes	
Pass Count	Yes	Yes		Yes	Yes	Yes	
Vibration Amplitude	Yes	Yes		Yes	No	Yes	
Vibration Frequency	Yes	Yes		Yes	Yes	Yes	
Vibration Settings (On or Off)	Yes	Yes		Yes	Yes	Yes	
IC Measurement Value	Yes	Yes		No	Yes	Yes	
Roller Jump Indication Value	Yes			No	No ^g	Yes	
Temperature	Yes	Yes		Yes	Yes	No	
Temperature Sensor Position	—	—		—	Ahead of front drum	No	

Notes:

SD – Smooth Drum; PD – Padfoot Drum

^a Only to Dynapac smooth drum machine units for soil and tandem rollers for asphalt with cabs dating back to 1998. Automatic feedback control cannot be retrofitted.

^b Only to any existing Sakai roller (both soil and asphalt).

^c We do not have a solution where information can be shared between rollers, however, the initial, breakdown and finishing rollers can all be equipped and instructed to each run a certain number of passes under certain conditions.

^d The documentation systems on each roller are operating independently and not linked.

^e We provide documentation of the HMA roller map coverage out of our CCS900 system. We have the Site Vision Office software with a Compaction Module to analyze the results.

^f Speed is measured by GPS and is shown on top of the screen display

^g Based on Sakai research, the Sakai CCV system does not require this value to evaluate the condition of over-compaction.

* The manufacturer requested more time for the response and will be provided as they become available.

Closing Comments/Questions from Participants

Following are excerpts from the closing comments by representatives from different state DOTs and equipment manufacturers.

Minnesota DOT

- Need to standardize the roller output values (e.g., with relationship to modulus) and also roller output files for the owner (ASCII files). Need to be able to calibrate the rollers mechanically to verify the roller output values.
- Would be interested to know how the logic of relating amplitudes and vibration of pile driving to bearing capacity of soil compares with IC vibratory based measurements to soil bearing capacity.
 - *David White Response:* We don't have direct experience on that topic, but it makes sense that fundamentally these relationships are linked.

Texas DOT

- How is moisture control criteria specified in Iowa DOT IC developmental specifications? We have problems using oven methods to measure moisture content on the projects due to time delay in getting the results. We have a minimum moisture content requirement. What does Iowa DOT use?
 - *David White Response:* Moisture control is accomplished via disking, and in some cases fly ash stabilization has been used, etc.
 - *Iowa DOT Response:* Moisture control of -2 to +2% of optimum moisture content is the acceptable range of variation for fine grained cohesive soils. It varies slightly deepening on the soil type. Fly ash is not generally used.

Georgia DOT

- Thanks for all the hosts for organizing the webinar. Adding standardized roller output value to the road map is a good addition to the road map. What are the next steps in regards to developmental specifications as part of the FHWA pooled fund project? We are interested in relating IC measurements to MEPDG design. Glad to see that topic on the road map. We are in the initial stages of IC implementation but would be interested to see the approach of linking IC measurements to MEPDG design parameters developed.
 - *David White Response:* FHWA study ends this August. Our role on the project is to provide support via laboratory and field testing. I believe Dr. Chang will be working on the final details with FHWA between now and August.
 - *David White comment on standardization of roller output values:* In my view, standardization of the specification should be a priority over standardization of the roller output values. The specification should, however, be technology independent.

New York DOT

- Interesting to hear everyone's perspective and status updates from different state DOTs. We are going to move forward with implementing various in-situ QA testing devices. Have there been any changes or modifications to the measurement technologies on the manufacturer's end since used on the Hwy 219 project in 2009 summer?
 - *Trimble Response:* In addition to viewing pass coverage and compaction results mapping, we have recently launched another possibility of fill mapping. The fill mapping feature allows the contractor to see the cuts/fills maps during compaction work. This will potentially help the contractor optimize their work.

Missouri DOT

- Thanks to the hosts for this setting up the webinar. Regarding upcoming projects in Minnesota and Iowa, who might be the point of contact if questions on specifications? We are gearing up on a project with IC this summer.
 - *Mn/DOT Response:* Contact Greg Johnson for HMA and Rebecca Embacher for soils.
 - *Iowa DOT Response:* David White can be the initial contact for the Iowa DOT spec information.

Maryland DOT

- Is there anything we can do to include or to correct IC data for seasonal variations, since we know the values are affected by seasonal variations? Has there been any progress on in-situ moisture content measurement?
 - *David White Response:* When the work is done we need to ensure that at least a minimum level of modulus/strength is achieved along with some minimum level of uniformity. If we can understand the effect of seasonal variation on modulus/strength of the material, then we can specify achieving some minimum value that can be sustained or at least designed for the life of the pavement.
- In Maryland, we did one demonstration project on HMA. Mapped the existing millings and the HMA layer and got good results. There was an issue with correlating density with IC measurements. We are able to get results from temperature sensors. University of Maryland is working on preparing the report. Demonstration was overall successful. Appreciate the opportunity to participate the webinar.

North Dakota DOT

- This is a great forum for exchange. Eight people from geotechnical design and pavement design groups were able to attend the meeting. We look forward for the upcoming FHWA IC pooled fund demonstration project this summer. Not a lot of development on the specification side, yet. I agree with David White that standardization of specification is important. We are interested in implementation and will need help with developmental specifications.

Michigan DOT

- Thanks for hosting the webinar. Happy to see that the focus for implementation has moved towards QC for contractor rather than QA. Next steps should involve correlations studies to current practices and case histories to help build confidence in the technology.

North Carolina DOT

- Thanks to ISU and Iowa DOT for organizing the webinar. We got quite a bit of information. We will put over thoughts together towards developing specifications. What do we need to do to overcome calibration work which involves quite a bit of work on-site? We are also interested in knowing how to link IC values to MEPDG.
 - *David White Response:* We spent a lot of time developing correlations between IC measurement values and various in-situ test measurements. Some of the important things to keep in mind are: (1) during the testing process, there is error introduced from the in situ test measurement and the roller measurements and (2) most in situ test measurements measure much less volume (depth) than what roller measures. We are learning how to best operate the roller in terms of what speed, amplitude, and frequency should be used to develop good correlations. This is based on a significant level of field experience. We are looking forward to developing standardized specifications that provide detailed steps to developing those correlations and providing a link to MEPDG design parameters. Still work to be done.

Virginia DOT

- This has been a very informative session. Thanks to Iowa DOT and all presenters. We definitely see this as a promising technology. At this point we see IC more as a QC tool rather than a QA tool. We want to get involved in more projects and are scheduling a HMA project later this year.

Wisconsin DOT

- We are planning to have a workshop and a demonstration on HMA as part of the FHWA IC pooled fund project. Appreciate the opportunity to participate.

Illinois DOT

- Appreciate the opportunity to learn more about the technology. Would like to see more contractors' input and participation on this topic.

Contractor

- There is an initial cost to afford with this technology. But there is some advantage as lot of times we are waiting for a test on some jobs and is kind of nice to have proof as you don't have to wait for somebody to test behind you. Also you have documentation on hand if there are issues with the paver or the rock and they are blaming it on the soils.

Trimble

- All the ideas about QC/QA during the discussion are very important. Whole issue with documentation is critical for successful projects. We are currently working with few state DOTs. Anxious to work with more DOTs to be able to quantify those to create reports that are useful.
- Great to see chat function in the webinar. This was a good networking opportunity with several clients.

IC Implementation Road Map

The IC Road Map, developed during the 2008 workshop meeting and updated at the 2009 meeting, was evaluated again this year via a survey of the webinar participants. The participants were given a copy of the 2009 IC Road Map, including action items, and were asked to assign “votes” to rank the road map elements. Each participant was allowed 10 votes and could apply the votes to any of the topic areas. The participants were further asked to provide comments regarding topics that should be removed, adjusted, or added.

The prioritized list of IC/CCC technology research/implementation needs for 2010, based on participant voting, is presented in Table 5. Two new elements were added to the list in 2010, and descriptions of the existing road map elements were modified this year (see Table 6) based on participants’ feedback. Similar to the 2009 workshop outcome, the top two needs remain (1) developing and providing evidence of correlations between IC/CCC measurements and in situ test measurements and (2) developing IC/CCC specifications/guidance.

Table 5. Prioritized IC technology research/implementation needs – 2010 workshop

Prioritized IC/CCC Technology Research/Implementation Needs

1. Intelligent Compaction and In Situ Correlations (91*)
2. Intelligent Compaction Specifications/Guidance (46*)
3. In Situ Testing Advancements and New Mechanistic Based QC/QA (43*)
4. Intelligent Compaction Technology Advancements and Innovations (21*)
5. Project Scale Demonstration and Case Histories (19*)
6. Understanding Impact of Non-Uniformity of Performance (18*)
7. Data management and Analysis (17*)
8. Standardization of roller output and output format files** (13*)
9. Understanding Roller Measurement Influence Depth (11*)
10. Education Program/Certification Program (6*)
11. Intelligent Compaction Research Database (6*)
12. Standardization of Roller Sensor Calibration Protocols** (4*)

* total votes are provided in parentheses

** newly added road map elements

Table 6. Revised IC road map research, implementation, and educational elements – 2010 workshop

IC Road Map Research, Implementation, and Educational Elements

1. **Intelligent Compaction and In Situ Correlations [2*].** This research element will develop field investigation protocols for conducting detailed correlation studies between IC measurement values and various in situ testing techniques for earth materials and HMA. Standard protocols will ensure complete and reliable data collection and analysis. Machine operations (speed, frequency, vibration amplitude) and detailed measurements of ground conditions will be required for a wide range of conditions. Relationships between HMA mix temperature, roller measurement values, and performance should be developed. A comprehensive research database and methods for establishing IC target values will be the outcome of this study. Information generated from this research element will contribute to research elements 2, 6, 9, 10, and 11.
2. **Intelligent Compaction Specifications/Guidance [1*].** This research element will result in several specifications encompassing method, end-result, performance-related, and performance-based options. This work should build on the work conducted by various state DOTs, NCHRP 21-09, and the ongoing FHWA IC Pooled Fund Study 954.
3. **In Situ Testing Advancements and New Mechanistic Based QC/QA [3*].** This research element will result in new in situ testing equipment and testing plans that target measurement of performance related parameter values including strength and modulus. This approach lays the groundwork for better understanding the relationships between the characteristics of the geo-materials used in construction and the long-term performance of the system.
4. **Intelligent Compaction Technology Advancements and Innovations [8*].** Potential outcomes of this research element include development of improved IC measurement systems, addition of new sensor systems such as moisture content and mat core temperature, new onboard data analysis and visualization tools, and integrated wireless data transfer and archival analysis. Further, this research element will also explore retrofitting capabilities of IC measurement systems on existing rollers. It is envisioned that much of this research will be incremental and several sub-elements will need to be developed.
5. **Project Scale Demonstration and Case Histories [6*].** The product from this research element will be documented experiences and results from selected project level case histories for a range of materials, site conditions, and locations across the United States. Input from contractor and state agencies should further address implementation strategies and needed educational/technology transfer needs. Conclusive results with respect to benefits of IC technology should be reported and analyzed. Information from this research element will be integrated into research element 2, 10, and 11.
6. **Understanding Impact of Non-Uniformity of Performance [4*].** This track will investigate relationships between compaction non-uniformity and performance/service life of infrastructure systems—specifically pavement systems. Design of pavements is primarily based on average values, whereas failure conditions are affected by extreme values and spatial variations. The results of the research element should be linked to MEPDG input parameters. Much needs to be learned about spatial variability for earth materials and HMA and the impact on system performance. This element is cross cutting with research elements 2, 6, 10.
7. **Data Management and Analysis [5*].** The data generated from IC compaction operations is 100+ times more than traditional compaction QC/QA operations and presents new challenges. The research element should focus on data analysis, visualization, management, and be based on a statistically reliable framework that provides useful information to assist with the construction process control. This research element is cross cutting with research elements 1, 2, 3, 4, 5, 10, and 11.

Table 6. Revised IC road map elements (continued)

IC Road Map Elements (continued)

8. **Standardization of Roller Outputs and Format Files**.** This research element involves developing a standardized format for roller output and format files. This element crosscuts specification development (element 2).
9. **Understanding Roller Measurement Influence Depth [7*].** Potential products of this research element include improved understanding of roller operations, roller selection, interpretation of roller measurement values, better field compaction problem diagnostics, selection of in situ QA testing methods, and development of analytical models that relate to mechanistic performance parameter values. This element represents a major hurdle for linking IC measurement values to traditional in situ test measurements.
10. **Education Program/Certification Program [9*].** This educational element will be the driver behind IC technology and specification implementation. Materials generated for this element should include a broadly accepted and integrated certification program that can be delivered through short courses and via the web for rapid training needs. Operator/inspector guidebook and troubleshooting manuals should be developed. The educational programs need to provide clear and concise information to contractors and state DOT field personnel and engineers. A potential outcome of this element would be materials for NHI training courses.
11. **Intelligent Compaction Research Database [10*].** This research element would define IC project database input parameters and generate web-based input protocols with common format and data mining capabilities. This element creates the vehicle for state DOTs to input and share data and an archival element. In addition to data management/sharing, results should provide an option for assessment of effectiveness of project results. Over the long term the database should be supplemented with pavement performance information. It is important for the contractor and state agencies to have standard guidelines and a single source for the most recent information. Information generated from this research element will contribute to research elements 1, 2, 5, 9, and 10.
12. **Standardization of Roller Sensor Calibration Protocols**.** IC rollers are equipped with measurement sensors (e.g., accelerometers in the case of vibratory-based technologies), GPS, data logging systems, and many on-board electronics. These sensors and electronics need periodic maintenance and calibration to ensure good repeatability in the measurement systems. This research element will involve developing a highly mobile mechanical system that could simulate a range of soil conditions and be deployed to a project site to periodically verify the roller output values. Further, establishment of a localized calibration center (similar to a falling weight deflectometer calibration center) by a state agency can help state agencies periodically verify the repeatability and reproducibility of the measurements from their sensors and other electronics

* 2009 ranking

** newly added road map elements

Workshop Outcomes and Proposed Action Items

Some of the key outcomes from this workshop were as follows:

1. Served as a forum for exchanging technical information and provided opportunities for future collaborations.
2. Updated and prioritized the IC/CCC technology research and implementation needs road map.
3. Established a network of people interested in partnerships and in implementing IC/CCC technologies and new QA/QC testing technologies into earthwork practice.
4. Developed plans for next year's workshop to further technology exchange activities and explore opportunities for implementation, education/training programs, and technological advancements.

Table 7 identifies a proposed action plan for advancing IC/CCC technologies into earthworks and HMA practice based on the information derived from the workshop sessions and the authors' perspective.

Table 7. Action plan for advancing IC technologies into earthwork and HMA practices

Action Plan for Advancing IC/CCC Technologies into Earthwork and HMA

1. Establish a Technology Transfer Intelligent Compaction Consortium (TTICC) to identify research gaps and implementation needs, develop problem statements for needed research, identify key partners, and form a national-level Specifications Technical Working Group to coordinate efforts.
2. Explore the possibility of conducting a National Highway Institute course or a one-day training course at conferences on IC/CCC technologies.
3. Develop several case histories (technical briefs) to demonstrate the technical aspects and benefits of the technologies.
4. Plan future webinar workshop meetings to facilitate technology transfer.

Appendices

Appendix A: Workshop Webinar Agenda

Intelligent Compaction for Earthworks and HMA March 1–2, 2010

Day 1—Monday, March 1, 2010

- 10:00 a.m. Introduction and Opening Remarks—David White, ISU
- 10:15 Iowa Demonstration Projects Discussion—David White and Pavana Vennapusa, ISU
- 11:00 FHWA Pooled Fund Study Update—David White and Pavana Vennapusa, ISU
- 11:15 Georgia DOT Status Update—David Jared, GDOT
- 11:30 New York State DOT Status—Brett Dening, NYSDOT
- 11:45 Texas DOT Status Update—Zhiming Si, TxDOT
- 12:00 p.m. Break
- 12:30 Mn/DOT Specification Development for Use of IC on Non-Granular and Granular Materials—Rebecca Embacher, Mn/DOT
- 12:55 Mn/DOT Specification Development for Use of IC on HMA—Greg Johnson, Mn/DOT
- 1:10 Mn/DOT Specification Development for Use of IC on Emulsion Stabilized FDR— Steve Adamsky, Mn/DOT
- 1:45 Next Steps: Comments and Discussion

Day 2—Tuesday, March 2, 2010

10:00 a.m. Manufacturer Updates (Moderator: Heath Gieselman)

- Dynapac— Fredrik Akesson
- Bomag— Chris Connolly
- Caterpillar— Dean Potts
- Trimble/XYZ— Derrick Darby
- Sakai— Todd Mansell

11:30 Missouri State DOT Status Update—Bill Stone, MoDOT

11:45 Illinois State DOT Status Update— Riyadh Wahab, IDOT

12:00 p.m. Break

12:30 Discussion and Questions on Developmental Specifications Presented on Day 1 (per TX, MN, and IA presentations)

1:00 Review IC Road Map Voting

1:10 Discuss Proposed Technology Transfer Intelligent Compaction Consortium (TTICC)— David White, ISU, and Sandra Larson, Iowa DOT

1:30 Review Evaluation Form

1:35 Closing Comments: IA, MN, TX, GA, NY, MO, MD, ND, KS, MI, NC, NJ, OH, UT, VA, WA, WI DOTs, Contractors, Industry (Bomag, CAT, Trimble, Sakia, Dynapac), and others.

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Appendix C: Iowa DOT Developmental Specifications

SP-090057a
(Replaces SP-090057)



Iowa Department of Transportation

SPECIAL PROVISIONS FOR INTELLIGENT COMPACTION-HMA

Ida County
NHSN-020-2(70)--2R-47

Effective Date
February 16, 2010

THE STANDARD SPECIFICATIONS, SERIES 2009, ARE AMENDED BY THE FOLLOWING MODIFICATIONS AND ADDITIONS. THESE ARE SPECIAL PROVISIONS AND THEY PREVAIL OVER THOSE PUBLISHED IN THE STANDARD SPECIFICATIONS.

In addition to the requirements of Section 2303 of the Standard Specifications, the following shall apply:

090057a.01 Description

This specification describes the Contractor's responsibilities for furnishing Intelligent Compaction (IC) equipped rollers, data acquisition, training, and transmitting data to the Engineer. IC for HMA is defined as the gathering of data from self-propelled vibratory roller systems involved with the measurement and recording of roller position, date/time, speed, vibration frequency, vibration amplitude, surface temperature, pass count, and travel direction. Real Time Kinematic (RTK) based Global Positions System (GPS) with base station corrections shall be used for determining the position of the roller. Results from the IC shall be displayed to the roller operator on a color coded computer screen in real-time during roller operations and the data saved for transfer and viewing by the Engineer.

Quality acceptance for IC-HMA will be based on cores according to Section 2303 of the Standard Specifications. The IC results will be used as a guide to supplement core sampling for research purposes. Secure a maximum of three additional cores per lot collected concurrently with acceptance cores based on viewing roller pass coverage, surface temperature during compaction operations, and IC compaction MVs. The Engineer will determine the location for the additional cores.

Submit to the Engineer an IC Work Plan at least two weeks prior to the Preconstruction Conference. Describe in the work plan the following:

- Compaction equipment to be used including:
 - Vendor
 - Roller model,
 - Roller dimensions and weights,
 - Description of IC measurement system,
 - GPS capabilities,
 - Documentation system,
 - Temperature measurement system, and
 - Software.

SP-090057a, Page 2 of 4

- Roller data collection methods including sampling rates and intervals and data file types.
- Transfer of data to the Engineer including method, timing, and personnel responsible. Data transfer shall occur at minimum once per day or as directed by the Engineer.
- Training plan and schedule for roller operators, Engineer's personnel, and Iowa State University's research personnel; including both classroom and field training.
- Communication protocol for informing the Iowa State University research team point of contact concerning construction progress and schedule to facilitate research field testing and data collection.

090057a.02 Equipment and Materials

A. Rollers

Comply with Article 2001.05 of the Standard Specifications for self-propelled vibratory rollers. Article 2001.05 applies to all rollers used in the breakdown position. Breakdown roller is defined as the roller(s) making the initial contact with the HMA.

Ensure that IC equipment can measure roller position, date/time, speed, vibration frequency, vibration amplitude, surface temperature, pass count, and travel direction. Provide a computer screen in the roller cab for viewing measured results. Ensure that results are stored for transfer to the Engineer for viewing on a laptop computer. Provide the Engineer and Iowa State University each with a copy of the IC roller vendor software for viewing results. Ensure that results are displayed as color coded spatial maps based on GPS coordinates.

B. Data Collection, Export, and Onboard Display

Provide and export the following data in a comma, colon, or space delimited ASCII file format:

- 1) Machine Model, Type, and Serial/Machine Number
- 2) Roller Drum Dimensions (Width and Diameter)
- 3) Roller and Drum Weights
- 4) File Name
- 5) Date Stamp
- 6) Time Stamp
- 7) RTK based GPS measurements showing Northing, Easting, and Elevation
- 8) Roller Travel Direction (e.g., forward or reverse)
- 9) Roller Speed
- 10) Vibration Setting (i.e., On or Off)
- 11) Vibration Amplitude
- 12) Vibration Frequency
- 13) Surface Temperature

Ensure that the roller's onboard display will furnish color-coded GPS based mapping showing number of roller passes, surface temperature, vibration frequency, and vibration amplitude on a computer screen in the roller operators cab. Provide displayed results to the Engineer for review upon request.

C. Local GPS Base Station

Provide a real time kinematic global positioning system (RTK GPS) to acquire northing, easting, and elevation data used in mapping of IC measurements. Ensure the system has the capability to collect data in an established project coordinate system. Furnish a local GPS base station used for broadcasting differential correction data to the rollers with a tolerance less than 0.1 foot in the vertical and horizontal.

D. Training

1. Preconstruction (classroom)

Make available all personnel responsible for roller operations to attend a one-day classroom training on IC. Classroom training will involve both the Contractor's and Engineer's personnel and

the Iowa State University research team. Training will shall be provided by IC equipment manufacturer and Contactor Iowa State University research personnel and scheduling coordinated by the Engineer. Classroom training will involve both the Contractor's and Engineer's personnel.

2. Field (prior to and during compaction operations)

Provide two working days of field training by the IC equipment manufacturer to roller operators and Engineer's personnel. Ensure the IC roller manufacturer provides onsite technical assistance the first two working days of IC roller use.

E. Geotechnical Mobile Lab Parking

Provide the Engineer an all weather access, parking for the Iowa State University Geotechnical Mobile lab trailer (8 feet by 44 feet), and parking for 3 vehicles at the HMA plant site or agreed upon alternative location. The lab trailer will be furnished and operated by Iowa State University which will be under contract with the Contracting Authority to perform IC-HMA research.

090057a.03 Construction

A. Roller Operations

Operate the IC roller according to manufacturer's recommendations to provide reliable and repeatable measurements. Keep vibration frequency and amplitude constant during roller operations. Permitted variation in vibration frequency is ± 125 vibrations per minute. Maintain rolling speed to provide a minimum of 10 impacts per linear foot and within ± 0.5 miles per hour during measurement passes. Record IC-HMA roller operations forward and reverse directions. Check and recalibrate, if necessary, IC equipment at the beginning of each workday.

Record all IC-HMA roller passes including forward and reverse directions. Check, verify and recalibrate, if necessary, IC equipment at the beginning of each workday to ensure proper performance.

B. Equipment Breakdowns

In the event of IC roller breakdowns/IC system malfunctions/GPS problems, the Contactor may operate with conventional rolling operations, but it is intended that IC data shall be collected and provided for a minimum 80% of the project surface and intermediate HMA quantity.

C. Data submittal

Furnish to the Engineer an electronic file in ASCII file format with information listed under Article SP-090057a.02, B. As a minimum, the file transfer shall occur immediately following the final compaction operations on each working day. The Engineer may request data any time during compaction operations.

090057a.04 Method of Measurement

None. Lump sum item.

090057a.05 Basis of Payment

- A. Payment for Intelligent Compaction-HMA will be the lump sum contract price.
- B. Payment is full compensation for all work associated with providing IC equipped rollers, transmission of electronic data files, two copies of IC roller manufacturer software, training, and preparing and maintaining work space for Iowa State University's IC trailer and associated parking. Partial payments will be made as follows:

1. Upon receipt of a signed contract, 50% of the lump sum bid price.

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2. The remainder 50% will be prorated based on the percent of the project HMA tonnage compacted using IC-HMA. (e.g.: to receive 100% payment for the item the Contractor will have to provide IC-HMA for at least 80% of the area of each HMA course.)

- C. Delays due to GPS satellite reception of signals to operate the IC equipment or IC roller breakdowns will not be considered justification for contract modifications or contract extensions.

SP-090058a
(Replaces SP-090058New)



Iowa Department of Transportation

**SPECIAL PROVISIONS
FOR
INTELLIGENT COMPACTION - HMA - ROLLER PASS MAPPING**

**Kossuth County
STP-009-4(44)--2C-55**

**Effective Date
February 16, 2010**

THE STANDARD SPECIFICATIONS, SERIES 2009, ARE AMENDED BY THE FOLLOWING MODIFICATIONS AND ADDITIONS. THESE ARE SPECIAL PROVISIONS AND THEY PREVAIL OVER THOSE PUBLISHED IN THE STANDARD SPECIFICATIONS.

In addition to the requirements of Section 2303 of the Standard Specifications, the following shall apply:

090058a.01 Description

This specification describes the Contractor's responsibilities for furnishing Intelligent Compaction (IC) – HMA Roller Pass Mapping equipped rollers, the required data acquisition and reporting method, the training program requirement, and the data file types and process for transmitting data to the Engineer. IC-HMA Roller Pass Mapping is herein defined as the documentation of roller pass coverage data from all rollers ~~used in the HMA compaction process~~. Real Time Kinematic (RTK) based Global Positions System (GPS) with base station corrections shall be used for determining the position of the rollers. Results from the IC roller pass coverage shall be displayed to the roller operator on a color coded computer screen in real-time during roller operations and the data saved for transfer and viewing by the Engineer. Data collection and reporting shall include roller position, date/time, speed, pass count, and travel direction.

Quality acceptance for IC-HMA Roller Pass Mapping will be based on cores according to Section 2303 of the Standard Specifications. The IC results will be used as a guide to supplement core sampling for research purposes. Secure a maximum of three additional cores per lot collected concurrently with acceptance cores based on viewing roller pass mapping data. The Engineer will determine the location for the additional cores.

Submit to the Engineer a work plan for IC-HMA Roller Pass Mapping at least two weeks prior to the Preconstruction Conference. Describe in the work plan the following:

- Compaction equipment to be used including:
 - Vendor
 - Roller model,
 - Roller dimensions and weights,
 - Description of IC-HMA Roller Pass Mapping measurement system,

SP-090058a, Page 2 of 3

- GPS capabilities,
 - Documentation system, and
 - Software.
- Roller data collection methods including sampling rates and intervals and data file types.
 - Transfer of data to the Engineer including method, timing, and personnel responsible. Data transfer shall occur at minimum once per day or as directed by the Engineer.
 - Training plan and schedule for roller operators, Engineer's personnel, and Iowa State University's research personnel; including both classroom and field training.
 - Communication protocol for informing the Iowa State University research team point of contact concerning construction progress and schedule to facilitate research field testing and data collection.

090058a.02 Equipment and Materials

A. Rollers

Comply with Article 2001.05 of the Standard Specifications for rollers.

Ensure that IC equipment can measure roller position, date/time, speed, pass count, and travel direction. Provide a computer screen in the roller cab for viewing measured results. Ensure that results are stored for transfer to the Engineer for viewing on a laptop computer. Provide the Engineer and Iowa State University each with a copy of the IC equipment vendor software for viewing results. Ensure that results are displayed as color coded spatial maps based on GPS coordinates.

B. Data Collection, Export, and Onboard Display

Provide and export the following data in a comma, colon, or space delimited ASCII file format:

- 1) Machine Model, Type, and Serial/Machine Number
- 2) Roller Drum Dimensions (Width and Diameter)
- 3) Roller and Drum Weights
- 4) File Name
- 5) Date Stamp
- 6) Time Stamp
- 7) RTK based GPS position measurements showing Northing, Easting, and Elevation
- 8) Roller Travel Direction (e.g., forward or reverse)
- 9) Roller Speed
- 10) Pass count

Ensure that the roller's onboard display will furnish color-coded GPS based mapping showing number of roller passes, on a computer screen in the roller operators cab. Provide displayed results to the Engineer for review upon request.

C. Local GPS Base Station

Provide a real time kinematic global positioning system (RTK GPS) to acquire northing, easting, and elevation data used in mapping of IC measurements. Ensure the system has the capability to collect data in an established project coordinate system. Furnish a local GPS base station used for broadcasting differential correction data to the rollers with a tolerance less than 0.1 foot in the vertical and horizontal.

D. Training

1. Preconstruction (classroom)

Make available all personnel responsible for roller operations to attend a one-day classroom training on IC. Classroom training will involve both the Contractor's and Engineer's personnel and the Iowa State University research team. Training ~~will~~ shall be provided by the IC equipment manufacturer and Contractor and scheduled in coordination with the Engineer.

2. Field (prior to and during compaction operations)

Provide two working days of field training by the IC equipment vendor to roller operators and Engineer's personnel. Ensure the IC roller manufacturer provides onsite technical assistance the first two working days of IC roller use.

E. Geotechnical Mobile Lab Parking

Provide the Engineer an all weather access, parking for the Iowa State University Geotechnical Mobile lab trailer (8 feet by 44 feet), and parking for 3 vehicles at the HMA plant site or agreed upon alternative location. The lab trailer will be furnished and operated by Iowa State University which will be under contract with the Contracting Authority to perform IC-HMA research.

090058a.03 Construction

A. Roller Operations

Record all IC-HMA roller passes including forward and reverse directions. Check, verify and recalibrate, if necessary, IC equipment at the beginning of each workday to ensure proper performance.

B. Equipment Breakdowns

In the event of IC equipment breakdowns/IC system malfunctions/GPS problems, the Contactor may operate with conventional rolling operations, but it is intended that IC-HMA Roller Pass Mapping data shall be collected and provided for a minimum 80% of the project surface and intermediate HMA quantity.

C. Data submittal

Furnish to the Engineer an electronic file in a comma, colon, or space delimited ASCII file format with information listed under Article SP-090058a.02, B. As a minimum, the file transfer shall occur immediately following the final compaction operations on each working day. The Engineer may request data any time during compaction operations.

090058a.04 Method of Measurement

None. Lump sum item.

090058a.05 Basis of Payment

- A. Payment for IC-HMA Roller Pass Mapping will be the lump sum contract price.
- B. Payment is full compensation for all work associated with providing IC equipped rollers, transmission of electronic data files, two copies of IC equipment manufacturer software, training, and preparing and maintaining work space for Iowa State University's mobile lab and associated parking. Partial payments will be made as follows:
 1. Upon receipt of a signed contract, 50% of the lump sum bid price.
 2. The remainder 50% will be prorated based on the percent of the project HMA tonnage compacted using IC-HMA Roller Pass Mapping. (e.g.: to receive 100% payment for the item the Contractor will have to provide IC-HMA Roller Pass Mapping for at least 80% of the area of each HMA course.)
- C. Delays due to GPS satellite reception of signals to operate the IC equipment or IC roller breakdowns will not be considered justification for contract modifications or contract extensions.

SP-090063
(New)



Iowa Department of Transportation

SPECIAL PROVISIONS FOR INTELLIGENT COMPACTION-EMBANKMENT

Sac County
NHSX-020-2(89)--3H-81

Effective Date
April 20, 2010

THE STANDARD SPECIFICATIONS, SERIES 2009, ARE AMENDED BY THE FOLLOWING MODIFICATIONS AND ADDITIONS. THESE ARE SPECIAL PROVISIONS AND THEY PREVAIL OVER THOSE PUBLISHED IN THE STANDARD SPECIFICATIONS.

090063.01 Description.

This specification describes the Contractor's responsibilities for furnishing an Intelligent Compaction--Embankment (IC-E) roller, the required data acquisition and reporting method, the training program requirement, and the data file types and process for transmitting data to the Engineer. IC-E is defined as the gathering of data from a self-propelled roller system involved with the measurement and recording of roller position, date/time, speed, pass count, travel direction, and a compaction measurement value (MV). Real Time Kinematic (RTK) based Global Positions System (GPS) with base station corrections shall be used for determining the position of the roller. Results from the IC shall be displayed to the roller operator on a color coded computer screen in real-time during roller operations and the data saved for transfer and viewing by the Engineer.

IC-E will be required only for materials subject to moisture control per DS-09003. The IC-E results will be used as a guide to supplement QA testing for research purposes. Data collection and reporting shall include roller position, date/time, speed, pass count, travel direction, and compaction measurement value.

Submit to the Engineer a work plan for IC-E at least two weeks prior to the Preconstruction Conference. Describe in the work plan the following:

- Compaction equipment to be used including:
 - Vendor
 - Roller model,
 - Roller dimensions and weights,
 - Description of IC-E measurement system and previous field verification results to show that the compaction measurement values are suitable for the project soils, which include cohesive soils as defined in Article 2102.02 of the Standard Specifications,
 - GPS capabilities,
 - Documentation system, and
 - Software.

SP-090063, Page 2 of 4

- Roller data collection methods including sampling rates and intervals and data file types.
- Transfer of data to the Engineer including method, timing, and personnel responsible. Data transfer shall occur at minimum once per day or as directed by the Engineer.
- Training plan and schedule for roller operators, Engineer's personnel, and Iowa State University's research personnel; including both classroom and field training.
- Communication protocol for informing the Iowa State University research team point of contact concerning construction progress and schedule to facilitate research field testing and data collection.

090063.02 Equipment and Materials.

A. Rollers.

The IC-E roller shall be a self-propelled roller with a padfoot configuration weighing at least 10,800 kg with an IC system and as approved by the Engineer. Ensure that IC equipment can measure roller position, date/time, speed, pass count, travel direction, and a compaction measurement value (MV). Provide a computer screen in the roller cab for viewing measured results. Ensure that results are stored for transfer to the Engineer for viewing on a laptop computer. Provide the Engineer and Iowa State University each with a copy of the IC equipment vendor software for viewing results. Ensure results are displayed as color-coded spatial maps based on GPS coordinates.

B. Data Collection, Export, and Onboard Display.

Provide and export the following data in a comma, colon, or space delimited ASCII file format:

- 1) Machine Model, Type, and Serial/Machine Number
- 2) Roller Drum Dimensions (Width and Diameter)
- 3) Roller and Drum Weights
- 4) File Name
- 5) Date Stamp
- 6) Time Stamp
- 7) RTK based GPS position measurements showing Northing, Easting, and Elevation
- 8) Roller Travel Direction (e.g., forward or reverse)
- 9) Roller Speed
- 10) Vibration setting, amplitude, and frequency (if vibration used)
- 11) Pass count
- 12) Compaction Measurement Value

Ensure that the roller's onboard display will furnish color-coded GPS based mapping showing number of roller passes and the compaction measurement value, on a computer screen in the roller operators cab. Provide displayed results to the Engineer for review upon request.

C. Local GPS Base Station.

Provide a real time kinematic global positioning system (RTK-GPS) to acquire northing, easting, and elevation data used in mapping of the IC-E measurements. Ensure the system has the capability to collect data in an established project coordinate system. Furnish a local GPS base station used for broadcasting differential correction data to the rollers with a tolerance less than 30 mm in the vertical and horizontal.

D. Training.

1. Preconstruction (classroom).

Make available all personnel responsible for roller operations and the IC equipment manufacturer representative to attend a one-day classroom training on IC. Classroom training will involve both the Contractor's and Engineer's personnel, and the Iowa State University research team. Training shall be provided by the IC equipment manufacturer and Contractor and scheduled in coordination with the Engineer.

2. Field (prior to and during compaction operations).

Ensure the IC roller manufacturer provides onsite technical assistance the first two working days of IC roller use.

E. Geotechnical Mobile Lab Parking.

Provide the Engineer an all weather access, parking for the Iowa State University Geotechnical Mobile lab trailer (2.5 m by 13.5 m), and parking for three vehicles at the project site or agreed upon alternative location. The lab trailer will be furnished and operated by Iowa State University which will be under contract with the Contracting Authority to perform IC-E research.

F. Test Strips.

Demonstrate that the IC-E roller and system meets the requirements of this specification by compacting test strips. Test strips shall be identified within the project limits and included with project earthwork operations and be a minimum 5 m wide by 75 m long. Test strips shall be compacted with 12 roller passes. Moisture content tests will be collected within the test strip area at five locations. The moisture content test locations will be selected in consultation with the Engineer and research team members and based on the IC compaction measurement values to represent areas of low to high compaction measurement values. Three test strip areas will be selected by the Engineer to represent different materials or conditions. Results from the test strips will be used for research purposes. Quality acceptance for the earthwork in the test strip areas will be as provided in DS-09003.

G. IC-E Proof Area Mapping.

IC-E proof area mapping is to be implemented for compacted fill within the project limits where quality acceptance follows DS-09003. The IC-E roller shall be used to record the compaction measurement value at the surface of the compacted layers at vertical intervals 0.6 m or less. The IC-E compaction measurement value shall be collected for the entire area at the top of the compaction layer at the specified minimum vertical interval. The surface for IC-E measurements shall be relatively smooth and uniform and shaped to approximately line and grade for each mapping area in accordance with manufacturer guidelines to provide reliable IC-E compaction measurement values. The results will be used to identify additional moisture content tests to be performed by the research team and a means for calculating nominal lift thickness for research purposes. The time between completion of compaction and IC-E proof area mapping should be kept to a minimum. Quality acceptance for the earthwork in the proof mapping areas will be as provided in DS-09003.

090063.03 Construction.

A. Roller Operations.

Record IC-E roller passes in forward direction only for test strips and IC-E proof mapping areas. Check, verify and recalibrate, if necessary, IC equipment to ensure proper performance. Operate the IC roller according to manufacturer's recommendations to provide reliable and repeatable measurements. Keep roller speed (and vibration frequency and amplitude settings, if operated in vibratory mode) constant during test strip and IC-E proof mapping.

B. Equipment Breakdowns.

In the event of IC equipment breakdowns/IC system malfunctions/GPS problems, the Contactor may operate without IC-E rolling operations, but it is intended that IC-E data shall be collected and provided for a minimum 80% of the required proof areas.

C. Data Submittal.

Furnish to the Engineer an electronic file in a comma, colon, or space delimited ASCII file format with information listed under Article SP-090063.02, B. As a minimum, the file transfer shall occur following the final compaction operations on each working day. The Engineer may request data any time during compaction operations.

090063.04 Method of Measurement.

None. Lump sum item.

090063.05 Basis of Payment.

- A. Payment for IC-E will be the lump sum contract price.
- B. Payment is full compensation for all work associated with providing IC equipped rollers, transmission of electronic data files, two copies of IC equipment manufacturer software, training, and preparing and maintaining work space for Iowa State University's mobile lab and associated parking. Partial payments will be made as follows:
 - 1. Upon receipt of a signed contract, 50% of the lump sum bid price.
 - 2. The remainder 50% will be prorated based on the percent of the project's cubic meters of material subject to moisture control compacted using IC-E. (e.g.: to receive 100% payment for the item the Contractor will have to provide IC-E for at least 80% of the cubic meters compacted for the project.)
- C. Delays due to GPS satellite reception of signals to operate the IC equipment or IC roller breakdowns will not be considered justification for contract modifications or contract extensions.

Appendix D: TxDOT Developmental Specifications

2004 Specifications

CSJ: 0172-09-031

SPECIAL SPECIFICATION

2008

Quality Compaction Using Intelligent Compaction Rollers

1. **Description.** Construct subgrade soil (treated or untreated) and flexible base using intelligent compaction (IC) rollers. This work shall consist of compacting these materials with a roller equipped with a measurement and documentation system that allows for measuring and recording of the compaction parameters and the roller location by a Global Positioning System (GPS).

Develop and implement a project specific Quality Control procedure for material construction that is based on the roller compaction parameters, moisture, density, and other Quality Control practices, and that will provide ongoing Quality Control data to the Engineer.

2. **Materials.** Furnish uncontaminated materials of uniform quality that meet the requirements of the plans and specifications in accordance with Item 110, "Excavation;" Item 132, "Embankment;" Item 247, "Flexible Base;" Item 251, "Reworking Base Courses;" Item 260, "Lime Treatment (Road-Mixed);" Item 263, "Lime Treatment (Plant-Mixed);" Item 265, "Fly Ash or Lime-Fly Ash Treatment (Road-Mixed);" Item 275, "Cement Treatment (Road-Mixed);" and Item 276, "Cement Treatment (Plant-Mixed)." Notify the Engineer of the proposed material sources. Notify the Engineer before changing any material source. The Engineer may sample and test project materials at any time throughout the duration of the project to assure specification compliance. Use Tex-100-E for material definitions.

3. **Equipment.** Furnish machinery, tools, and equipment necessary for proper execution of the work in accordance with the plans and the applicable Specification Items listed in "Materials."

Provide self-propelled IC rollers in accordance with the approved IC roller list shown on the Department's Approved Product List, "[Intelligent Compaction Rollers](#)."

All IC rollers shall have capability to measure and record compaction parameters in an ASCII (American Standard Code for Information Interchange) format data file. At a minimum, the following data shall be contained in the measurement pass data files:

- Machine Model
- Machine Type
- Drum Width
- Drum Diameter
- Machine Weight

- File Name
- Date Stamp
- Time Stamp
- GPS XYZ Coordinates or Locations
- Direction (i.e., forward, backward, stationary)
- Roller Speed
- Vibration (i.e., On or Off)
- Frequency
- Amplitude
- Roller Measurement Values (RMV)

Ensure the IC roller manufacturer provides a knowledgeable representative on the project to ensure proper operation of the equipment.

4. **Construction.** Construct each layer uniformly, free of loose or segregated areas, and with the required density and moisture content per the plans and the applicable Specification Items listed in "Materials." Provide a smooth surface that conforms to the typical sections, lines, and grades shown on the plans or as directed.
 - A. **Preparation of Subgrade or Existing Base.** Prepare subgrade or existing base in accordance with the plans and the applicable Specification Items listed in "Materials." Proof roll the finished roadbed in accordance with Item 216, "Proof Rolling," using the IC roller. Provide the Engineer both the printed and electronic compaction data files in ASCII format.
 - B. **Placing.** Spread and shape the materials into a uniform layer in accordance with the plans and the applicable Specification Items listed in "Materials."
 - C. **Pulverization.** Pulverize or scarify existing materials in accordance with the plans and the applicable Specification Items listed in "Materials."
 - D. **Application of Stabilizers.** Uniformly apply stabilizers in accordance with the plans and the applicable Specification Items listed in "Materials."
 - E. **Mixing.** Thoroughly mix the materials with stabilizers in accordance with the plans and the applicable Specification Items listed in "Materials."
 - F. **Compaction.** Compaction consists of using both IC rollers and regular rollers.
 - 1) **Test Strip Compaction.**
 - a) The Contractor and Engineer will agree on location(s) within the project to construct the control strip(s). Before constructing the first course, complete a control strip using the IC roller to determine the level of compaction necessary to achieve 100% of the maximum dry density in accordance with Tex-113 or 114-E depending on the materials being compacted, unless otherwise shown on the plans.

- b) Complete at least one control strip to establish a rolling pattern for each layer of material. Construct additional control strips whenever a change is made in the source, gradation, type of subgrade, type of base aggregate, layer thickness, or as directed by the Engineer. Leave each control strip in place to become part of the project. Unless the Engineer approves otherwise, construct the control strip to a minimum length of 500 feet and to the full width of the material course. Place the material in lifts and limit the thickness of compacted material to 8 in., unless otherwise approved by the Engineer. Use the same IC roller and procedures intended for the construction of the remainder of the courses.
 - c) After two passes of the IC roller, mark and take three density and moisture content measurements in accordance with Tex-115-E, Part I at randomly selected test sites at least 2 feet from the edge of the material course. Take additional density and moisture content measurements at the three original locations after every 2 subsequent passes of the roller.
 - d) Continue to compact the control strip until 100 % of the target maximum dry density is obtained. The Engineer will witness the tests and confirm the material achieves the density requirements.
 - e) The Engineer will determine the seismic modulus at the same locations on respective measurement passes as for density measurements. Determine and record IC compaction parameters (mapping) immediately before density, moisture, and seismic modulus tests are performed.
 - f) Determine the moisture content of the material at the beginning of and during compaction in accordance with Tex-103-E, Part I or Tex-115-E. Maintain moisture during compaction at not less than 1 percentage point below the optimum moisture content determined by Tex-113-E.
 - g) Proof roll the finished courses over the full width of the course using the same IC rollers throughout the project. Provide the Engineer both printed and electronic copies of the compaction data files in ASCII format before placing successive courses.
- 2) Project Compaction.** Compact the materials in one lift using density control unless otherwise shown on the plans. Compact the materials in accordance with the plans and the applicable Specification Items listed in "Materials."
- a) The Engineer will determine the in-place seismic modulus after compaction in accordance with Tex-147-E.
 - b) Proof roll the finished courses over the full width of the course using the same IC rollers throughout the project. Provide the Engineer both the printed and electronic compaction data files in ASCII format.

Final compaction acceptance by the Engineer will be based on the Department-performed field density and moisture content measurements within 24 hours after completion of compaction. The Engineer may accept the section if no more than one of the five most recent density tests is below the target density and the failing test is no more than 3 pcf below the target density. In cases of dispute, the sand cone method may be used to determine density in accordance with Tex-115-E, Part II, and moisture content may be determined in accordance with Tex-103-E, Part I.

Rework, recompact, and refinish material that fails to meet the applicable Specification Items listed in "Materials." or that loses required moisture, density, stability, or finish before the next course is placed or the project is accepted. Continue work until specification requirements are met. Perform the work at no additional expense to the Department.

- G. Finishing.** Immediately after completing compaction of the final course, finish the final section in accordance with the plans and the applicable Specification Items listed in "Materials."
- H. Curing.** Cure the finished section in accordance with the plans and the applicable Specification Items listed in "Materials."
- 5. Measurement.** Materials will be measured by the ton, cubic yard, or square yard in accordance with the plans and the applicable Specification Items listed in "Materials."
- 6. Payment.** The work performed and materials furnished will be paid for at the unit price bid in accordance with the plans and the applicable Specification Items listed in "Materials." This price is full compensation for furnishing and disposing of materials; storing, mixing, hauling, placing, sprinkling, compacting, finishing, curing, and maintaining and reworking; and equipment, labor, tools, and incidentals.

Sprinkling and rolling, except proof rolling, will not be paid for directly but will be subsidiary to this Item, unless otherwise shown on the plans. When proof rolling is shown on the plans or directed by the Engineer, it will be paid for in accordance with Item 216, "Proof Rolling."

Appendix E: Webinar Evaluation Comments

Did the workshop meet your expectations?

- Yes, I enjoyed the workshop. I work for Sauer-Danfoss and it is helpful to understand the direction the industry and our customers are going.
- I really did not know what to expect.
- Yes.
- Yes, the webinar concept worked very well.
- Yes.
- Yes.
- Yes, it was very informative
- My expectations for this workshop were met.
- Yes. I am glad I attended.
- Yes.
- Yes—very concentrated, streamlined update on IC activities since last year
- With the exception of the background music being played during the first day, the workshop met my expectations.
- No. I did not see anything that has much application to engineering a better sub-grade or fill. Much of what was presented was just curiosity items for researchers.
- Yes.
- Mostly. I felt the workshop was geared more toward government agencies rather than contractors. The discussion of specifications and implementation of IC into DOT projects was not useful for contractors and our group did not get a lot out of that portion of the workshop.

How useful and informative were the workshop sessions?

- The workshop sessions were very informative. I'm relatively new to road building and IC technology. It was helpful to participate.
- I found the sessions very informative. But I will find the usefulness somewhat limited in my current position.
- Very informative.
- It presented a lot of useful information and allowed exchange between participants.
- Provided us with a better understanding of the potential benefits of IC technology.
- Very useful considering the first attempt at a web format.
- For the most part the presenters had very applicable information

- The information contained in the workshop is useful.
- Very useful as I am interested in the current status of IC.
- It was informative, but will not have direct impact the job I have as a roadway designer.
- Overall, quite informative. I didn't see much value in the talks by states with no IC project experience.
- The information on the various projects involving intelligent compaction and the dot specifications.
- Good. Liked webinar format.
- The sessions overall were informative. Again, discussion of specifications and implementation were not valuable from a contractor standpoint. As a side note, I would not consider the sample specifications that were presented for IDOT very "contractor friendly." The specifications say that the contractor will not get paid unless he uses the technology over 80% of the work site. However, they also state that if the GPS goes down and you can't use the technology, it is at the contractor's expense. So, the specs are requiring the contractor to use the technology, but if it does not work (beyond the contractor's control, i.e. equipment malfunction) the cost goes to the contractor. You may find it very hard to get contractors to agree to these stipulations.

What was the most useful part of the workshop?

- I think most useful was learning about the research projects on the morning of Day 1. Also, enjoyed hearing about what the manufacturers are doing.
- I will find the way the workshop was presented, over the internet, as a useful alternative as future topics are considered for distribution and access to nationwide attendees.
- Specification Development and Manufacturer Updates.
- All parts were useful.
- Knowing the potential benefits
- State presentations and draft specifications.
- Discussions
- What other States are doing and looking to do with this technology.
- Technical issues such as relating soil stiffness to target values and correlation accuracy.
- Just to see what might happen with the new technologies that are out there.
- State DOT updates—how technologies are being applied, including successes and challenges
- The information on the various projects involving intelligent compaction.
- There may be a way to check density other than cooking the dirt or a nuclear gage.
- Demonstration project histories. (Day 1).

- Information about pilot projects as well as presentations by manufacturers was very useful. I would like to hear more about the issues that were had in using the technology. The presentations are all about how great the technology works, but do not discuss the problems that were encountered. I know that some machines have broken down or problems have arisen during the initial “hook-up” of the machine. It would be useful for everyone to hear about the common problems and shortcomings of the IC technology. Or, discuss common “growing pains” that every project goes through in the initial phases of IC implementation.

What suggestions would you make to improve the next workshop?

- Keep web access available for the next workshop. During the general questions for the manufacturers, it have been good to state the question and direct the manufacturers to answer or ask them to “raise their hand” if they wanted to respond. Add note “not to put your phone on hold”, just mute them.
- Make sure that the proper potential participants are informed. Primarily, the construction offices in the central complex and the district offices.
- This format is fine if a physical meeting is not feasible.
- Possibly be more explicit in directions to speakers on desired content of their presentations. One speaker in particular went out into left field. A summary of the FHWA pooled fund work might be useful next year.
- Invite contractors to give them the opportunity to present their perspective.
- Host in traditional format. Much is learned in casual conversations during breaks and over dinner.
- For some of the newer people spelling out what some abbreviations stand for the first time they are used would help.
- Make the equipment portion of the workshop more general (what technologies are available and how do they operate). It would be interesting to see end product specifications that encourage the use of IC. Showing how IC relates to total cost would be beneficial. This would show how the technology adds value and might push industry to implement it faster.
- Minor but annoying. The moderators made mention several times to put your phone on mute. They need to mention not to put the call on hold or else all attendees will get the call on hold music during the presentation.
- None at this time.
- Longer lunch break (45 to 60 minutes). In-person meeting tops a webinar, especially for networking. If in-person meeting is not possible, consider video for speakers.
- During the webinar a participant of the webinar had their phone on hold and music began to play. After an announcement was made for all participants to check their phones, instead of continuing with the webinar, the presenters should have stopped the webinar, disconnected everyone, and then have everyone re-enter. It was absolutely impossible to

concentrate on the material that was being presented while the music was playing, and I know that everyone else in the room that watched it with me felt the same way.

- You really need to make a true correlation between the concept of density and stress to construct a better fill. It also appears that until the manufacturers adopt a standard means to measure what the stress and or density. During this presentation, they were trying to present their research, which was not relative to the other manufacturers or the proposals for the research. At best, it was confusing.
- Longer breaks at lunch.
- As a contractor, I'd like to hear more about the contractor's experience. I know it is difficult to do so in a webinar setting, but it would be good to have break out sessions where the DOTs can talk about issues common to them and contractors could meet to discuss potential issues from their point of view. I think this would help everyone get the most out of the workshop.

Appendix F: Proposed Problem Statement for TTICC

----- DRAFT -----

TECHNOLOGY TRANSFER INTELLIGENT COMPACTION CONSORTIUM

Pooled Fund Project

Problem Statement February, 2010

PROJECT TITLE

Establishment of a Technology Transfer Intelligent Compaction Consortium (TTICC) to identify, advise, and fund research and technology transfer for intelligent compaction technologies.

PROBLEM STATEMENT

Increasingly, state departments of transportation (DOTs) are challenged to design and build longer life pavements that result in a higher level of user satisfaction for the public. One of the strategies for achieving longer life pavements is to use innovative technologies and practices. In order to foster new technologies and practices, experts from state DOTs, Federal Highway Administration (FHWA), academia and industry must collaborate to identify and examine new and emerging technologies and systems. The purpose of this pooled fund project is to identify, support, facilitate and fund intelligent compaction research and technology transfer initiatives.

The Iowa DOT will serve as the lead state for the execution of the pooled fund project described in this proposal. The Iowa DOT, through the Earthworks Engineering Research Center (EERC) at Iowa State University, will handle all administrative duties associated with the project. The EERC will also serve as the lead research institution for the project.

PROJECT GOALS

The goal of the TTICC is to:

- Identify needed research projects
- Develop pooled fund initiatives
- Plan and conduct an annual workshop on intelligent compaction for soils and HMA.
- Provide a forum for technology exchange between participants
- Develop and fund technology transfer materials
- Provide on-going communication of research needs faced by state agencies to the FHWA, states, industry, and the EERC.

It is anticipated that this consortium would become the national forum for state involvement in the technical exchange needed for collaboration and new initiatives, and be a forum for advancing the application and benefit of intelligent compaction technologies for soils, bases, and asphalt pavement uses.

State participation in this process will be through the pooled fund. FHWA, industry and others will be invited to participate in the project discussions and activities.

BACKGROUND

In 2008 and 2009 the Iowa Department of Transportation and the EERC hosted an annual workshop on Intelligent Compaction for Soils and HMA. As part of the workshop a roadmap for addressing the research and educational needs for integrating intelligent compaction technologies into practice was developed. An ongoing forum is needed to provide broad national leadership that can rapidly address the needs and challenges facing STAs with the adoption of intelligent compaction technologies. The vision for the road map was to identify and prioritize action items that accelerate and effectively implement IC technologies into earthwork and HMA construction practices. Coupled with the IC technologies are advancements with in situ testing technologies, data analysis and analytical models to better understand performance of geotechnical systems supported by compacted fill, software and wireless data transfer, GPS and 3D digital plan integration, new specification development, and risk assessment. What follows in Table 1 is the road map with the 2008 and 2009 priority rankings. For information on the first two workshops please refer to the workshop reports at the EERC website:

<http://www.eerc.iastate.edu/publications.cfm>

RESEARCH PLAN AND DELIVERABLES (PROJECT DESCRIPTION)

The proposed project is for the establishment of a pooled fund for state representatives to continue this collaborative effort regarding intelligent compaction. The TTICC will be open to any state desiring to be a part of new developments in intelligent compaction leading to the implementation of new technologies which will lead to longer life pavements through the use of an integrated system of emerging innovative technologies. Two workshop meetings will be conducted each year. One of the meetings will be in person and is anticipated to occur during fall. The location of the in-person workshop meetings will be determined by the Executive Committee and moved regionally each year to participating states. The second meeting will be a webinar and occur in early spring hosted by the EERC.

All efforts by the TTICC will be focused towards these project activities and deliverables:

- Identify and guide the development and funding of technology transfer materials such as tech brief summaries and training materials from research results
- Review the IC Road Map as updated annually and provide feedback to the FHWA, industry, states, and the EERC on those initiatives
- Be a forum for states and researchers to share their experience with IC technologies
- Provide research ideas to funding agencies
- Identify and instigate needed research projects
- Include current activities and deliverables of the pooled fund on the TTICC website
- Maintain pooled fund project website with current activities and deliverables
- Develop pooled fund research projects for solutions to intelligent compaction issues
- Act as a technology exchange forum for the participating entities
- Contribute to a technology transfer newsletter on intelligent compaction research activities every six months in cooperation with the EERC
- Post minutes to the website following web meetings
- Post a report following each workshop to the website

EXECUTIVE COMMITTEE

An Executive Committee will be formed from the TTICC to review and approve the pooled fund activities and budget. The Executive Committee will meet at a schedule to be determined by the Executive Committee via conference calls.

RESEARCH TEAM

The project managers for the TTICC will be the EERC; lead by Dr. David White.

Dr. White is the director of the Earthworks Engineering Research Center (EERC) at Iowa State University. Dr. White's M.S. and Ph.D. research involved large-scale field testing to evaluate embankment construction methods and development of design and construction guidelines for stabilized subgrade. Since Dr. White's start as an assistant professor at Iowa State University in August 2001 he has been successful in directing research from a diverse group of organizations for a total of aggregate dollar total of over \$10 million. Dr. White has ten years of experience with earthwork and pavement foundation layer improvement, ground systems, QC/QA testing, specification development, and six years of experience evaluating intelligent compaction systems. Dr. Pavana Vennapusa and Mr. Heath Gieselmann will also contribute to the project and have extensive experience with intelligent compaction technologies.

This project will be conducted through the EERC. The EERC works with partners to bring about rapid advancements in quality, economy, and performance of the geotechnical aspects of civil infrastructure through a fundamental understanding of earth mechanics, and by providing enabling technologies and supportive public policies.

The EERC's main offices are located at the Institute for Transportation (InTrans) in the Iowa State University Research Park, roughly three miles from both the ISU campus and the Iowa DOT's headquarters in Ames, Iowa.

ESTIMATED PROJECT DURATION and COST

The pooled fund project duration is for five years. The annual cost of participation for one person is \$7,000, which includes travel expenses and registration for the annual workshop and web-based meeting. Additional participants can be added for \$2000/year.

The pooled fund sponsorship goal is participation from ten states.

SUMMARY OF PROJECT SPONSOR REQUIREMENTS

- Financial support
- Meeting participation twice a year, in person and via a webinar
- Active collaboration with each other and others to identify, support, facilitate and fund intelligent compaction research and technology transfer initiatives.
- Championing within their state the deliverables from the pooled fund, such as technical material to key staff, and facilitate implementation of new technologies and practices.

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Table 1. Intelligent Compaction Road Map for Research and Training

IC Road Map Research and Educational Elements

1. **Intelligent Compaction Specifications/Guidance (4^{*})**. This research element will result in several specifications encompassing method, end-result, performance-related, and performance-based options. This work should build on the work conducted by various state DOTs, NCHRP 21-09, and the ongoing FHWA IC Pooled Fund Study 954.
2. **Intelligent Compaction and In-Situ Correlations (2^{*})**. This research element will develop field investigation protocols for conducting detailed correlation studies between IC measurement values and various in situ testing techniques for earth materials and HMA. Standard protocols will ensure complete and reliable data collection and analysis. Machine operations (speed, frequency, vibration amplitude) and detailed measurements of ground conditions will be required for a wide range of conditions. A database and methods for establishing IC target values will be the outcome of this study. Information generated from this research element will contribute to research elements 1, 9, and 10.
3. **In-Situ Testing Advancements and New Mechanistic Based QC/QA (8^{*})**. This research element will result in new in situ testing equipment and testing plans that target measurement of performance related parameter values including strength and modulus. This approach lays the groundwork for better understanding the relationships between the characteristics of the geo-materials used in construction and the long-term performance of the system.
4. **Understanding Impact of Non-Uniformity of Performance (10^{*})**. This track will investigate relationships between compaction non-uniformity and performance/service life of infrastructure systems—specifically pavement systems. Design of pavements is primarily based on average values, whereas failure conditions are affected by extreme values and spatial variations. The results of the research element should be linked to MEPDG input parameters. Much needs to be learned about spatial variability for earth materials and HMA and the impact on system performance. This element is cross cutting with research elements 1, 5, and 9.
5. **Data management and Analysis (9^{*})**. The data generated from IC compaction operations is 100+ times more than traditional compaction QC/QA operations and presents new challenges. The research element should focus on data analysis, visualization, management, and be based on a statistically reliable framework that provides useful information to assist with the construction process control. This research element is cross cutting with research elements 1, 2, 3, 6, 8, 9, and 10.
6. **Project Scale Demonstration and Case Histories (3^{*})**. The product from this research element will be documented experiences and results from selected project level case histories for a range of materials, site conditions, and locations across the United States. Input from contractor and state agencies should further address implementation strategies and needed educational/technology transfer needs. Conclusive results with respect to benefits of IC technology should be reported and analyzed. Information from this research element will be integrated into research element 1, 9, and 10.
7. **Understanding Roller Measurement Influence Depth (6^{*})**. Potential products of this research element include improved understanding of roller operations, roller selection, interpretation of roller measurement values, better field compaction problem diagnostics, selection of in situ QA testing methods, and development of analytical models that relate to mechanistic performance parameter values. This element represents a major hurdle for linking IC measurement values to traditional in situ test measurements.
8. **Intelligent Compaction Technology Advancements and Innovations (7^{*})**. Potential outcomes of this research element include development of improved IC measurement systems, addition of new sensor systems such as moisture content and mat core temperature, new onboard data analysis and visualization tools, and integrated wireless data transfer and archival analysis. It is envisioned that much of this research will be incremental and several sub-elements will need to be developed.
9. **Education Program/Certification Program (5^{*})**. This educational element will be the driver behind IC technology and specification implementation. Materials generated for this element should include a broadly accepted and integrated certification program than can be delivered through short courses and via the web for rapid training needs. Operator/inspector guidebook and troubleshooting manuals should be developed. The educational programs need to provide clear and concise information to contractors and state DOT field personnel and engineers. A potential outcome of this element would be materials for NHI training courses.
10. **Intelligent Compaction Research Database (1^{*})**. This research element would define IC project database input parameters and generate web-based input protocols with common format and data mining capabilities. This element creates the vehicle for state DOTs to input and share data and an archival element. In addition to data management/sharing, results should provide an option for assessment of effectiveness of project results. Over the long term the database should be supplemented with pavement performance information. It is important for the contractor and state agencies to have standard guidelines and a single source for the most recent information. Information generated from this research element will contribute to research elements 1, 2, 6, 9.

*2008 Workshop Ranking