INTELLIGENT COMPACTION

Never Guess Again

Jimmy Si, Ph.D., P.E. Tempe, AZ, Nov. 13, 2013

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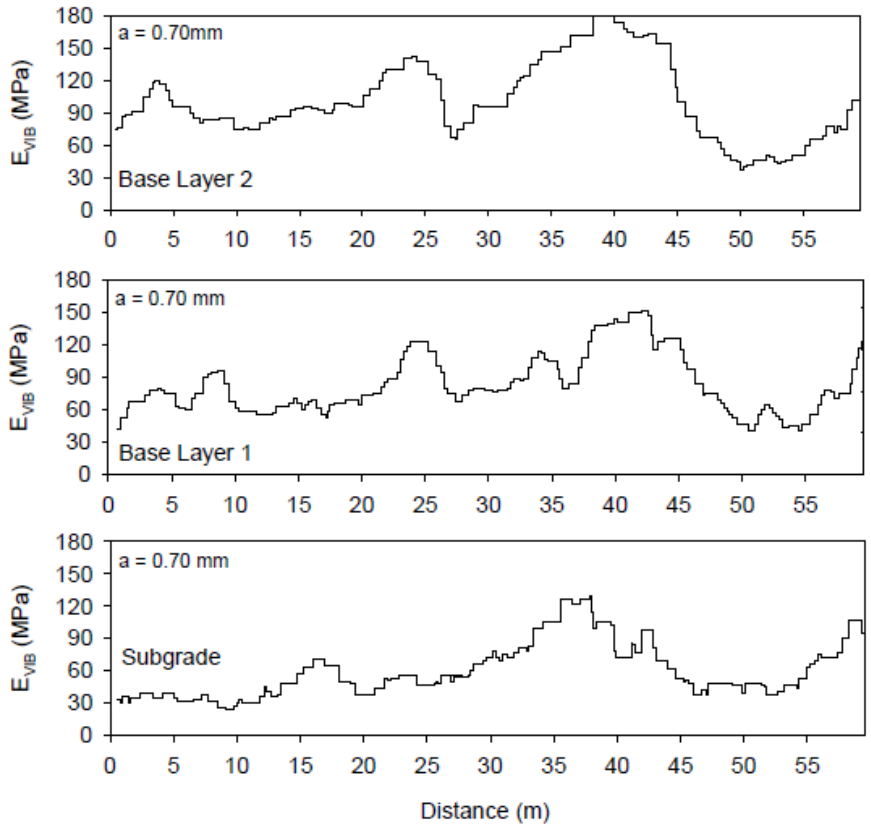
Significance of Quality Compaction

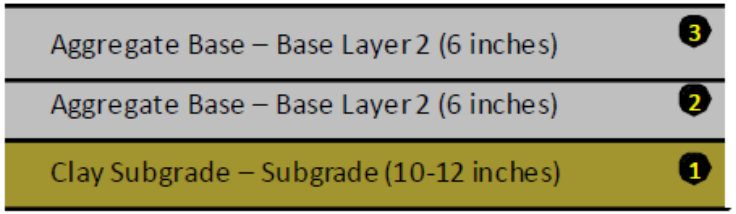
We've known it for a long time ……

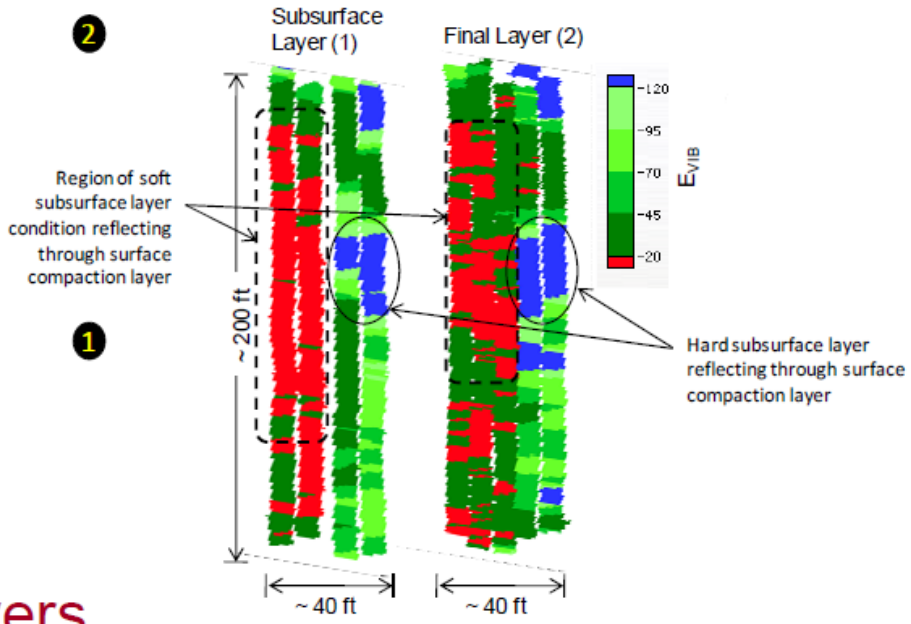
"The importance of compaction in highway construction has long been recognized. Recent laboratory and field investigation have repeatedly emphasized the value of thorough consolidation in both the base and surfacing courses."

Reference --"Public Roads, **May 1939**, authors J.T. Pauls and J.F. Goode"

Significance of Quality Compaction







Reflection of underlying non-uniformity to overlying layers

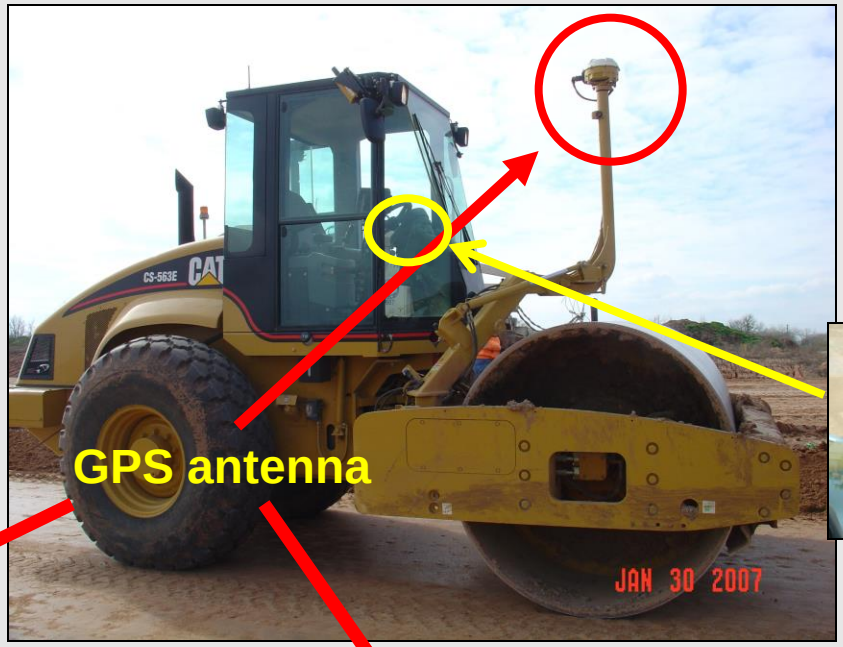
What Is Intelligent Compaction (IC)?

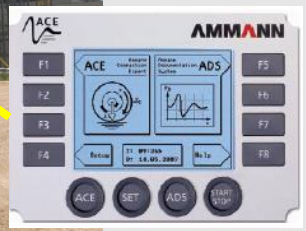
- Intelligent Compaction (IC) is an innovation continuous compaction control process that
  - **measures** material stiffness during the compaction process,
  - **analyzes** the information being collected,
  - **makes** an adjustment of vibratory roller parameters, and
  - **executes** the change to optimize the compaction effort.

What Is Intelligent Compaction (IC)?

- **Vibratory rollers with a feedback control measurement system**
  - Measures material stiffness
  - Control system automatically changes parameters (amplitude and frequency) based on the measured material stiffness
- **GPS-based documentation system**
  - Continuous monitoring material's stiffness and corresponding roller locations
  - Real-time displaying color-coded mapping of stiffness

What Is Intelligent Compaction (IC)?



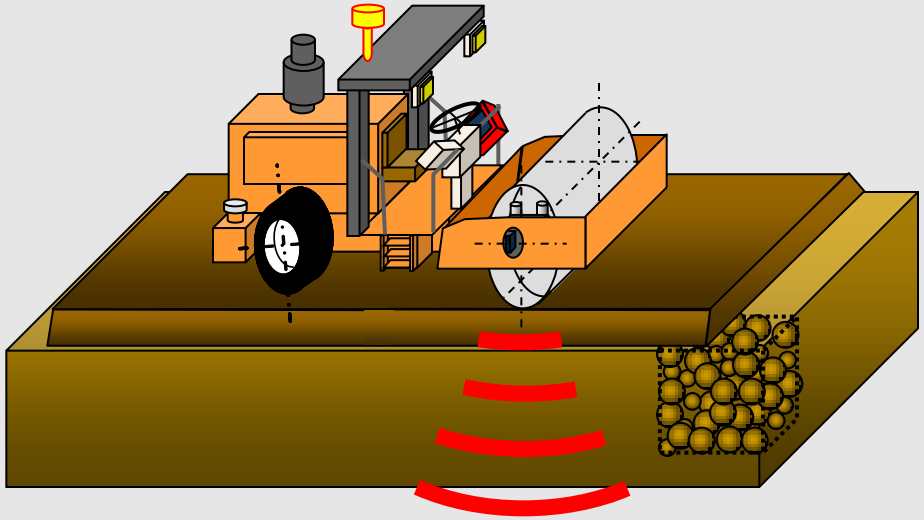


Display Panel

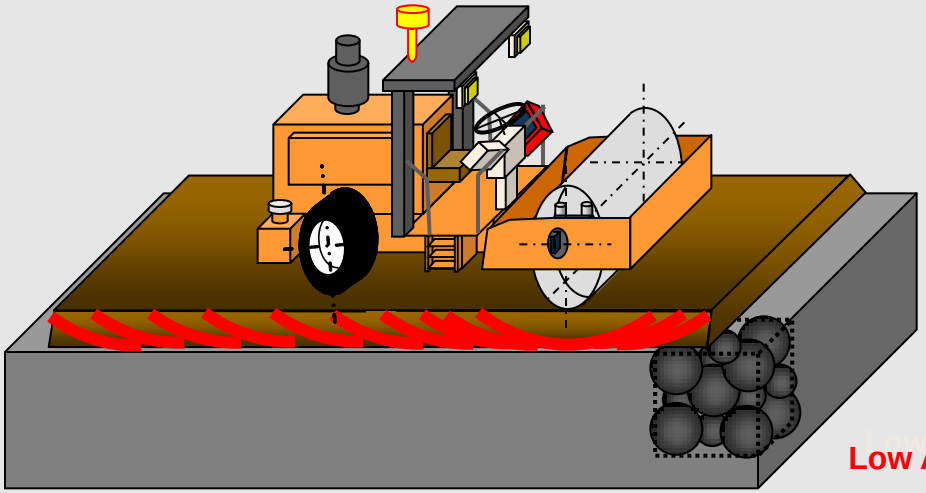
How Does It Work?

Amplitude & Frequency Control

Soft Soil, poorly compacted; acting as a spring



High Amplitude, Low Frequency, Penetrate Deeper

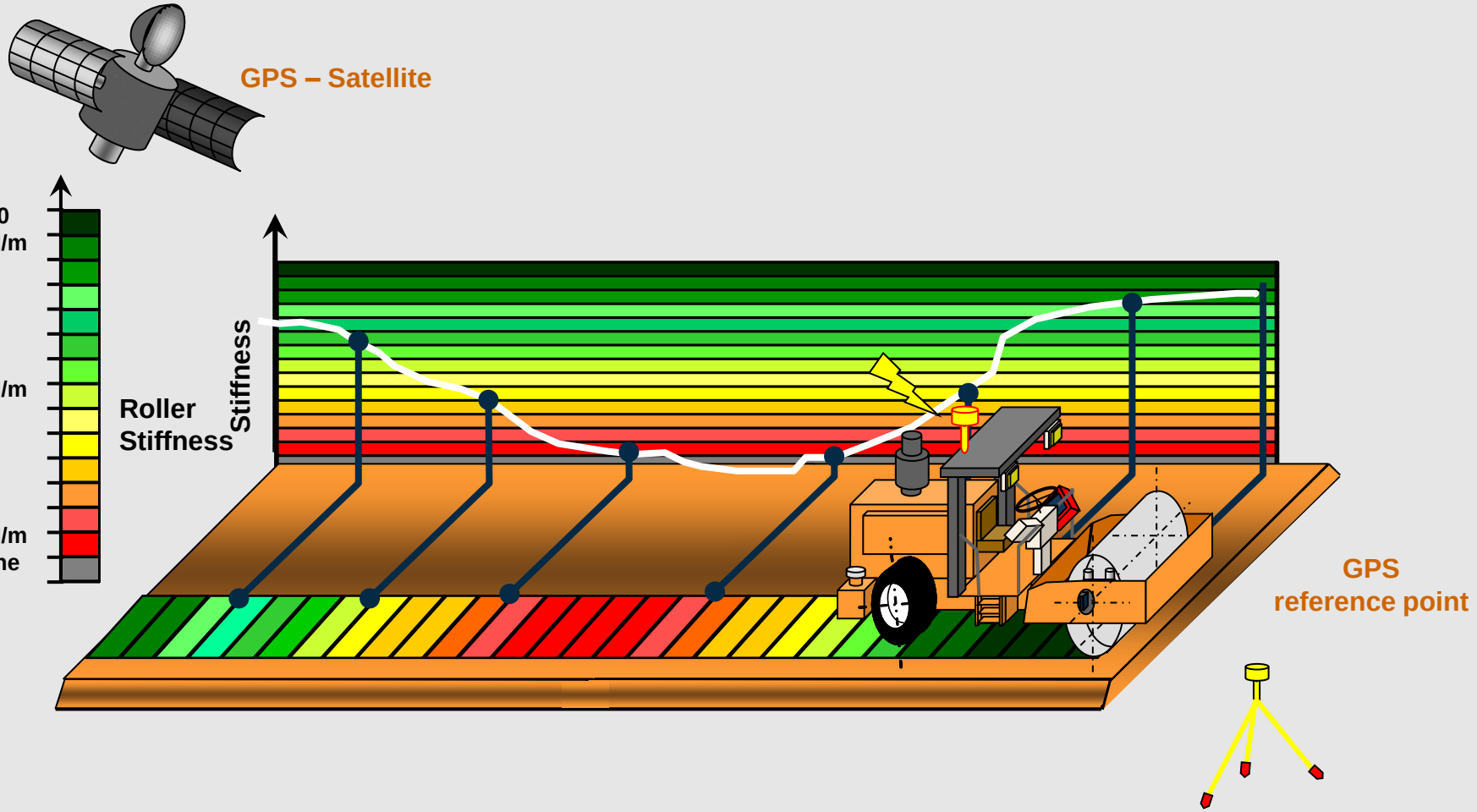


Hard Soil, well compacted; acting as an anvil

Low Amplitude, High Frequency, Compact Surface

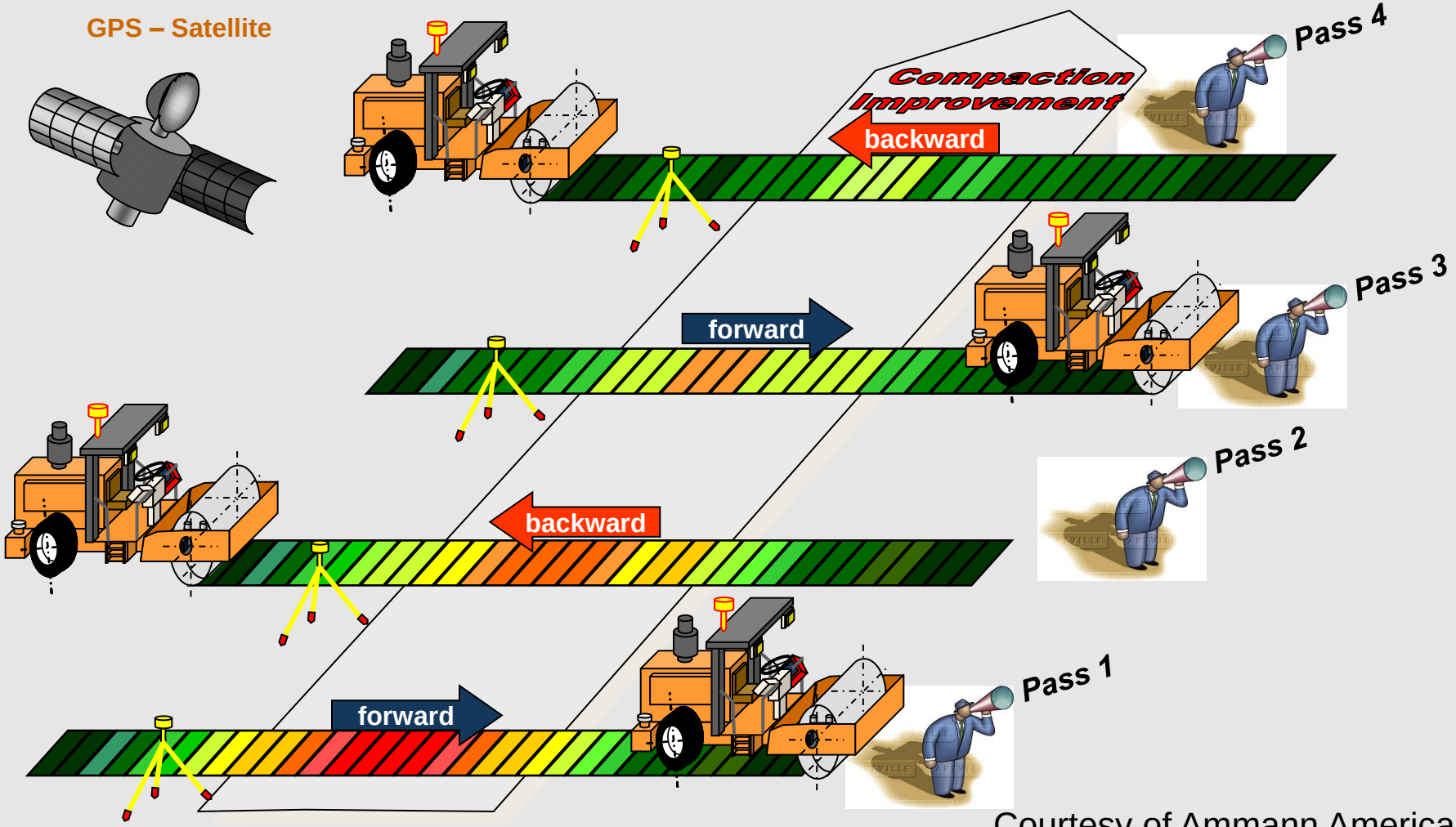
Courtesy of Ammann America

GPS-based Compaction Measurement



Courtesy of Ammann America

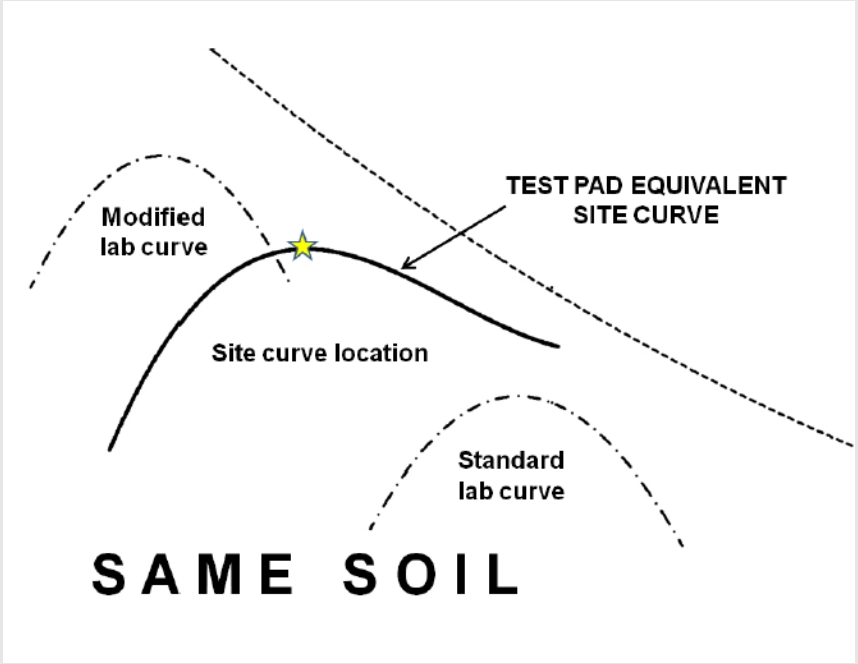
Compaction Control Process



Courtesy of Ammann America

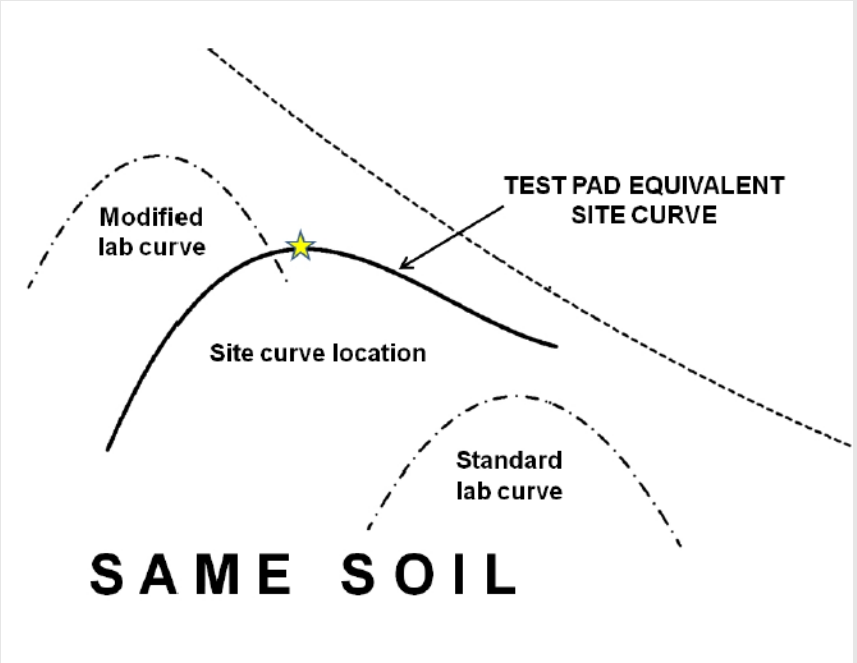
Why Do We Need It?

- **Current Practice**
  - Lab Compaction
    - Tex-113-E and Tex-114-E
  - Field Compaction
    - Ordinary Compaction (Proof Rolling)
    - Density Control
      - Sand cone replacement test
      - Nuclear gauge test (density and moisture)



Why Do We Need It?

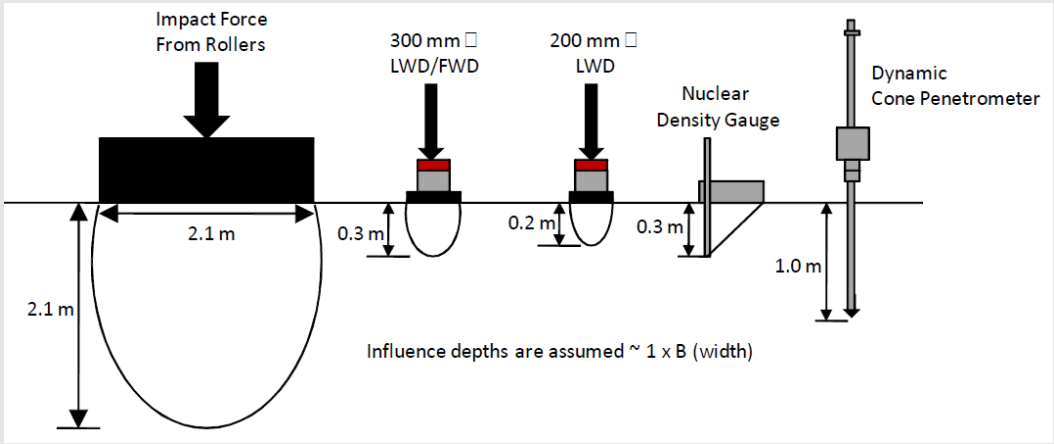
- **Problems**
  - Compactive Energy
  - Moisture Content
  - Material Type
  - Compact Lift Thickness
  - Underlying Conditions



- **Is density measurement the best way to asses the quality of compaction?**
  - Density is not used in pavement design
  - Density is not correlated well with modulus/stiffness

Why Do We Need It?

- How do we know the target density is achieved?
  - –Contractor
  - –Proof rolling
  - –Density by NDG



- Density measurements are spot check and layer specific, and not representing the entire section (no info about uniformity of compaction)
- Density is only measured after compaction is complete (no feedback in real time)

Why Do We Need It?

- Intelligent compaction can greatly improve the quality and uniformity of compaction which are critical for long-lasting performance of pavements
  - When and how much of compaction is achieved, avoiding under or over compaction
  - Where compaction is achieved or not achieved

Faster, Better, Smarter, and Safer

Never Guess Again

National and TxDOT Research

- NCHRP 21-09

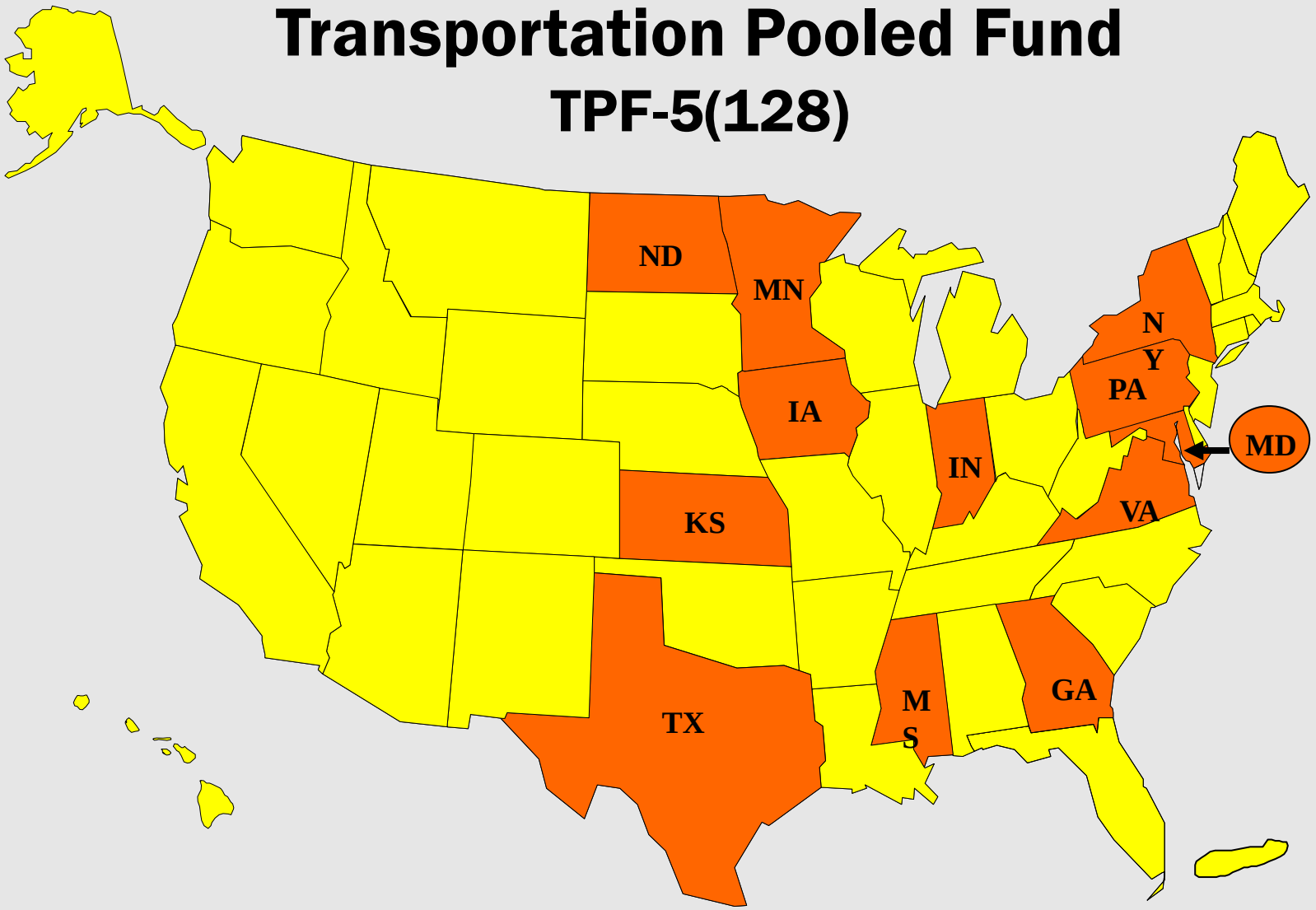
  "Examining the Benefits and Adoptability of Intelligent Soil Compaction"

  - Colorado School of Mines, Michael Mooney and David White, et al
  - Final report (NCHRP report 676, "Intelligent Soil Compaction Systems") has been released, http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_676.pdf

- FHWA TPF-5(128)

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

  - The Transtec Group, Inc., George Chang, David White, and Larry Michael, et al
  - Final report (FHWA-IF-12-002) has been released, http://www.intelligentcompaction.com/downloads/Reports/FHWA-TPF_IC_Final_Report.pdf


Transportation Pooled Fund
TPF-5(128)
ND
MN
IA
KS
TX
M
S
IN
N
Y
PA
MD
VA
GA

National and TxDOT Research

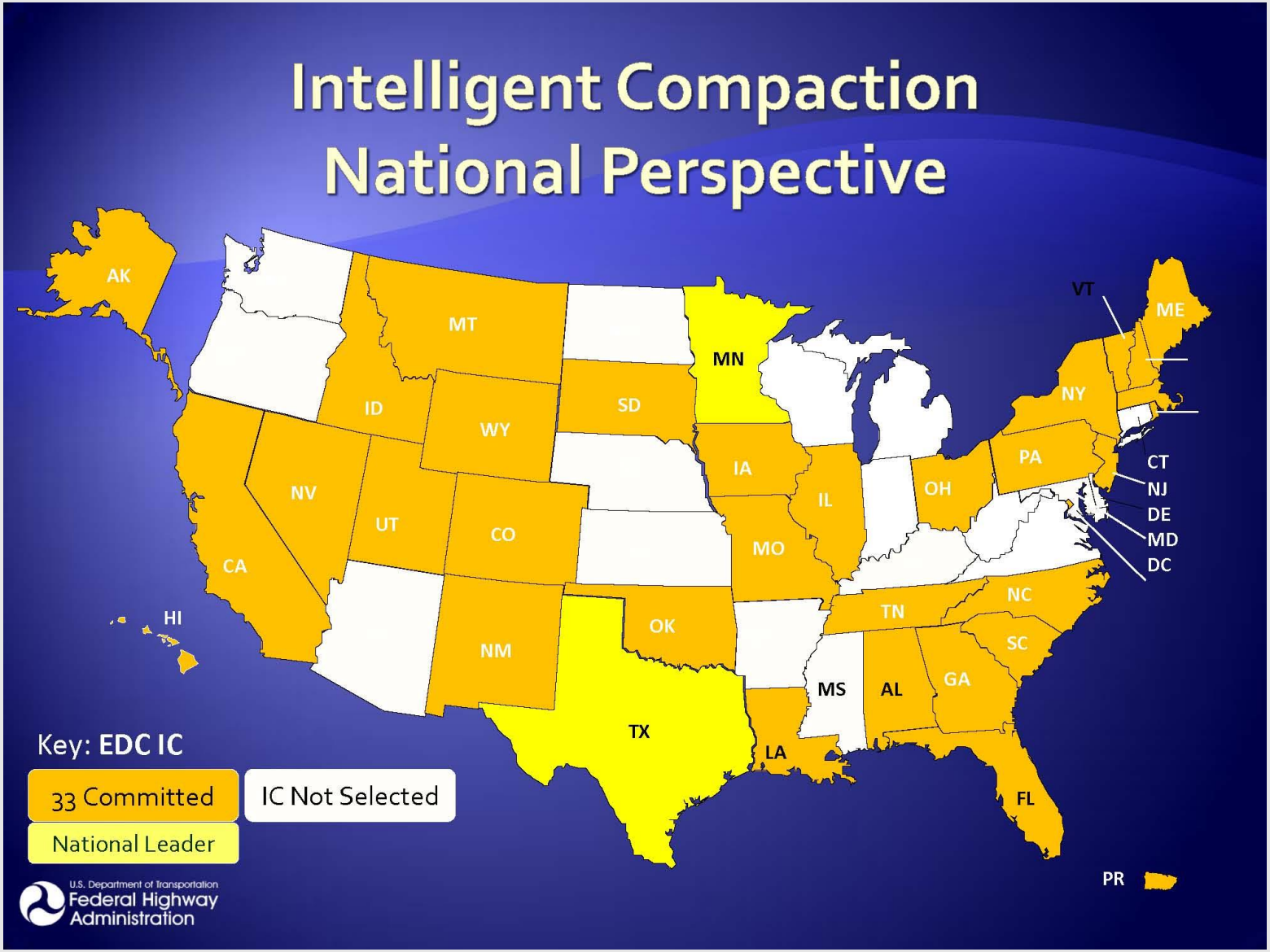
- **FHWA EDC2 Initiative**
  Report on the EDC2 Summits
  http://www.fhwa.dot.gov/everydaycounts/pdfs/edc2_2013.pdf

Intelligent Compaction

Accelerating Project Delivery	Reducing Construction Time	Innovative Contracting
Safety	Environment	Mobility

More info: http://www.fhwa.dot.gov/everydaycounts/edctwo/2012/ic.cfm

National and TxDOT Research



National and TxDOT Research

- **FHWA TIDP 130(096)**

"Intelligent Compaction Roller Retrofit Kit Validation"

  – University of Texas at El Paso, Soheil Nazarian and George Chang, et al

- **TxDOT 0-6740**

"Improvement of Construction Quality Control by Using Intelligent Compaction Technology for Base and Soil"

  – University of Texas at El Paso, Soheil Nazarian, et al




TXDOT IC PROJECTS

5 Districts, 14 IC projects

TxDOT IC Projects

Amarillo (1)
LP335

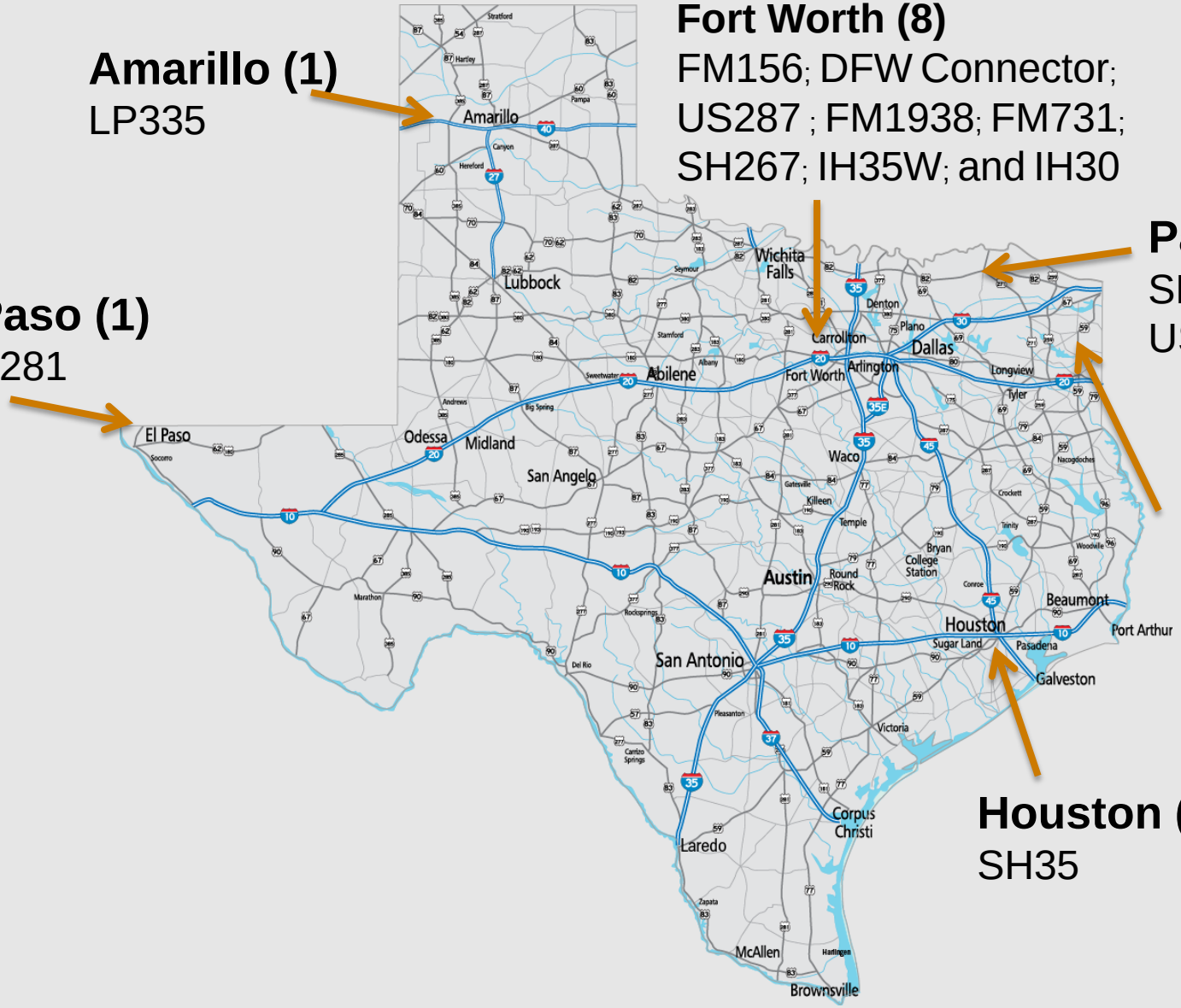
Fort Worth (8)
FM156; DFW Connector; US287 ; FM1938; FM731; SH267; IH35W; and IH30

Paris (2)
SH24
US75

El Paso (1)
FM1281

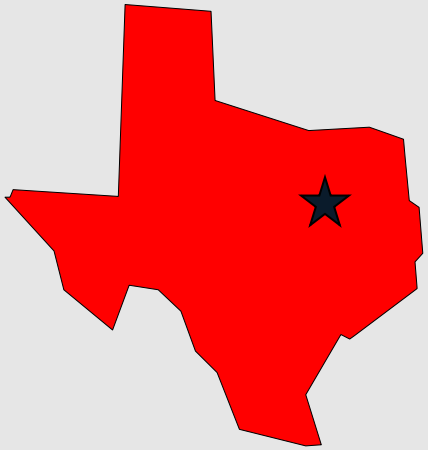
Atlanta (1)
FM450

Houston (1)
SH35



TxDOT FM156 Project

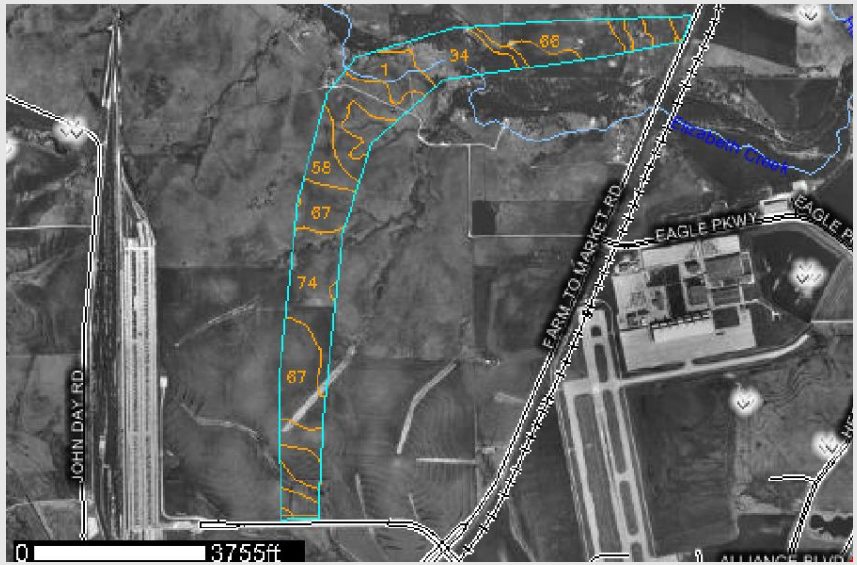
- FM 156, Fort Worth, TX, 2008
- FHWA/TPF IC Study
- Cohesive SG, Lime Stabilized SG, and Aggregate Base (Flex Base)



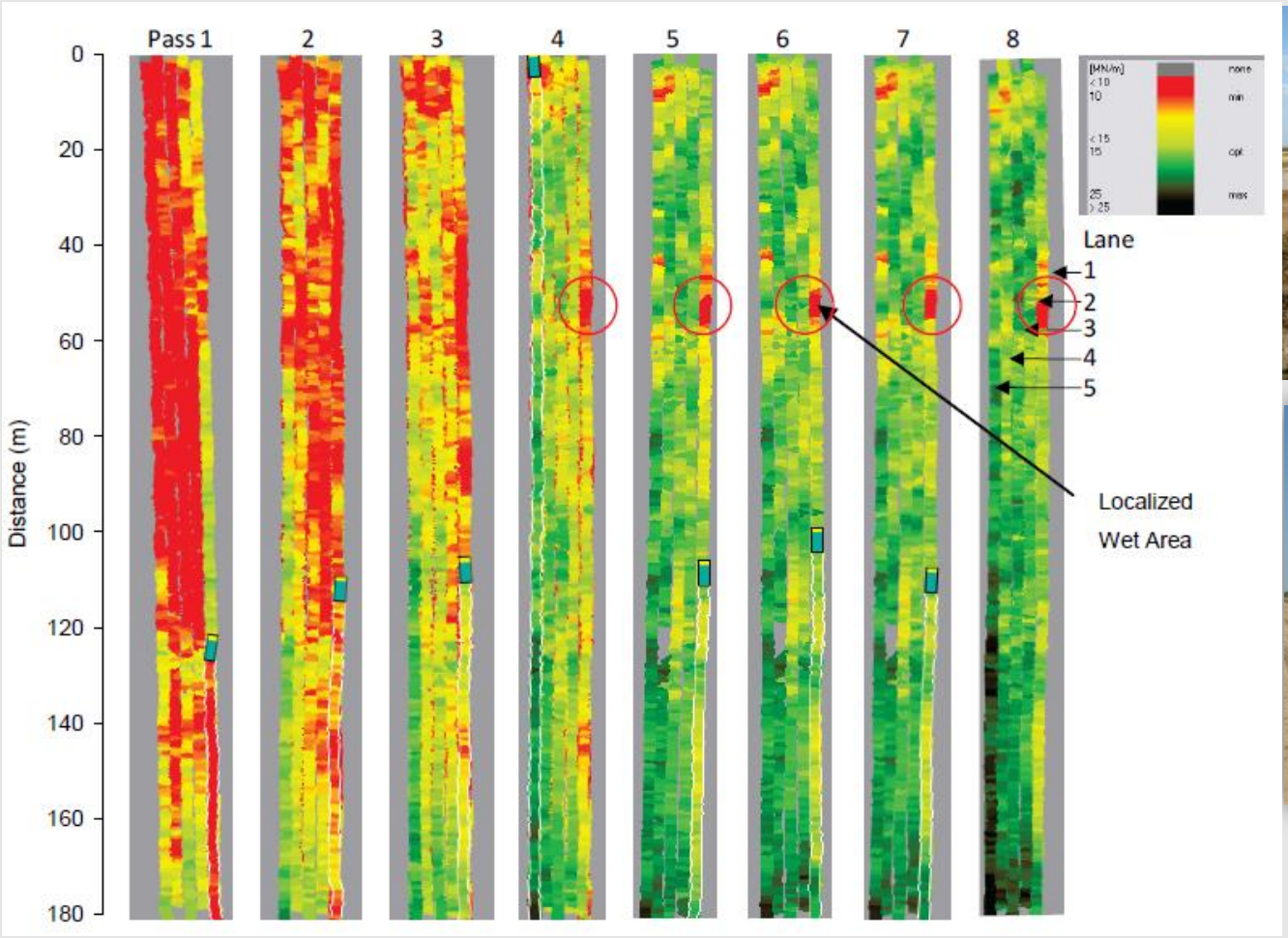
padfoot drum IC roller

smooth drum IC roller

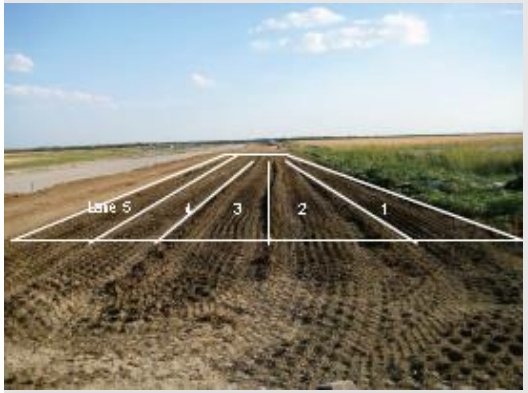
Dynapac Single Smooth drum IC roller



K_s shows compaction progress and a soft area



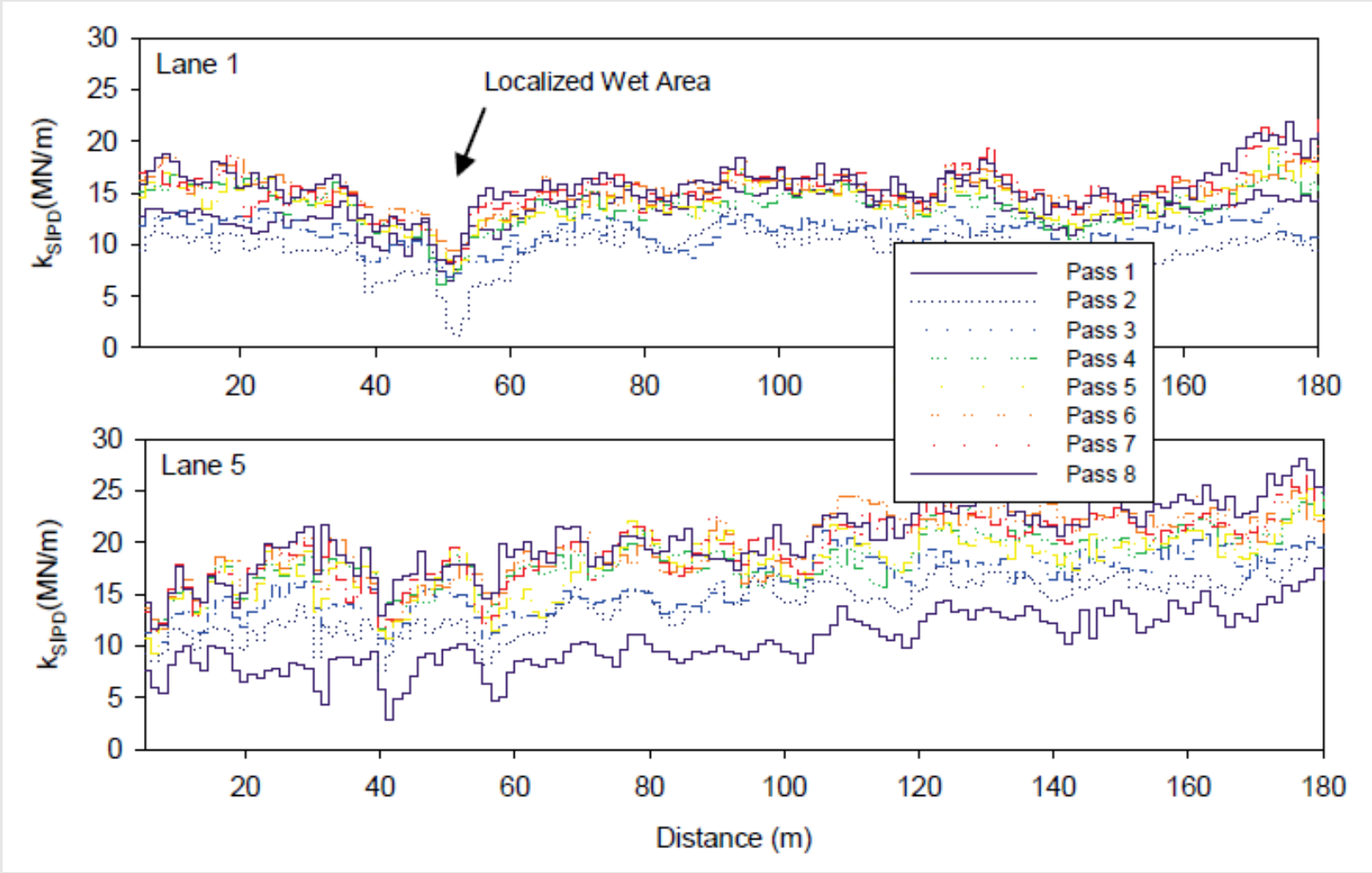
Screen shots of k_{SIPD} maps for different passes on TB 1



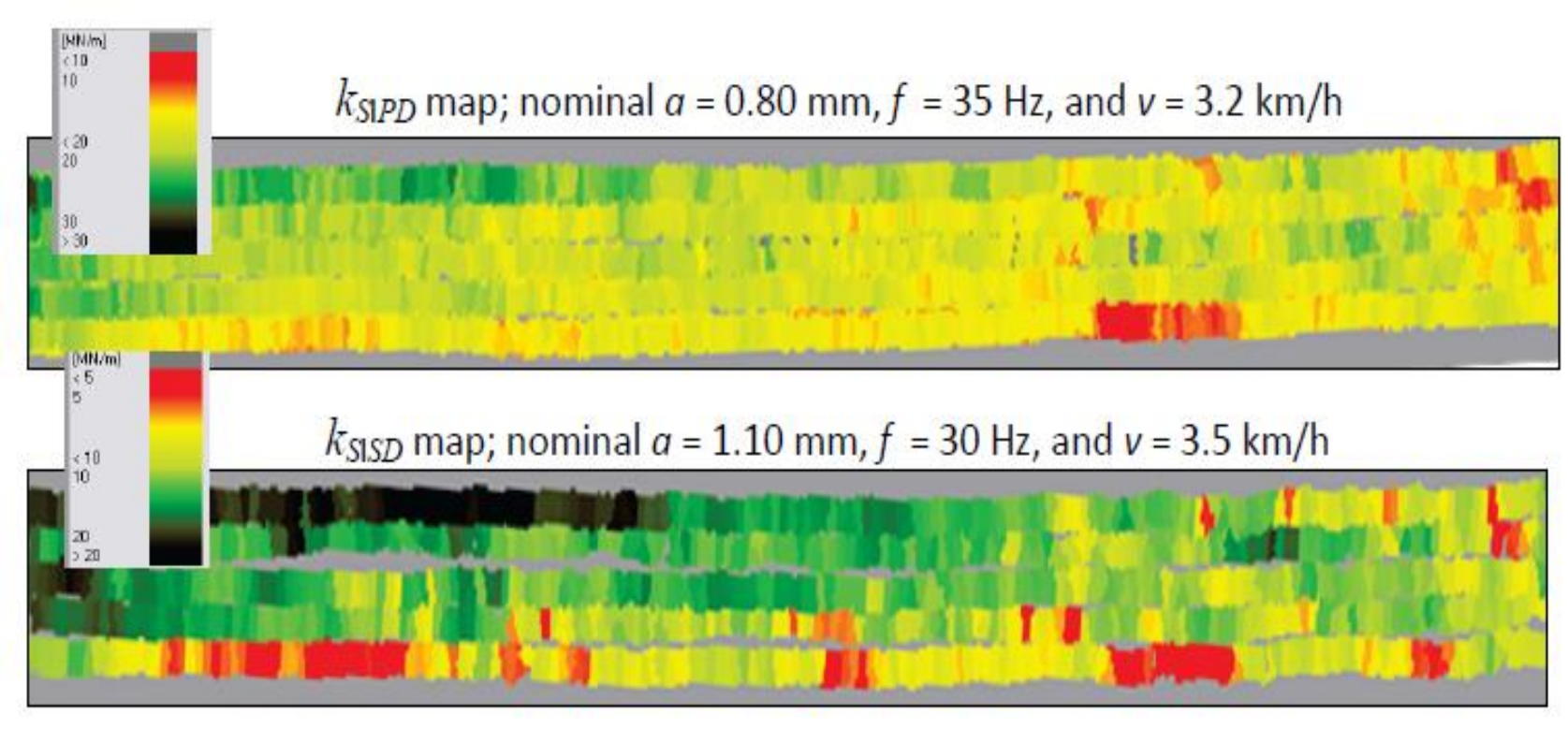
Case/Ammann Single-drum padfoot IC roller

TxDOT FM156 Project

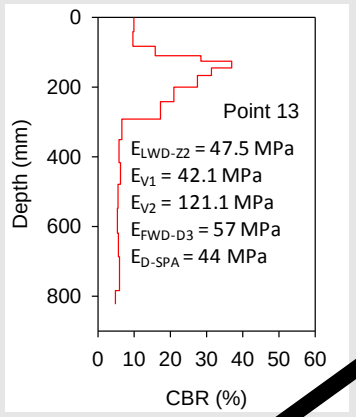
k_{SIPD} measurement from different passes on TB1 lanes 1 and 5 (nominal a = 0.8 mm, f = 35 Hz, and v = 3.5 km/h)

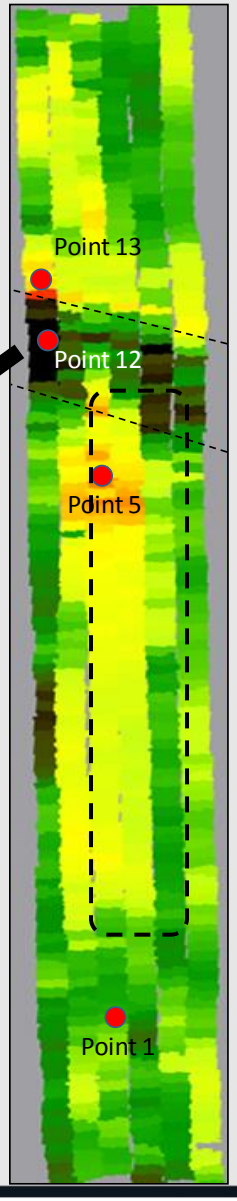


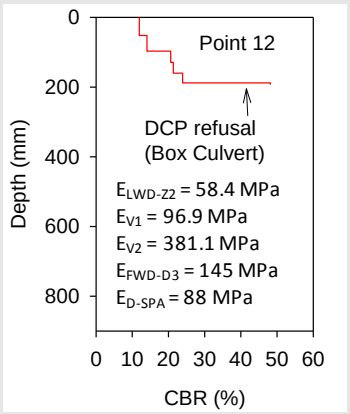
Spatial comparison of k_{SIPD} and k_{SISD} maps (TB 1 – subgrade clay material).



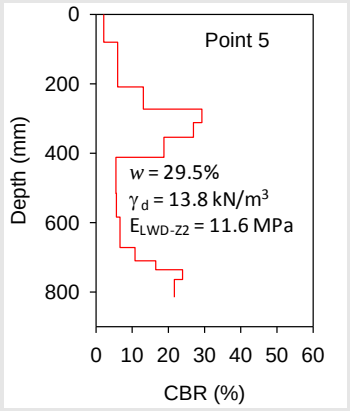
TxDOT FM156 Project

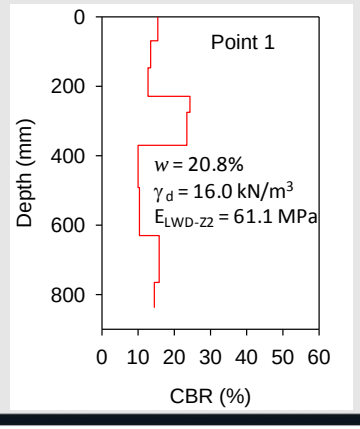


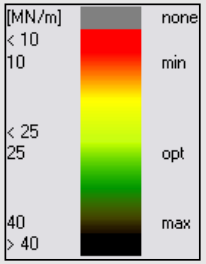




Box Culvert



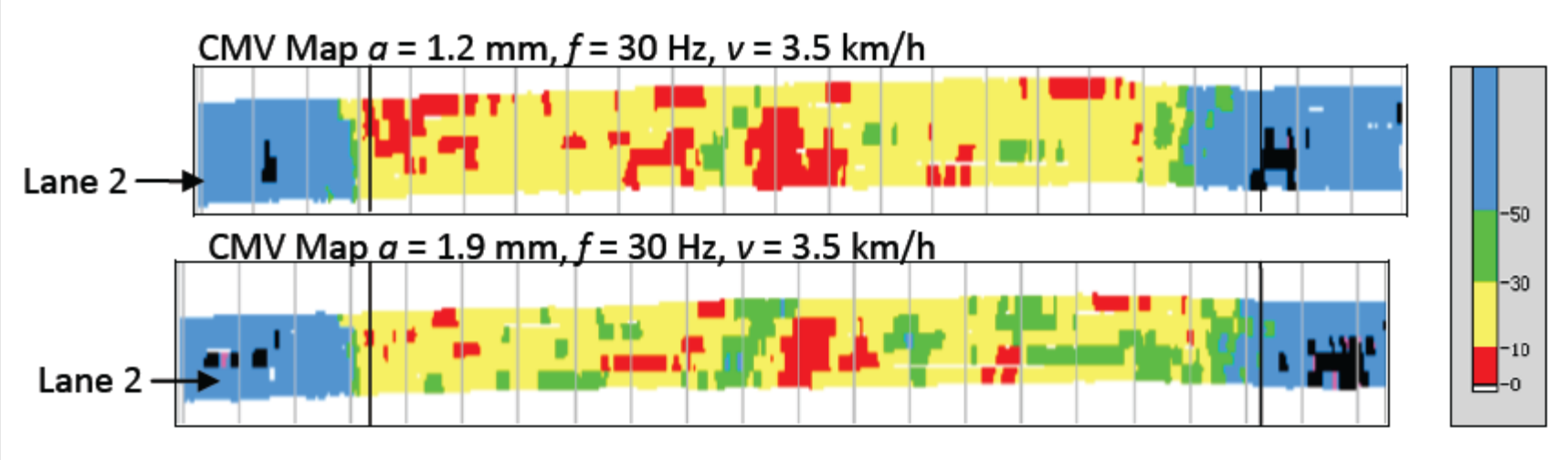




Underground Structures

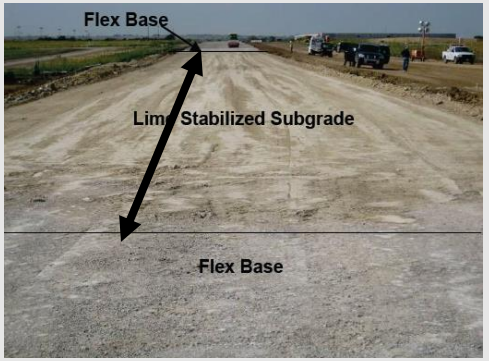
Case/Ammann Single-drum padfoot IC roller

Identify Different Materials

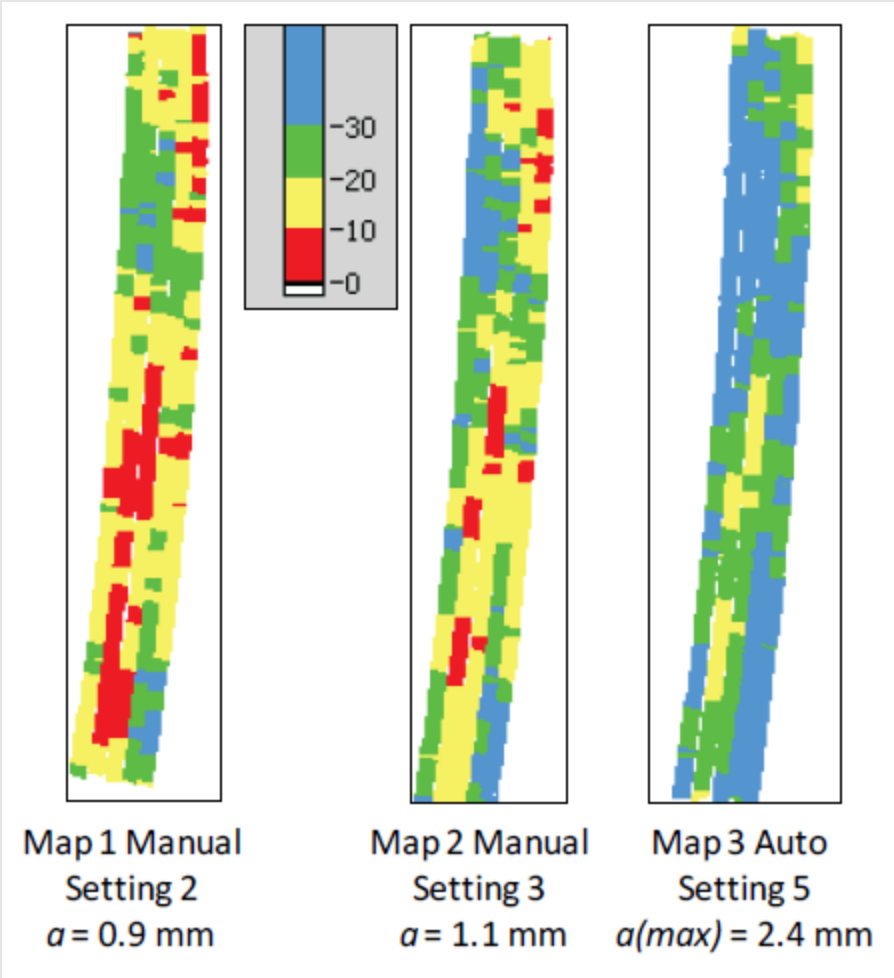


Flex Base **Lime Stabilized SG** **Flex Base**

Dynapac
Single
Smooth drum
IC roller



CMV maps on TB 7 with different operation settings

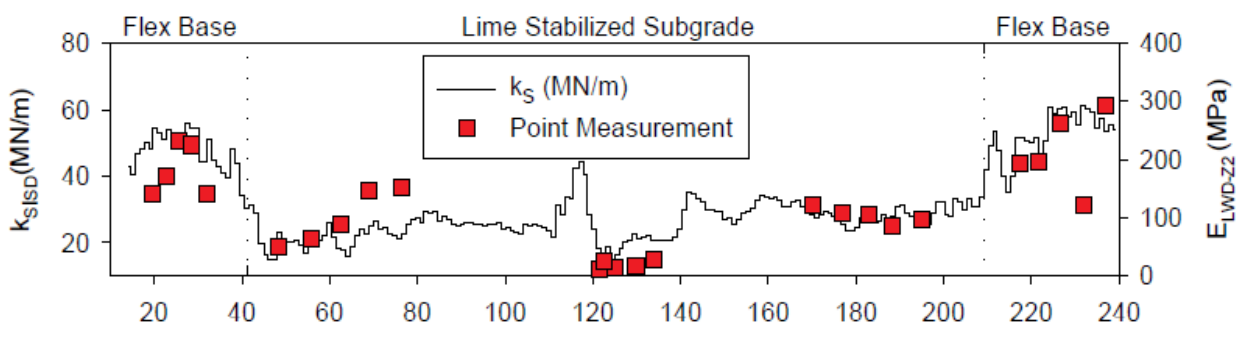


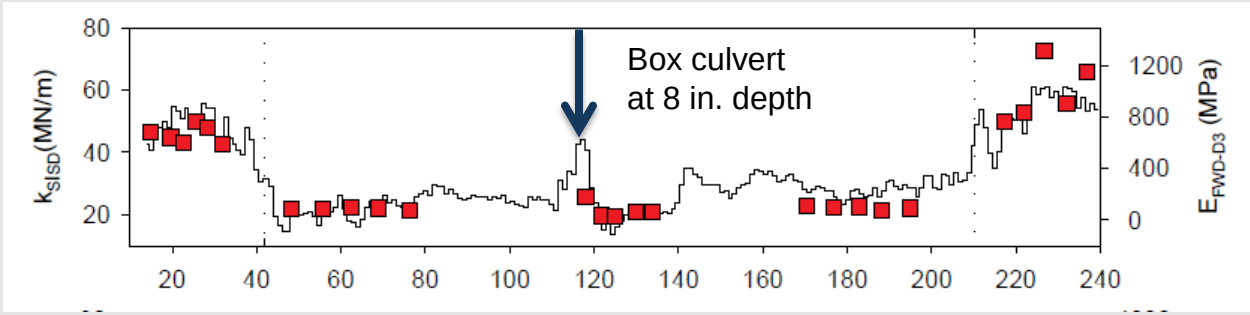
Map 1 Manual
Setting 2
a = 0.9 mm

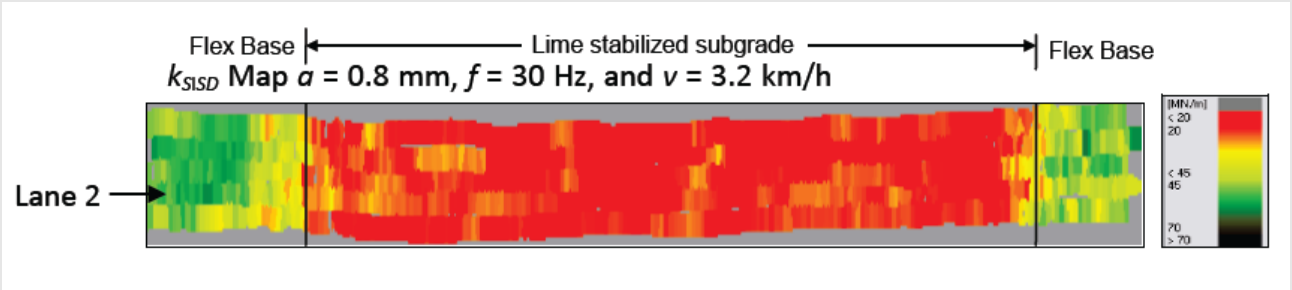
Map 2 Manual
Setting 3
a = 1.1 mm

Map 3 Auto
Setting 5
a(max) = 2.4 mm

IC vs. Conventional Tests

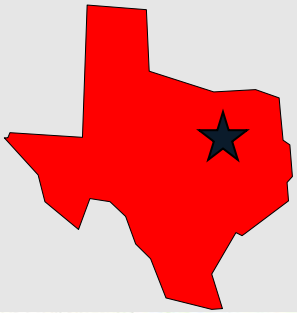






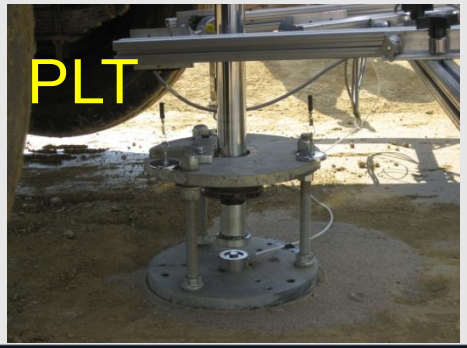
TxDOT DFW Connector DB Project

- 8-mile highway that connects SH114 and SH121 and adjacent roadways located north of the DFW International Airport
- $1.1 billion design-build project (CDA)
- Groundbreaking Feb. 17, 2010. Expected to complete in 2014
- Approximately half the construction time needed as opposed to traditional contracts

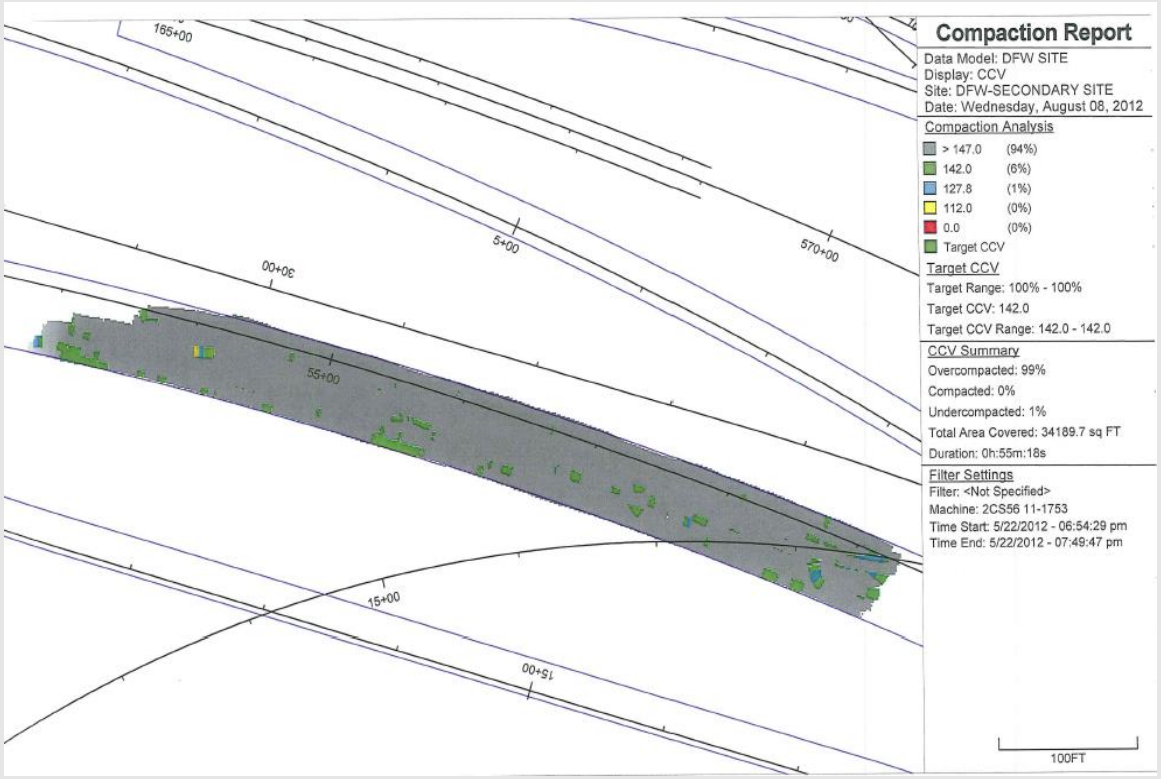


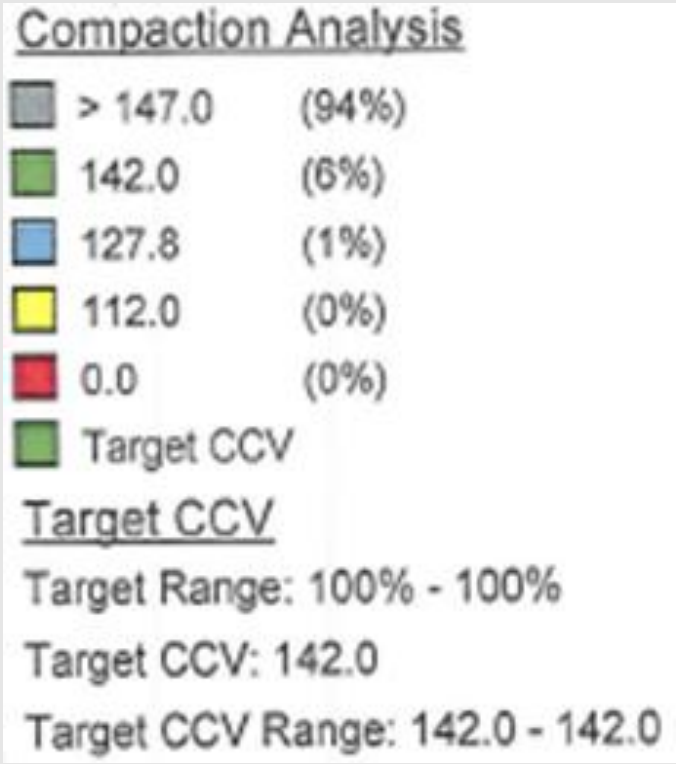
DFW CONNECTOR

- **Materials**
  - SG, lime treated SG, and flex base
- **IC Implementation (MDP)**
  - Production Rolling
  - Proof Mapping
    - QC Testing (verified by LWD)
    - QA Testing (verified by PLT, not yet implemented)

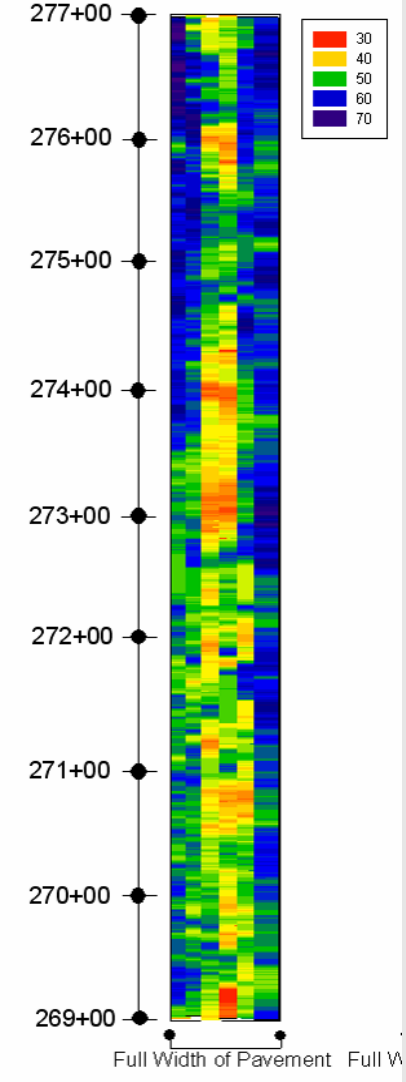


TxDOT DFW Connector DB Project





DFW Secondary Site Base Compaction Report



Compaction Target Value (CTV) = 42

% Target	CCV	IC Data	
>130%	55	26%	} 94%
90-130%	38 - 55	68%	
80-90%	34 - 38	4%	
70-80%	29 - 34	1%	
<70%	< 20		

Current TxDOT QA Criteria:
>90% of IC Data should be equal to or greater than the 85% of CTV

Benefits and Challenges of IC

- **Benefits**
  - Cover 100% of the rolling area, resulting in better control of density and its uniformity
  - Replace conventional proof rolling
  - Identify soft spots in real time
  - Improve pavement performance
  - Improve site safety
- **Challenges**
  - Extensive educational training
  - Data Management and Standardization
  - Moisture content measurements and variations
  - Poor correlation between density and modulus/stiffness

What Is Next?

- Increase awareness and encourage the use of IC technology in all districts
- Conduct training workshops and/or Webinars in all 25 TxDOT districts for IC technology implementation including IC retrofit kits

What Is Next?

- Conduct demonstration or pilot projects in TxDOT subgrade/base construction using IC technology
- Revise TxDOT current OUT (one-time-use) project-based IC special specification
- Develop a state-wide use IC specification
  - Short Term: density acceptance based on IC mapping
  - Long Term: eliminate NDG density acceptance

QUESTIONS?

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