



Intelligent Compaction Technology



An Innovation in Compaction
Control and Testing

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Intelligent Compaction, IC



What is “Intelligence?”

- Oxford Dictionary: “...*able to vary behavior in response to varying situations and requirements*”
- Ability to:
 - Collect information
 - Analyze information
 - Make an appropriate decision
 - Execute the decision



FHWA IC Team



- 12 State Pooled Fund Partners...
- Roller & Test Equipment Manufacturers
- V. Lee Gallivan, HIPT
- Michael Arasteh, RC
- Fred Faridazar, R&DT
- Tom Harman, RC
- John D'Angelo, HIPT
- Bob Horan, SaLUT (*Support Staff*)

We've come a long way!



A black and white photograph of a vintage car, possibly a Ford Model A, stuck in a deep, muddy rut on a dirt road. The car is facing the viewer, with its front wheels partially submerged in the mud. The license plate reads '2391'. The background shows a rural landscape with several houses, a wooden fence, and bare trees, suggesting a winter or early spring setting. The sky is overcast.

Because we always ask...

How can we do it better?

What's the next innovation?

Roadway Compaction



- Proper in-place density is vital for good performance
- Conventional compaction procedures have some limitations...
- Intelligent compaction technology appears to offer “*a better way*”



Conventional Limitations



- The Compaction Process...



Limited “On Fly” Feedback

Over or Under-Compaction
Can Occur

Conventional Limitations



- Density Acceptance...



Limited Number of Locations

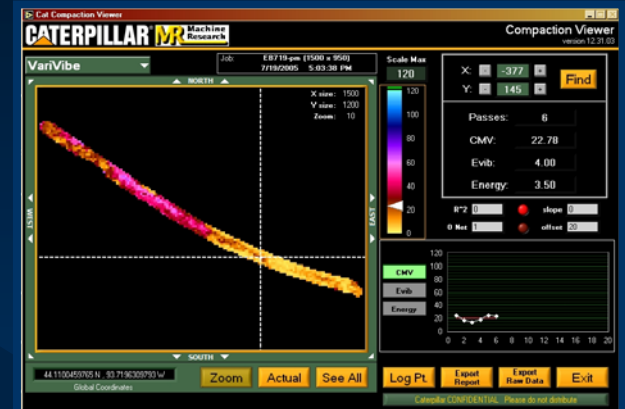


After Compaction is Complete

Intelligent Compaction



Can we make the process...smarter?



Improved Roller Technology

Sophisticated / Clear Documentation Systems



Advanced Hardware & Software

IC – Goals / Benefits



- **Short Term**

- Improve density... better performance
- Improve efficiency... cost savings
- Increase information... better QC/QA

- **Long Term**

- Comprehensive Compaction Control (CCC)
- Estimate pavement moduli?
- Tie to M-E Design Guide (verify design)?
- Performance specifications?

Importance of 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. Thorough compaction is known to produce the following desirable results:

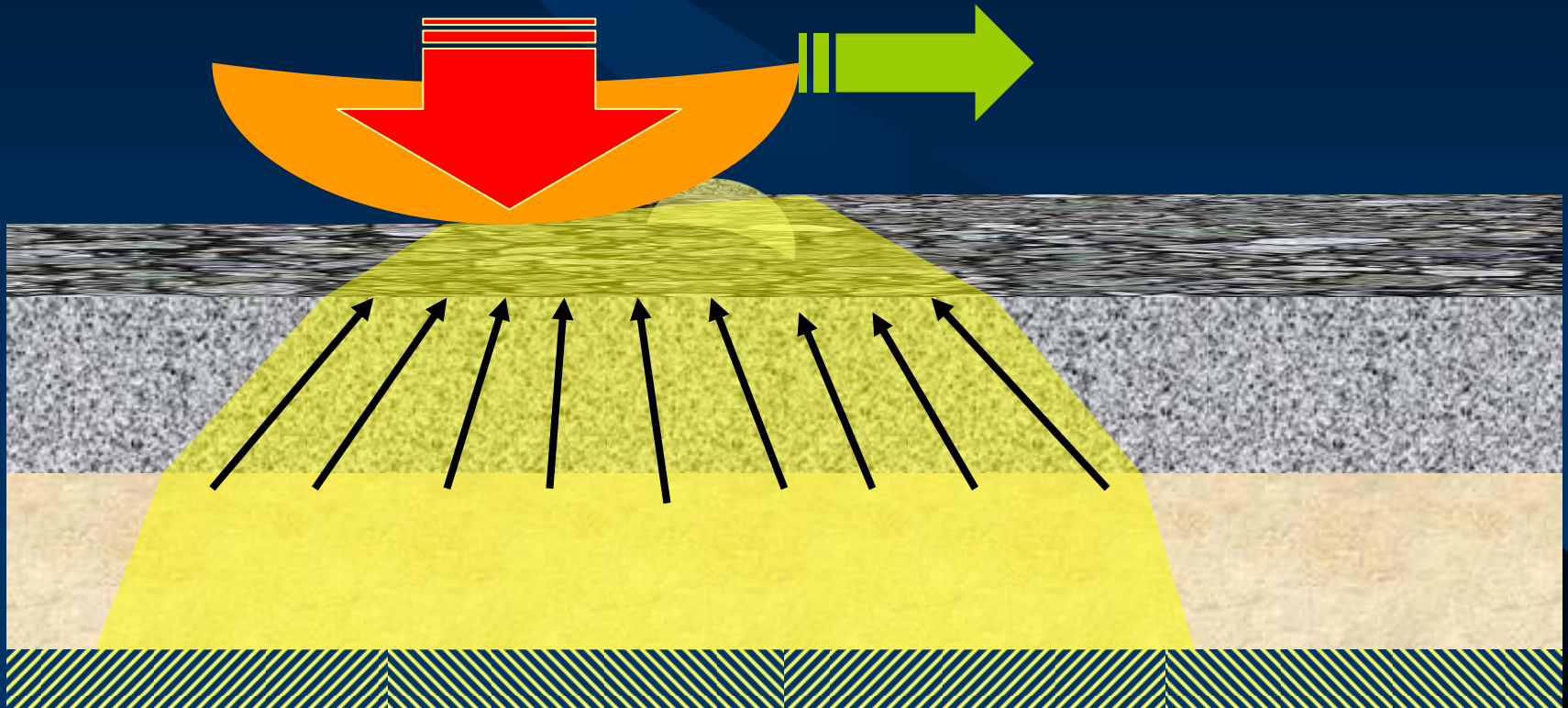
1. It increases interlocking of the aggregate particles, which is the primary factor in developing a high degree of stability.
2. It retards the entrance of moisture, thus preventing excessive loss of stability under adverse service conditions.
3. It reduces the flow of air and water through bituminous mixtures and is therefore an effective means of lessening damage from weathering and film stripping."

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

Basics of Compaction



- Effort (Roller) versus Resistance...



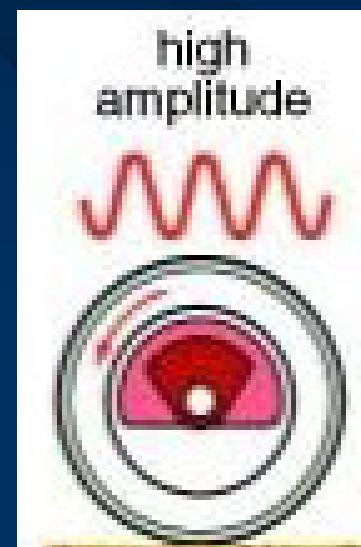
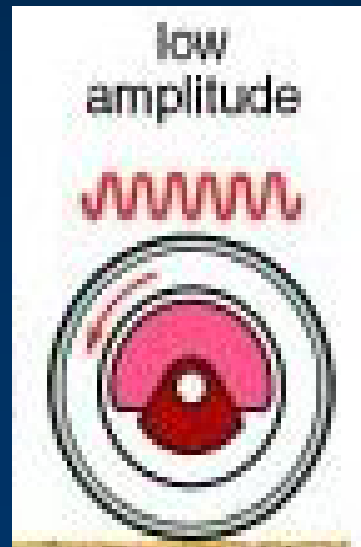
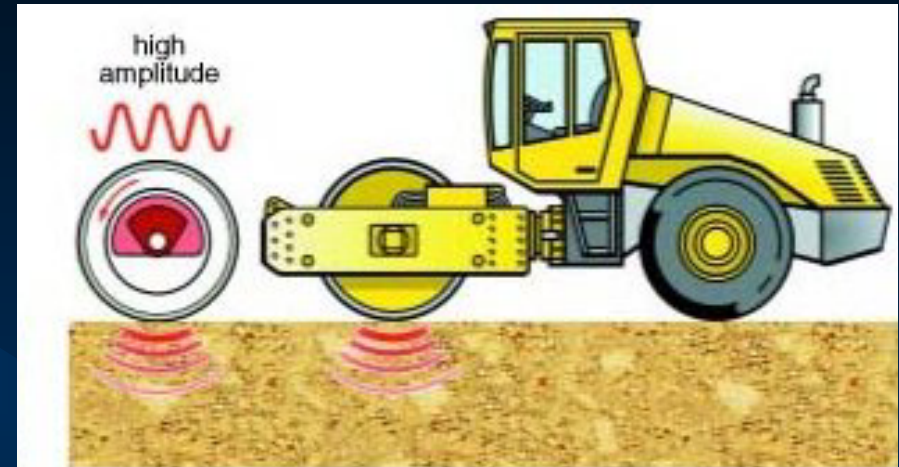
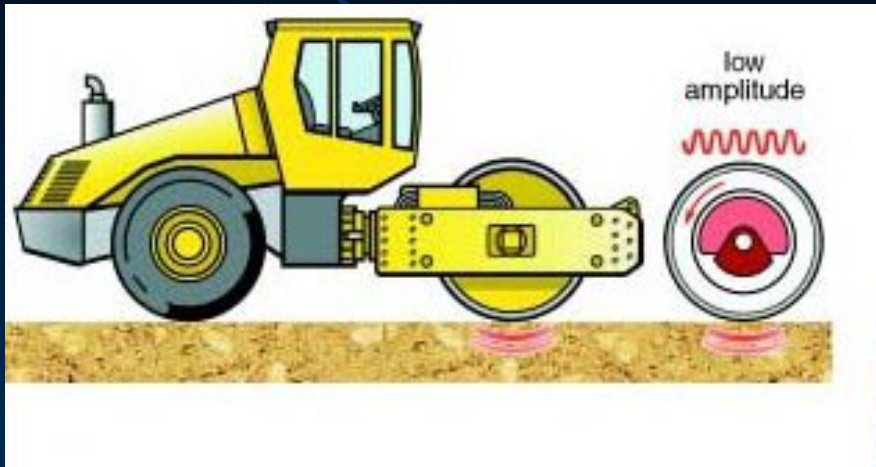
Basics of Compaction using Vibratory Rollers



- Constant Mass
- Variables of Vibration
 - Frequency, f (Hz)
 - Amplitude, A
 - Roller speed, v (fps)



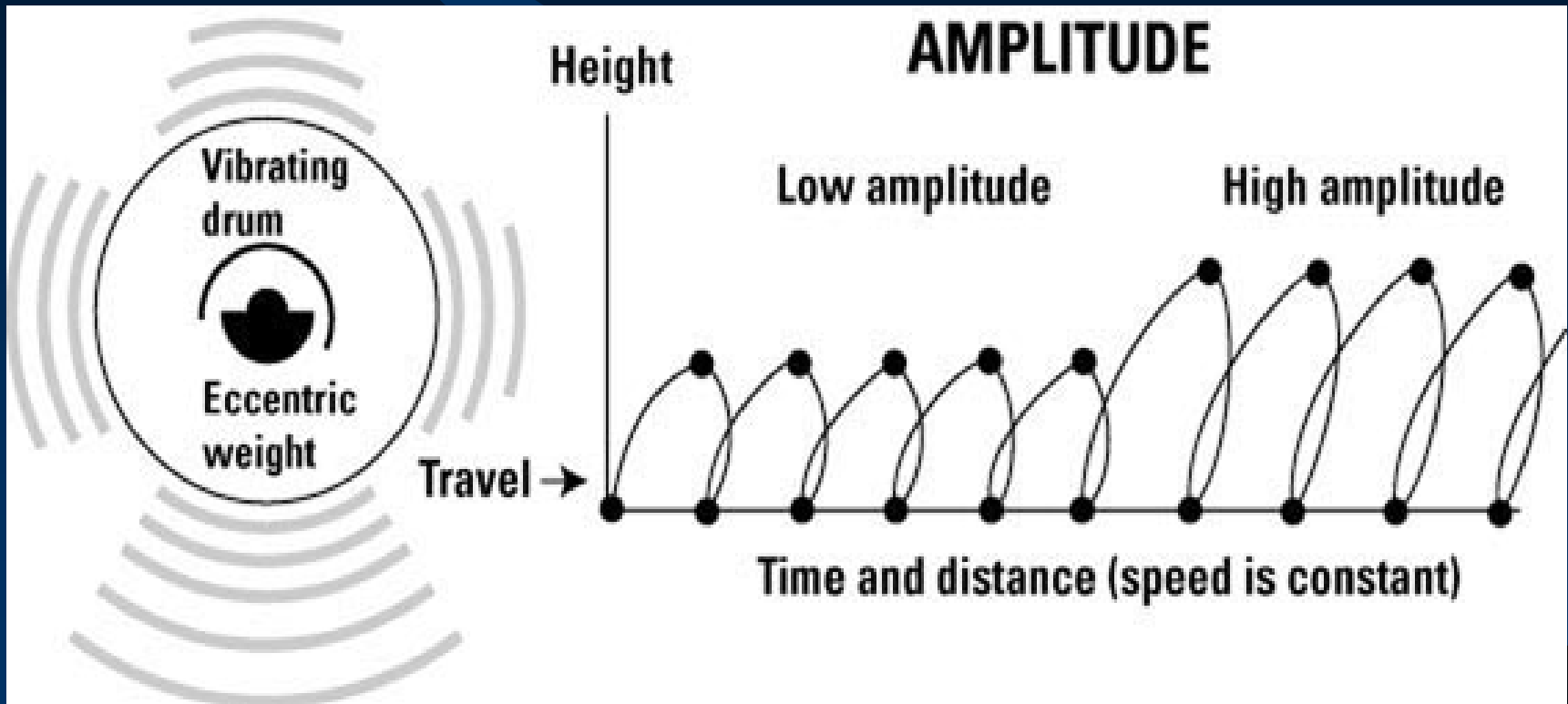
Basics of Compaction using Vibratory Rollers



Amplitude

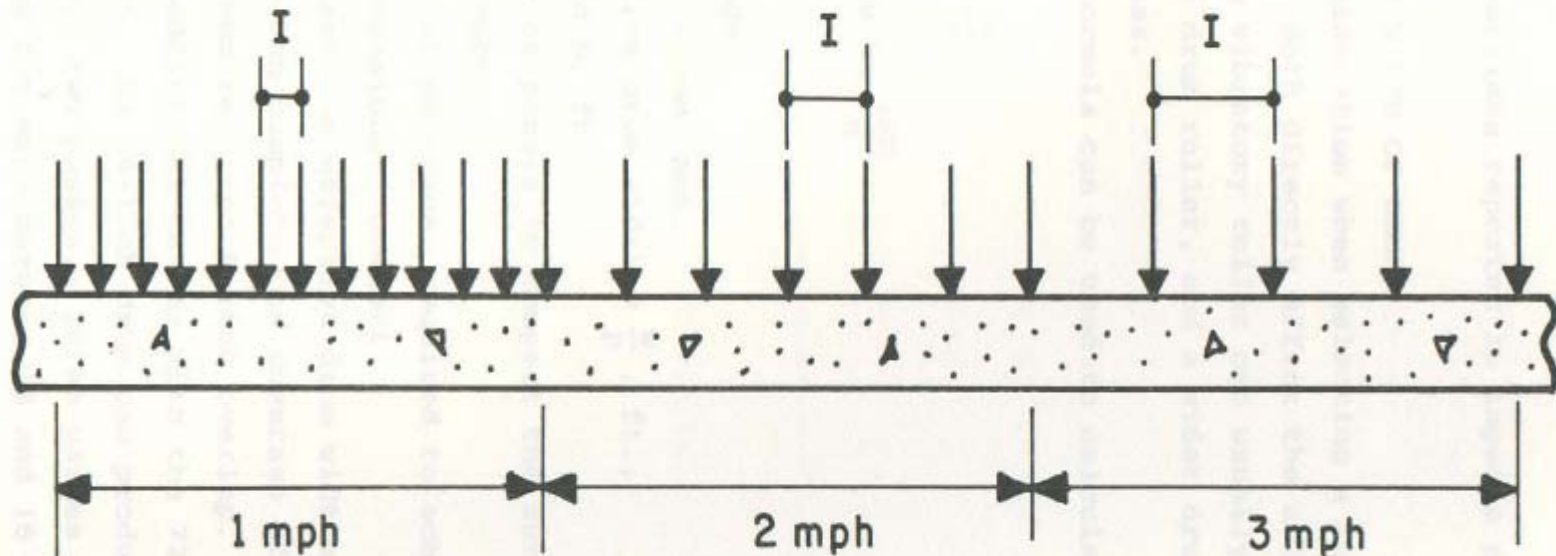


- Amplitude determines impact force



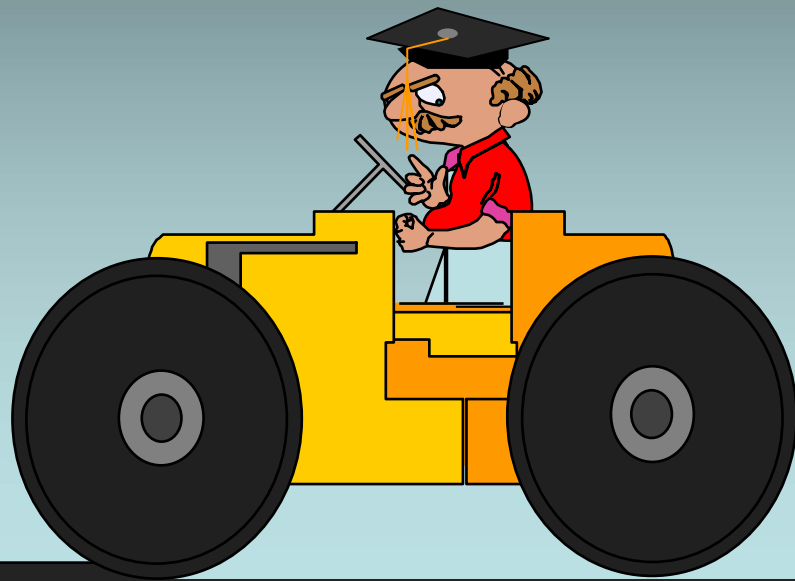
Impact Spacing, $I = f(v, \text{Hz})$

$$\text{Impact Spacing (I)} = \frac{\text{Roller Speed, fps}}{\text{Frequency, Hz}}$$





Intelligent Compaction, IC



IC TPF / FHWA Definition



1. Vibratory rollers with measurement / control system
 - Measurement system, ex. material stiffness
 - Control system automatically changes parameters (amplitude and possibly frequency) based on measurement...



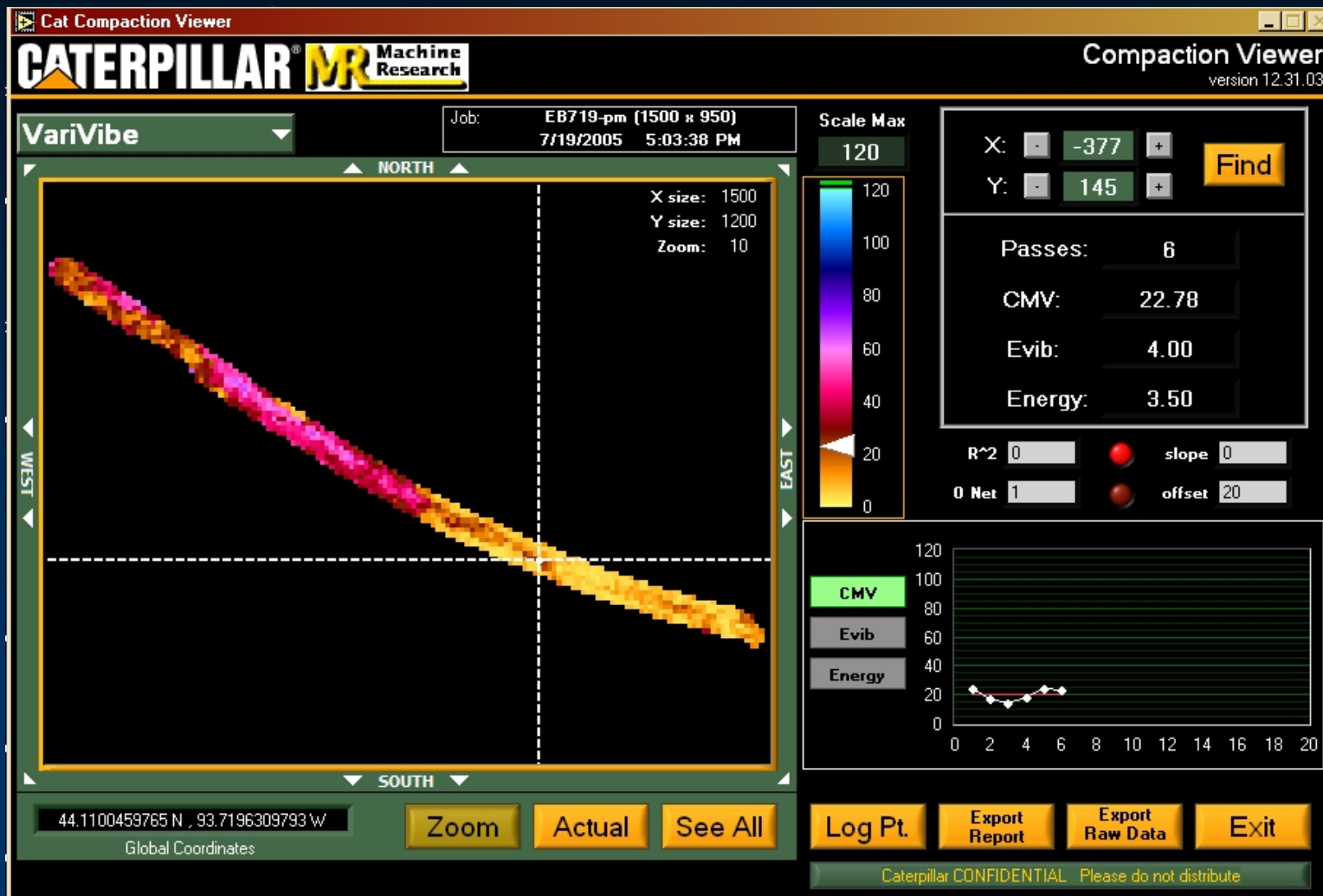
IC TPF / FHWA Definition



2. GPS-based documentation systems
 - Continuous recordation of materials stiffness
 - Continuous recordation of corresponding roller location
 - Color-coded mapping of stiffness



Ex. Caterpillar



Ex. Sakai...



Controller Units



Thermo Gauge



Accelerometer



PC Display

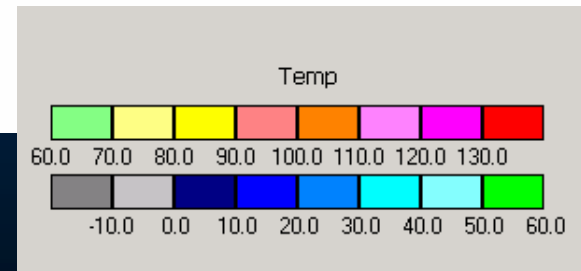
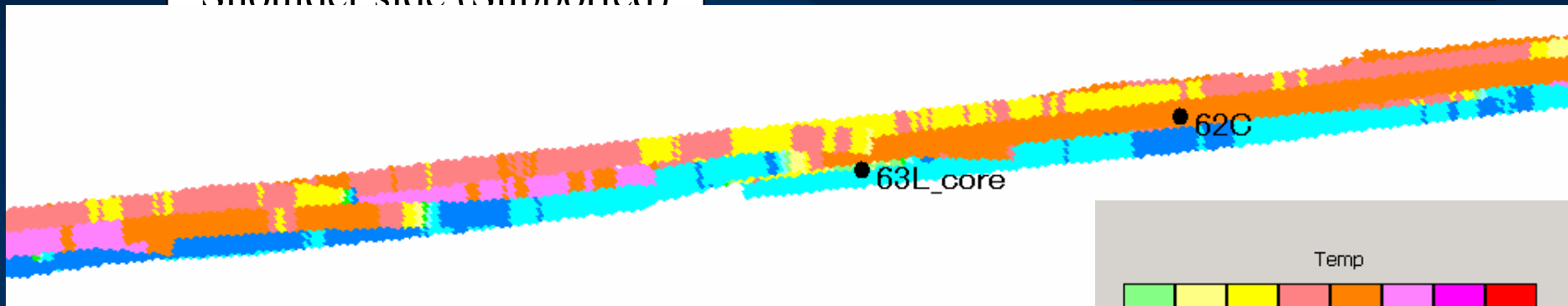
Sakai IC Roller Project



- Temperature

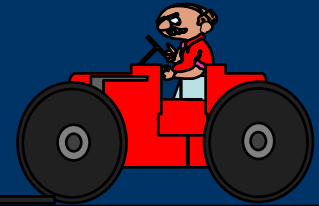
Shoulder side (Supported)

Paving Direction



Longitudinal Joint

Benefits of IC



- **Maximum productivity** of the compaction process
- **Improved density** of pavement materials
- **Measurement and recordation** of materials stiffness values
- **Identification** of non-compactable areas
- **Improved depth** of compaction
- **Reduction in highway repair costs**

Some Critical Research Topics...



- Construction specs on 4 different material types
 - Granular subgrade soil
 - Cohesive subgrade soil
 - Aggregate base and subbase
 - Asphalt pavement material
- Comparison of IC and conventional—
Is IC really better?

National Research Efforts



-
-
- NCHRP 21-09 “Examining the Benefits and Adoptability of Intelligent Soil Compaction”
 - Transportation Pooled Fund #954 – “Accelerated Implementation of Intelligent Compaction Technology for Embankment Subgrade Soils, Aggregate Base and Asphalt Pavement Material”

NCHRP 21-09 (Soils)



- Study of IC of subgrade soils (limited aggregate base/subbase)
- Objectives: Based on data / information obtained from field studies:
 - Develop generic IC construction specifications for subgrade soils
 - Evaluate the reliability of IC system components

NCHRP 21-09 Phase One Project



July 2006; MnROAD Research Center

NCHRP 21-09 Phase One Project

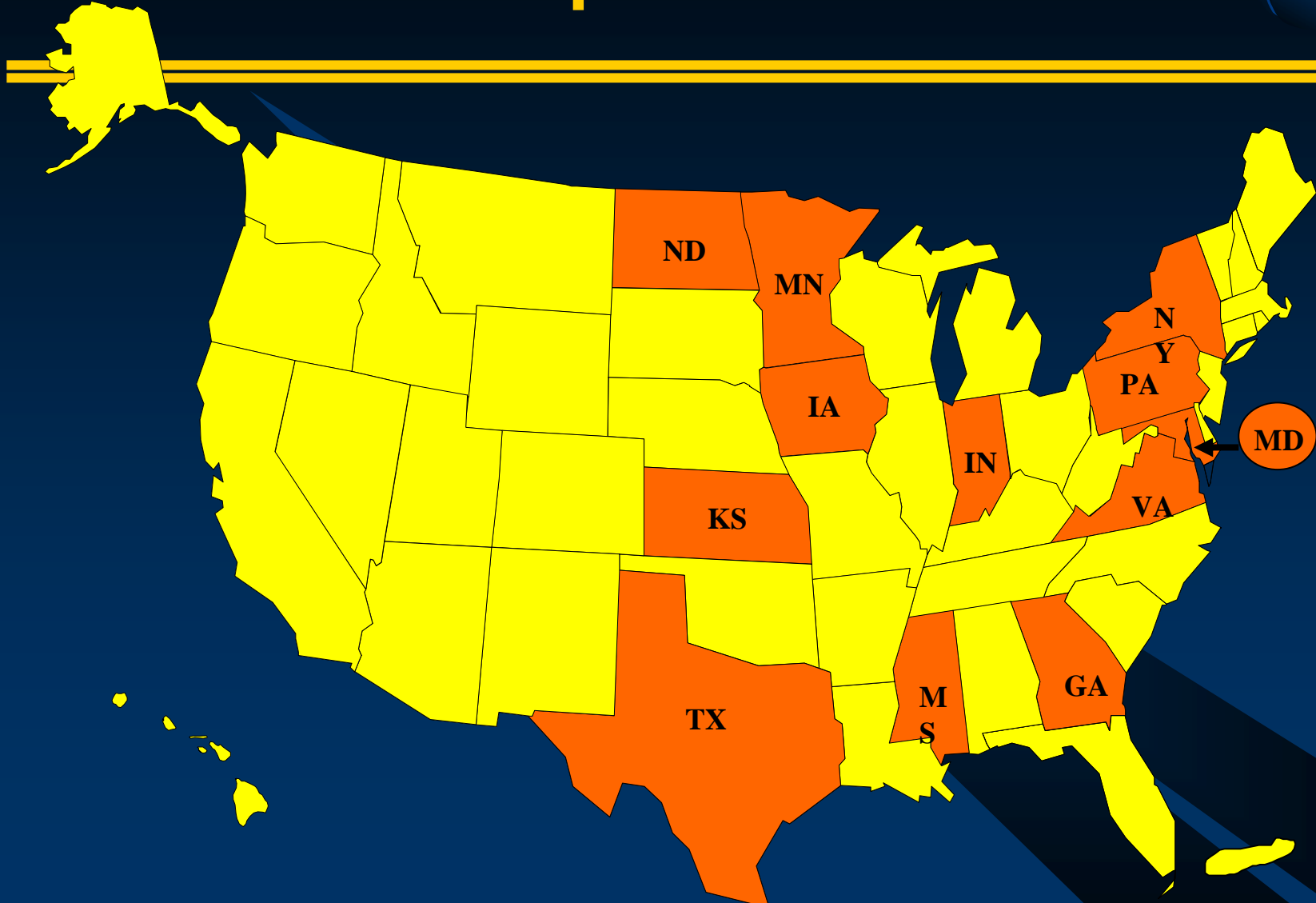


Pooled Fund (Soils / HMA)



- 3 year study of IC for all materials
- Solicitation period ended on Dec 2005
- 12 participating states
- Estimate 1 project / State / year ~ 30?
- Close coordination with NCHRP project
- Stated goal to work closely with roller suppliers to increase the number of IC rollers and manufacturers

Accelerated Implementation of IC



Pooled Fund, Objectives



- Objectives: Based on data obtained from field studies:
 - Accelerated development of QC/QA specifications for granular and cohesive subgrade soils, aggregate base and asphalt pavement materials...

Pooled Fund, Objectives



- Develop an experienced and knowledgeable IC expertise base within Pool Fund participating state DOT personnel
- Identify and prioritize needed improvements to and/or research of IC equipment and field QC/QA testing equipment (DCP, FWD, GeoGauge, etc)

State DOT IC Research



- Limited number of projects by several State DOTs (MN, NC, MD)
- Mn/DOT has conducted an ongoing research effort over last several years
 - 5 projects complete
 - Subgrade soils only
 - 3 different roller manufacturers
 - Compare roller-generated output to in-situ test methods (DCP, LWD and GeoGauge)
 - Required GPS-based, color coded mapping of roller output and locations

IC Rollers

Current Status



- 5 Roller Manufacturers have announced their intentions to supply IC rollers in US
 - 4 have announced plans to have both single drum soils rollers and tandem drum asphalt rollers
 - 1 has only single drum soils rollers, at this time
- 4 Manufacturers that currently have IC rollers for public display, at this time:
 - Bomag America (both single and tandem drum)
 - Ammann America (single drum)
 - Caterpillar (single drum)
 - Sakai America (tandem drum)

Special Issues for Asphalt IC

- Thin lift construction
- Allowable temperature ranges
- Surface vs. internal temperature measurement
- Non-destructive, in-situ stiffness / modulus companion tests

What have we learned so far?



- IC technology appears to have great potential to improve the compaction process
- Improved and more uniform density should increase pavement service life
- There is a great deal of interest among federal and state DOTs to learn more about it

What have we learned so far?



- Roller manufacturers are responding to this interest by performing R&D, providing rollers and by coordinate efforts with state and national research efforts
- Preliminary findings from studies in US are encouraging

Intelligent Compaction



The Objectives

FHWA Strategic Plan

- Accelerate the development of IC
- Increase awareness and encourage acceptance
- Conduct needed research to clarify the advantages and appropriate uses of the technology
- Provide organizational support for the process of developing intelligent compaction technologies

IC – Goals / Benefits



- **Short Term**

- Improve density... better performance
- Improve efficiency... cost savings
- Increase information... better QC/QA



A stylized landscape with a road leading to a sunset. The sky is dark blue at the top, transitioning to a bright yellow sun setting behind black silhouettes of mountains. The foreground consists of green rolling hills and a grey road with a dashed white center line that recedes into the distance.

Thank you!

Intelligent Compaction Technology

An Innovation in Compaction Control and Testing