IOWA STATE UNIVERSITY

Center for Earthworks Engineering Research

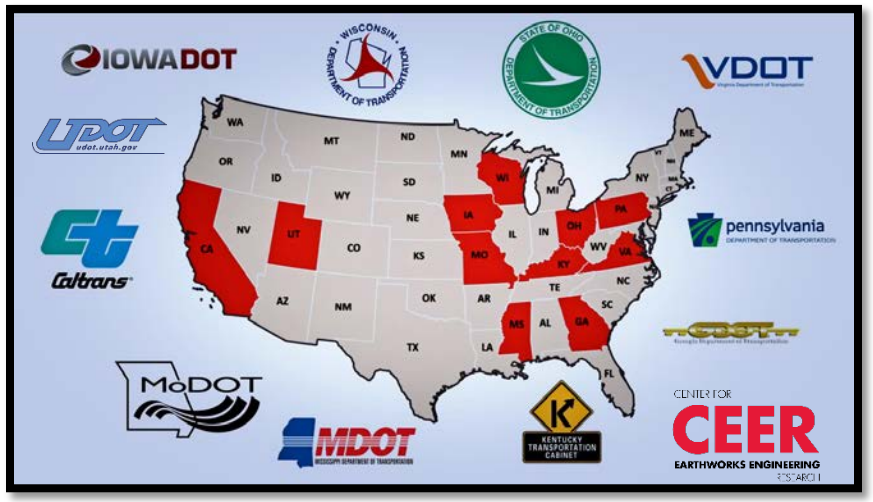
Intelligent Compaction

for Soils, Aggregate, and HMA

Original: October 20, 2014
Updated: February 16, 2015

David J. White, Ph.D., P.E.
Richard L. Handy Professor of Civil Engineering
Director, CEER
Department of Civil, Construction and Environmental Engineering
Iowa State University, 515.294.1463
djwhite@iastate.edu

Pavana K. R. Vennapusa, Ph.D., P.E.
Research Assistant Professor of Civil Engineering
Assistant Director, CEER
Department of Civil, Construction and Environmental Engineering
Iowa State University, 515.294.2935
pavanv@iastate.edu



Technology Transfer for Intelligent Compaction Consortium (TTICC)
Federal Highway Administration Pooled Fundy Study TPF-5(233)

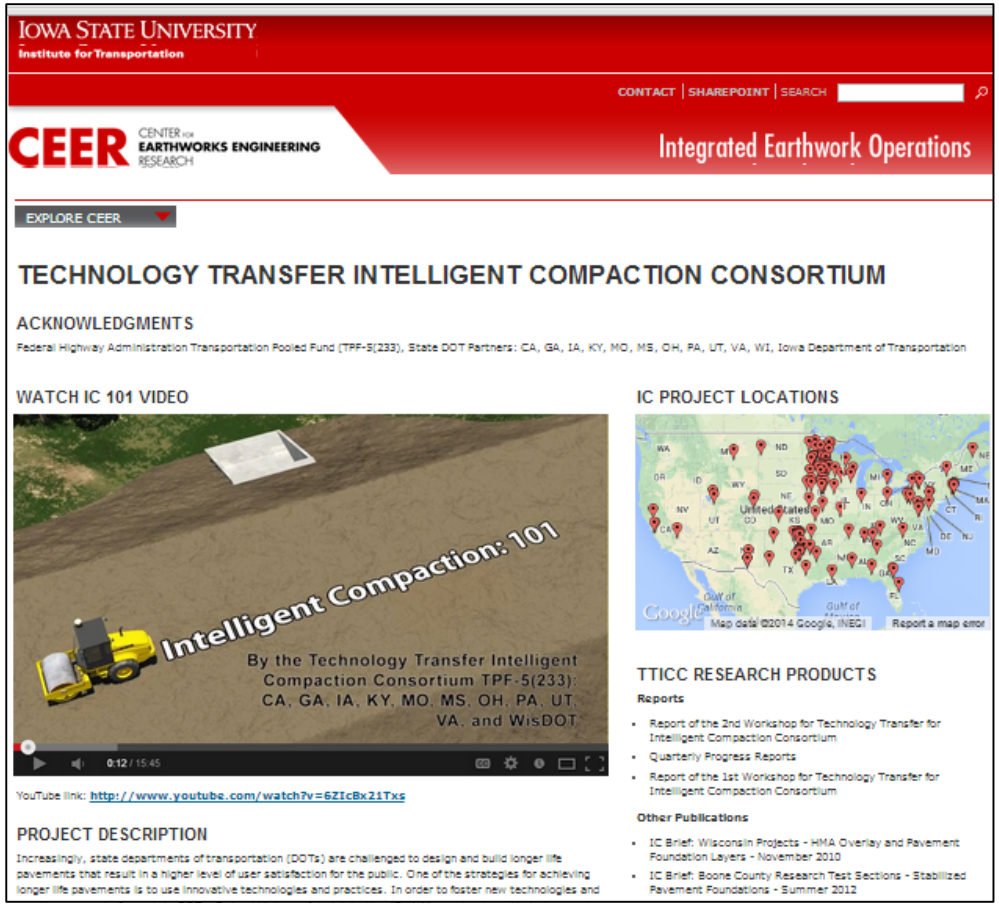
IC 101 video provides a broad overview of the technology – developed by TTICC

YouTube

Date Published: 1/31/2014

Statistics as of 2/16/2015 :
No. of views: 2,457
No. of Countries: 70

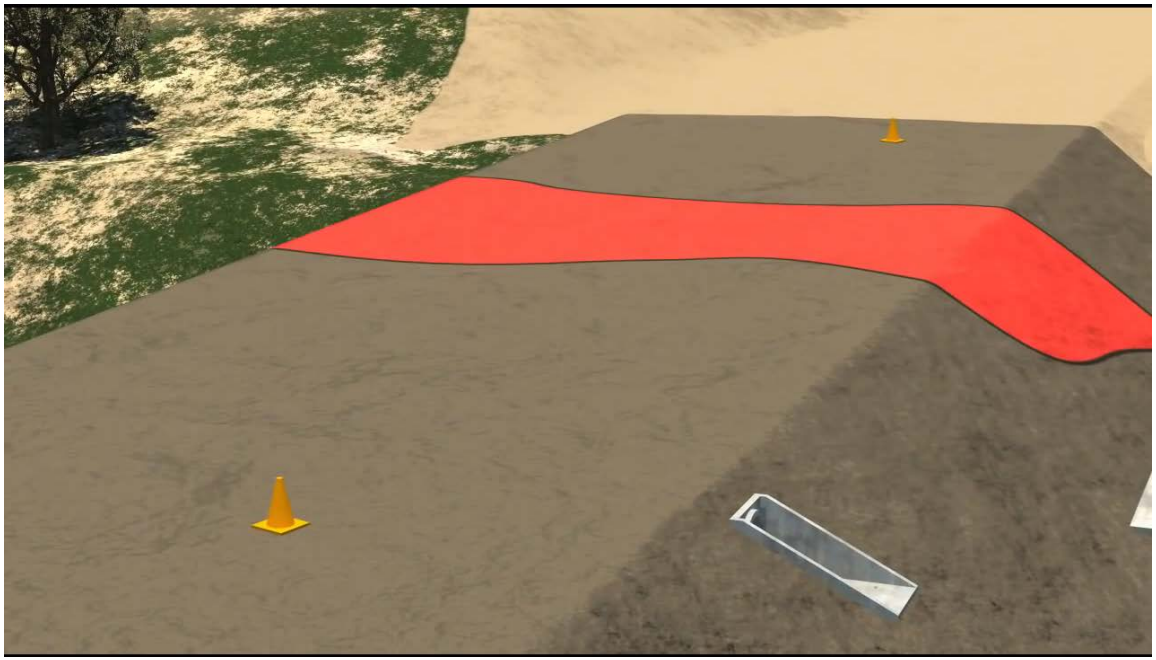
TTICC website hosts IC101 video, T2 summaries, and a database of IC projects



www.ceer.iastate.edu/tticc

IC technology presents a paradigm shift in earthwork construction QC/QA

- Traditional QC/QA @ 1:1,000 to 1,000,000 ft^3 to 1:1 using IC measurements



Random testing can be a hit and miss proposition in catching “weak” areas during construction

IC rollers for soils and aggregates

Caterpillar:
CMV, RMV, MDP

Dynapac:
CMV, BV

Bomag: E_{VIB}

IC rollers for soils and aggregates

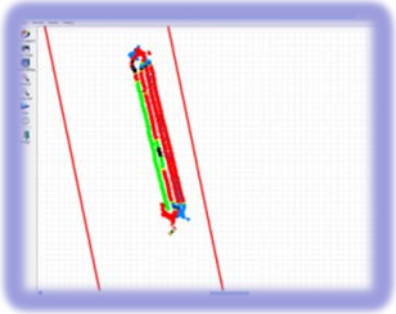
Volvo: CMV

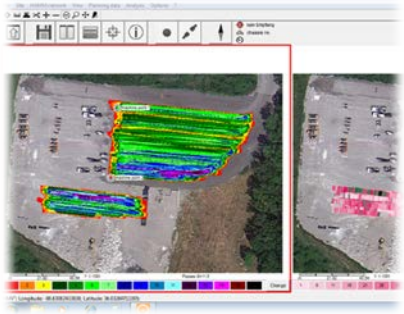
Sakai: CCV

Case/Ammann: k_s

Hamm: CMV/OMV

IC rollers for HMA





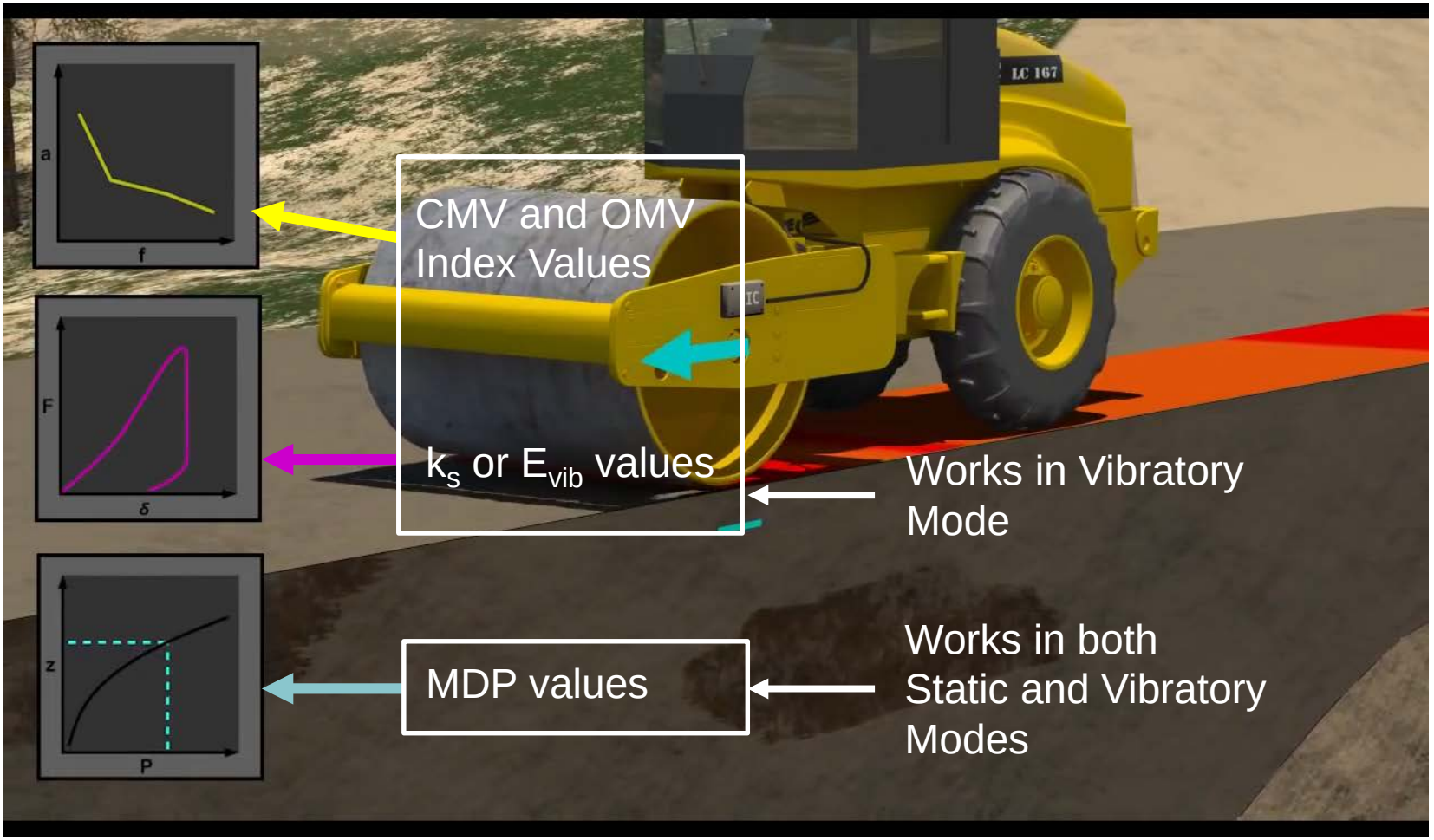
Caterpillar:
CMV, Temp, Pass Count

Bomag:
E_{VIB} , Temp, Pass Count

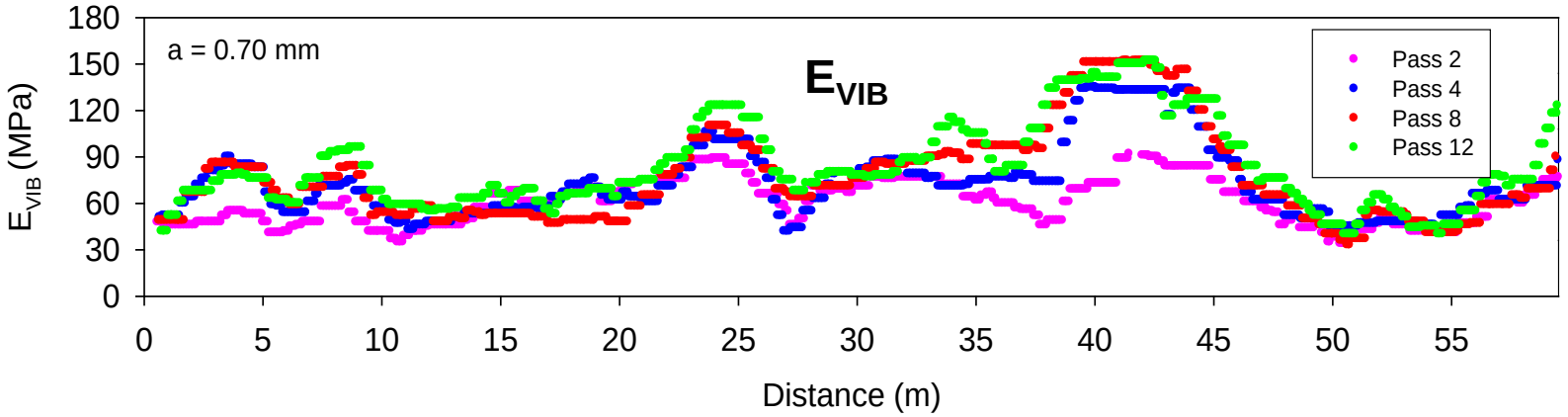
Sakai:
CCV, Temp, Pass Count

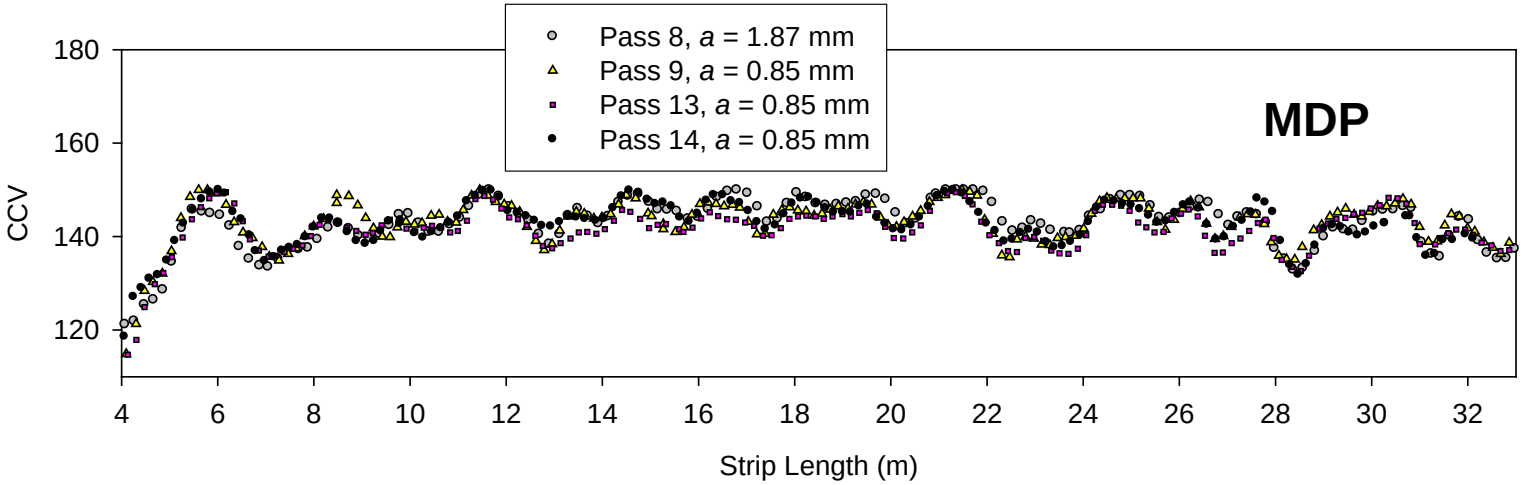
Hamm:
CMV, Temp, Pass Count

Overview of different IC measurements for Soils, Aggregate, and HMA



IC measurements provide repeatable measurements





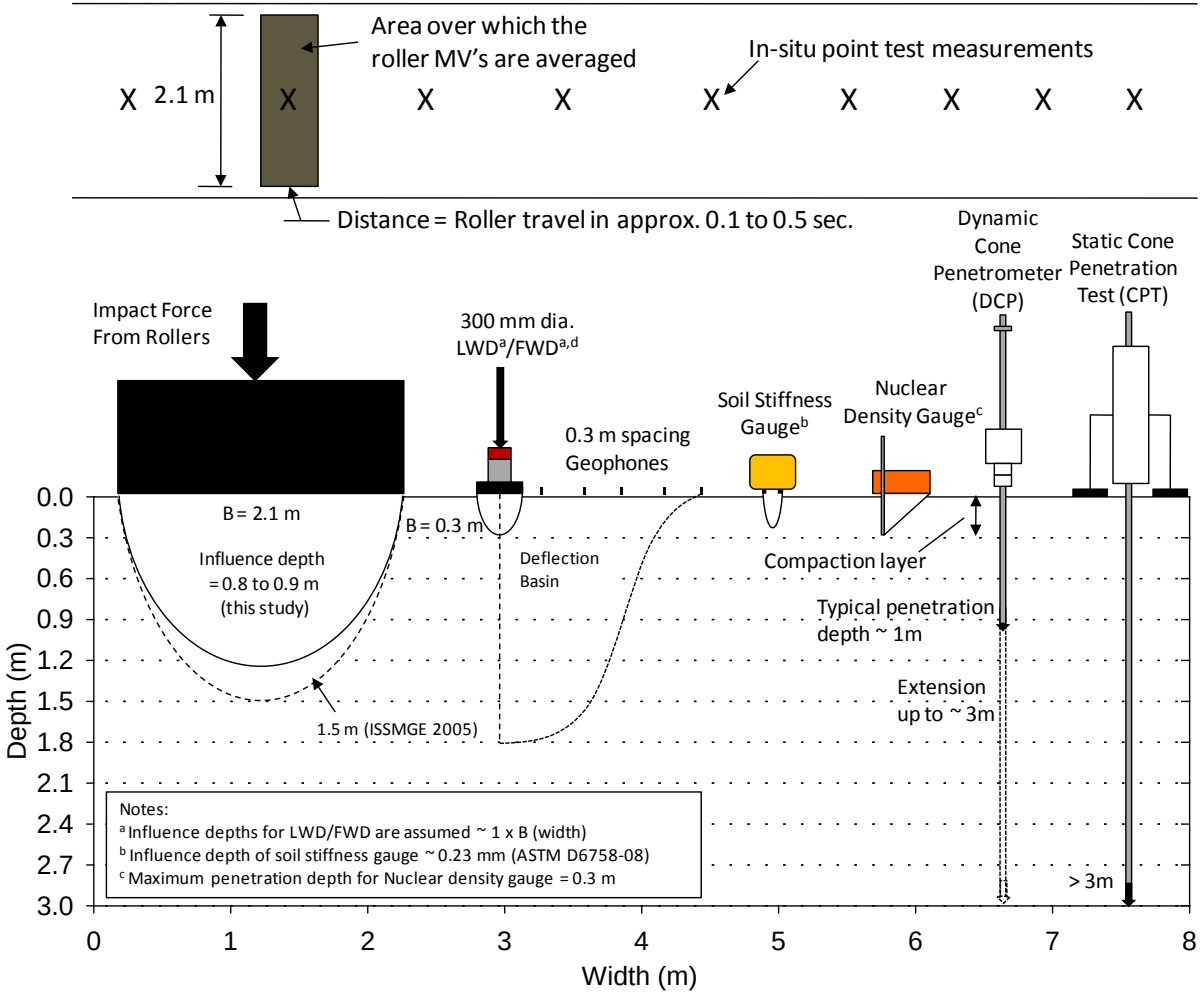
IC measurements are empirically related to:

- Stiffness / Modulus
- Shear Strength
- Moisture content
- Dry Density - in limited scenarios!

IC measurements are influenced by:

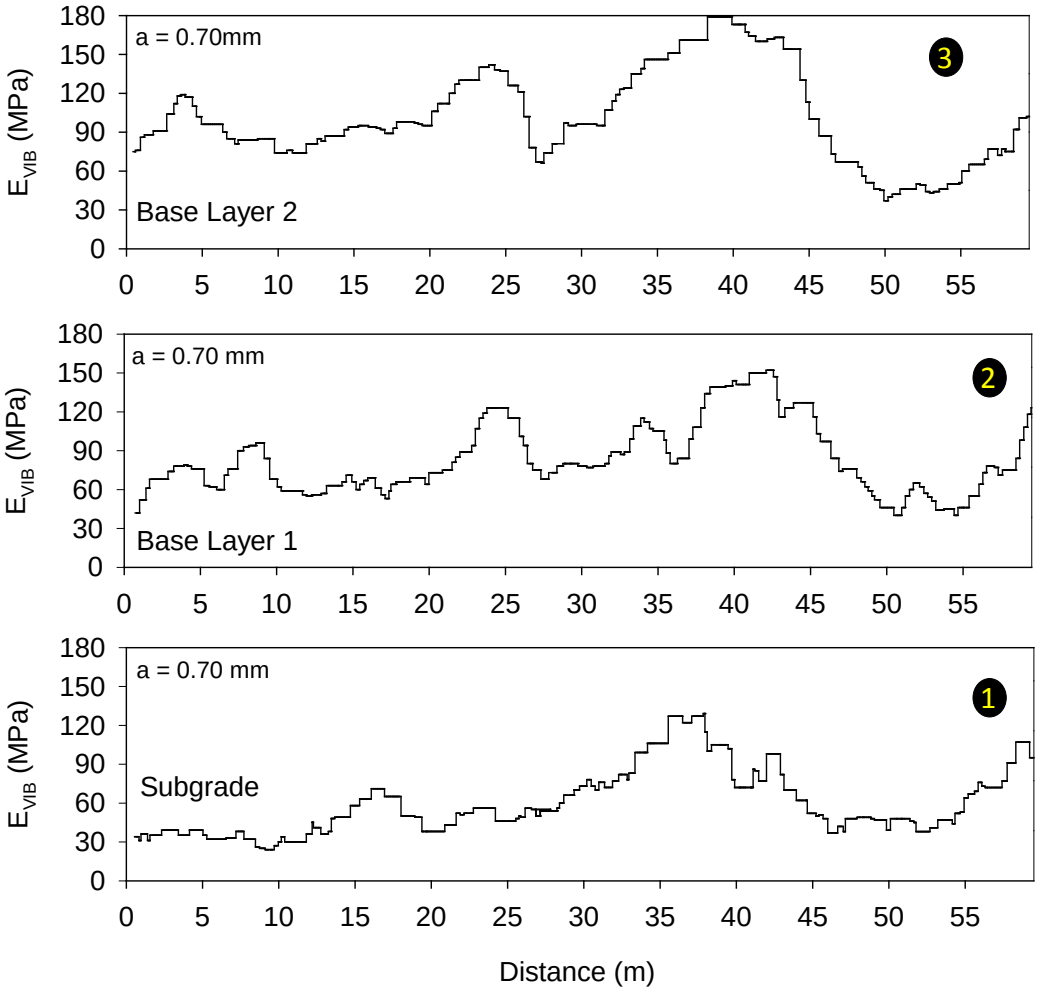
- Roller size
- Vibration amplitude & frequency
- Roller speed
- Soil type and stratigraphy

IC measurements have a deeper measurement influence depth than other *in situ* tests

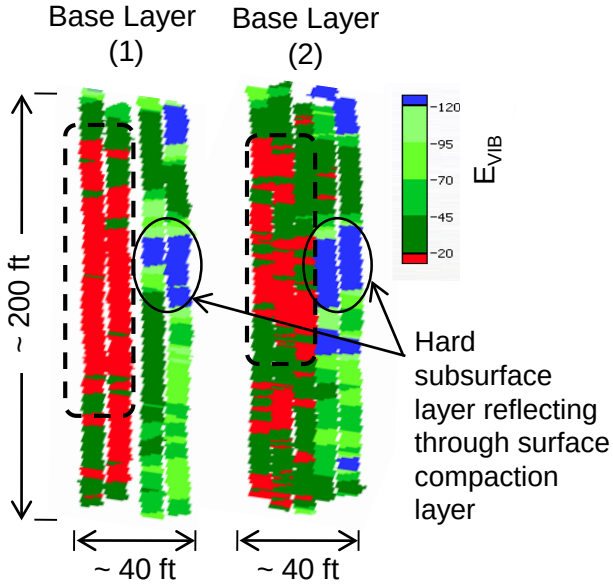


Vennapusa et al. (2012)

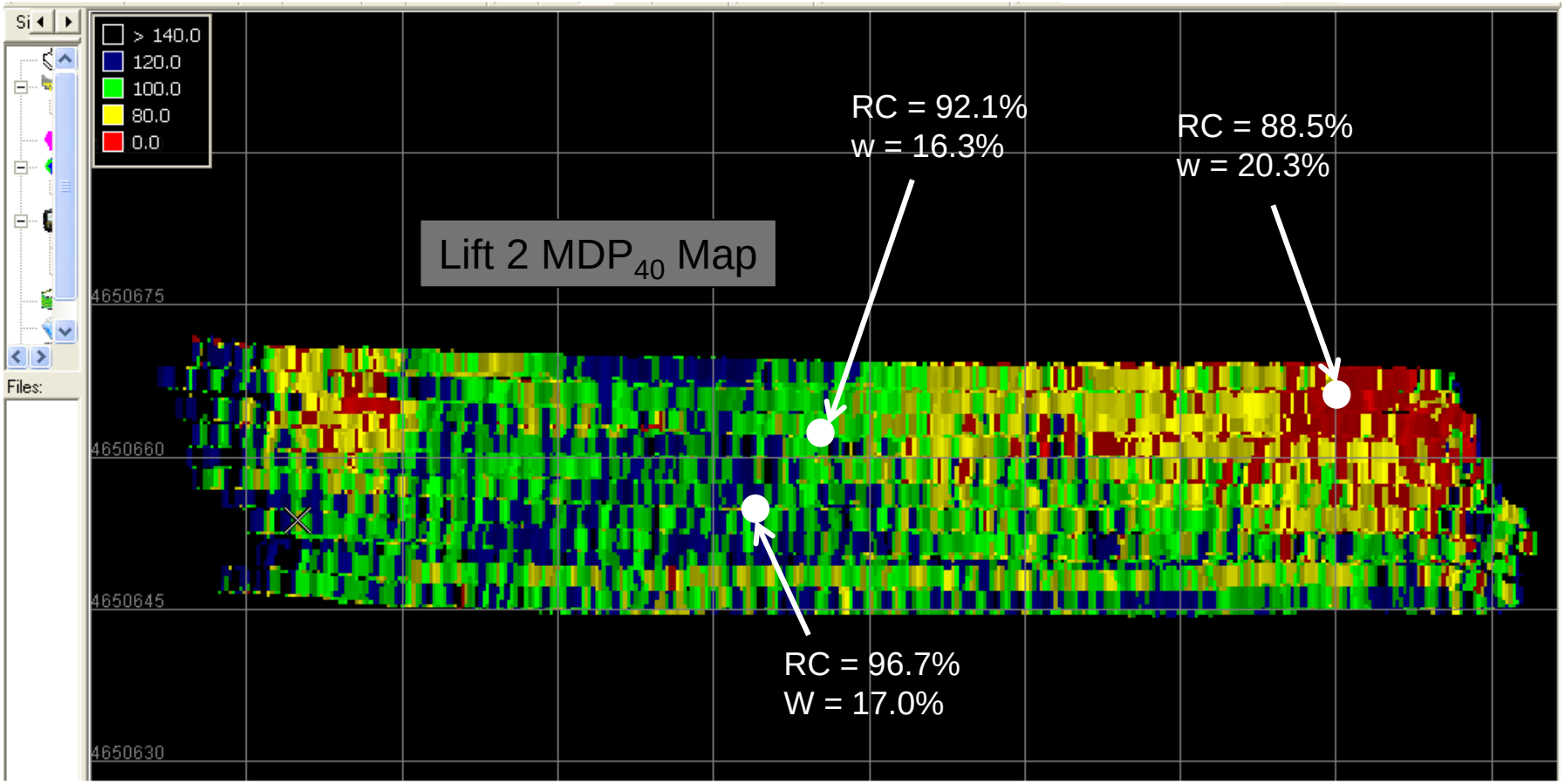
“Weak” areas in subgrade reflect to the surface



Aggregate Base – Base Layer 2 (6 inches)	3
Aggregate Base – Base Layer 1 (6 inches)	2
Clay Subgrade – Subgrade (10-12 inches)	1

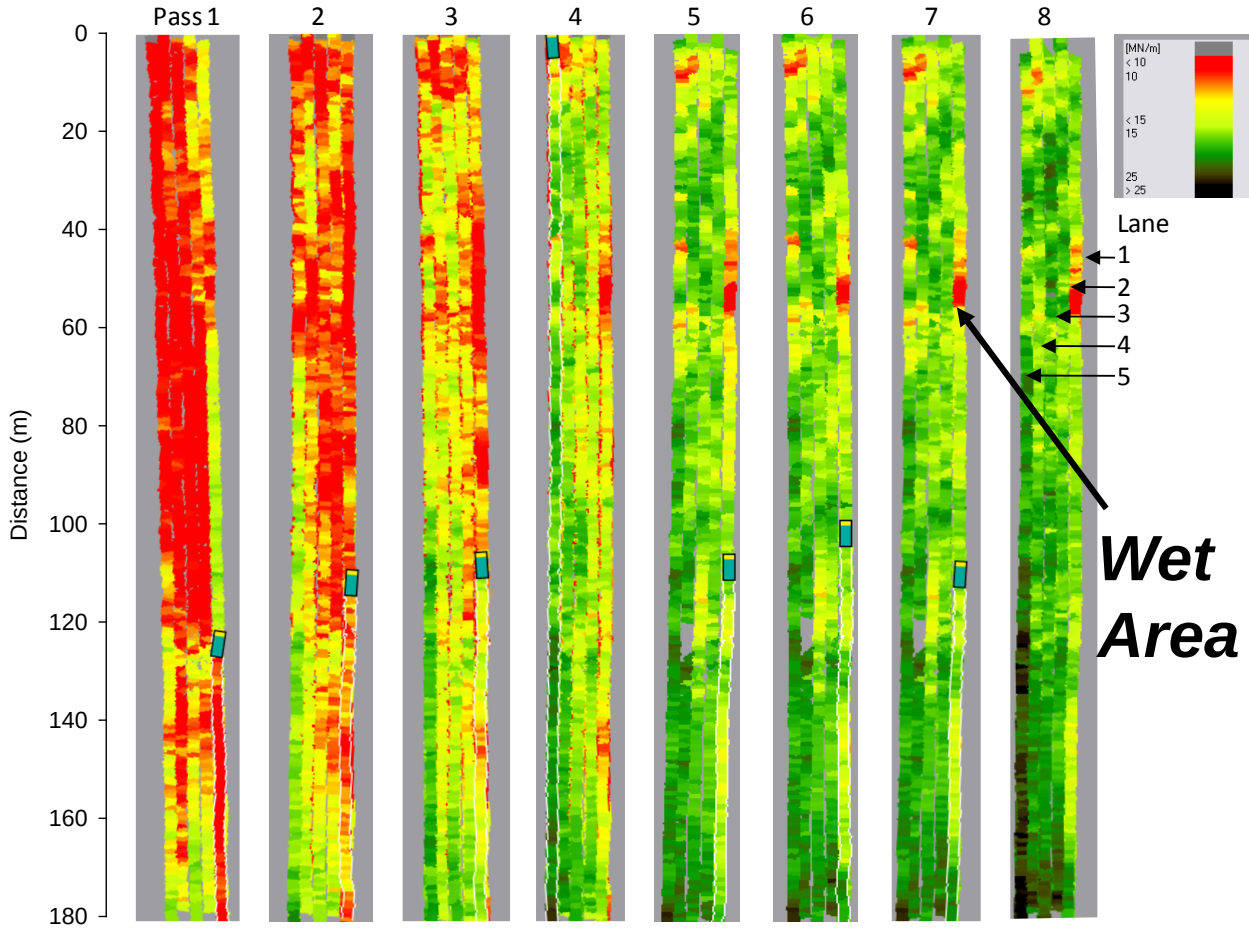


IC output on cohesive embankment construction project show soft area with higher moisture content



White et al. (2010)

IC measurements over eight passes on lime stabilized subgrade show compaction improvement

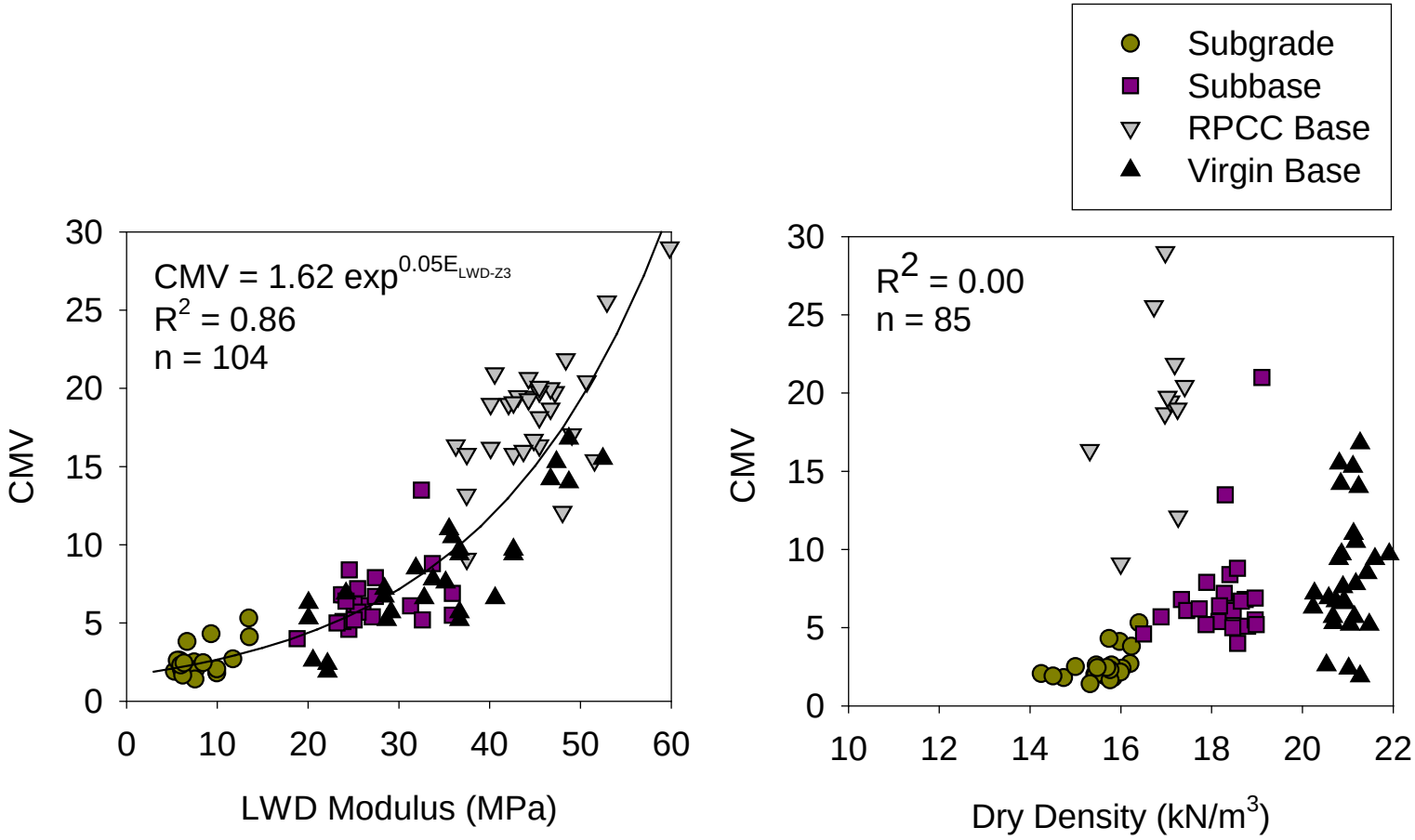


White et al. (2008)

IC measurements identified isolated concrete culvert beneath the base layer

White et al. (2010)

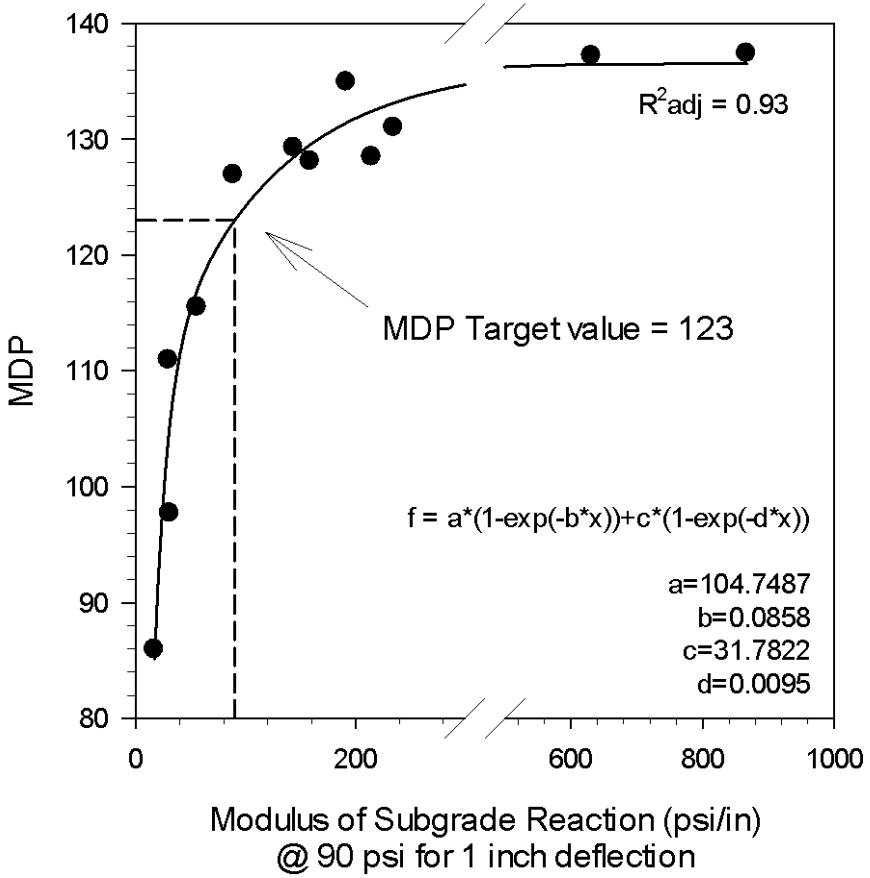
IC measurements correlate better with modulus compared to density measurements

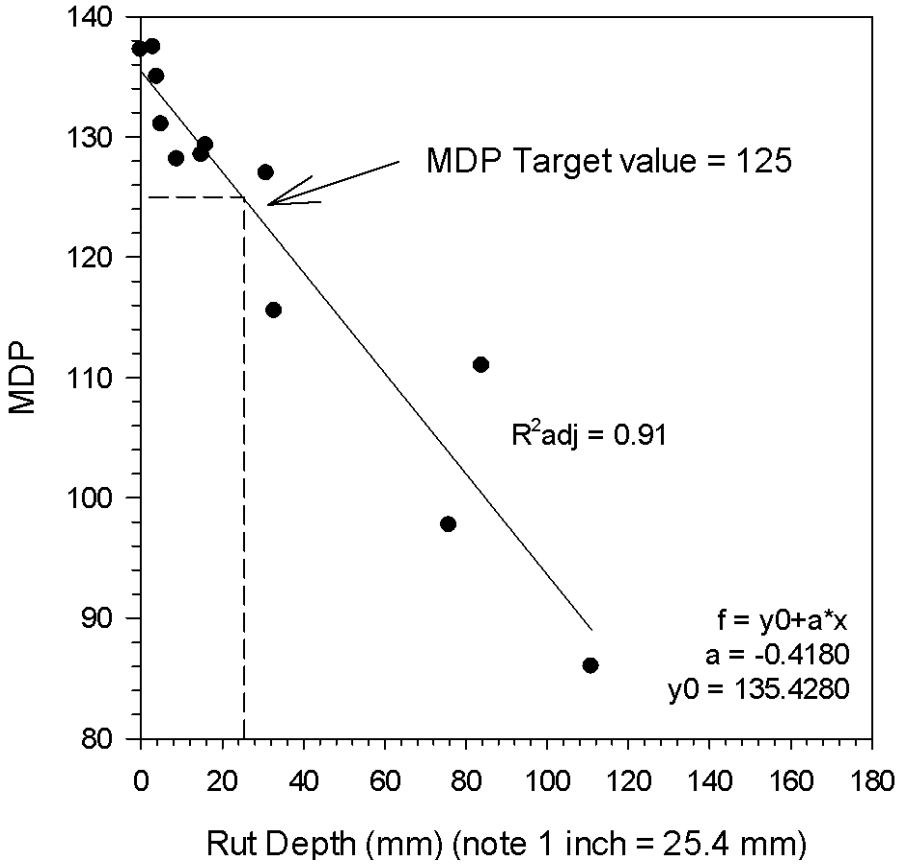


White et al. (2010)

IC measurements are related to rut measurements and plate load test moduli

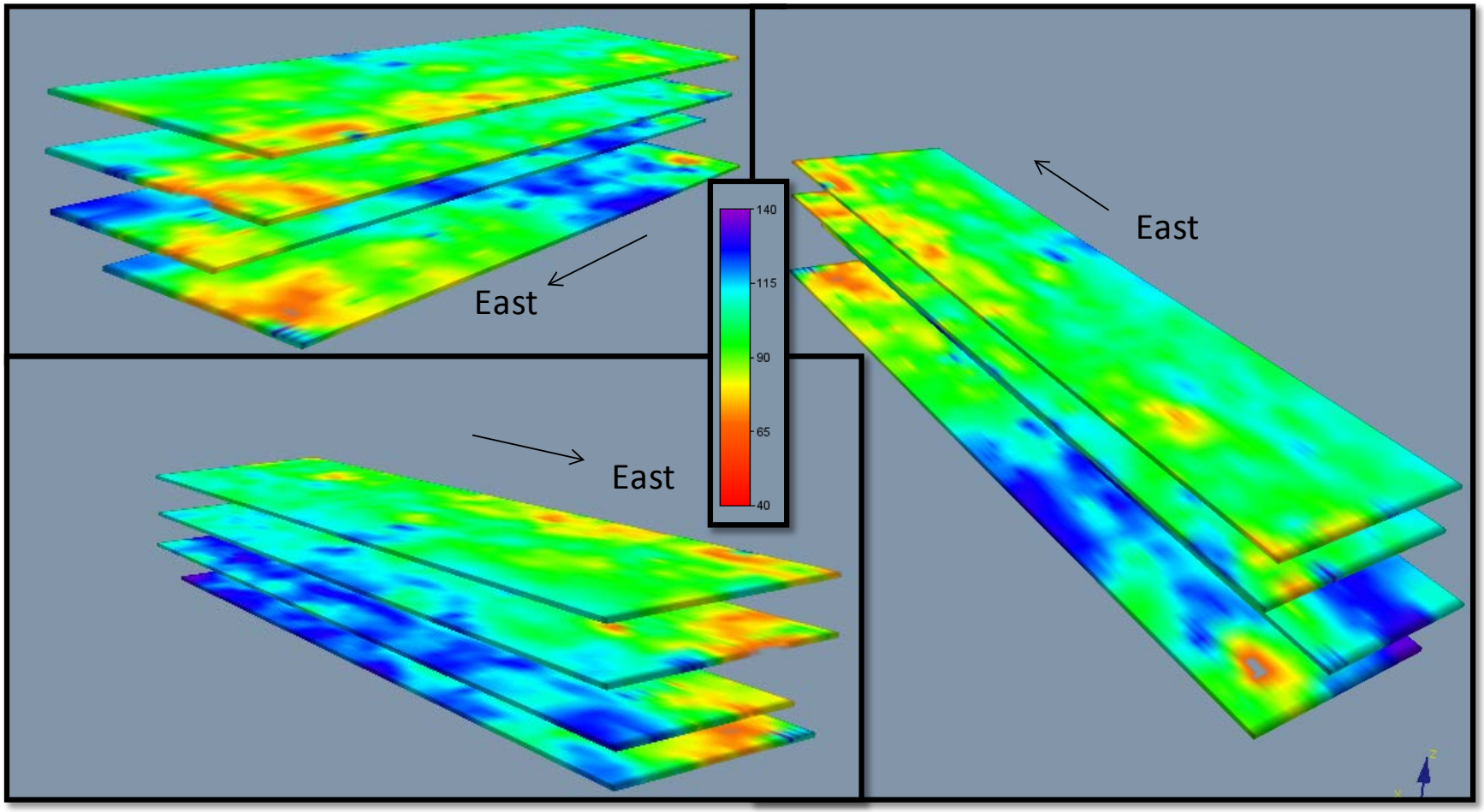
IC measurements are related to rut measurements and plate load test moduli





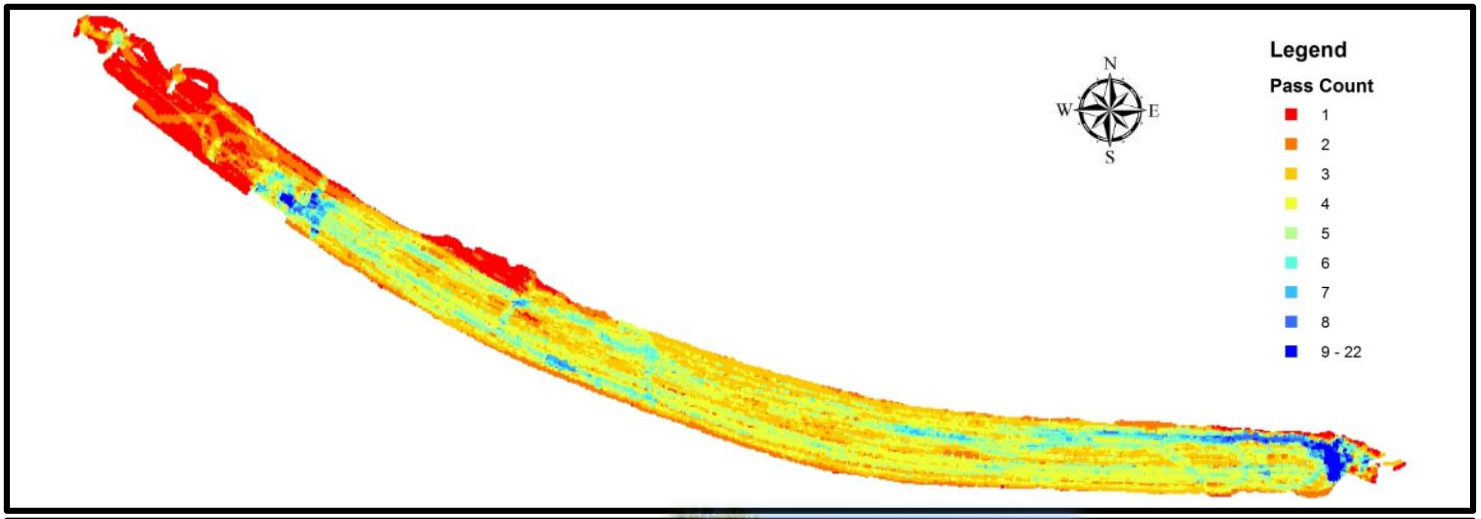
White and Vennapusa (2013)

IC data on multiple embankment layers provides the opportunity for 3D visualization of the data



White et al. (2010)

IC roller pass coverage and MDP values on cohesive embankment project



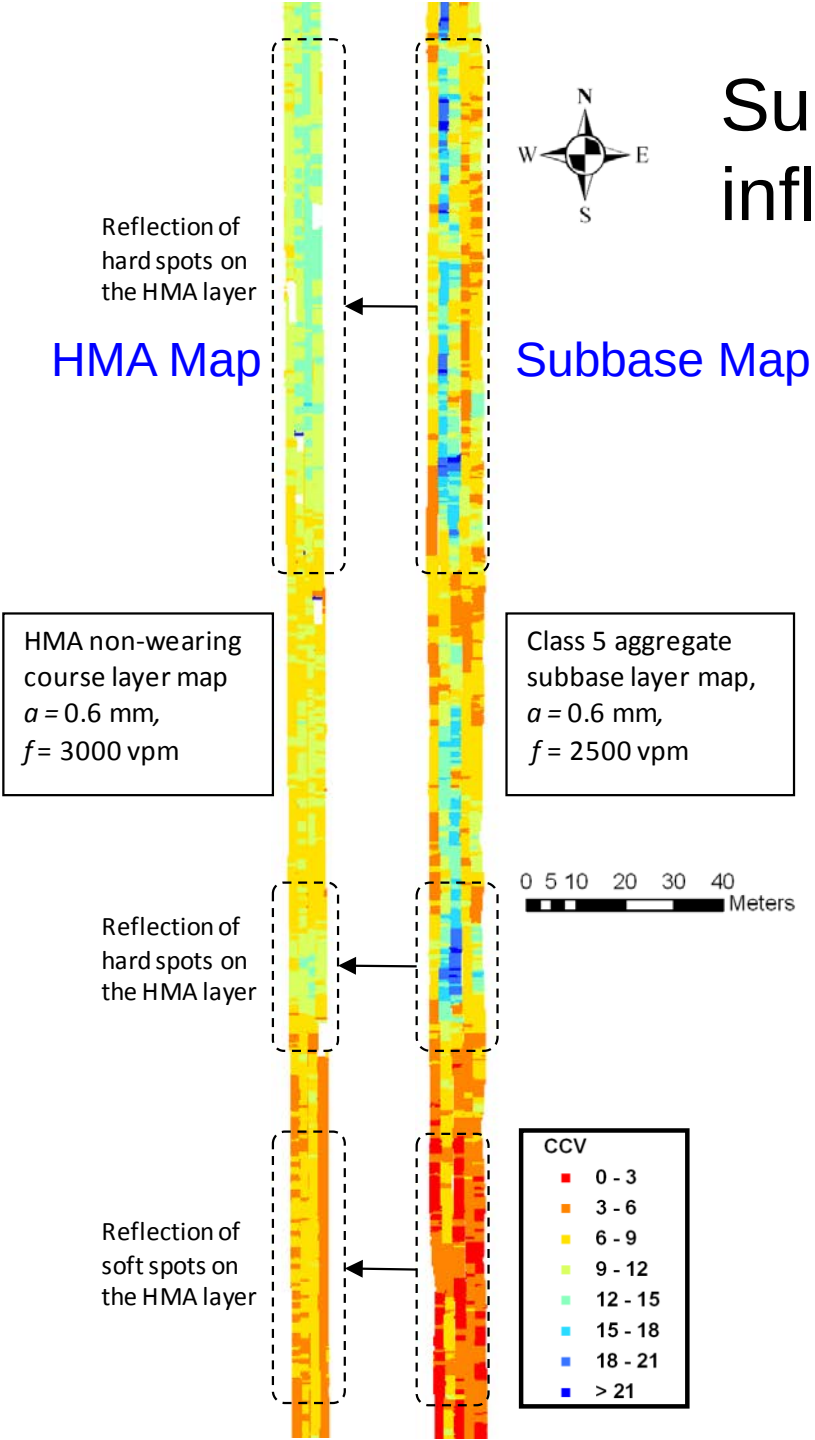
Perspective from contractor after using the IC roller on an earthwork project in Iowa

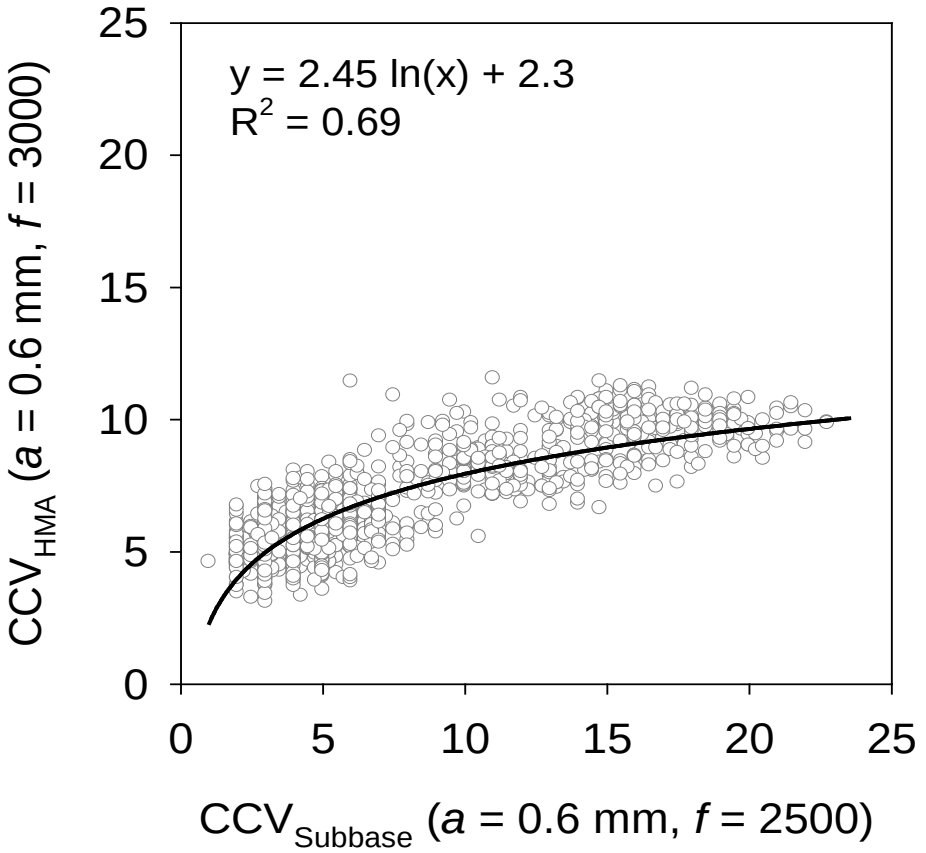
- "You can add a lot of road life with (road base) uniformity," Taylor said. "States spend a lot of their transportation money on maintenance. If the base has no weaknesses, you'll only have to replace a wear course from time to time. That is a huge cost savings at a time when every dime is being watched."

- "Most of those passes are a waste," Taylor said. "Many times on jobsites, we could probably get compaction densities with haul trucks. We might not even need rollers. But the specs call for eight passes, so we make them."

- "You can't leave technology like this on the shelf," he said. "You would have better measurements, and better roads, at a lower cost. Those are tough points to argue."

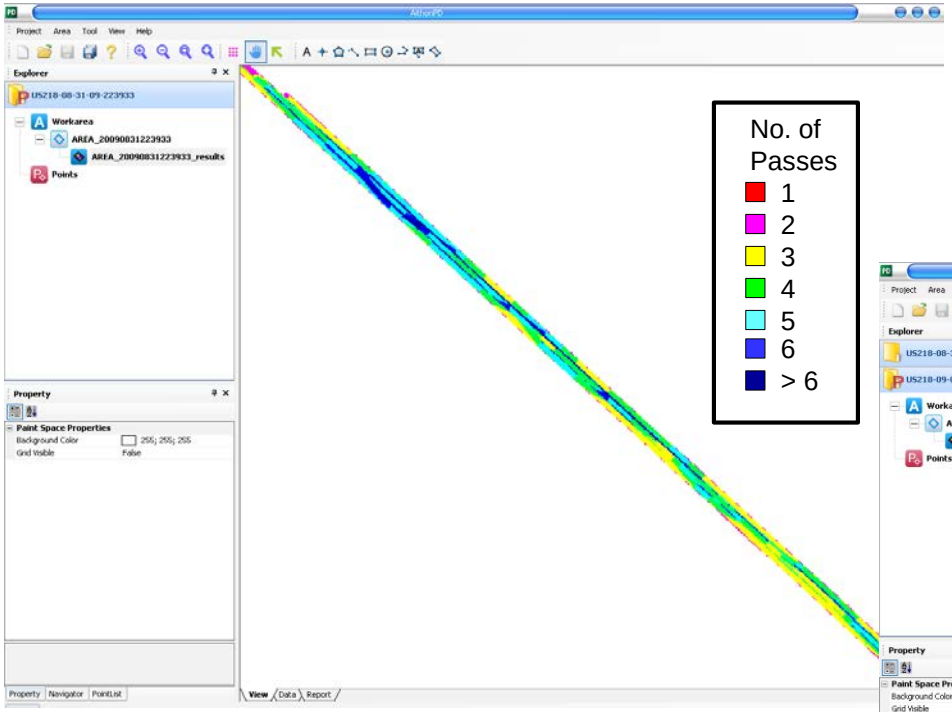
Subbase layer conditions show influences values on HMA layer





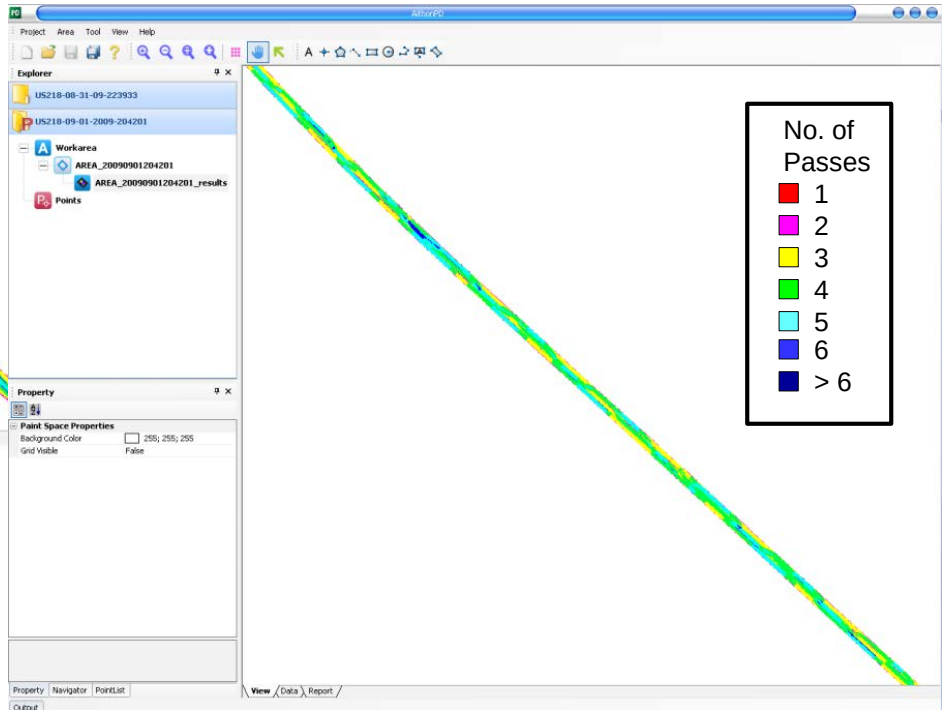
White and Vennapusa (2008)

Roller pass coverage can be improved using IC data on HMA pavements



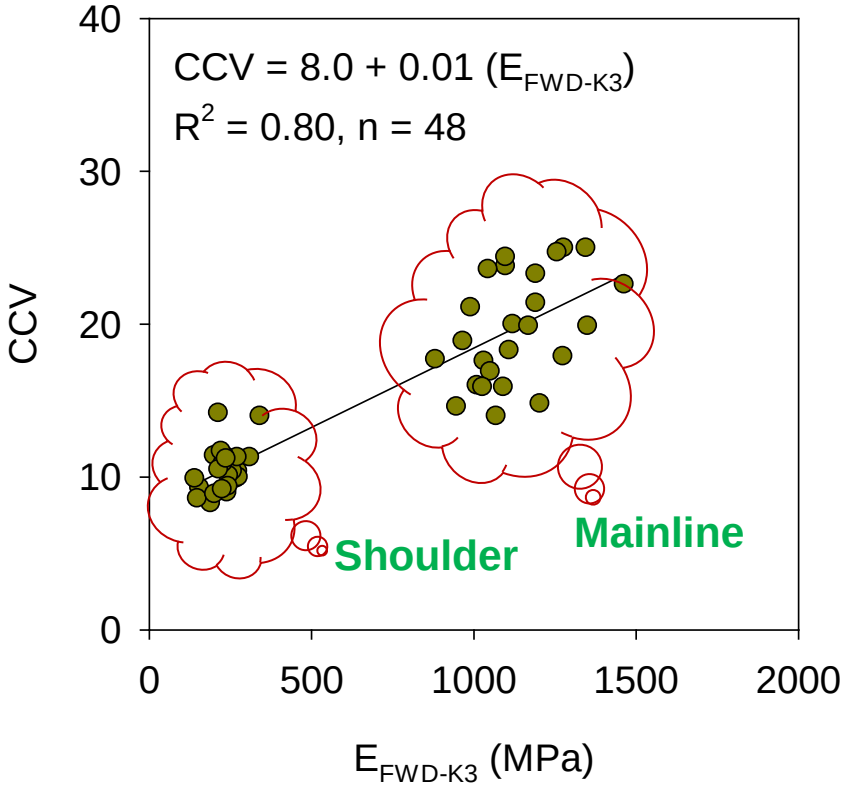
08/31/09 Blind Study – Pass Coverage Map

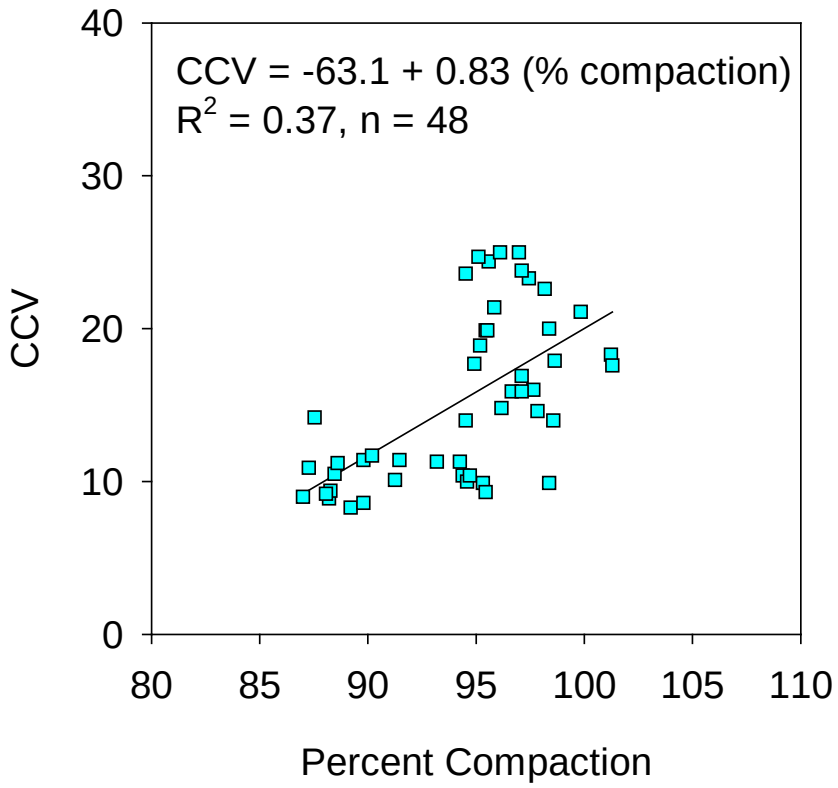
09/1/09 Using On-Board Monitor – Pass Coverage Map



White et al. (2011)

IC measurements correlate better with modulus compared to density



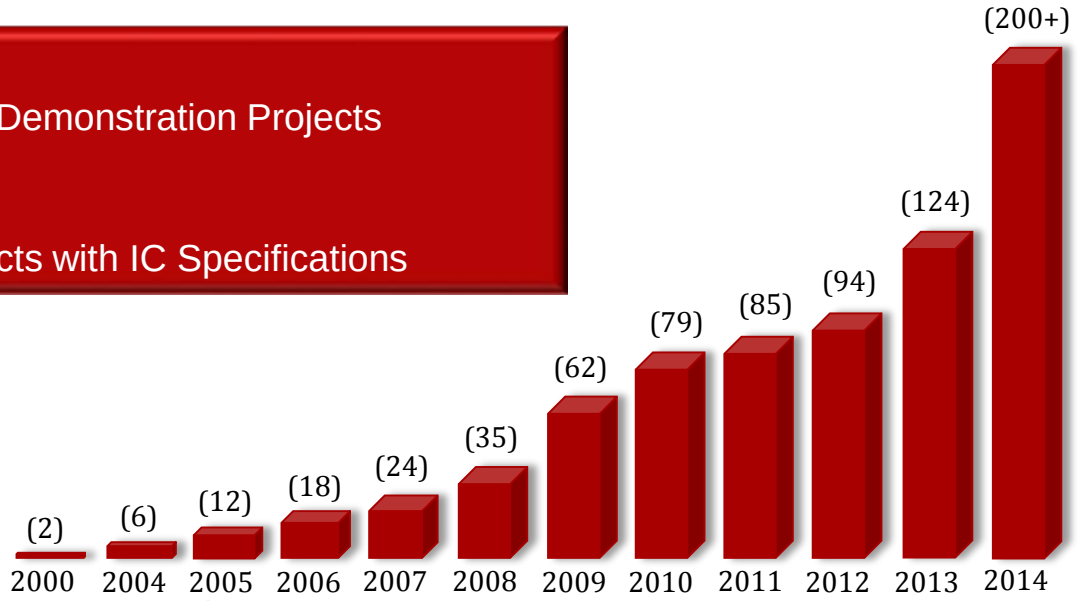


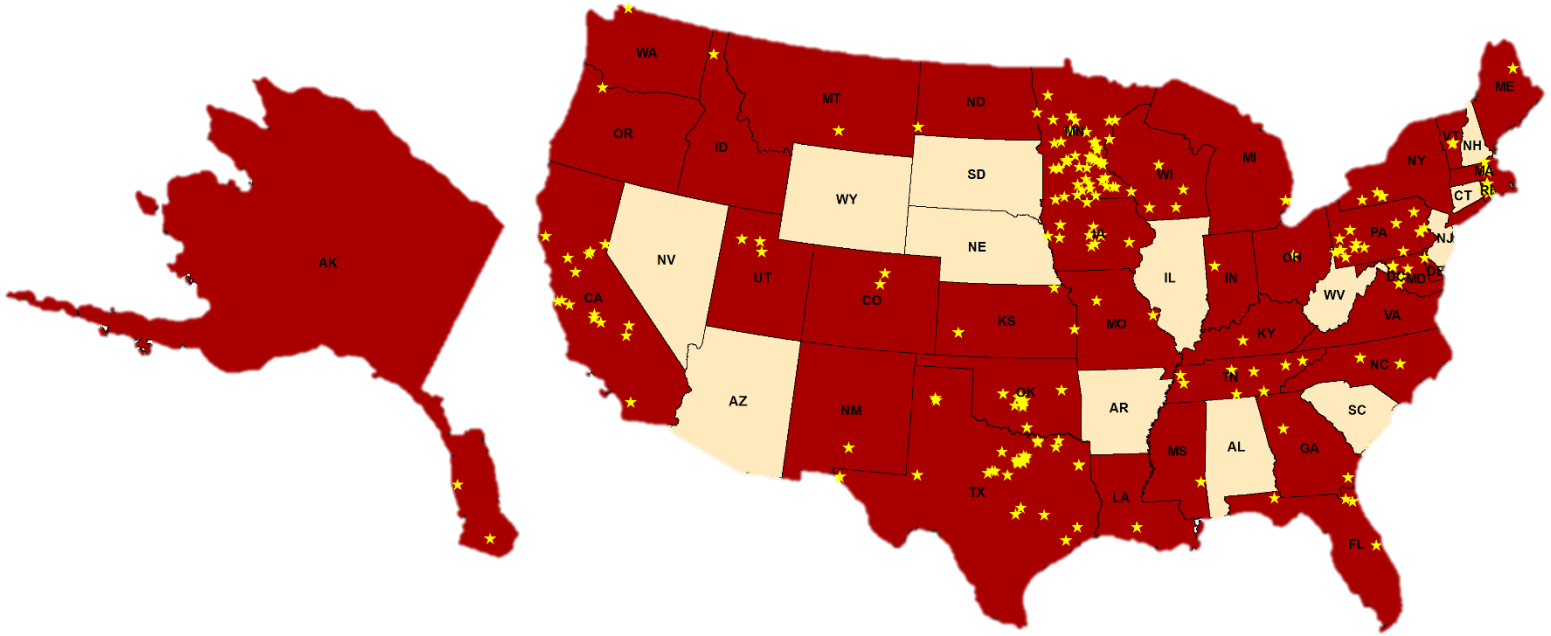
Results on HMA project on US218 Overlay Project, Iowa White et al. (2011)

70+
Research/Demonstration Projects

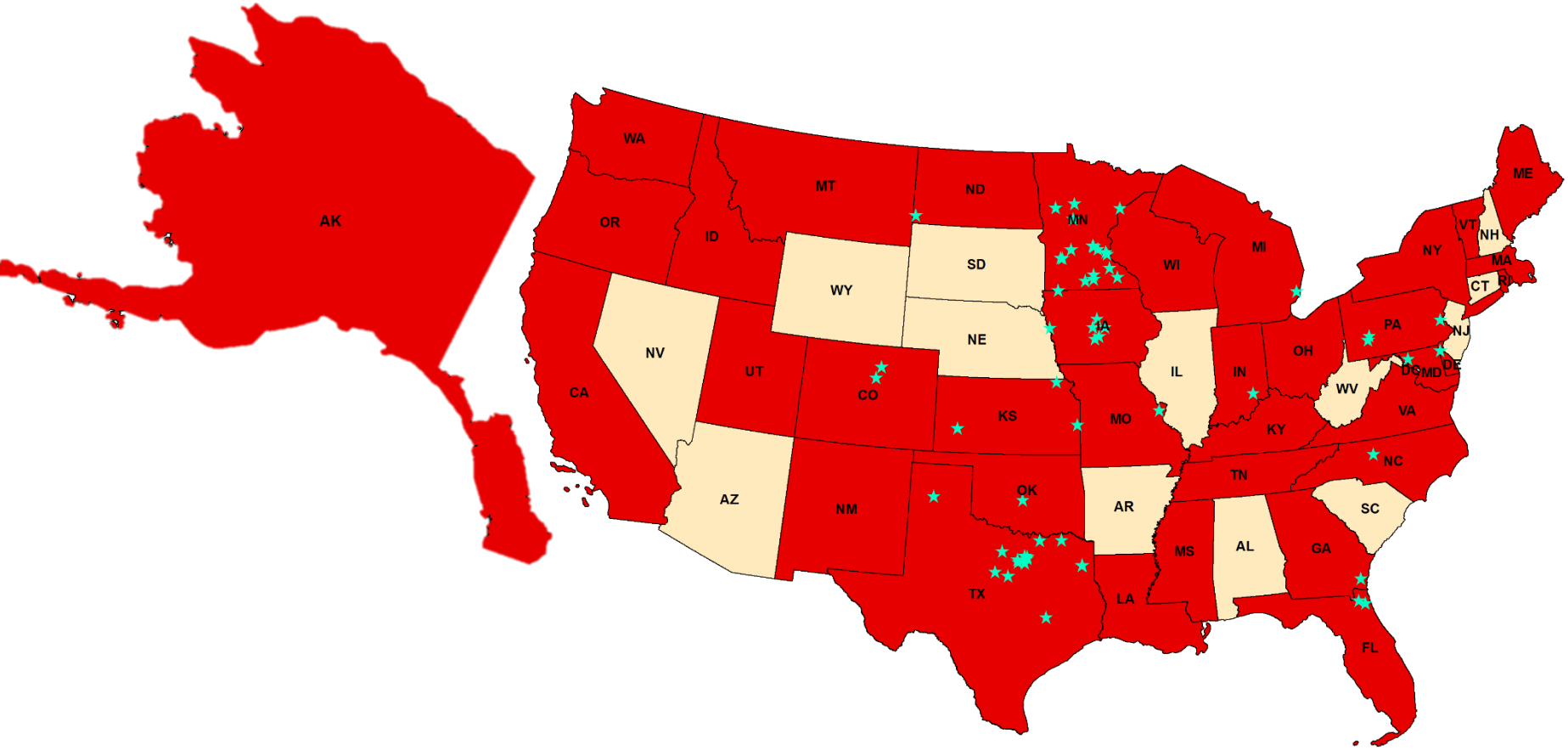
130+
Pilot Projects with IC Specifications

Cumulative Number of Projects

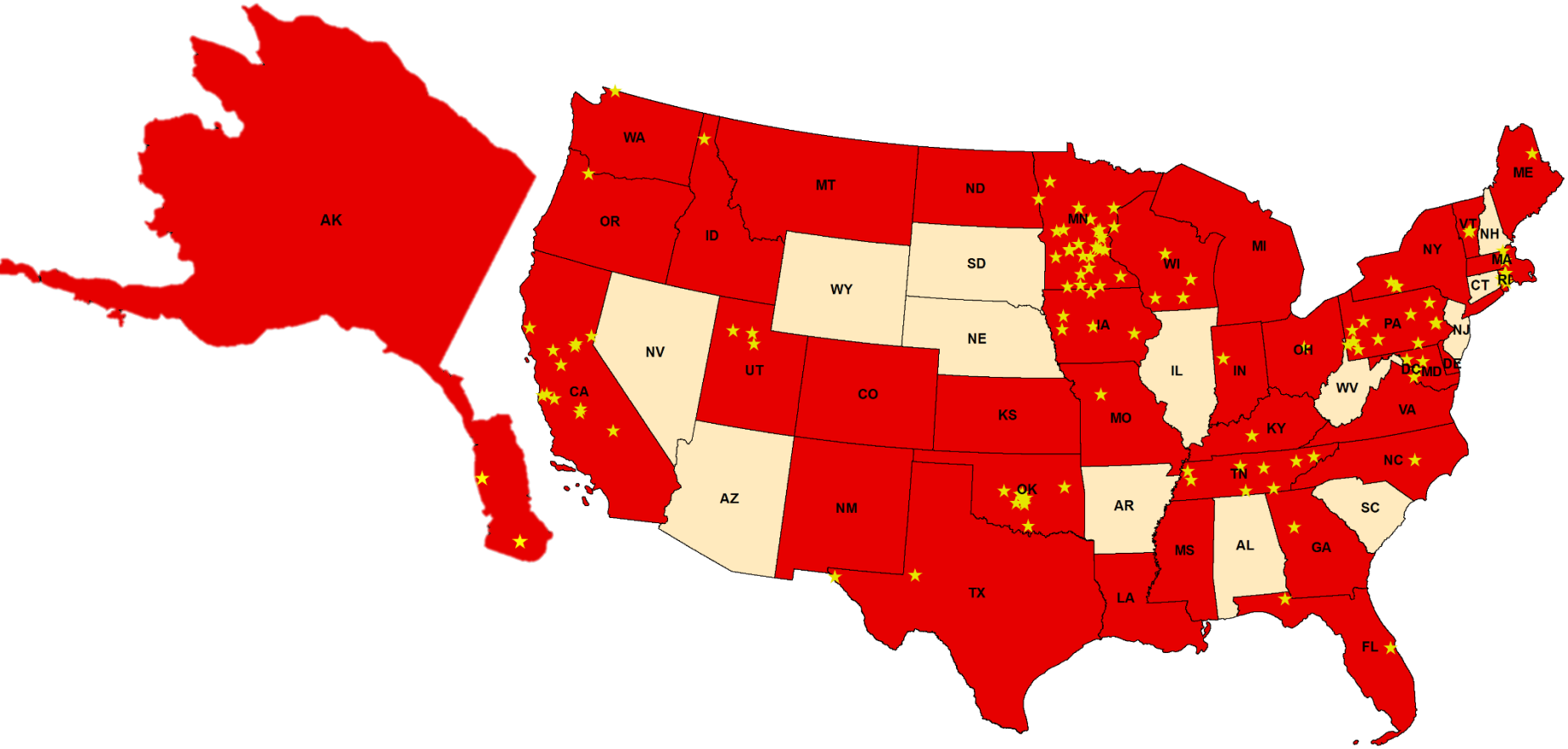




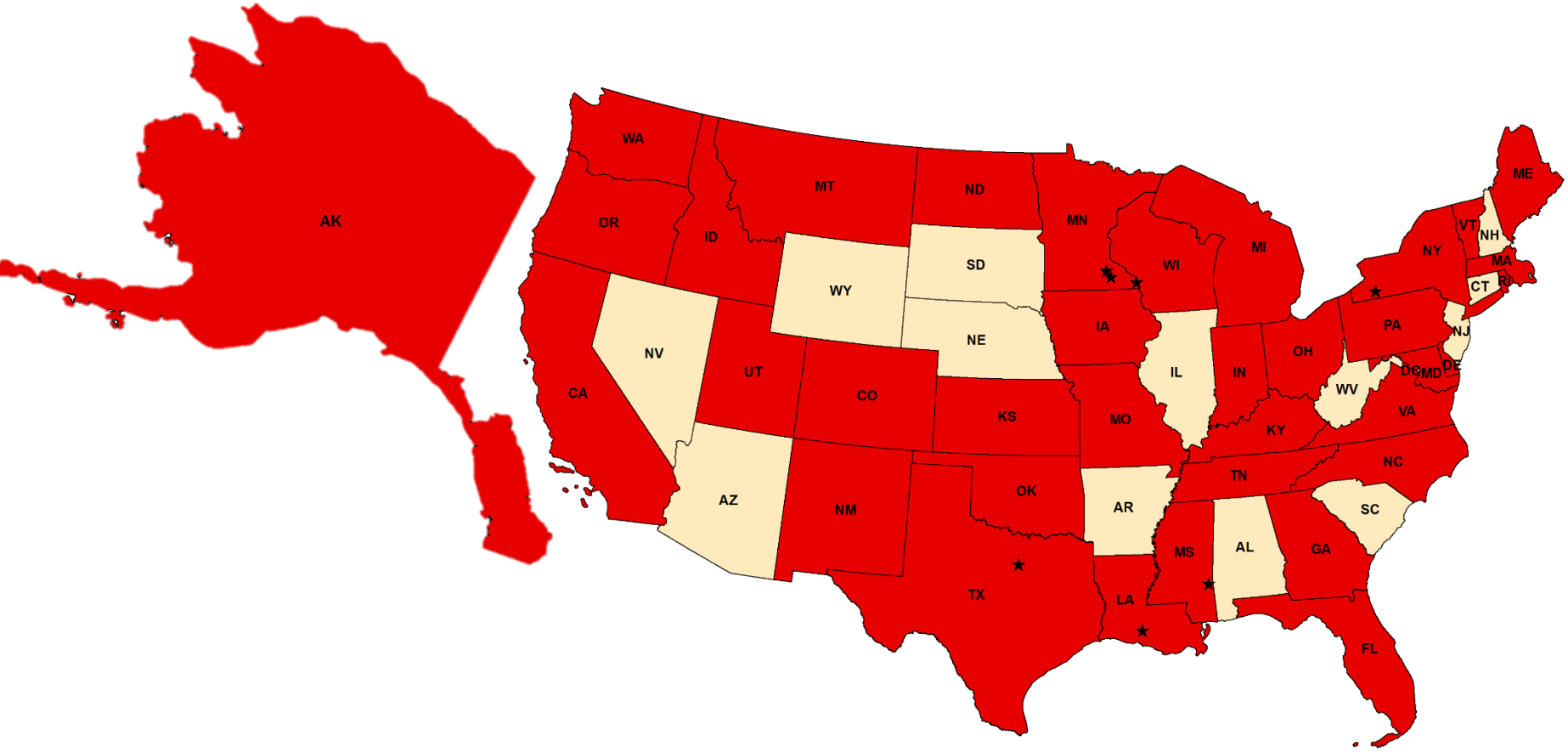
IC Earthwork Projects in US: 63



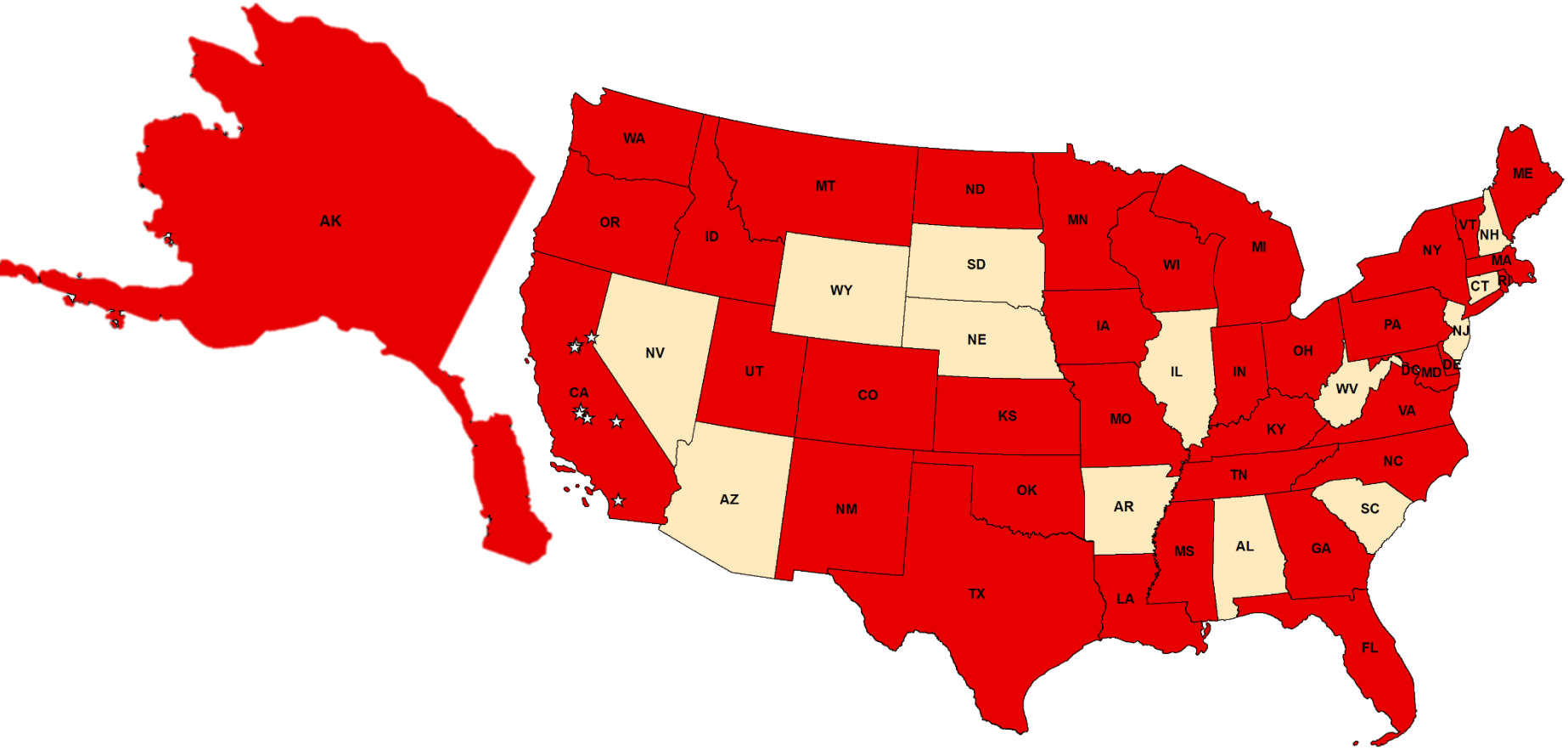
IC HMA Projects in US: 121



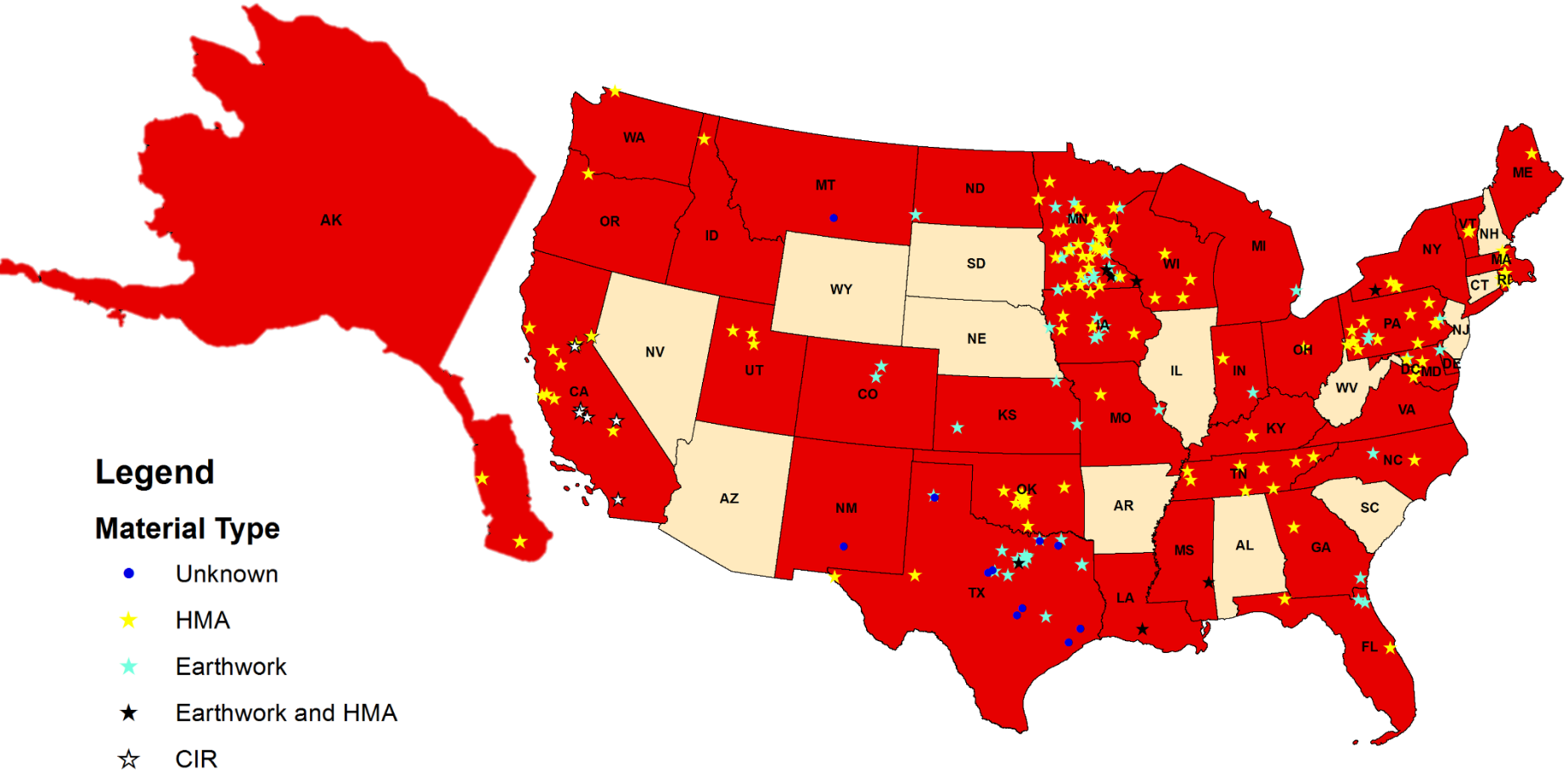
IC HMA & Earthwork Projects in US: 9



IC CIR Projects in US: 9



All IC Projects in US: 212



IC specifications for Soils and HMA in U.S.

Developed By	HMA (Year)	Soils (Year)
Alaska DOT	Yes (2013)	No
California DOT	Yes (2014)	No
Georgia DOT	Yes (2012)	Yes (2012)
Iowa DOT	Yes (2013)	Yes (2010)
Indiana DOT	Yes (2014)	No
Massachusetts DOT	Yes (2013)	No
Minnesota DOT	Yes (2014)	Yes (2014)
Missouri DOT	No	Yes (2009)
North Carolina DOT	Yes (2013)	Yes (2012)
Nevada DOT	Yes (2012)	No
Oklahoma DOT	Yes (2014)	No
Pennsylvania DOT	Yes (2014)	No
Rhode Island DOT	Yes (2013)	No
Tennessee DOT	Yes (2013)	No
Texas DOT	No	Yes (2013)
Utah DOT	Yes (2013)	No
Vermont DOT	Yes (?)	Yes (?)
SHRP2 R07	No	Yes (2014)
FHWA (Generic Specs)	Yes (2014)	Yes (2014)

IC increases cost as bid item…what's it worth?

+1.1%

Source: White, D.J., Vennapusa, P., Harland, J., Quist, S. (2011). *Iowa DOT Roller Integrated Compaction Monitoring Technology Research and Implementation – Phase II (Hot Mix Asphalt)*, Final Report, Center for Earthworks Engineering Research, Iowa State University, Ames, Iowa. http://www.intrans.iastate.edu/reports/Whiteet%20al.%202011_Iowa%20IC%20Phase%20II.pdf

Table 4. Top seven bid prices for implementing RICM-HMA SP on each project

Project	Bidder	Total Bid	% Over Low Bid	Cost for implementing RICM-HMA SP	% of Total Project Cost	Unit Cost/mile
SP-090048 (RICM coverage with roller pass count, temperature, and compaction data on one breakdown roller only)						
US30 Harrison County – 8.09 mile long two lane highway HMA resurfacing (RICM on breakdown roller Only)	**1***	**$3,637,427.50**	**0.00**	**$50,000**	**1.4**	**$6,180**
	2	$3,828,672.23	5.25	$4,000	0.1	$494
	3	$3,867,951.42	6.33	$50,000	1.3	$6,180
	4	$3,951,688.43	8.63	$116,652	3.0	$14,419
	5	$4,164,111.01	14.47	$150,000	3.6	$18,541
	6	$4,242,421.16	16.63	$136,500	3.2	$16,873
	7	$4,386,013.92	20.58	$30,000	0.7	$3,708
	Average	$4,011,183.67	10.27	$76,736	1.9	$9,485
	Std. Dev.	$224,249.22	6.17	$60,997	1.5	$7,540
SP-090057a (RICM coverage with roller pass count and temperature on one breakdown roller only)						
US20 Ida County – 11.20 mile long two lane highway HMA resurfacing (RICM on breakdown roller Only)	**1**	**$3,975,334.01**	**0.00**	**$35,000**	**0.9**	**$3,125**
	2	$4,152,496.87	4.45	$5,000	0.1	$446
	3	$4,216,738.94	6.07	$20,000	0.5	$1,786
	4	$4,282,603.28	7.72	$50,000	1.2	$4,464
	5	$4,621,687.46	16.25	$30,000	0.6	$2,679
	Average	$4,249,772.11	6.90	$28,000	0.7	$2,500
	Std. Dev.	$237,312.48	5.97	$16,808	0.4	$1,501
SP-090058 (RICM coverage with roller pass count on all compaction equipment)						
IA 9 Kossuth County – 10.73 mile long two lane highway HMA resurfacing (RICM on full compaction train)	**1**	**$4,062,409.63**	**0.00**	**$40,000**	**1.0**	**$3,728**
	2	$4,179,222.66	2.87	$68,000	1.6	$6,337
	3	$4,521,721.37	11.30	$10,000	0.2	$932
	4	$4,632,077.66	14.02	$100,000	2.2	$9,320
	5	$4,679,072.51	15.17	$100,000	2.1	$9,320
	6	$4,771,151.13	17.44	$274,925	5.8	$25,622
	7	$5,259,900.22	29.47	$150,000	2.9	$13,980
	Average	$4,586,507.88	12.90	$106,132	2.2	$9,891
	Std. Dev.	$396,432.57	9.76	$87,139	1.8	$8,121

** Winning bidders indicated by #1 and highlighted in bold.*

IC Research/Implementation/Educational Element Ratings – TTICC 2008-2012

Rating	2008[1]	2009[2]	2010[3]	2011[4]	2012
1	**Correlations**	**Specifications**	**Correlations**	**Correlations**	**Data Management**
2	Education	**Correlations**	**Specifications**	**Specifications**	**Specifications**
3	Moisture Content Influence	Mechanistic QC/QA	Mechanistic QC/QA	**Data Management**	**Correlations**
4	**Data Management**	Non-Uniformity	IC Advancements	Demo Projects	Non-Uniformity
5	Demo Projects	**Data Management**	Demo Projects	Education	Output Standardization
6	Mechanistic QC/QA	Demo Projects	Non-Uniformity	Non-Uniformity	Sensor Calibration
7	Non-Uniformity	Influence Depth	**Data Management**	Output Standardization	Education
8	**Specifications**	IC Advancements	Output Standardization	Database	Influence Depth
9	Influence Depth	Education	Influence Depth	Mechanistic QC/QA	Demo Projects
10	Promoting Best Practices	Database	Education	Influence Depth	Mechanistic QC/QA
11	—	—	Database	IC Advancements	IC Advancements
12	—	—	Sensor Calibration	Sustainability	Database
13	—	—	—	Sensor Calibration	Sustainability

White et al. (2014)

IC Research/Implementation/Educational Element Ratings – TTICC 2014 vs. 2013

Description (*# of votes)	2014 ranking	2012/2013 ranking
Data Management (*31)	1	1
Education (*18)	2	7
Correlations (*17)	3	3
Sustainability (ROI) (*15)	4	13
Specifications/Guidance (*14)	5	2
Non-Uniformity (*13)	6	4
Mechanistic Based QC/QA (*12)	7	10
Sensor Calibration (*8)	8	6
Measurement Influence Depth (*8)	9	8
IC Advancements (*6)	10	11
Research Database (*6)	10	12
Demonstrations (*4)	12	9
Output Standardization (*0)	13	5

Voting performed by 30 representatives from agency, industry, and academia

Handling data remains the top challenge followed by Education (Knowledge gaps), Correlations, and need to establish ROI

Picture at TTICC meeting in Harrisburg, PA on September 3-4, 2014

IC implementation challenges

1. Easy to use data management solutions are needed
2. Engineers need proper training on interpreting IC measurements and relevant software's
3. Calibration protocols with correlating IC measurements with design parameters are needed