



SHRP2 SOLUTIONS
TOOLS FOR THE ROAD AHEAD

RDM Experience in Texas

SHRP2 RDM Peer Exchange

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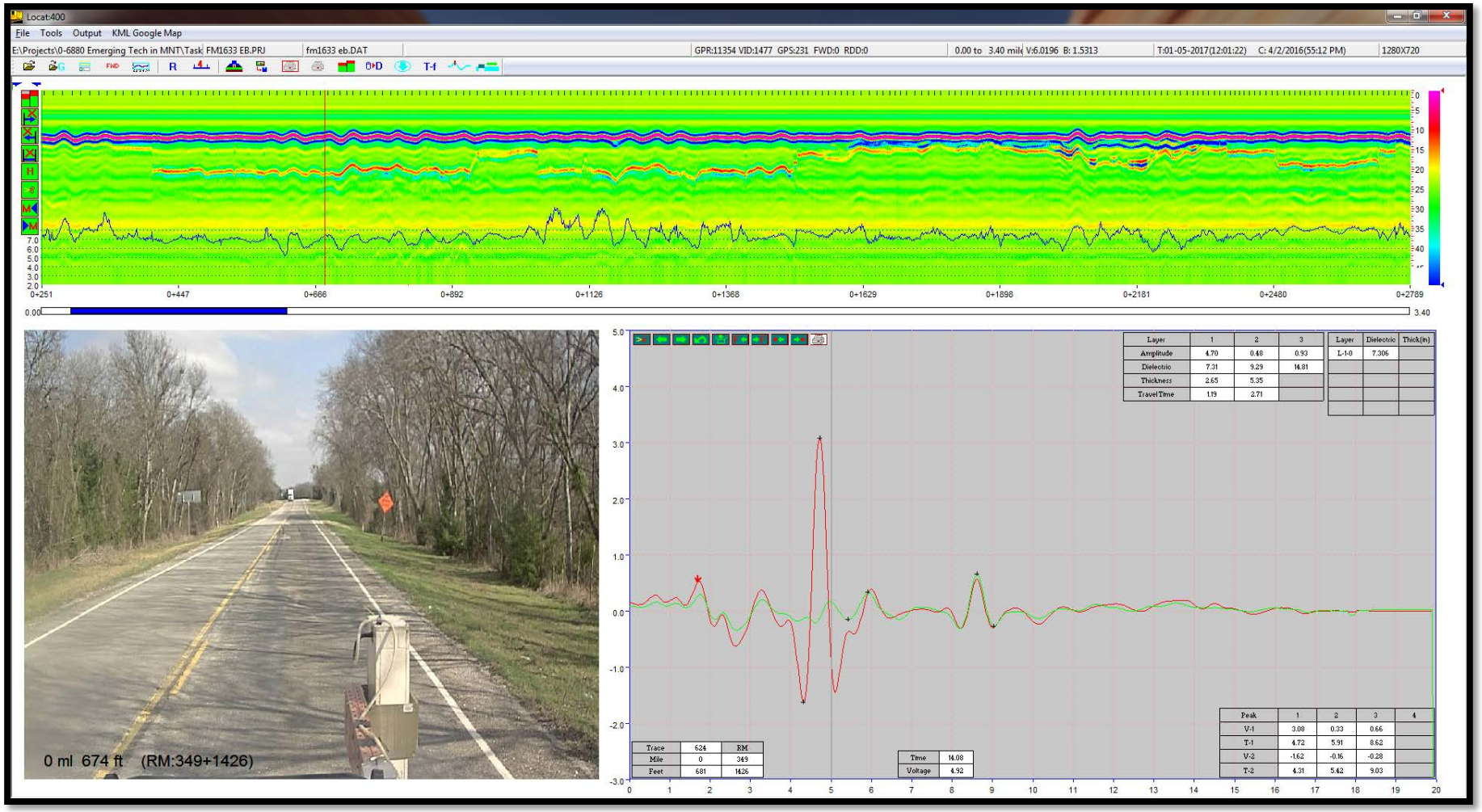
History of GPR in TX

- 1 GHz antenna
- Forensic investigation
- Rehab analysis
- Corridor analysis
- Defects in layer(s)

Typical GPR View (PaveCheck)



Initial RDM Experience

R06C Phase III
(2012-2013)

- "1st" and "2nd" gen RDM
- Calibration – mix specific
- RDM well suited to thin layers
- Thin-lift layer thickness?

TxDOT Thin Overlay Research
(2014-2016)

- Good correlations to density, surface texture (MPD), and "flow time"

Recent Experience

Gen 1 and 2

Recent Experience

Objectives

- Define expected precision, bias, and accuracy
- Optimize field test procedures
- Identify best calibration method
- Improve system hardware and user interface

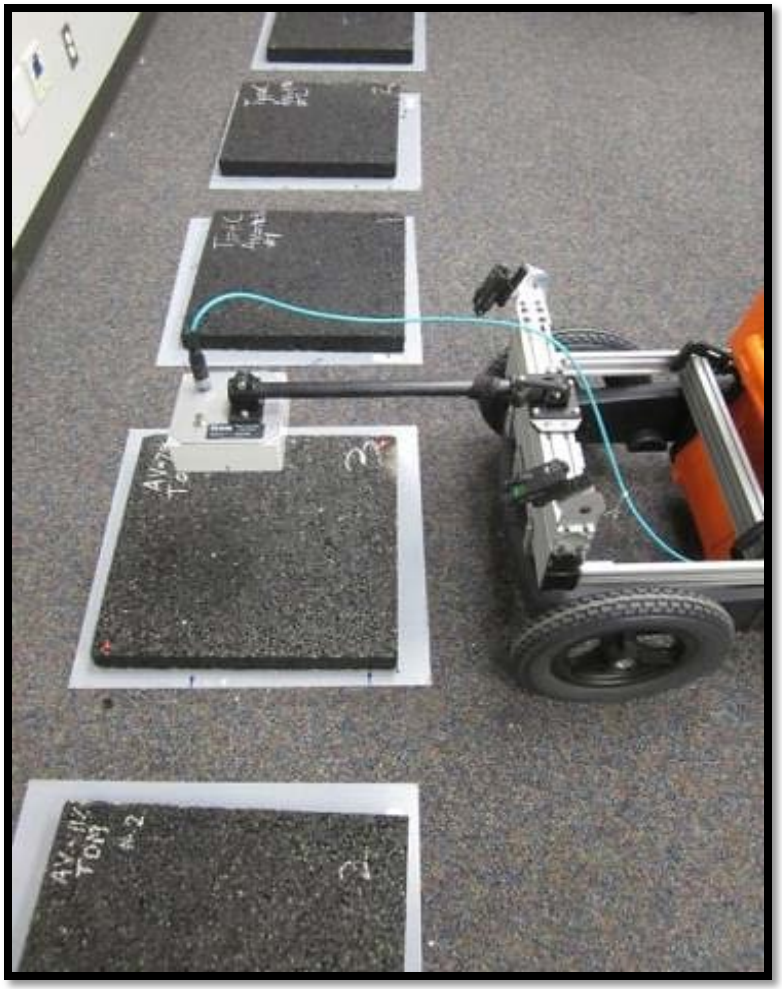
Activities

- Measurement of precision
- Deployment on projects
  - Analysis of calibrations
  - Analysis of air void measurement bias and accuracy
- Collaboration with stakeholders

Precision

Methods

- Lab environment
- 6 materials
- 4 antennas
- Data processed by methods in ASTM E 691



General test arrangement

Precision – Tabular Summary

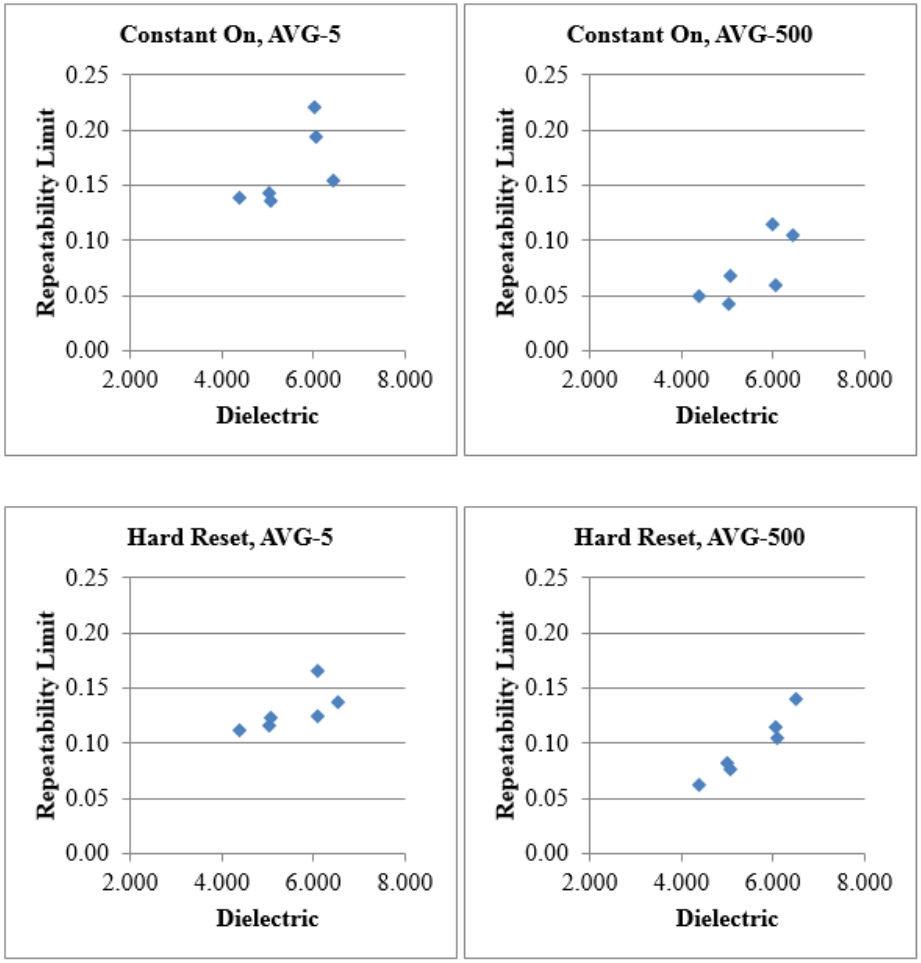
Constant On

Average Slab Dielectric	Repeatability St. Deviation S_r	Reproducibility St. Deviation S_R	Repeatability Limit r	Reproducibility Limit R
4.37	0.018	0.045	0.05	0.13
5.02	0.015	0.041	0.04	0.11
5.06	0.024	0.078	0.07	0.22
6.00	0.041	0.052	0.11	0.15
6.06	0.021	0.081	0.06	0.23
6.43	0.038	0.116	0.11	0.33

Hard Reset

Average Slab Dielectric	Repeatability St. Deviation S_r	Reproducibility St. Deviation S_R	Repeatability Limit r	Reproducibility Limit R
4.38	0.022	0.030	0.06	0.08
5.02	0.030	0.031	0.08	0.09
5.07	0.027	0.031	0.08	0.09
6.07	0.041	0.073	0.12	0.21
6.09	0.037	0.070	0.10	0.20
6.51	0.050	0.107	0.14	0.30

Precision – All Tested Conditions



More scans =
More precision

Higher dielectric =
Less precision (possibly)

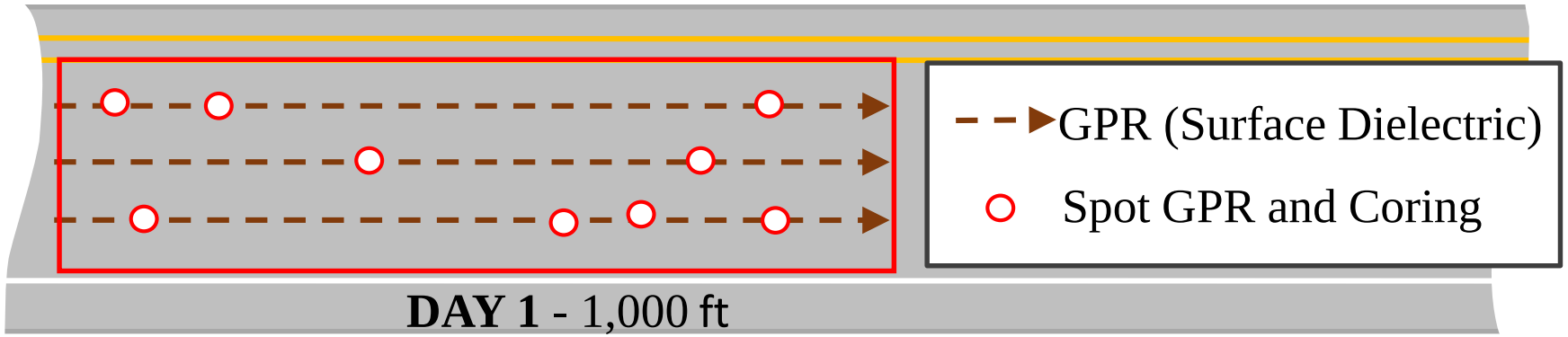
“Constant on” precision =
“Hard reset” precision

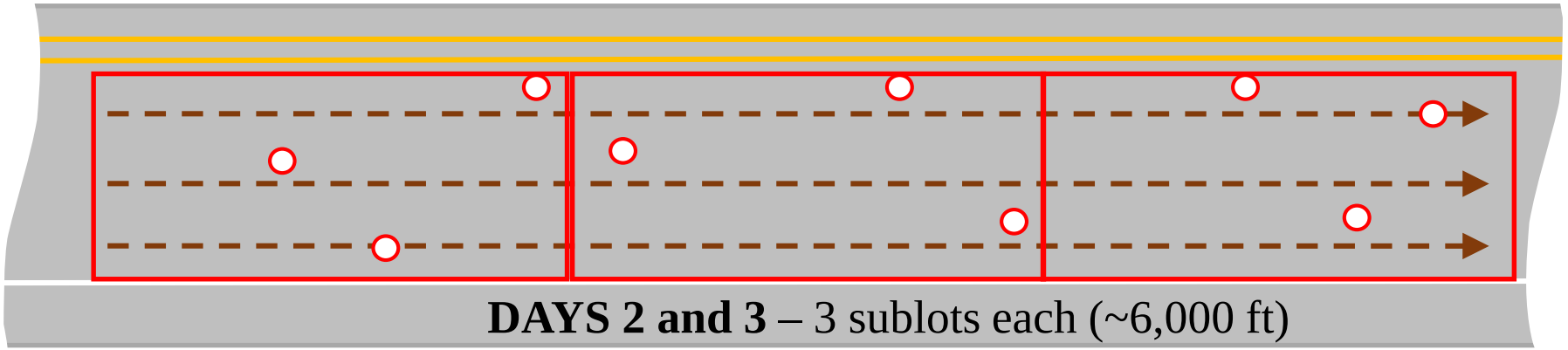
Deployment on Projects

Methods

- Deploy on multiple projects for 3 days of paving.
- Daily void-dielectric calibration.
- Full-coverage density prediction.
- Compare to TxDOT QA results and pay factors.

Deployment on Projects

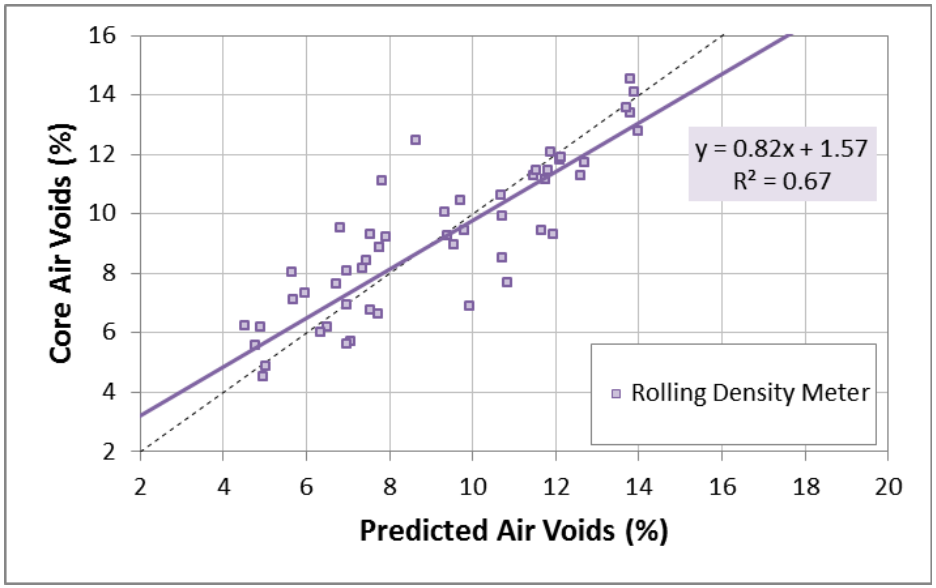




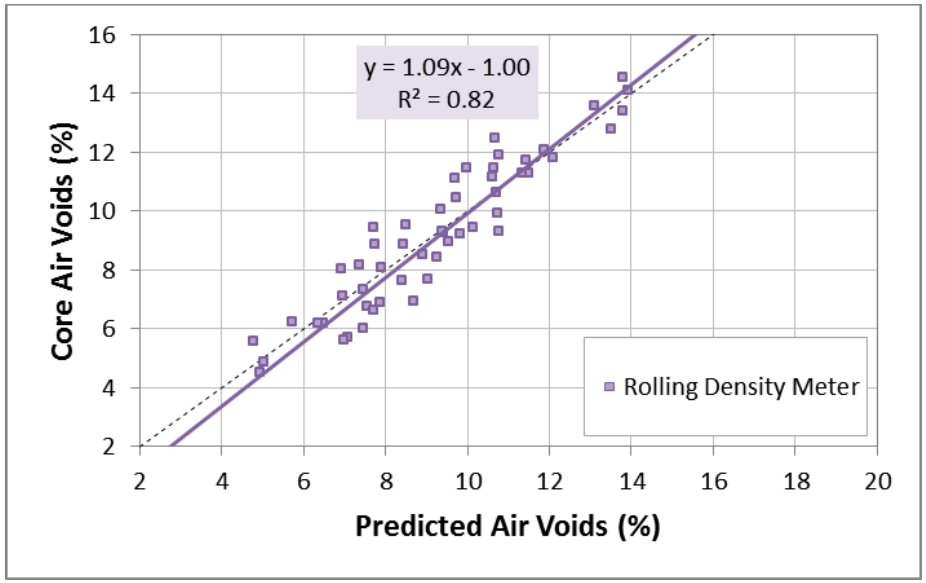
Deployment on Projects

		Project	Mix Type	NMAS (in.)	Binder Type	Optimum AC (%)	Aggregate Type	Theo. Max SG	Thickness (in.)
Gen 1 & 2		FM 1887	TOM-C	3/8	70-22	6.7	Limestone	2.474	1.0
		RM 12	TOM-F	1/4	76-22	7.3	Sandstone	2.348	0.5
		Riverside	DG Ty-C	1/2	76-22	4.8	Limestone	2.447	2.0
Gen 3	Phase I	US 183	TOM-F	1/4	76-22	7.2	Sandstone	2.376	0.75
		US 90	SP Ty-D	3/8	70-22	5.2	Quartzite Limestone	2.443	1.5
		IH 10	SP Ty-C	1/2	64-22	5.1	Sandstone Limestone	2.462	2.0
		FM 31	DG Ty-D	3/8	64-22	5.4	…	2.481	2.0
	Phase II	SH 6-VM	DG Ty-D	3/8	64-22	5.2	Dolomite Gravel	2.447	2.0
		SH 6-Waco	TOM-C	3/8	76-22	6.6	Sandstone Dolomite	2.434	1.25
		SH 30	SMA-C	1/2	76-22	6.0	Sandstone Dolomite	2.405	2.0

Calibrations – General Observations



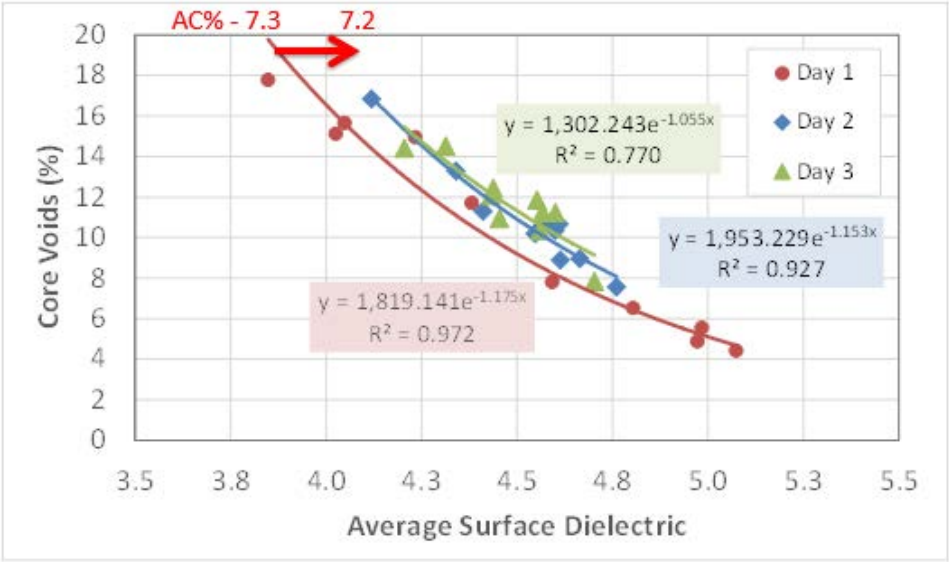
Phase II Projects
Using Day 1 Calibration



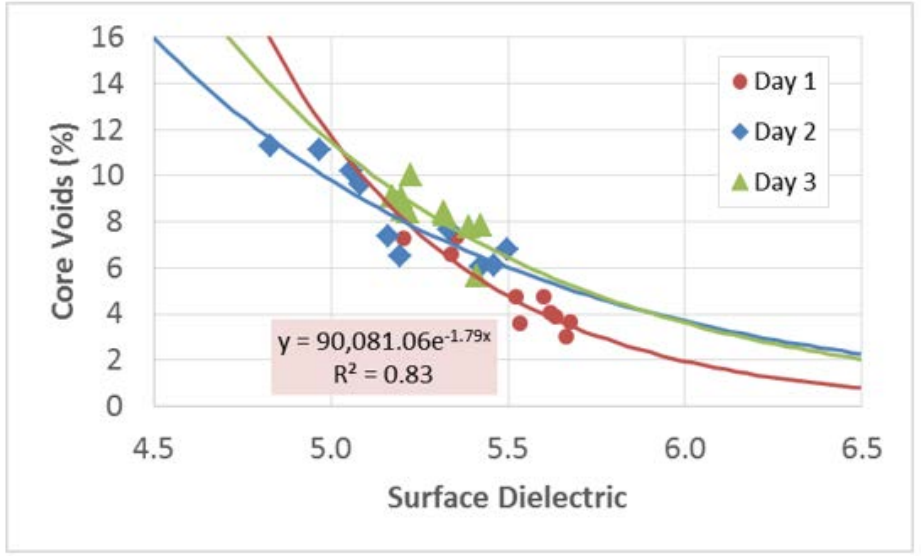
Phase II Projects
Daily Calibration

Calibrations - Challenges

Shift in Mix Design

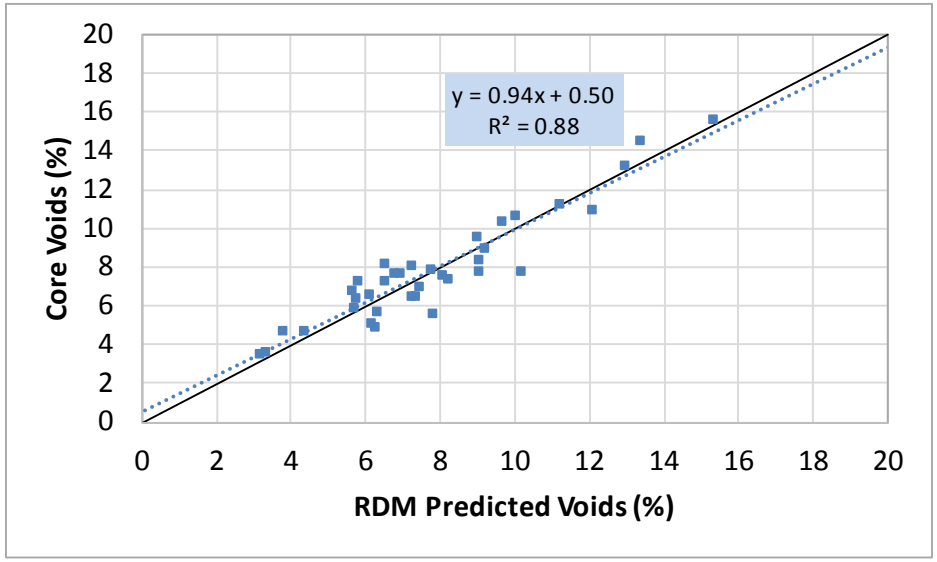


Sampling and Model



Accuracy and Bias

Example iteration of one possible air void prediction scenario



Overall Accuracy and Bias Results (TxDOT Phase I Projects)

Prediction Method	Bias		Error Standard Deviation (% voids)	Accuracy 95% Confidence Interval (% voids)
	Avg. Error (% voids)	p-value		
GPR Dielectric (empirical)	0.02	0.463	0.99	0.02 ± 1.94

Key Findings from Recent Work

Results

Dielectric repeatability limit

0.15 when average 5 scans

0.09 when average 500 scans

Dielectric reproducibility limit

0.22 when average 5 scans

0.18 when average 500 scans

Field empirical calibration

Accuracy **±1.94%** air voids

Conclusions

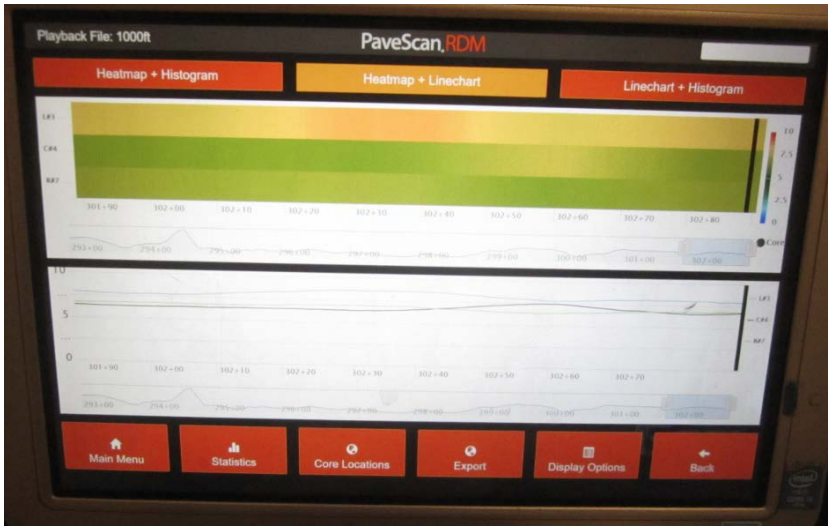
Higher sampling rate improves precision

When RDM is calibrated:

- Unbiased (avg. error is zero)
- Individual measurement error within ~2% air voids

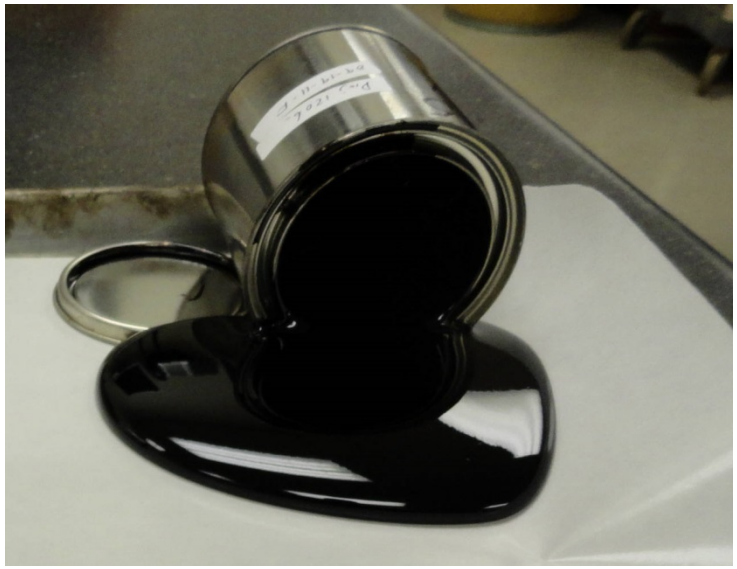
Anticipated Future Needs and Activities

- Vehicle-mount RDM system
- Hardware / user interface updates
- Deploy technology on additional projects
  - 5 more anticipated through 2018



Anticipated Future Needs and Activities

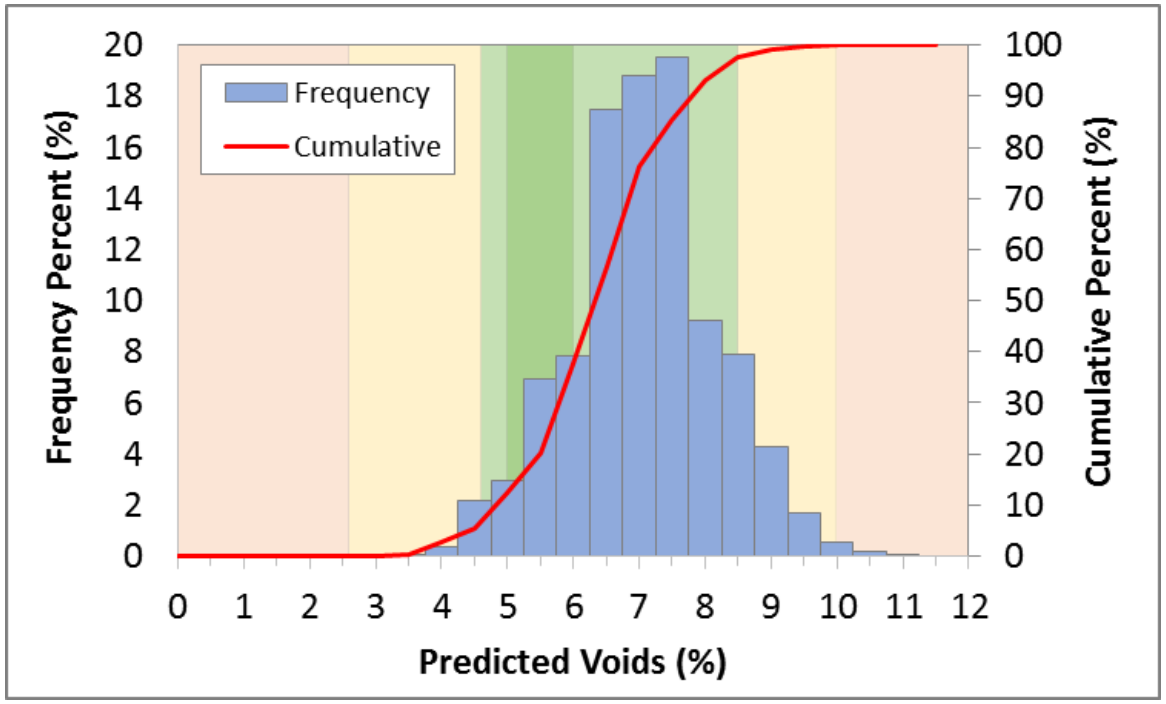
- Mechanics Calibration
- Mechanics-Empirical Calibration



Reduce/eliminate core calibrations?

Anticipated Future Needs and Activities

- Implementation as QA tool
  - Majority of respondents at recent TxDOT event indicated preference to some association to pay factor



Measurement Method	Payment
Weighted Pay Factor	1.022
90th Percentile Pay Factor (Avg. at 5% and 95%)	1.006

Questions / Discussion...