Illinois Center for Transportation
University of Illinois at Urbana-Champaign

ILLINOIS

Pavement Density Using Dielectric Mapping

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Asphalt Concrete Density

- **AC Mat density is an AQC* in all US states**
- **Contractors are subjected to incentives/disincentives based on AQCs**

State	Acceptance Quality Characteristics (AQCs)*
Illinois	Air voids, VMA, Mat density
New Jersey	Mat density, Thickness, Ride quality
Pennsylvania	Asphalt content, Percent passing the #200 sieve, Percent passing primary control sieve, Mat density
Maryland	Air voids, Mat density
Minnesota	Air voids, Asphalt content, Aggregate gradation, Asphalt film thickness, Mat density, Confined edge density, Unsupported edge density
⋮	⋮

Motivation

- Compaction and quality control are two processes
- Sparse checks at random locations by extracting cores or nuclear gauge readings
- Too late for any fixes…

- Compaction and quality control are merged
- Checking all spots
- Constant feedback for roller operator during construction
- Fix on the go!

Density Prediction

Estimate the pavement dielectric constant (ε_{AC}) after some corrections

Mix Design Sheet
G_{mm}
G_{se}
P_b
Aggregate Type/Source

Estimate aggregate dielectric constant (ε_s) using our database

Aggregate Type	Quarry Location	Dielectric Constant
Dolomite	Troy Grove, IL	7.40-7.57
Limestone	McDowel, IL	7.64-7.82
⋮	⋮	⋮

ALL Model

$(\varepsilon_{AC}, \varepsilon_s, G_{mm}, G_{se}, P_b)$

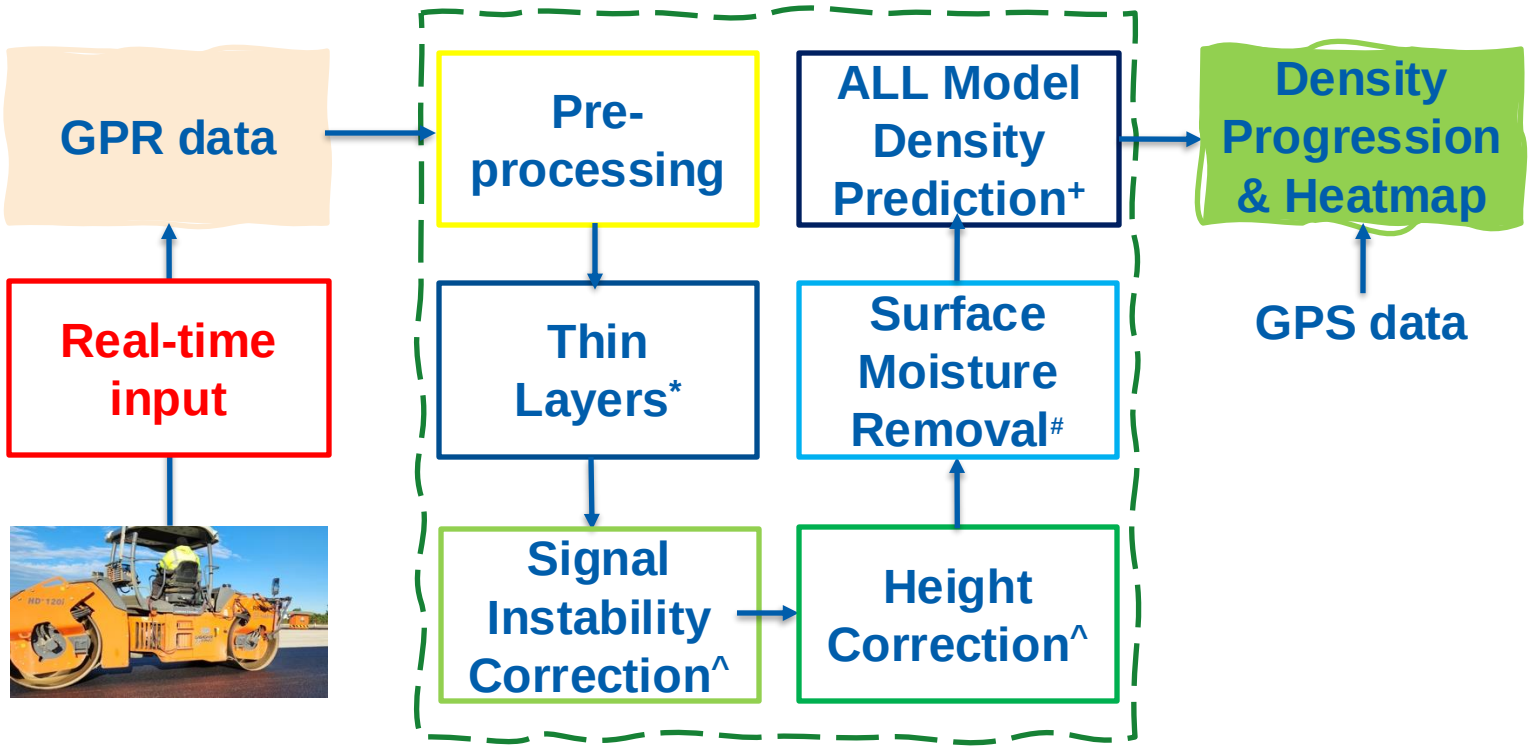
G_{mb}

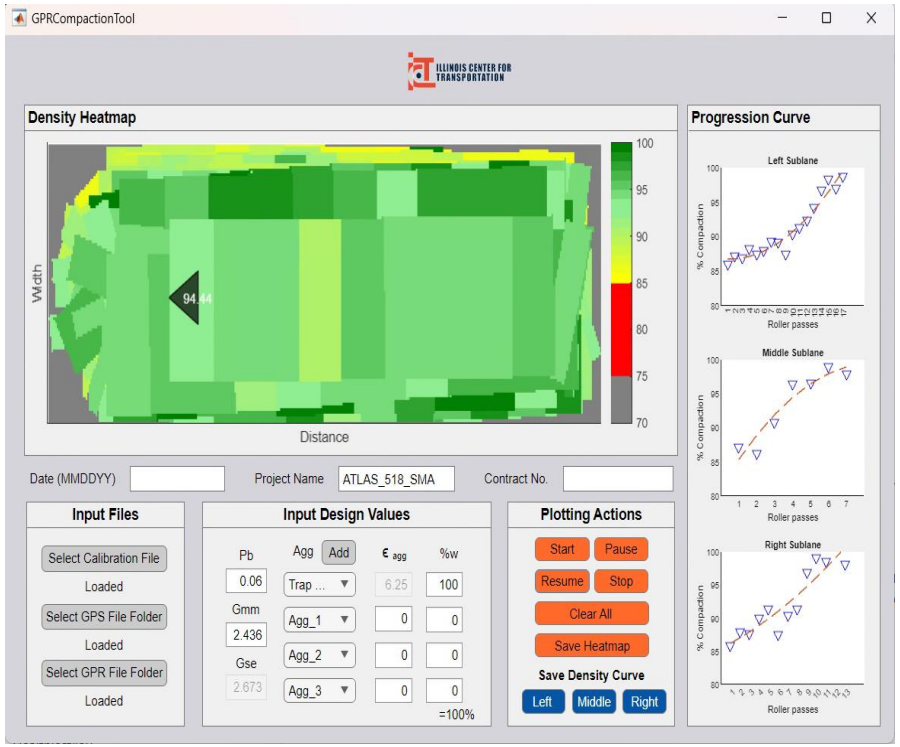
Percent Compaction = $\frac{G_{mb}}{G_{mm}} * 100\%$

Each project has a range (93-97%)

GPR Signal Processing

- GPR signals are affected by several factors
- Processing is required to correct GPR signals





Output: Density heatmap and sub-lane progression curves

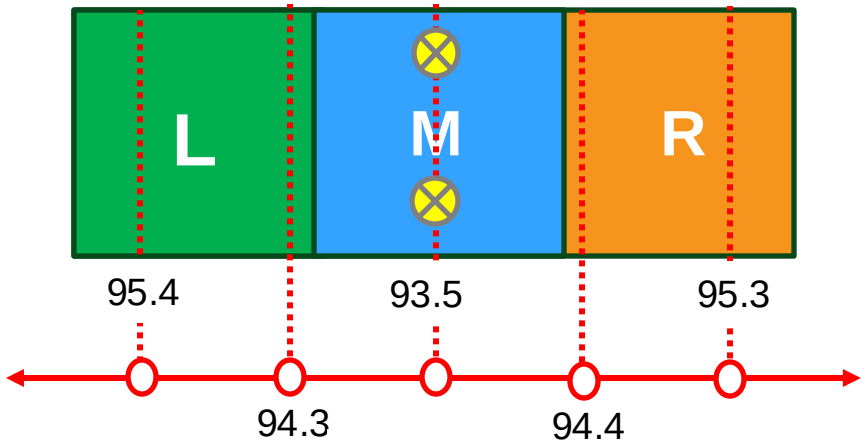
* Zhao et al., 2018; ^ Cao and Al-Qadi, 2021; # Abufares et al., 2025; + Leng et al., 2011

Validation (Last Year)

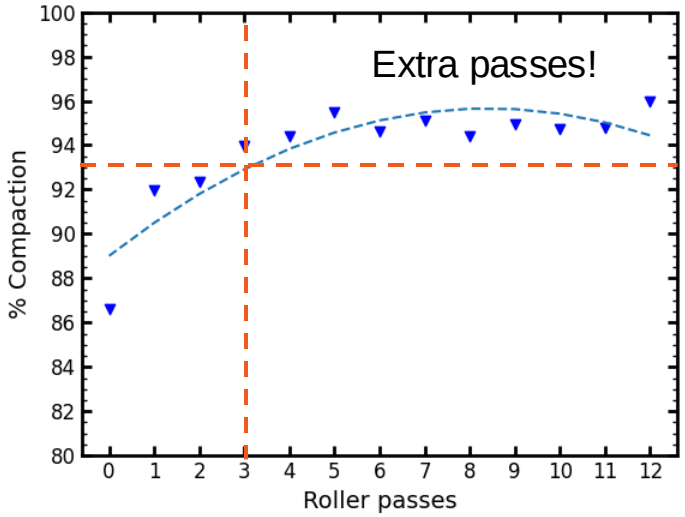
- Six different SMA sections
- Example section with Traprock aggregates
- Environmental and cost benefits when avoiding over-compaction

Method	Avg. %density in the middle
GPR	95.7
Core ⊗	95.9
Nuclear gauge ○	93.5

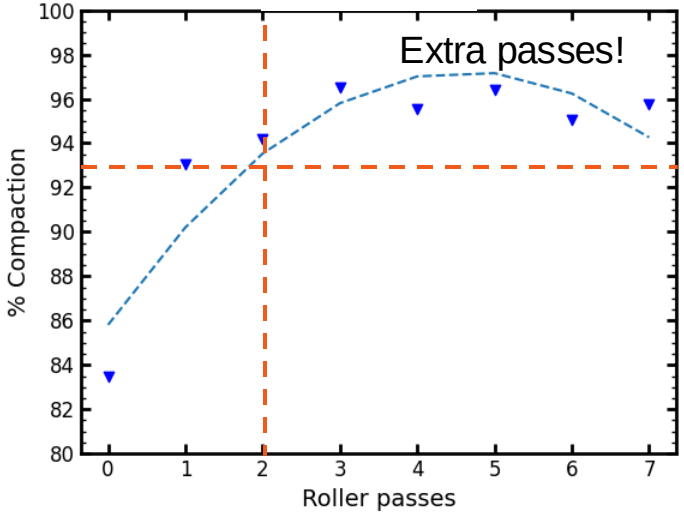
Nuclear gauge readings



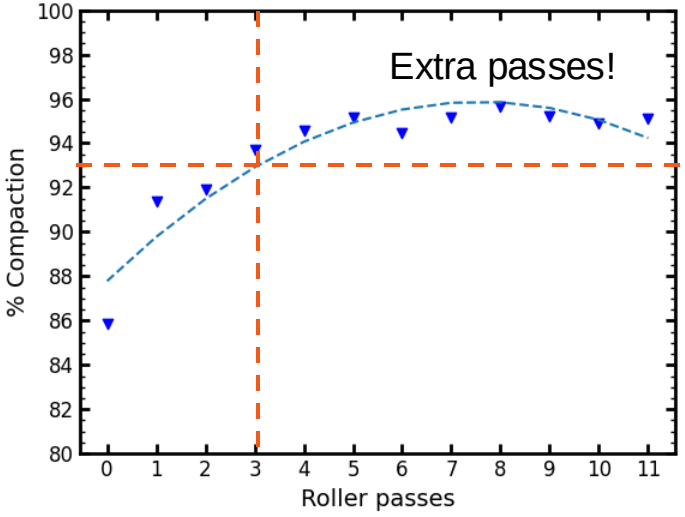
Left



Middle

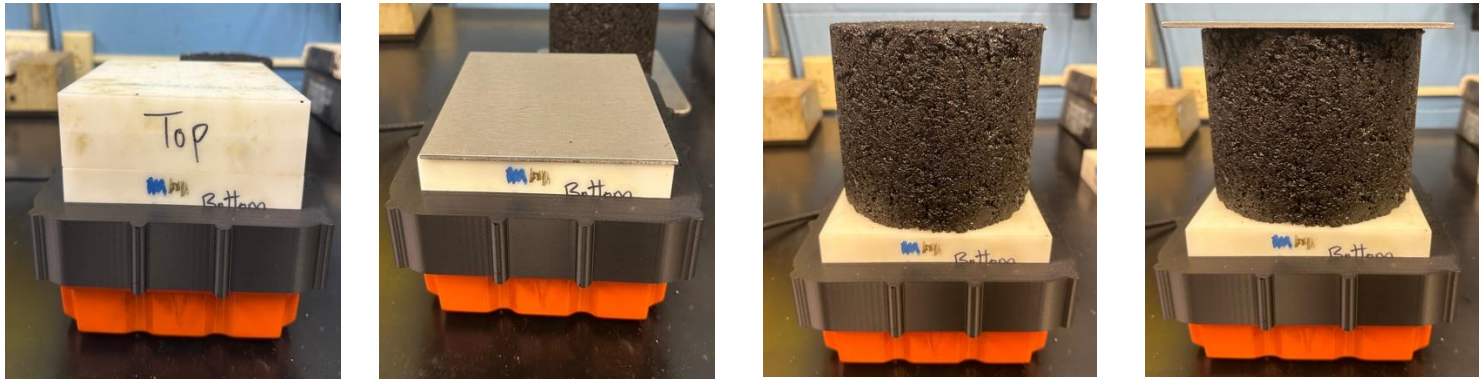


Right

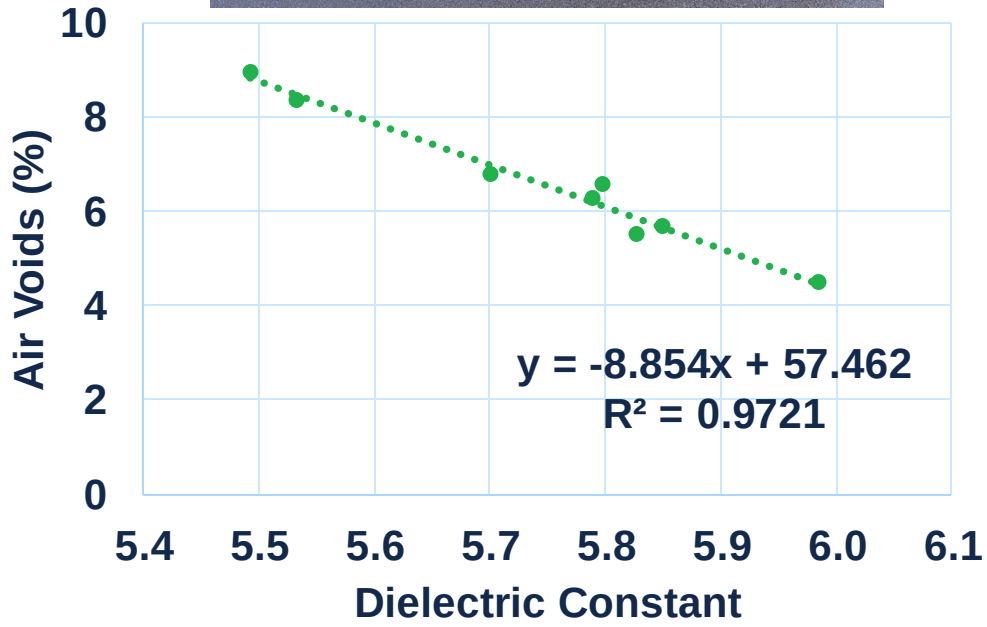


Dielectric Profiling System

- DPS is a 3-antenna GPR system mounted on a pushcart
- DPS may be used after compaction
- Lab-fabricated pills are used to develop a linear calibration curve

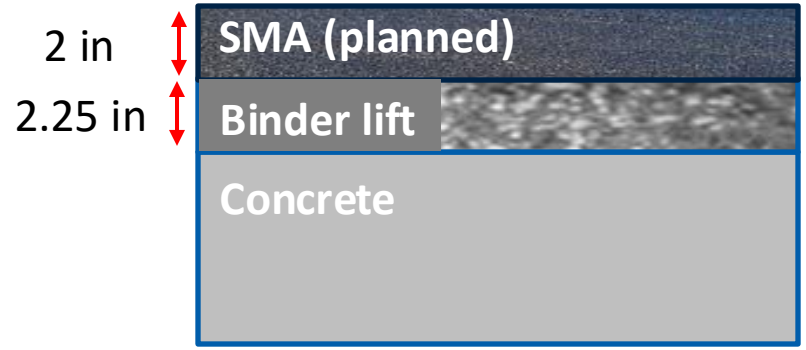


*LDMS: Laboratory dielectric measurement system



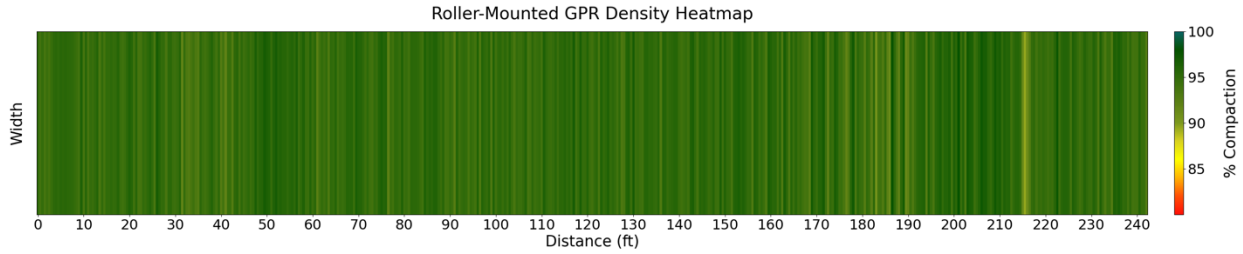
I-57 Field Project

- Pay for Performance project (PFP)
- Accepted density range is 90-98%
- Construction was done by Iroquois Paving Co. the NB right lane near Gilman, IL
- 2.25in IL19.0 binder lift (with 17% FRAP) on top of a concrete surface
- Two rollers in echelon mode: GPR roller was driving on the left sub-lane
- DPS measurements were obtained after compaction
- Both nuclear gauge and core data are available at specific locations

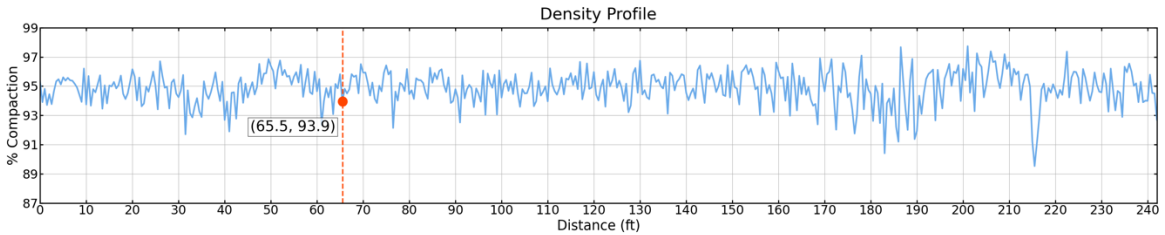


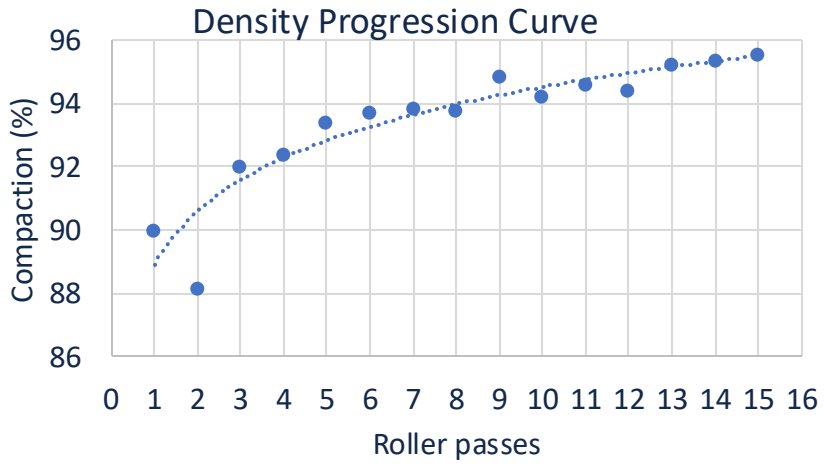
Data Analysis – Section 3

Roller-Mounted GPR

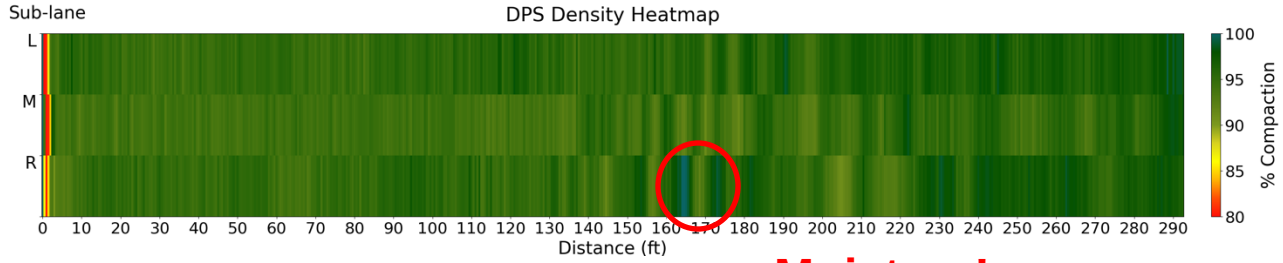


No moisture!

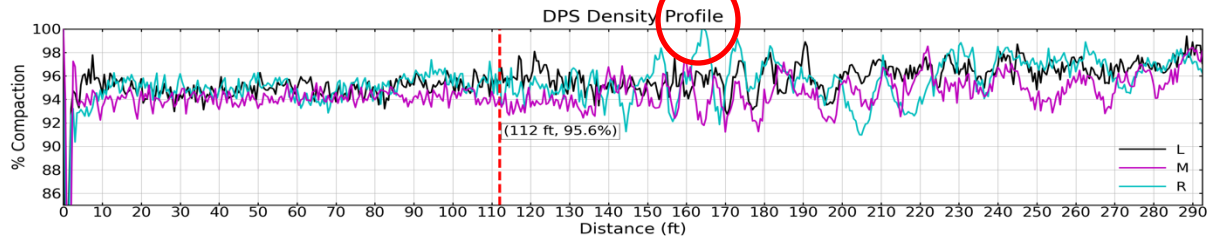




Pushcart DPS



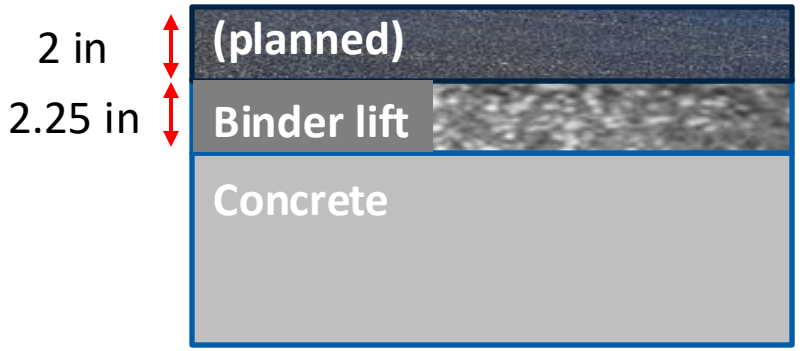
Moisture!

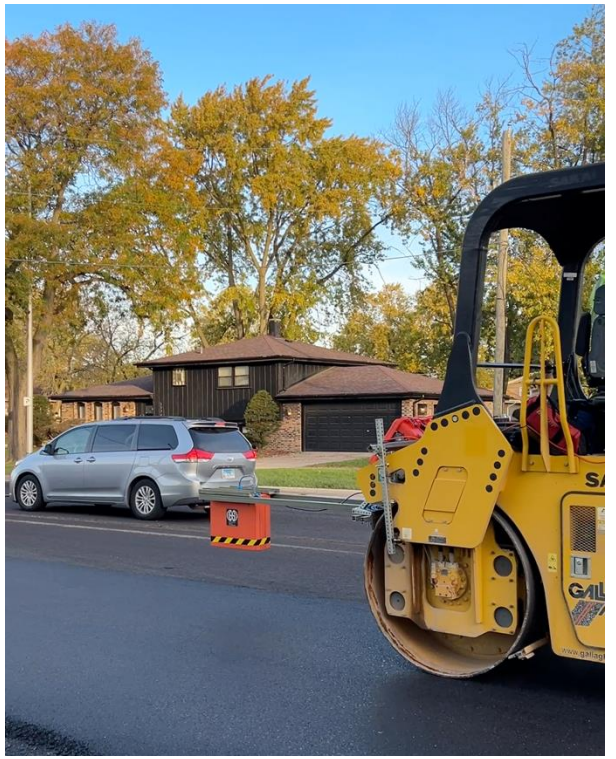


Method	Spot %compaction
Roller-mounted GPR	93.9
Pushcart DPS	95.6
Nuclear gauge	93.0
Core	92.9

South Holland Field Project

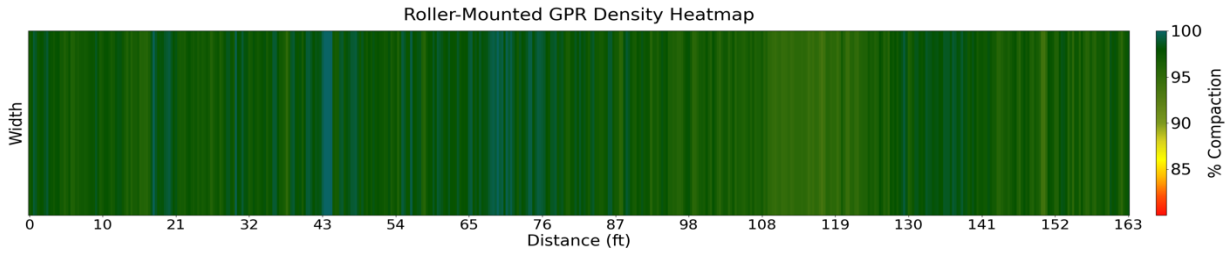
- 154th St in South Holland, IL (4 lanes)
- 2.25in N50 binder lift on top of concrete
- Construction was on the two outer lanes
- Accepted density range is 93-97.4%
- GPR roller was the finishing roller (third roller), moving on left and right sub-lanes
- DPS measurements were obtained after compaction
- Both nuclear gauge and core data are available at specific locations



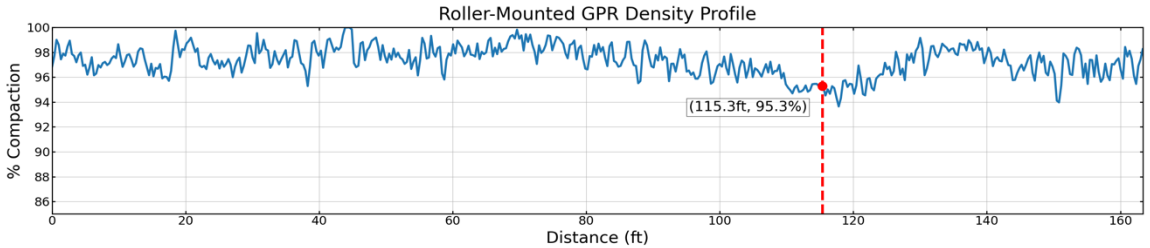


Data Analysis – Section 8

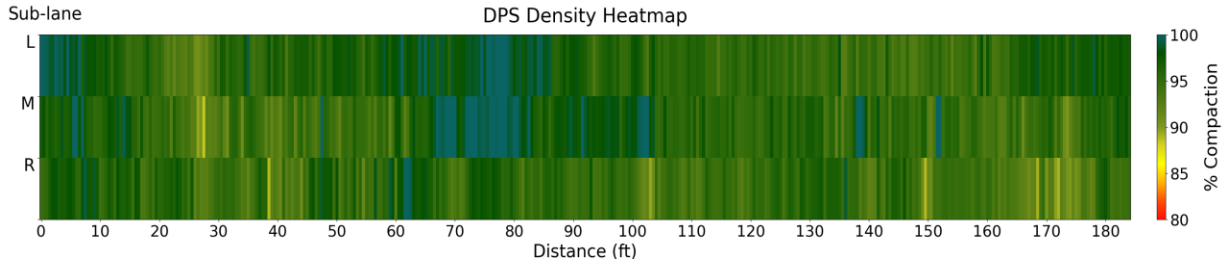
Roller-Mounted GPR



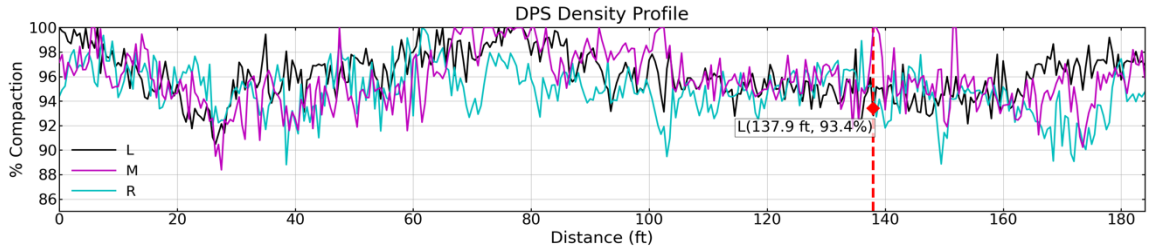
Some moisture remaining

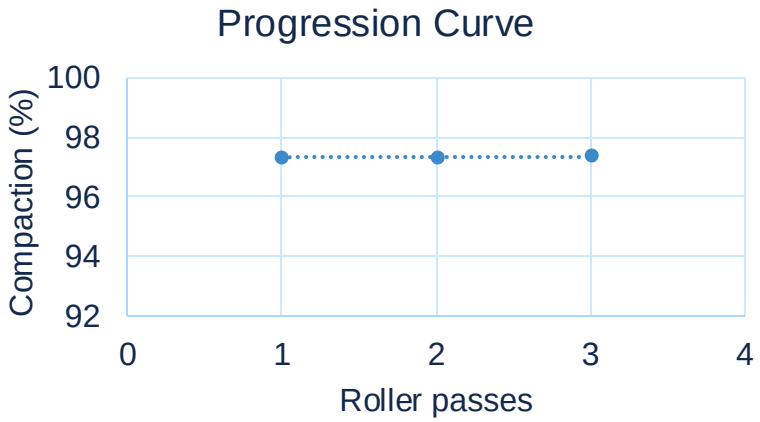


Pushcart DPS

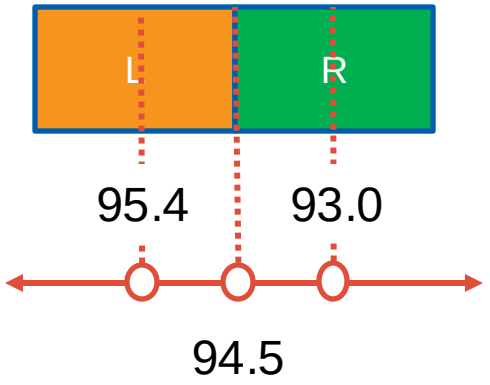


Moisture





Method	Spot %compaction
Roller-mounted GPR (L)	95.3
Pushcart DPS (L)	93.4
Nuclear gauge (L)	95.4
Core (L)	94.9



Summary

- **Non-destructive monitoring** of asphalt density during construction is important for contractors and agencies
- **More validation** of our roller-mounted GPR was done on different projects (parking lot, rural road, and interstate)
- Our approach was **compared** to the commercial DPS approach

Acknowledgement

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THANK YOU

Any Questions?

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