Sensors & Software

Pavement Density Profiler 'PDP'

Overview & Presentation for

TRAFIKVERKET
SWEDISH TRANSPORT ADMINISTRATION

SAMFERDSELSDEPARTEMENTET

LVM LIIKENNE- JA VIESTINTÄMINISTERIÖ

Outline

- Sensors & Software and PDP overview
- Testing and development of the PDP
- Synopsis of the PDP Field Trial with MnDOT
- Summary
- Acknowledgements

1972 - Apollo 17
Surface Electric Properties

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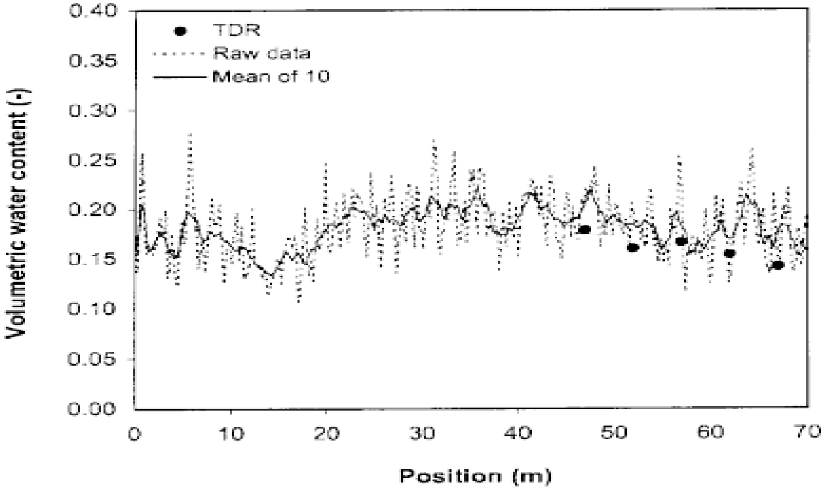
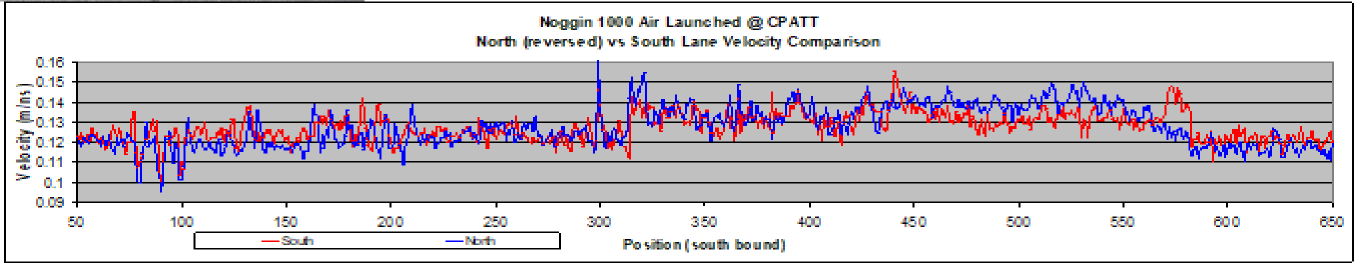
Pavement Density Profiler - PDP

- Recent interest in pavement density
- Prior air launch work provides basis
- Goal is a simple practical tool
- Started PDP about 1 year ago
- Currently doing field trials to evaluate efficacy

Surface Reflection for Soil Moisture ~ 2002



Pavement Permittivity Estimate (RoadMap ~2008)



GPR Solutions – 3 elements

1. Instrumentation
2. Electrical structure interpretation model
3. Translation to application need

Instrumentation

- Focus is ***GPR data*** acquisition
- Must be ***simple*** to use
- Must acquire ***calibrated*** signal.
- Must acquire data with ***time fidelity***
- Must acquire data with ***amplitude fidelity***
- Simple ***performance validation***

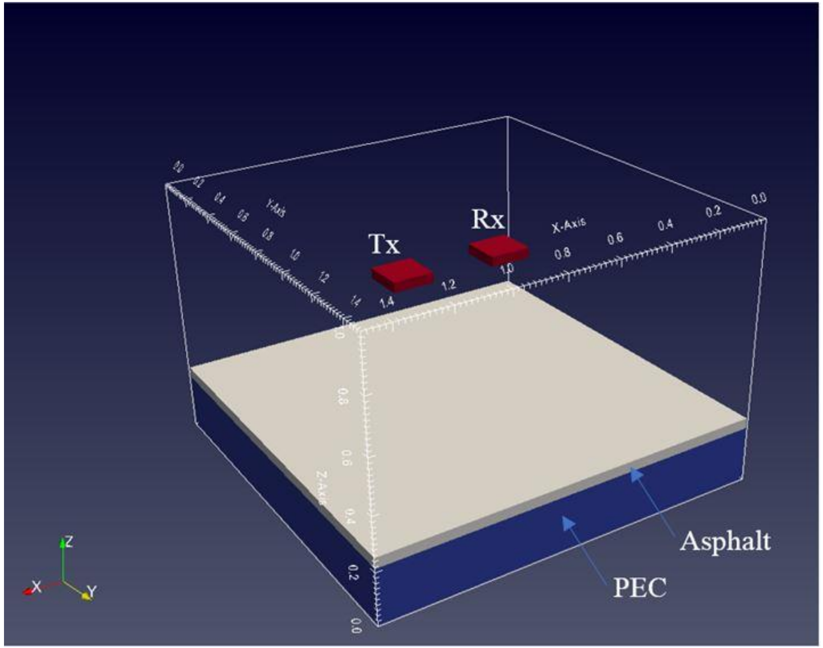
The PDP Solution

Deployments
- Cart mount
- Vehicle mount

Pavement Density Profiler

- Push cart or vehicle mount
- Factory Calibration
- Standard performance validation
- Real time display of dielectric/density properties
- Data display in numeric or profile form
- Integrated or external GPS
- Free run, or odometer triggering
- Data exported in .csv form
- Automated reports in PDF available

Numerical Simulation Key to Design

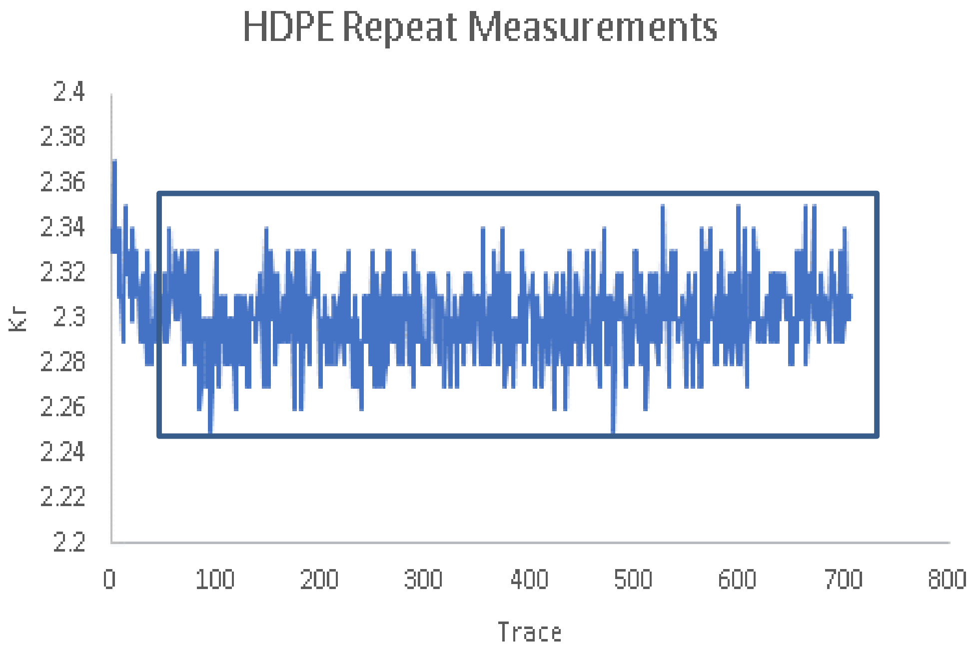


Model used for evaluating effective sampling depth

Factory Calibration

Dielectric measurements on HDPE, with a known dielectric of 2.3

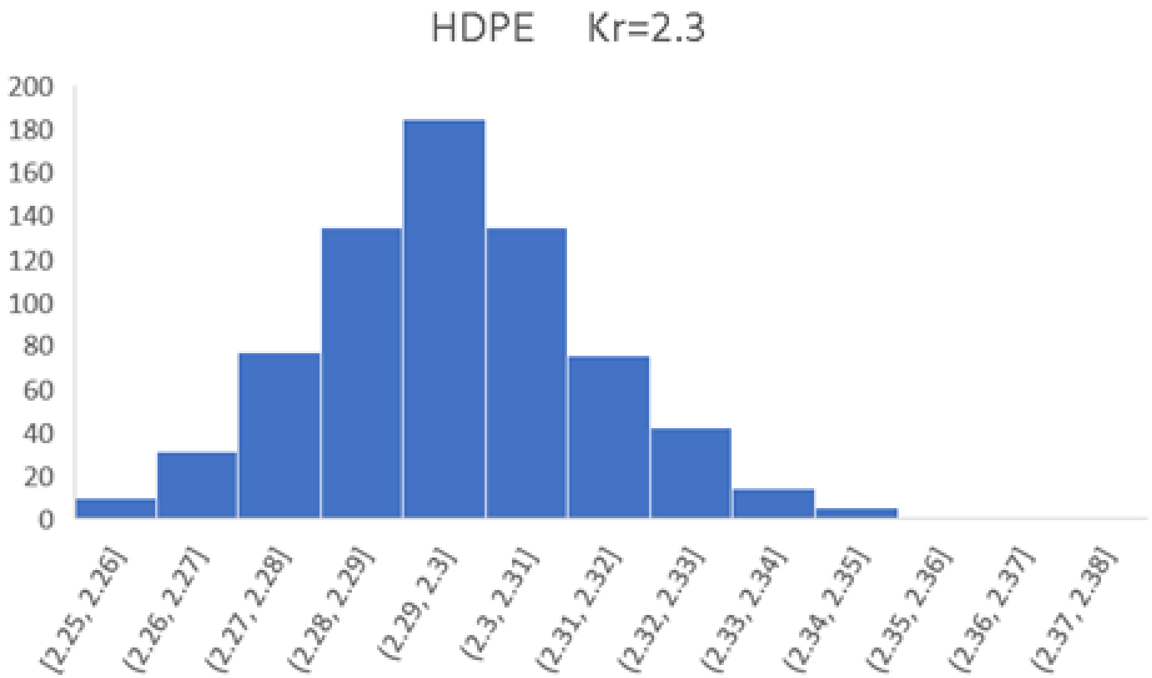
HDPE Validation



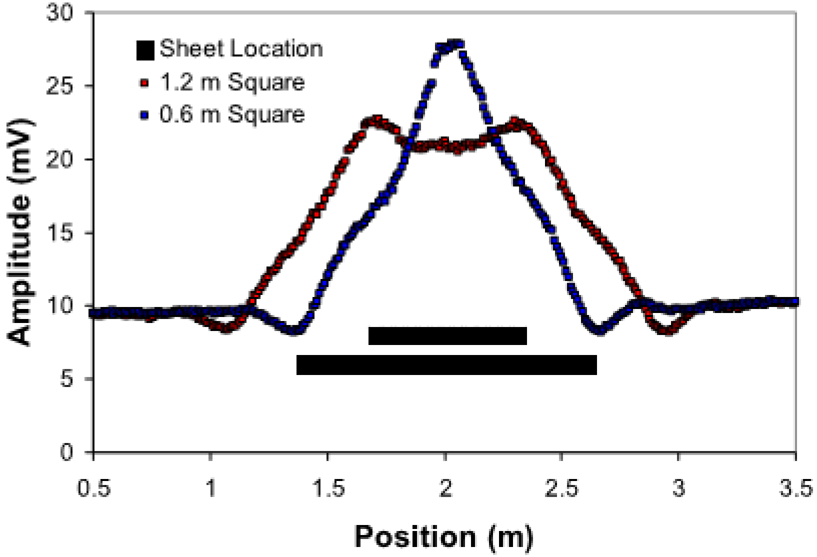
Average=2.301

STD=0.0173

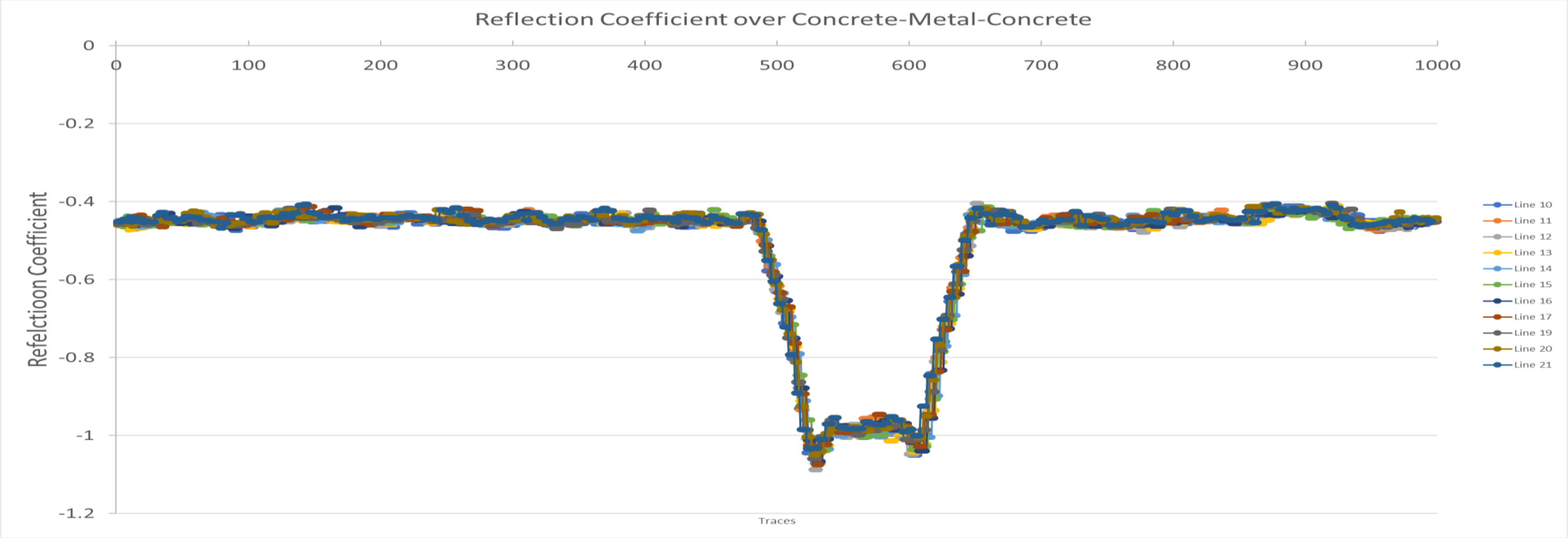
HDPE Histogram



Metal Sheet Validation



Metal Sheet Validation - Repeatability Tests



Instrument summary

- Should produce calibrated data
- Should not need in-field calibration
- Should have in-field performance validation protocol
- Should be simple to use
- Must enable user to focus on the problem to be solved

MN DOT Field Trial

Test program focused on 3 data acquisition trials, plus corollary data to validate

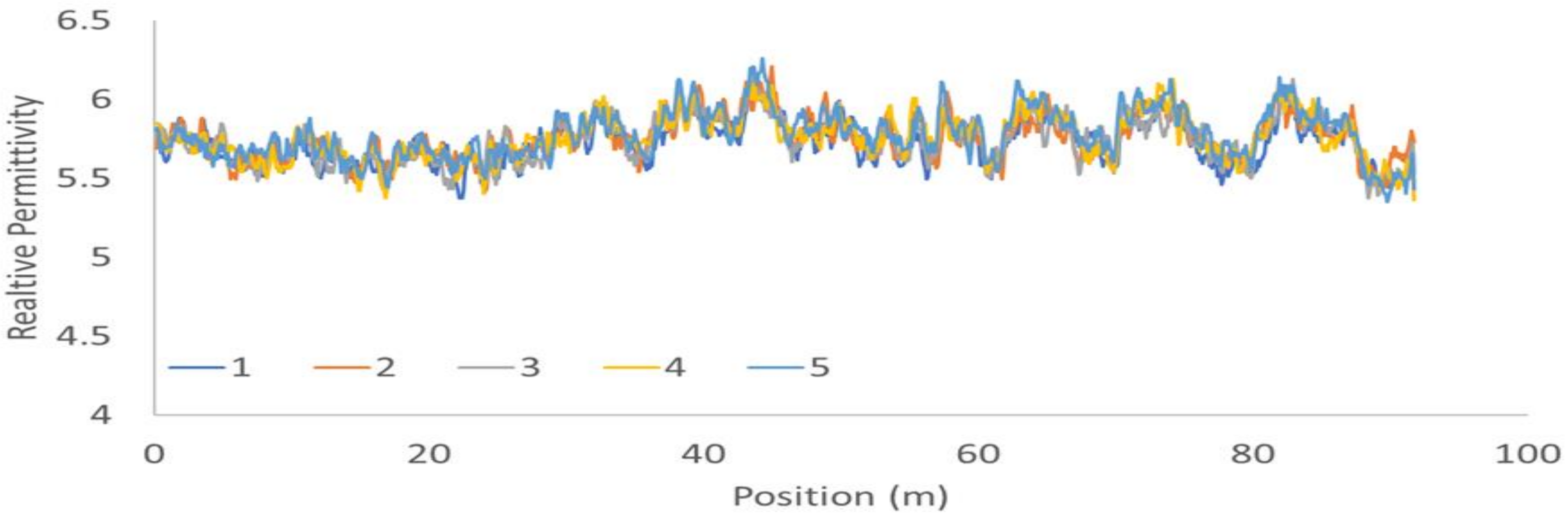
1) 300 ft line, Repeatability Trial
2) Cross Lane Repeatability Trial
3) Full Lane Map Trial

Field Trial #1

300 foot Repeatability Trial

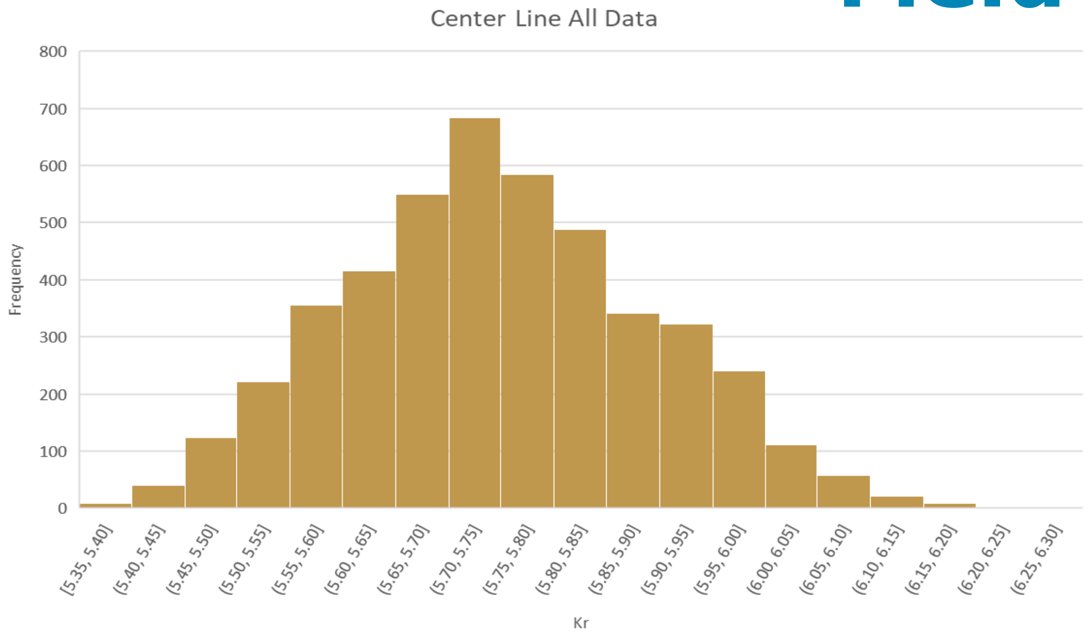
View in the SB direction showing the new pavement. The center line seam is visible just to the right of the yellow markers.

Field Trial #1



The 300 ft repeat line data for 5 passes showing the apparent dielectric permittivity

Field Trial #1



Histogram of permittivity values obtained with the 5 repeat measurements.

Field Trial #2

Cross Lane Repeatability Trial

The transect started at the W side of the road and crossed to the east.

The transect crossed the center line at about 4m and moved off the newly paved area at about 8m, moving onto a milled shoulder area about 2-3m wide.

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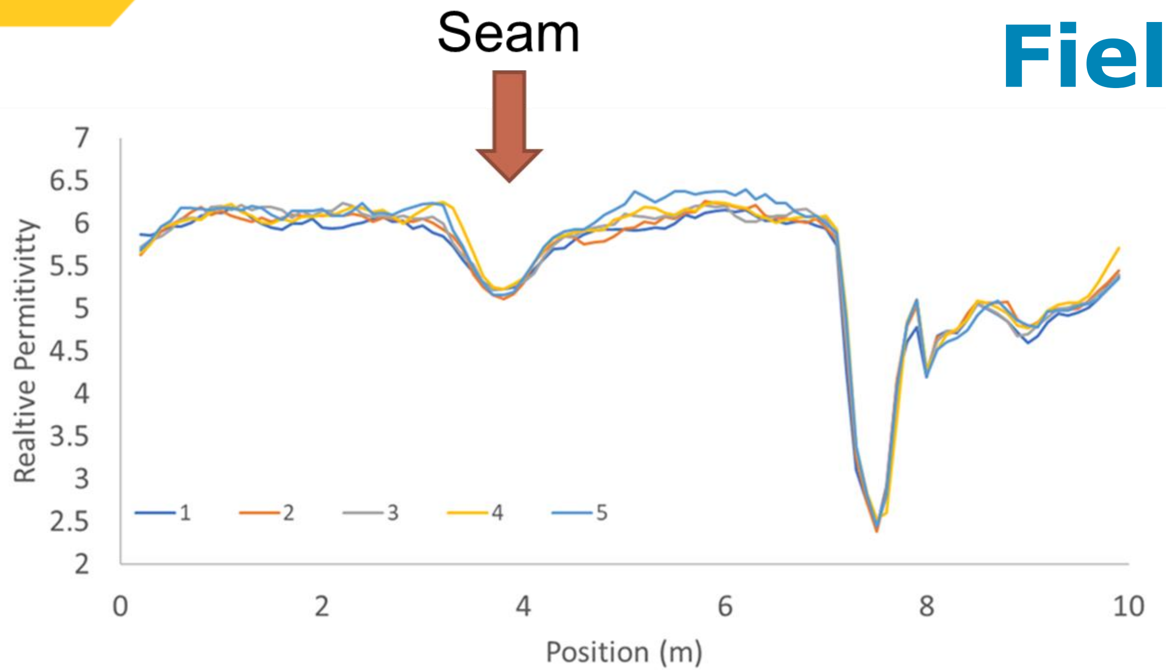
Field Trial #2



Plot of the permittivity for 5 repeat passes along the cross lane test area. The low permittivity at the center line seam is clearly visible. The abrupt amplitude drop is associated with the PDP crossing onto the old milled asphalt surface.

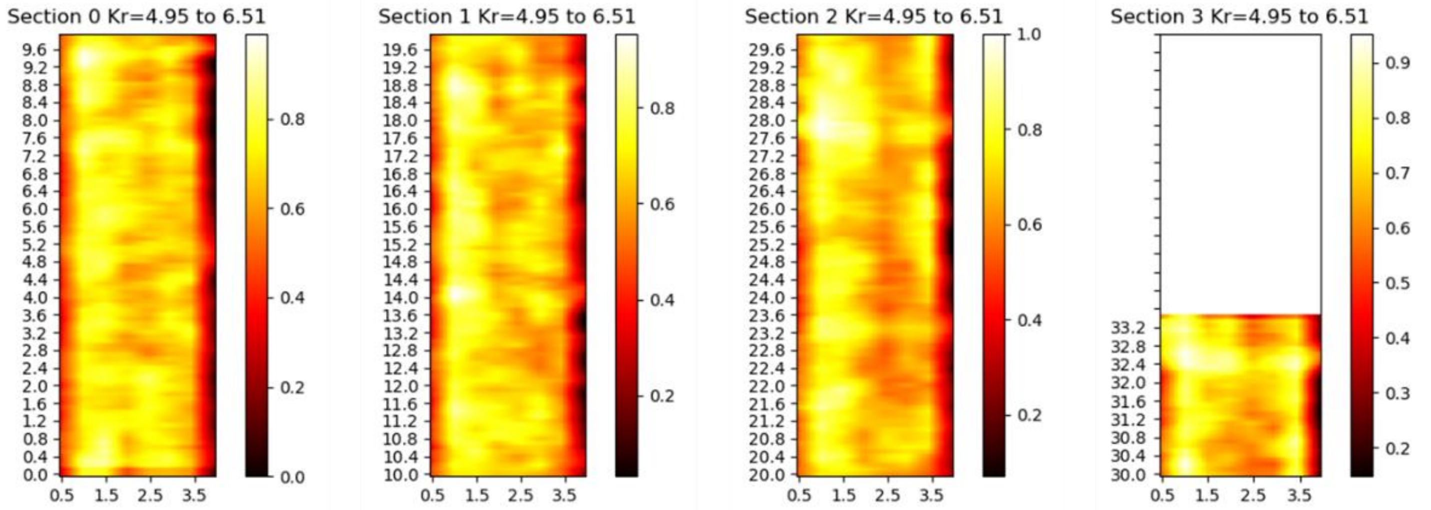
Field Trial #3

Full Lane Map Trial

The primary goal of MnDOT is to map the full lane width to obtain a good indication of HMA density variability.

Eight parallel lines were surveyed at 0.5m spacing.

Field Trial #3



Plan maps of the dielectric permittivity in the grid area. The darker areas are low permittivity and are most prevalent along the center line seam (left) and at the pavement edge (right)

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Static PDP Test Results

	Position (m)	Static Kr		Moving Kr		Nuclear Density (lb/cu ft)
Location		Average	St Dev	Average	St Dev	
Core 1/NG 1	30.02	5.64	0.0538	5.68	0.090	145.40
Core 2/NG 2	40.90	5.95	0.0593	5.81	0.069	150.72
Core 3/NG 3	68.70	5.64	0.0554	5.71	0.057	144.86
NG 4	79.46	5.43	0.0487	5.64	0.025	143.60
NG 5	91.20	5.59	0.0494	5.58	0.072	145.41

Table 2

The static test GPR data consists of about 1000 repeat observations collected in about 100 seconds. These data were analyzed to generate the mean and standard deviation for the permittivity at each of the sites. The results are presented in Table 2.

Static PDP Test Results

- In addition to the static permittivity values, the moving profile permittivity data along the 300 ft test for the 5 repeats were tabulated for the specific location and the average and standard deviation computed.
- The standard deviation of the static Kr data is about 0.05 which is well under the desired current US DOT needs which is specified 0.08.
- The permittivity to density conversion is still in assessment. The correlation observed with the limited number of nuclear density data provides the basis of conversion. Unfortunately, the core density data are not available. When available, we will add them to this report.

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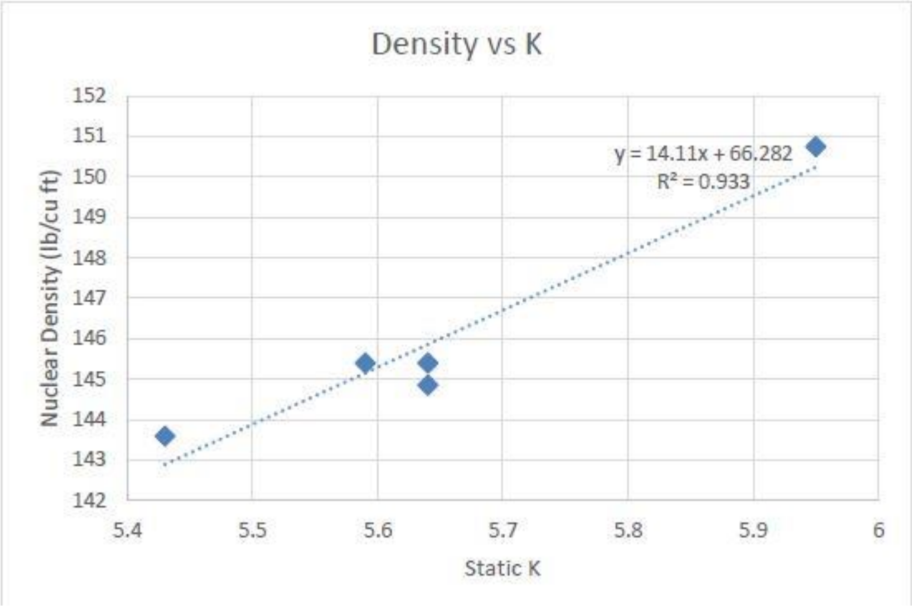
Density vs K



Correlation between the nuclear density and the static PDP permittivity data. A linear model is fit to the data.

Permittivity to Density Conversion

To illustrate the final step of estimating density, we use the correlation estimate from above to transform the cross-road permittivity data to density.

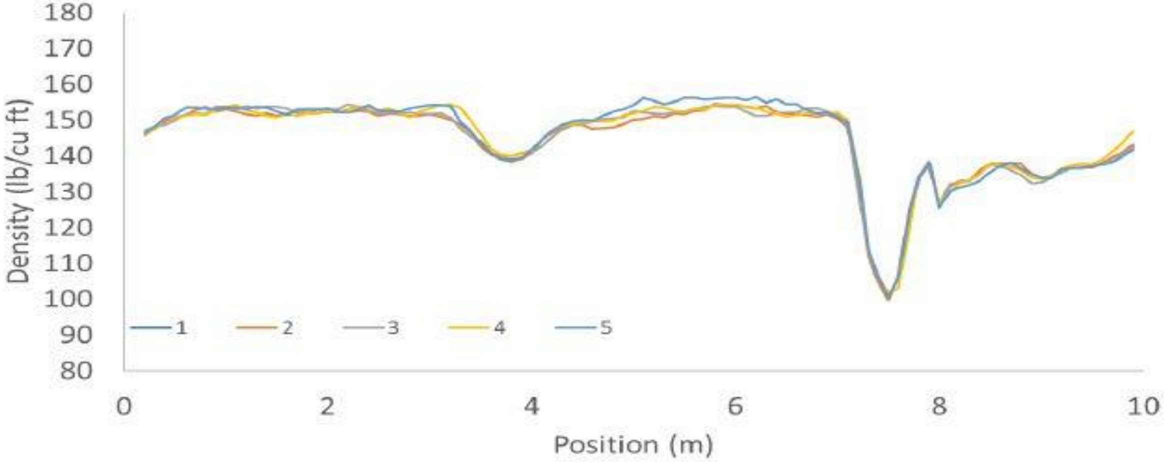


Figure 16. Example of cross-road K_r data (Figure 12) transformed to density using the correlation of nuclear gauge density with permittivity (see Figure 14).

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K to ρ **Summary**

- Topic still needs analysis
- Many proposed ways
- Most approaches just measure core density and GPR K at core location then fit a curve
- Need for standardized “density” or “air void” conversion approach.

K *to* ρ **Summary**

- MnDOT developing a lab based reference of known density (pucks) and corresponding dielectric permittivity.
- Opportunity of fewer cores in the field.
- Opportunity to view variability of density over newly paved roadways.

Summary and Conclusion

From the tests to date, there are a number of observations that are clear.

1. A factory calibrated instrument that determines permittivity is clearly viable.
2. The ability to almost instantaneously deploy the PDP demonstrates the practicality of making the permittivity measurements quick and easy.
3. The user operation is simple.
4. The translation of permittivity to density still needs serious industry assessment. (Efforts such as work by MnDOT to have a standard way of characterizing asphalt to generate a permittivity to density conversion are critical to success.)
5. A unified user acceptance of what measurement unit (Density, Permittivity, or Void Content) should be the "standard" is desirable.

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Acknowledgement

Sensors & Software are continuing our field trials and to work in collaboration to continue studies on the correlation of permittivity to density.

We greatly appreciate the opportunity to work with The Swedish Transportation Administration and the openness and desire to share results and experiences of Torstan Nordgren.

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