# How Low is too Low?

## Assessing the Risk of Low Air Voids using Accelerated Pavement Testing

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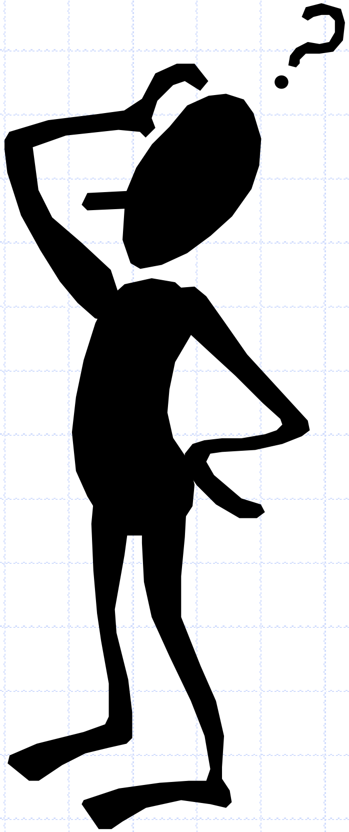
# Low Air Voids

- During construction
  - Excess binder
  - Excess fines
- Too low
  - Plastic flow
  - Rutting and shoving under traffic
  - Flushing and bleeding
  - Increased maintenance
  - Shorter pavement life

# What to Do?

- Remove and replace?
  - Contractor risk – mix might still perform
- Leave in place with reduced pay?
  - How much reduction?
  - DOT risk – mix might fail



# How Low is Too Low?

- Design at 4% or 3-5%
- Foster – in situ air voids ≤ 2.5% shoved
  - Instability at 3% for 4.75 mm DGA
- NCAT – rutting mixes had air voids ≤ 3%
- Harvey and Tsai recommend design AV = 2% (perpetual pavement base)
- WesTrack – minimal rutting in section with 1.6% air voids in situ

# Factors Affecting Severity

- Type of roadway, traffic level, climate
- Depth within pavement structure
- Strength/stiffness of mix

*How do you know if it is safe to leave in place?*

# Indiana History

- Implemented Superpave in 1992-93
- Began volumetric acceptance of HMA in 2001
- Volumetric acceptance on all HMA in 2003
- Pay factors depend on binder content, VMA, air voids and density
- Plate sampling and density cores

# Substandard Results

- If first sample “fails,” backup sample is tested
- If backup sample also fails, suspect sublot is referred to Failed Materials Committee for disposition
  - Leave in place at reduced pay
  - Remove and replace

# Concern

- Some sublots exhibited air voids <2%
- Removal and replacement was indicated
- Costly for contractors ($30/Mg × 1000 Mg)
- Testing variability issues and extenuating circumstances
- Wanted more objective way to determine action

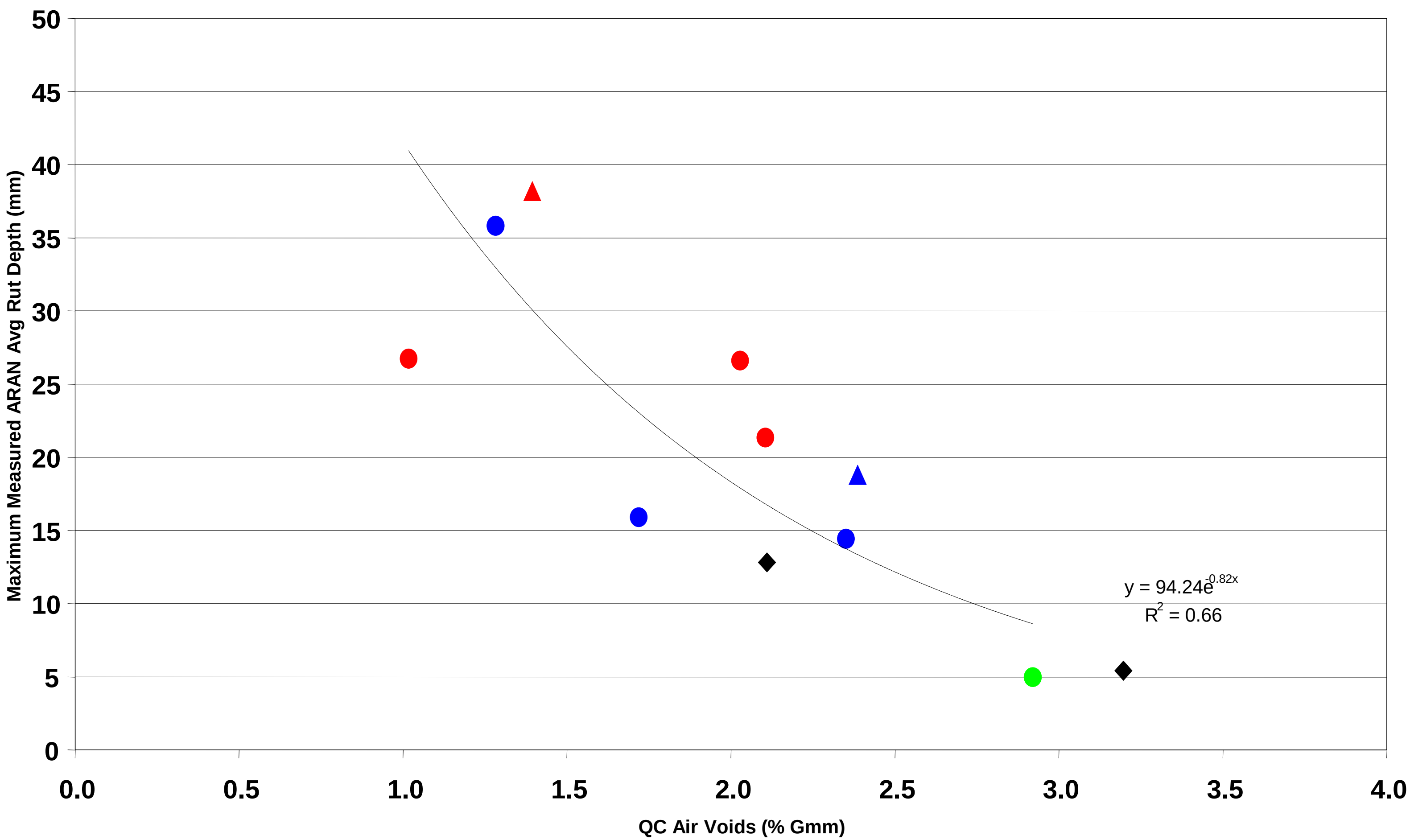
# Initiated Research

- Two Pronged Approach
  - NCAT Test Track 2006
  - INDOT/Purdue Accelerated Pavement Testing (APT) Facility
- Assess agency and contractor risk
- Recommend decision strategy for managing risk when accepting or rejecting low air void mixes

# NCAT Phase III

- Sections S7 (A&B) and S8 (A&B)
- 50 mm (2 in) surface removed and replaced with low void mix

# Low QC Voids Experiment



# APT Experiment

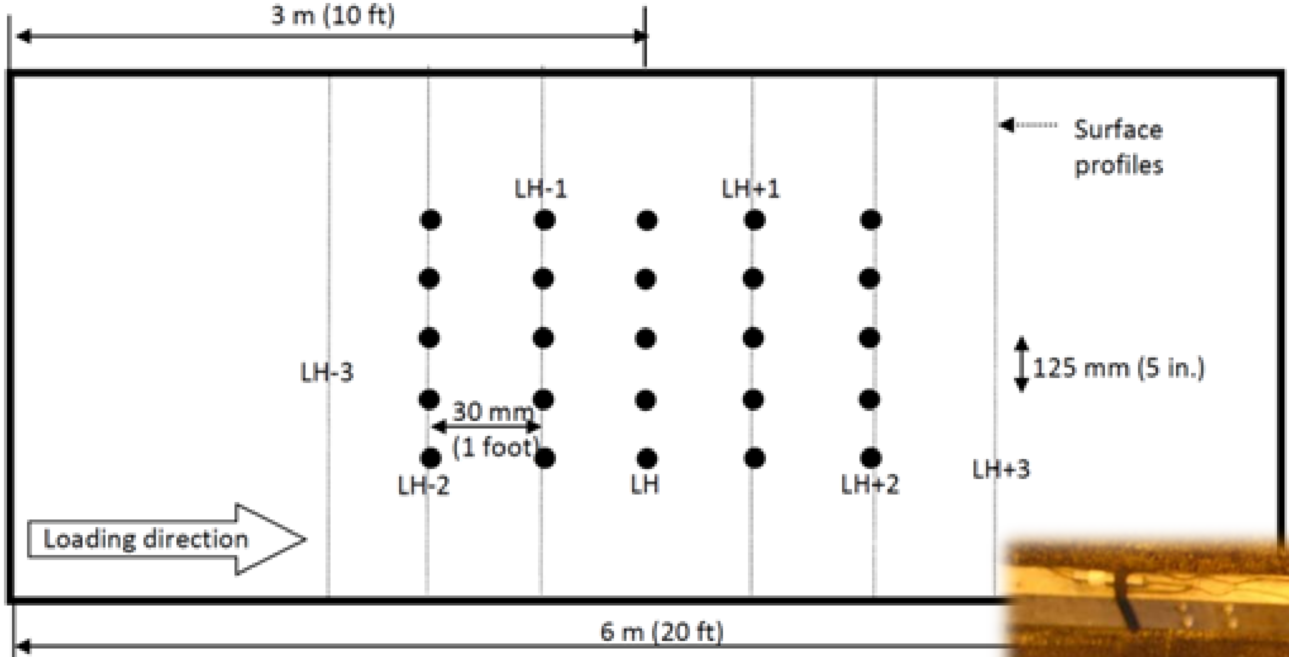
# Air Voids in APT

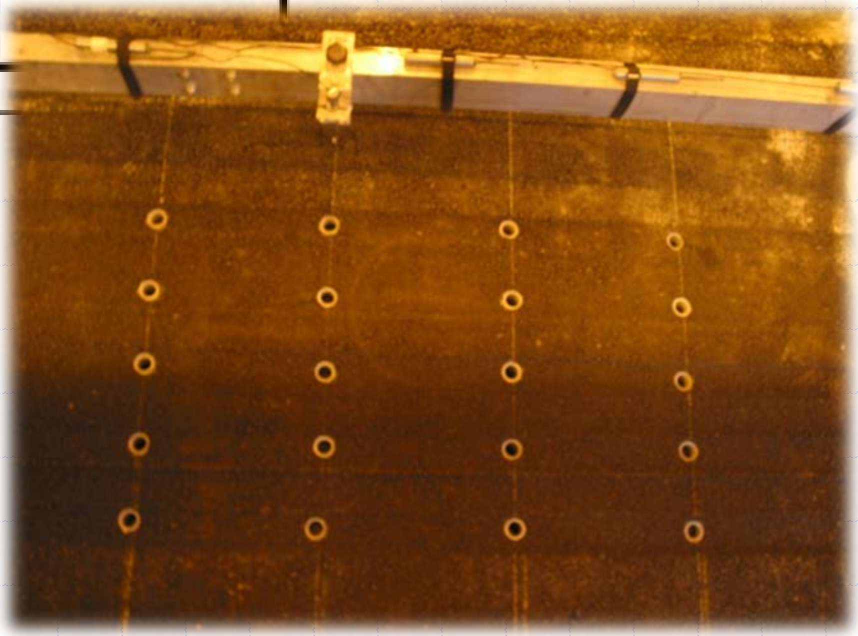
| Lane | Top 50 mm | Lower 50 mm | Cause |
|---|---|---|---|
| 1 | ~4% | ~2% | High binder |
| 2 | ~4% | ~2% | High fines |
| 3 & 4 | ~2% | ~4% | High binder |

Each lane is 1.5 m (5 ft) wide and 6 m (20 ft) long.

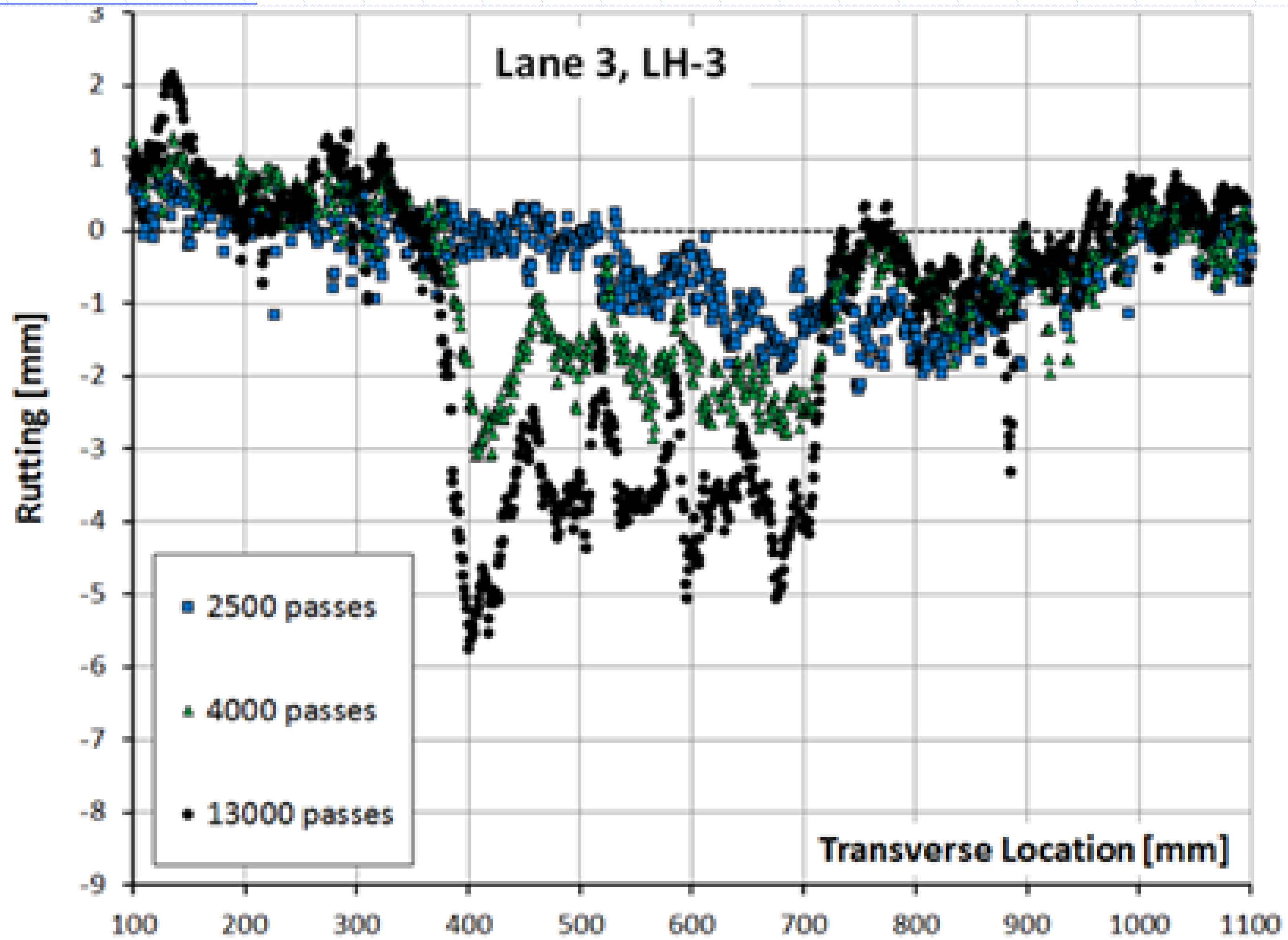
355 to 430 mm (14 to 17 in.) pavement on 405 mm (16 in.) cement stabilized soil.

# Drilling Plan



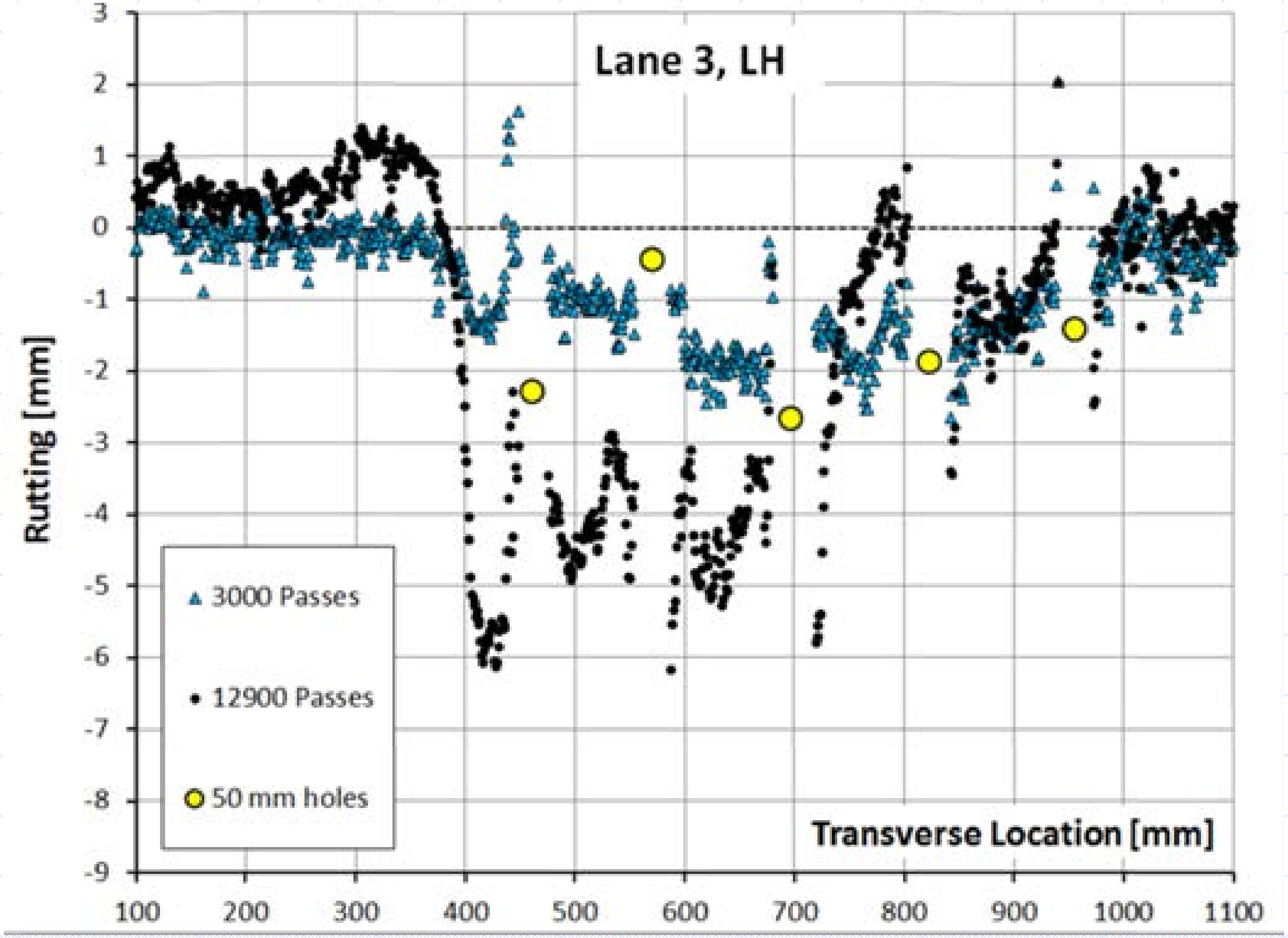



# Rut Depths



Lane 3, LH-3
Rutting [mm]
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
2500 passes
4000 passes
13000 passes
Transverse Location [mm]
100
200
300
400
500
600
700
800
900
1000
1100

# Rut Depths



Lane 3, LH
Rutting [mm]
Transverse Location [mm]
3000 Passes
12900 Passes
50 mm holes
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
100
200
300
400
500
600
700
800
900
1000
1100

# Modeling

- Rutting 'driving forces'
  - Shear - shape change
  - Volumetric - density change
- Subsystem approach
- A simple VP model

$$\dot{\varepsilon}_{ij}^{vp} = \frac{s_{ij}}{\eta_S} + \frac{p\delta_{ij}}{\eta_V}$$

$$s_{ij} = \sigma_{ij} - \frac{\sigma_{kk}}{3}\delta_{ij}$$

$$p = \frac{\sigma_{kk}}{3}$$

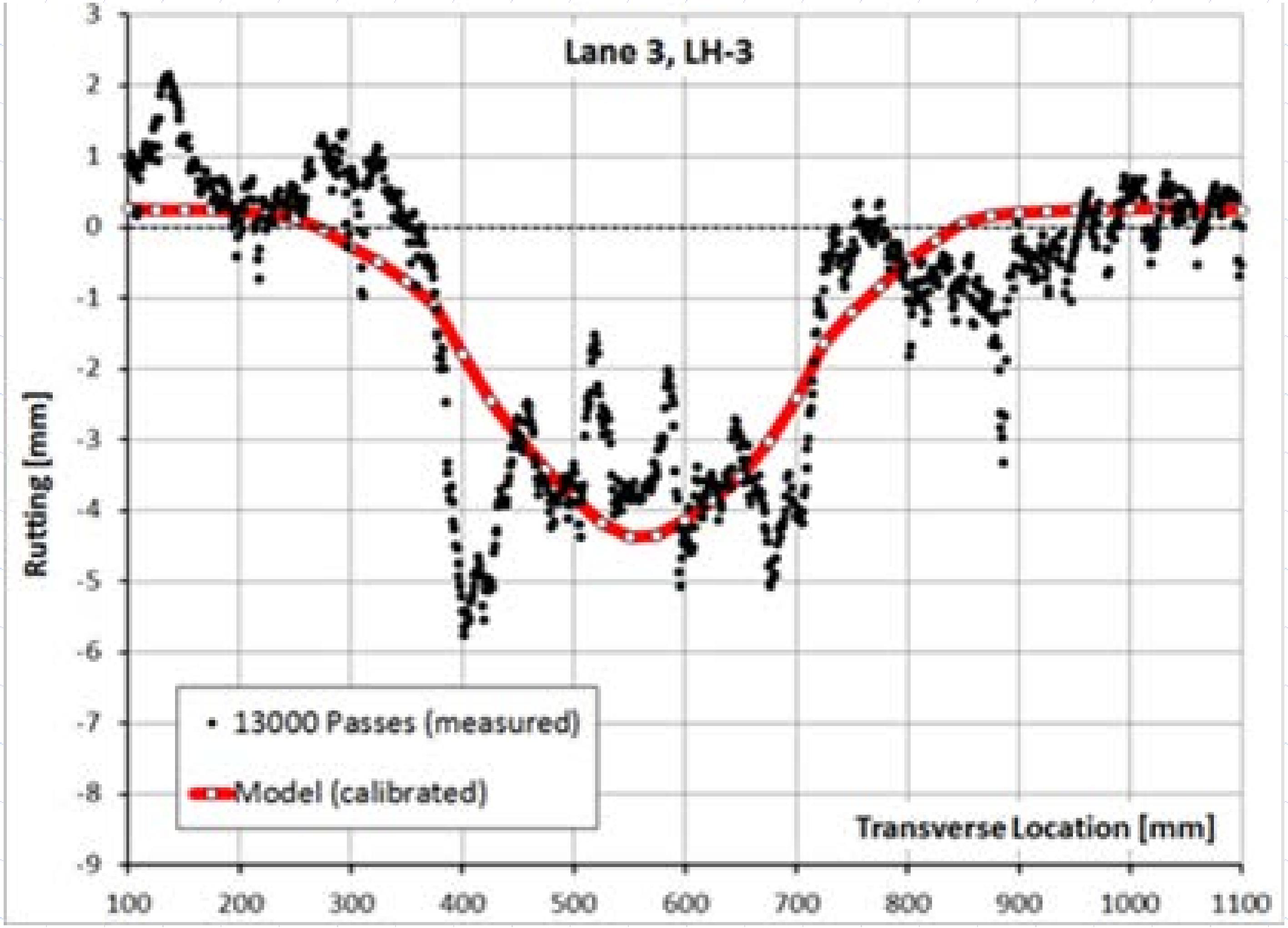
Resistance to shear deformation

Resistance to volumetric deformation

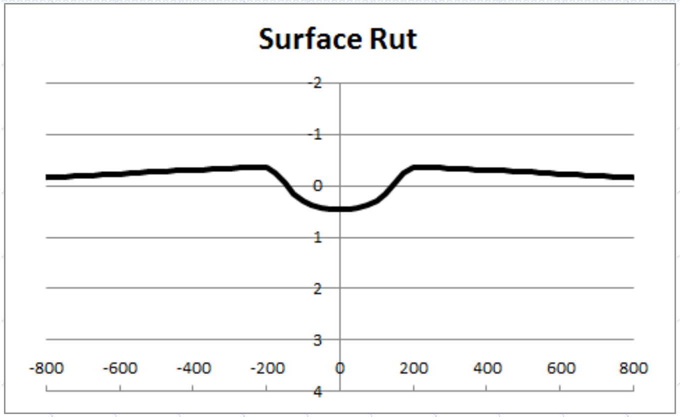
# Modeling

- Four layer system
- Assumed Poissson’s ratio
- Backcalculated moduli from FWD
- Simulated moving wheel load
- Computed profiles compared to measured
- Refined model and simulation repeated

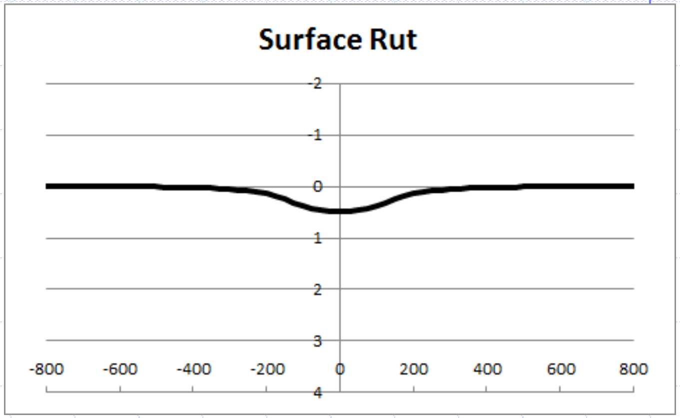
# Modeled Rut Depth



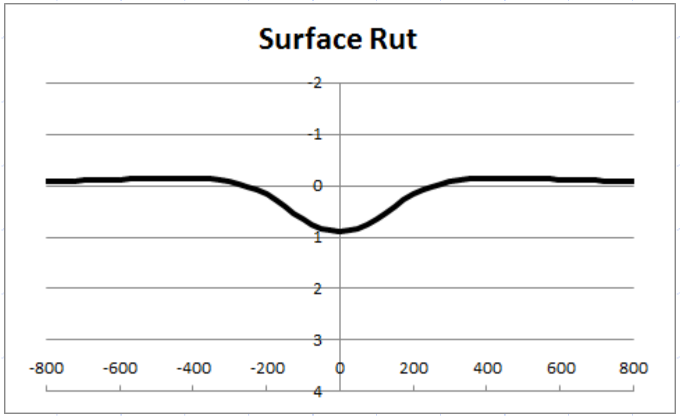
# Modeling




**Low AVC @ z=0**




**Reference case**




**Low AVC @ z=8”**

# Decision Support Tool

| AVC [%] | Traffic intensity (20 year) | |
|---|---|---|
| | Low | High |
| 3.0 | 1 | 1 |
| 2.9 | 1 | 2 |
| 2.8 | 2 | 2 |
| 2.7 | 2 | 2 |
| 2.6 | 2 | 3 |
| 2.5 | 3 | 3 |

1 = Accept
2 = Reduce Pay
3 = Reject

# Monetary Reduction

- How to determine appropriate pay reduction?
- Assess impact on life cycle
  - QRSS (NCHRP 9-22) – based on MEPDG
  - As-designed vs. As-built
  - How much was life cycle reduced?
  - Rough rule of thumb $10,000/lane mile/yr
- Analysis in progress

# Conclusions

- Currently air void levels below 2-3% appear problematic regardless of position.
- Cause of the low voids does not matter.
- Risk to agency and contractor.
- Preliminary decision support tool being refined to consider impact on service life.
- Drilled holes provide some insight – need refinement.

# For more information:

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***Modeling questions***:

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