Effect of Low Air Voids

Rebecca McDaniel

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Air Voids

- Too High
  - Rutting under traffic
  - Increased binder aging

High Air Voids

- Research and experience show high air voids can be a major problem
- Increased permeability
  - Increased binder aging, cracking and raveling
  - Increased moisture damage
  - Increased densification under traffic
- Big problem in some states with early Superpave projects

Impact of High Voids

Ravelling increases as air content increases.

Service life reduced about 10% for each 1% air voids over 7%!

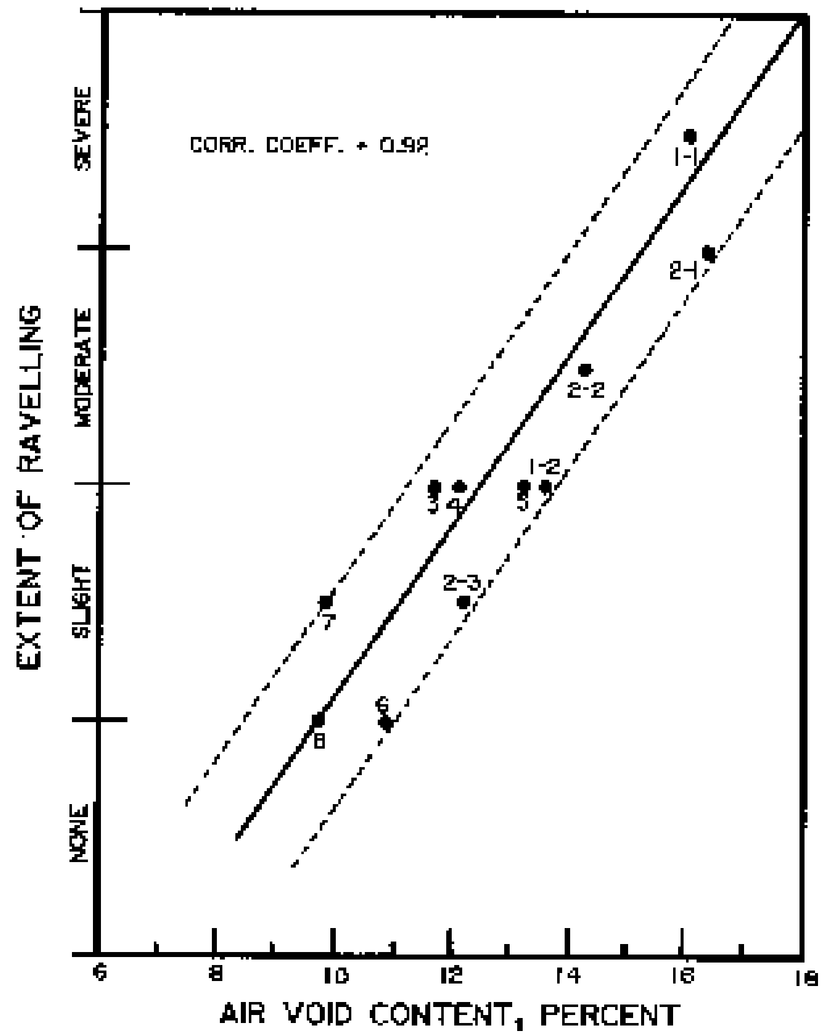


Figure 2–34. Air Void Content Versus Extent of Ravelling (after Kandhal, 43)

Air Voids

- Too low
  - Plastic flow
  - Rutting and shoving under traffic
  - Flushing and bleeding

High Voids

- Typically a compaction problem
- Change rollers, rolling patterns, temperature, etc.

Low Voids

- Typically mix problem
  - Mix design problem
  - Poor quality control

- Redesign or adjust mix
- Remove and replace

How Low is Too Low?

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

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

- Aggressively implemented Superpave beginning in 1992-93
- Began implementing 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 ($\$30/\text{Mg} \times 1000\ \text{Mg}$)
- Testing variability issues and extenuating circumstances

Referee Testing

- INDOT offered referee testing at contractor's option and cost
  - Traffic control, coring, testing
- Low air void mixes tested for mix stiffness
- Results considered when determining pay factors or remove/replace

Rationale

- Low air void mixes could exhibit stability problems
- If mix stiffness is adequate rutting would likely not develop
- Low air voids *and* low stiffness would likely signal performance problems
- Adequate stiffness ≥ 250 MPa (36,200 psi) at 10 Hz and 40°C (SST Frequency Sweep)

Application of Results

- If average of three tests $\geq$ 250 MPa, remain in place at reduced pay
- If average $\leq$ 250 MPa, remove and replace at contractors expense
- Relatively few cases overall
  - Almost no cases after 1-2 years
  - About half the results favored leaving in place
  - When left in place, pay reductions ranged from 15-50%
  - No performance problems observed

Tool Worked – Why Change?

- Low voids still occur occasionally
- Referee testing no longer used
- SST testing temperamental, uncommon
- No technical guidance on pay reduction
- Applied equally to all mixes, roads, etc.
- Risk to agency (poor performance) and contractor (cost)

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 Test Track

- INDOT sponsored two sections in 2006
- NCAT subdivided each
  - Four 31.5m (100 foot) test sections
- Another section serves as control
- Perpetual pavement sections
- 50mm (2 in) surface removed and replaced with low void mix

Comparison of Sections

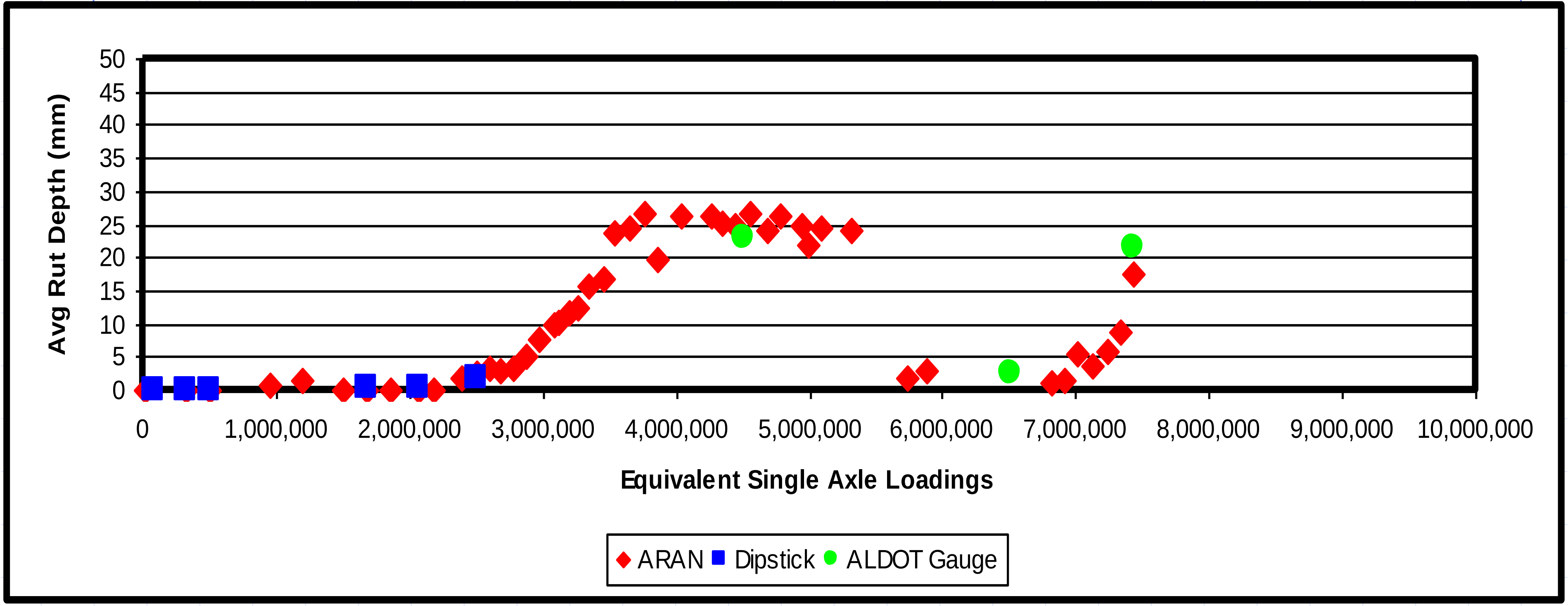
Section	Design Air Voids %	In Situ Air Voids %	Binder Content %
S7A	1.4	2.2	6.5
S7B	2.1	3.9	6.1
S8A	2.0	3.9	6.2
S8B	1.0	2.3	6.1
N5*	4.0	5.2	5.8

*Control

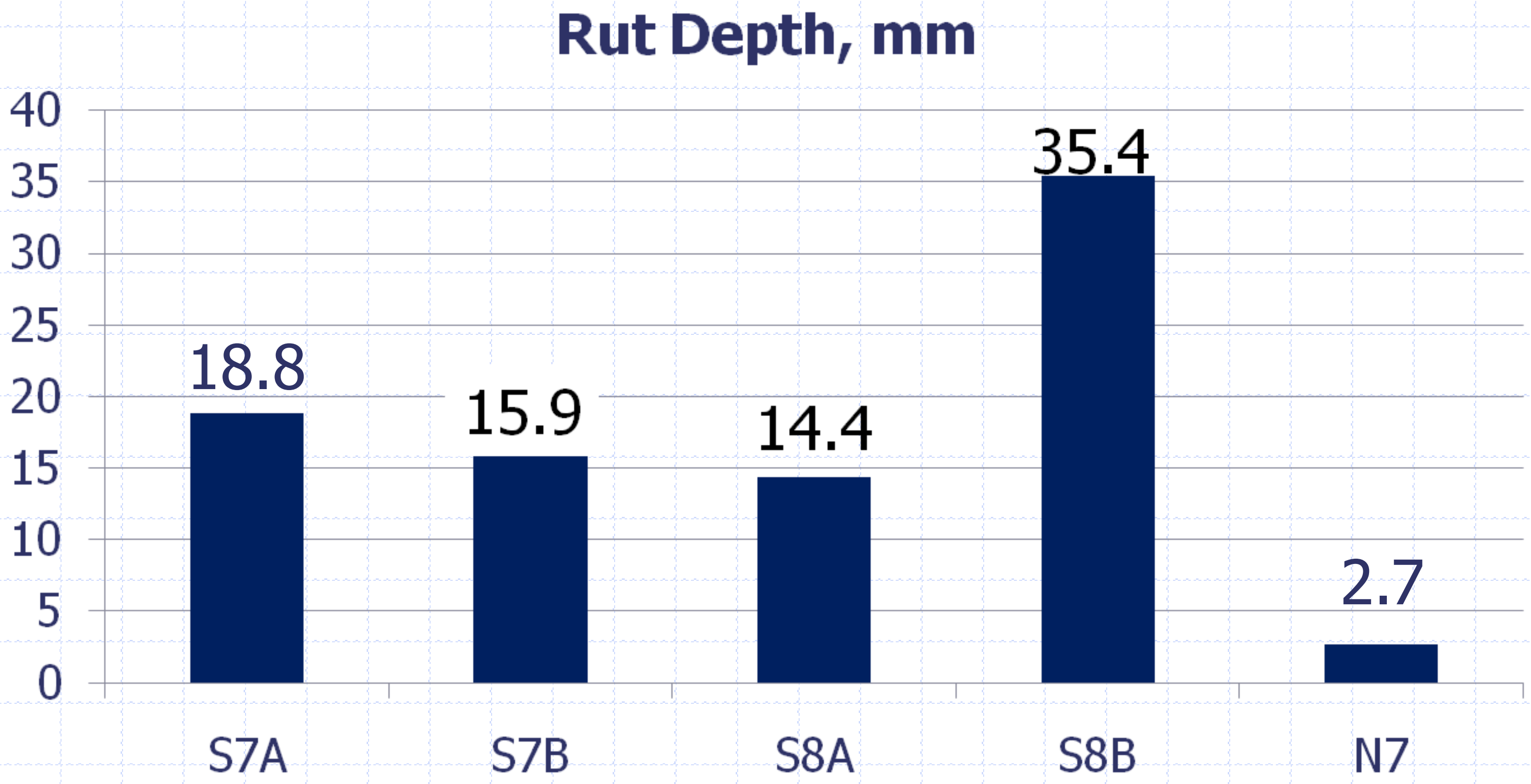
S7A Performance 2007

Rutting in 2008

Rutting Performance



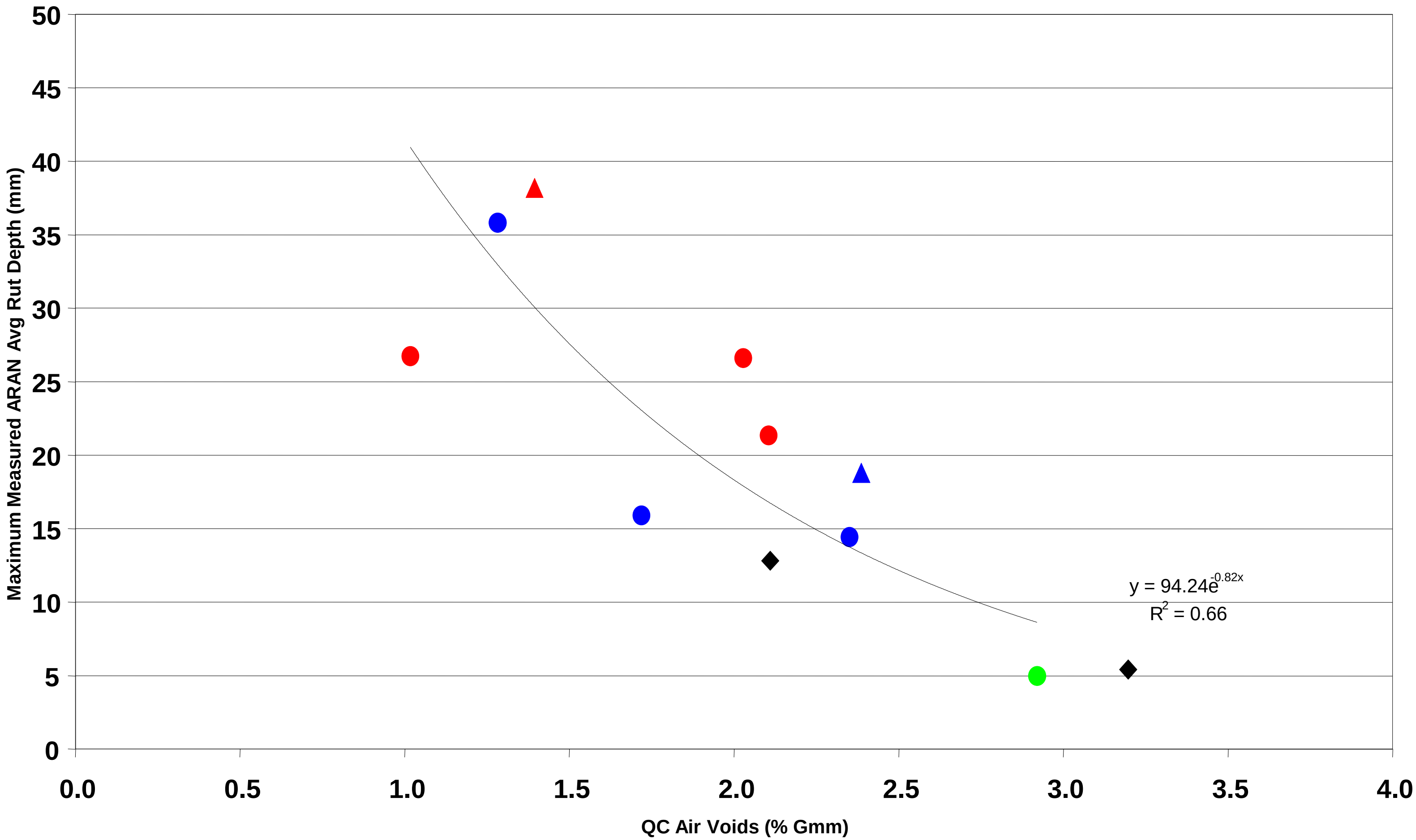
Rutting Comparison



Poor Performance

- All four sections rutted severely by 2-08 (~5.6×10^6 ESALs)
- Safety concern for trucking
- Mixes removed and replaced with more low void mixes in 2-08
- New mixes also rutted beginning 5-08

Low QC Voids Experiment



APT Experiment

Air Voids in APT

Lane	Top 50mm	Lower 50mm	Cause
1	~4%	~2%	High binder
2	~4%	~2%	Gradation
3	~2%	~4%	High binder
4	~2%	~4%	Gradation

Constructed December 2009, loading in progress.

Potential Products

- Minimum air void content specification
  - Establish level to remove and replace
- Test method to determine when to remove and replace (dynamic modulus?)
- Decision tree considering life cycle

NCHRP 9-22 Performance Related Specifications

- Fugro Consultants
- Software to predict pavement performance based on as-built volumetrics and material properties
- QRSS – Quality-Related Specification Software
- Compare to as-designed to assess change in service life
- Evaluating applicability to low voids issue

Conclusions

- Currently air void levels below 2-3% appear problematic
- Occasionally lower void mix can perform acceptably
- Risk to agency and contractor
- There are options to consider
  - Test stiffness or modulus of mix
  - Evaluate performance/life cycle impacts

For more information:

Rebecca S. McDaniel
Technical Director
Your North Central Superpave Center
765/463-2317 ext 226
rsmcdani@purdue.edu
https://engineering.purdue.edu/NCSC