Asphalt Compaction Operations – Effects on Durability

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Primary Causes of Poor Durability

Cause	Result
Low Binder Content	Raveling Brittleness Cracking
Binder Aging	Early asphalt hardening Cracking
High Voids Content	Disintegration/ravelling

Understand the causes
so we can prevent the results.

Raveling

- Insufficient binder
- Insufficient fine aggregate
- Lack of compaction
- High dust to binder ratio
- Water sensitivity
- "Dirty" aggregates

- *Mix design*
- *Changes during production*
- *Inadequate compaction*

Cracking

- Fatigue
  - Pavement thickness
  - Low binder content
  - Moisture sensitivity
  - Stiff binder
- Thermal
  - Low binder content
  - Stiff binder
  - High dust to asphalt

- *Pavement design*
- *Mix design/material selection*
- *Changes during production*
- *Inadequate compaction*

Binder Aging

- Oxygen reacts with binder
- Leads to hardening of binder
- Increases raveling and cracking

- *Material Selection*
- *Overheating*
- *Poor compaction*

Air Voids Too Low

1.5% air

Air Void Content Too High

- Traffic densification (rutting)
- Increased binder aging (cracking)

IMPACT OF HIGH VOIDS

Raveling increases as air content increases.

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

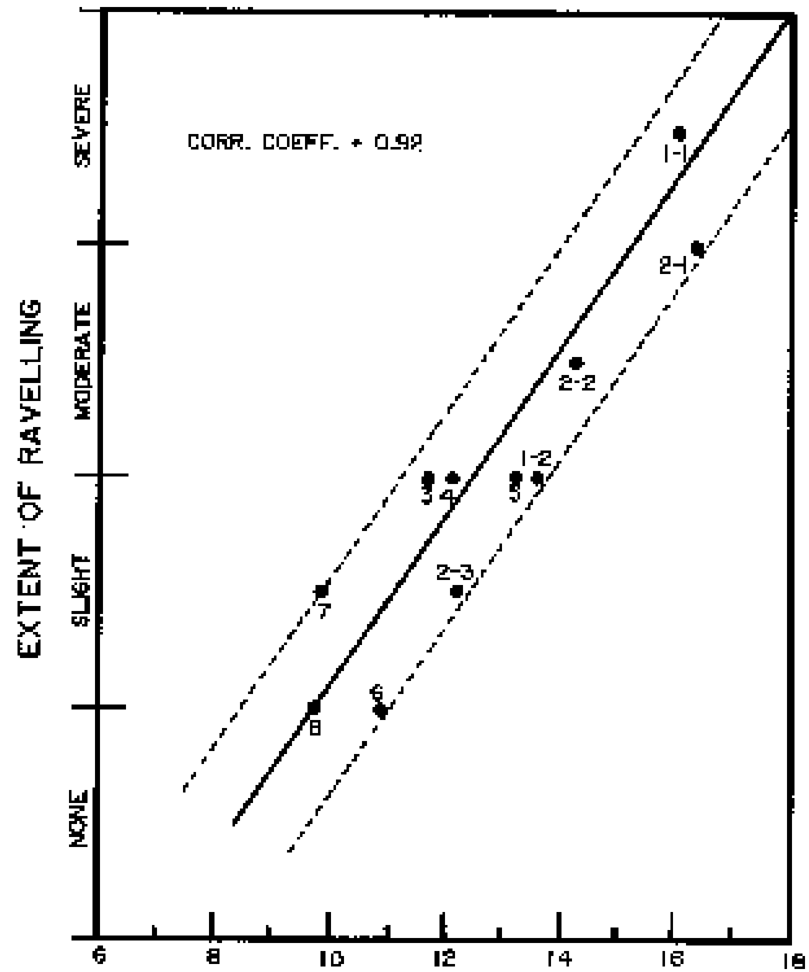
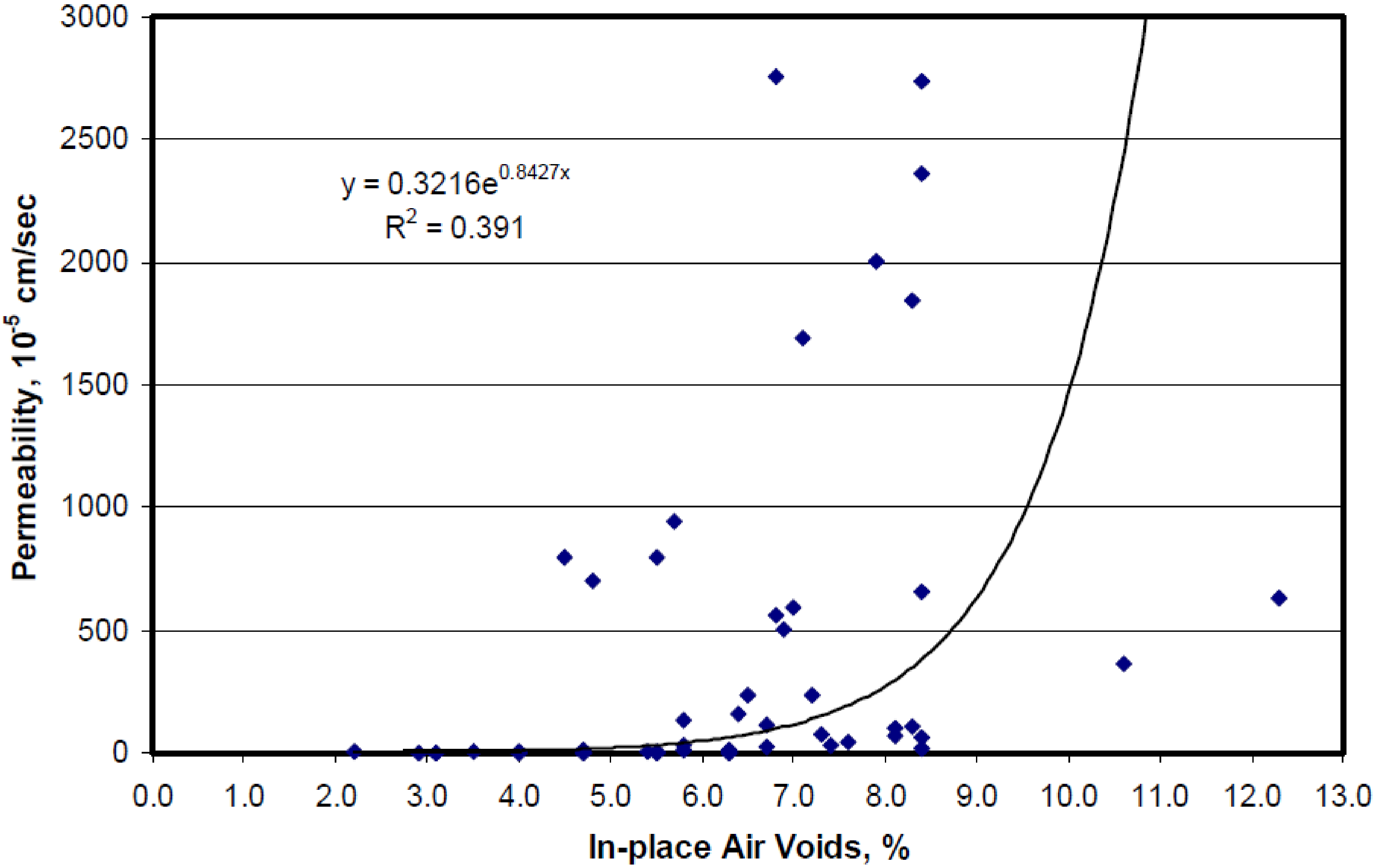


Figure 2–34. Air Void Content Versus Extent of Ravelling (after Kandhal, 43)

NCAT STUDY (Report 03-02, Mallick et al.)



Factors Affecting Compaction

- Mix Properties
  - Aggregate gradation, shape and texture
  - Binder stiffness and content
  - Mix temperature
- Environmental Conditions
  - Air and surface temperature
  - Wind
  - Humidity

Factors Affecting Compaction

- Layer Thickness
- Joints
- Segregation
- Equipment
  - Enough
  - Speed
  - Type

Layer Thickness

- Achievable density related to thickness relative to NMAS (NCHRP 531)
- Recommended thickness ≥ 3 times NMAS for fine graded and ≥4 times NMAS for coarse graded mixes and SMA

How to Decrease Voids and Increase Durability?

- Increase field density while maintaining effective binder content and VMA
- Mixes need to be more compactable

Concept

- Make changes in mix design to make mixes easier to compact in field
- Design and compact mixes to 5% air
- French mixes have no traffic densification

Changing Gyration Levels

- With same aggregate stockpiles
  - Same crushed faces, FAA and hardness
- Decreasing gyrations→
  - Change in gradation
  - Lower mix stiffness in lab
  - Easier compaction in field
- Need equal or better final mechanical properties to prevent traffic densification

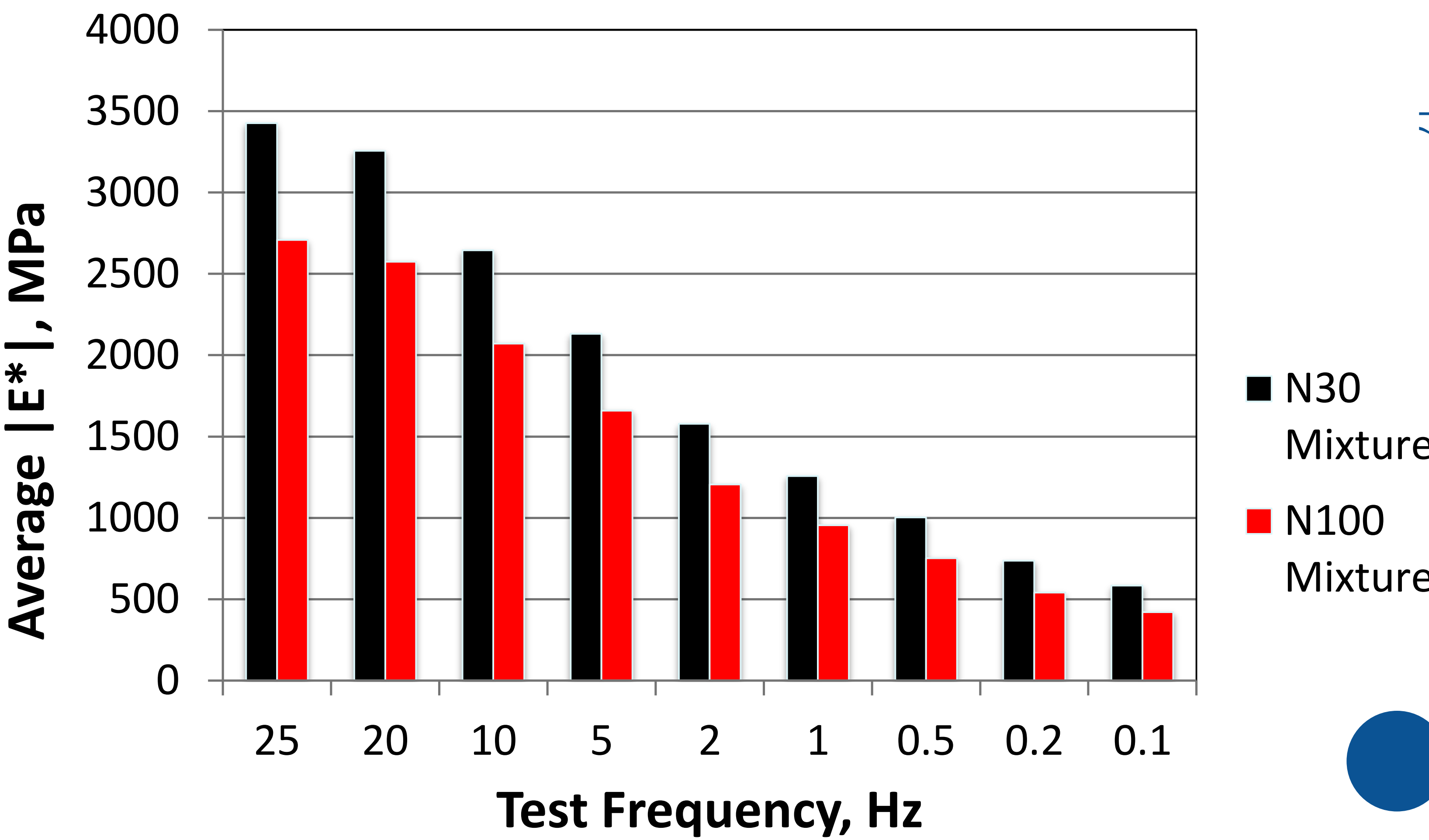
LAB FINDINGS

- With changes in gradation, mixes can be designed at 5% air voids in the lab
- Re-designed mixes at 5% air can have higher stiffnesses and higher rut resistance than mixes designed at 4% air and compacted to 7% air
- Concept looks promising
- Field trial recommended and identified

Field Trial

- Mill and overlay on state road (SR13)
- 9.5 mm surface for 10-30 million ESALs
  - Steel slag and limestone coarse agg
  - Manufactured and natural sands
  - 7% RAS
- N100 mix re-designed at 30 gyrations
  - Changed during production to N50

SR13 Mix Designs



SR13 Mix Design FN Test

Original (N100) mix – FN = 841

N30 mix – FN = 1181

- Bigger is better, more rut resistant
- Air voids ~1% low on both mixes
- Statistically significant difference

- Things look promising

Estimated Properties at N30

Property	Sublot 1	Sublot 2	Sublot 3	Average
Air Voids, %	5.1	4.8	4.7	4.9
VMA, %	17.2	16.6	17.2	17.0

Based on field data and Bailey method calculations.

Field Compaction

Sublot	Density 1	Density 2	Average
1	92.30	94.53	93.42
2	93.59	94.68	94.13
3	96.29	96.69	96.49

Overall Average Core Density = 94.7%

Target 95%

No change in compaction equipment nor patterns!

Plant Produced Mix Results

- N100 was stiffer than N50
  - Statistically significant difference
  - Both mixes were reheated
- N100 had higher flow number and lower strain than N50
- Contrary to lab and mix design results
  - Does not necessarily mean N50 will rut
  - Time will tell…

Conclusions

- Mixes designed at 5% air in lab can be compacted to 5% in the field with minimal to no changes in compaction process
- Results of testing reheated plant produced mixes did not agree with lab research nor mix design
- Field trial will show if rutting develops

Anticipated Benefits

- Potential 2–3 years of increased service life
- Potential savings of $20–30 million a year
  - Based on $300 million HMA rehab budget and that 50% of the HMA pavements reaching end of life do so because of durability problems

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