So You Think You Have A Problem!

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THE FIRST STEP IS ADMITTING YOU HAVE A PROBLEM
What Is The Problem?

Cracking

Rutting
What Is The Problem?

Structural – Bottom Up Failure
What Is The Problem?

Structural – Bottom Up Failure  Functional – Just Plain Rough
IF YOU DO NOT HAVE A RUTTING PROBLEM, THEN LET’S FOCUS ON CRACKING, WHERE DOES IT COME FROM?
I-66 Broad Run

Surface Cracking
- Longitudinal Cracking

Surface Crack Due to Delamination
I-66 Fauquier County

Surface Cracking

Notice Crack in Surface Only
Surface Cracking

Cracking Due to Delamination
SR 244 Fairfax County

Surface Cracking

Top-Down Cracking
Each Crack Is Addressed Differently

• Pavement Design Methods
  – 1993 or older AASHTO
  – Pavement ME / MEPDG
  – Does It Matter if the AC is Thick Enough?

• Construction Techniques/Procedures
  – Proper base preparation/repair
  – Proper tacking and tacking materials
  – Adequate in-place density

• Mix Design
Mix Design

• SCDOT and Most Other States Adopted SUPERPAVE™
• SUPERPAVE™ was developed to address rutting and flushing (national issue in 1980s)
• Initial plan was to move from volumetrics to performance based designs
So What Are The Mix Design Issues?

- High gyrations?
- Coarse gradations?
- Low AC contents?
- Incorrect volumetric values?
- RAP?
- RAS?
- Gsb?
Sample of Current Efforts

Changes Made
Efforts/Discussions Underway
Lab Compactive Effort
# Lab Compactive Effort - $N_{design}$

## NCHRP Report 573 Recommendations

<table>
<thead>
<tr>
<th>20-Year Design Million ESALs</th>
<th>Current $N_{design}$ M 323</th>
<th>$N_{design}$ for $&lt;\text{PG 76-XX}$</th>
<th>$N_{design}$ for $\geq \text{PG 76-XX or mixes}$ $&gt;100$ mm below the surface</th>
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<tbody>
<tr>
<td>&lt; 0.3</td>
<td>50</td>
<td>50</td>
<td>N/A</td>
</tr>
<tr>
<td>0.3 to 3</td>
<td>75</td>
<td>65</td>
<td>50</td>
</tr>
<tr>
<td>3 to 30</td>
<td>100</td>
<td>80</td>
<td>65</td>
</tr>
<tr>
<td>&gt; 30</td>
<td>125</td>
<td>100</td>
<td>80</td>
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Choosing a Gradation

![Graph showing percent passing versus sieve size for different blends. The graph includes data for 0.075 to 19.00 mm sieve sizes and shows the trend for Blend 2, Blend 3, and Blend 4.]
Choosing a Gradation

- Finer Gradations
- More Compactable
- More Workable
- Less Permeable
Optimum Asphalt Content of Mixes

Balanced Mix Design
**Volumetric Principles**

\[ V_{MA} = V_a + V_{be} \]
Lowering the Target Air Voids to Increase Asphalt Contents

OK for mixes using polymer-modified binders, mixes for lower layers, and mixes with moderate RAP contents.
Voids in Mineral Aggregate (VMA)

\[
VMA = 100 - \frac{G_{mb} P_s}{G_{sb}}
\]

\[VMA = V_a + V_{be}\]
Challenges with $G_{sb}$

1. Time Consuming Tests
   - Reduces frequency of checking
   - Shortcuts
2. Lack of precision
   - Agency verification is weak
3. Lack of guidance on determining $G_{sb}$ for RAP and RAS
Voids in Mineral Aggregate (VMA)

\[ VMA = 100 - \frac{G_{mb} P_s}{G_{sb}} \]

\[ VMA = 100 - \frac{2.444 \times 95}{2.700} = 14.0\% \]

\[ VMA = 100 - \frac{2.444 \times 95}{2.750} = 15.6\% \]
Can you use $G_{se}$ as a surrogate for $G_{sb}$? **NO**

Can you use $G_{se}$ to estimate $G_{sb}$?

Only if asphalt absorption does not change. But it’s not possible to know unless you measure both $G_{se}$ and $G_{sb}$.

However, checking $G_{se}$ should be part of mix design and QC.
How often should $G_{sb}$ be checked?

It depends! — on how much $G_{sb}$ of aggregates change.
Recommendations

RAP Aggregate $G_{sb}$

One method of determining RAP aggregate $G_{sb}$ will not work for all material types. Agencies should evaluate options to find the best method for their materials. The method that gives the lowest $G_{sb}$ will result in the lowest mix VMA. This is desirable since it will lead to higher asphalt contents and better durability.
Flexibility from Asphalt Binders

Flexibility does not just depend on the volume of asphalt, it also depends on the characteristics of the asphalt.
Binders from Recycled Materials

- Recycled binder “activation” can’t be determined from volumetric properties.
- Softer virgin binders do improve durability of high RAP content mixes.
- RAP and RAS binders are not the same.

Asphalt recovered from tear-off shingles
Success with RAP

• Using RAP in HMA has a long history of success
  – National average RAP content is 20%
  – Some states routinely use more than 30% RAP
  – NCAT Test Track sections with 50% RAP outperformed all-virgin sections in all measures. No distresses in RAP sections after 6 years and 20 million ESALs
  – Norway and Japan currently use about 50% RAP on average.
Barriers to Increasing RAP

• Uncertainty with Gsb of RAP aggregate
• Determining how to counter the effect of aged RAP binder
Limitations of Current Mix Design

- Volumetric properties alone are insufficient to assure satisfactory performance
  - Different layers should be designed for different critical stresses
  - VMA is highly dependent on accurate Gsb which is challenging to measure and verify
  - The impact of modified binders, recycled binders, and other additives is unclear

- Mix performance tests are needed to better engineer mixes and overcome limitations of the legacy specifications
Potential Tests for Assessing Cracking Resistance or Durability
So What Should SCDOT Consider?

• First, what is the problem?
• For Virginia, cracking was our primary failure
Phase I – Superpave Designed Mix Analysis

- Comparisons
  - Volumetrics for 50 and 65 Gyrations
  - Volumetric results for 50 and 75 blow Marshall

- Mix gradations

- Bag samples for future phases
Phase I - Results

• VTM (%AV) – Superpave Gyratory (SGC) produces approximately 2% lower VTM than the Marshall hammer.

• VMA – SGC produces approximately 1-2% lower VMA than the Marshall hammer.

• Review of the data did not produce a definitive “simple solution” (i.e., just reduce the number of gyrations).
Phase II - Results

• Sampled and tested plant produced SM-9.5 mixes (3/8” NMAS)

• Targeted mixes with 23% or less passing #30 sieve and at least 58% passing #4 sieve

• Test Results:
  – Determined that volumetrically in design, these mixes typically could safely handle 0.2 additional binder.
  – Performance tested for initial mix, mix at optimum, mix at optimum plus 0.2% binder, and mix at optimum plus 0.4% binder. In general all appeared to produced acceptable results from a rutting and cracking perspective.
Phase III

• Finalized select use special provision with changes to:
  • Design Gradations (#30 and #4 sieves)
  • Design Gyrations (50)
• Solicited demonstration projects from across state
• Design and produce experimental mixes to meet referenced criteria
• Paved control (65 gyrations and 4% VTM (AV)) and experimental mixes
• Retrieve mix (control and experimental) for additional lab performance testing
  • Flow Number and APA for rutting
  • Fracture Energy for cracking
• Collect density data from control and experimental sites
Improving Dense-Graded Mixtures
Fall 2015 Status – In-Place Sampling

Field Sampling:
• 30 six-inch cores per set over ~1500’
  • 15 Trial
  • 15 Control
• In-place Voids/Permeability

<table>
<thead>
<tr>
<th>Mix Type</th>
<th>Binder Designation</th>
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<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td>SM-9.5</td>
<td>3</td>
</tr>
<tr>
<td>SM-12.5</td>
<td>2</td>
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</table>
Density – Trial vs. Control

Frequency

Density - % MTD

Minimum Ctrl Strip (92.2 to 92.5)
Density – Trial vs. Control

Minimum Ctrl Strip (92.2 to 92.5)

Theoretically acceptable outside control strip with nuclear
Permeability – Trial vs. Control

Target = 150
Permeability – Trial vs. Control

The graph illustrates the relationship between permeability and density for trial and control mixes. The x-axis represents density (% MTD), while the y-axis shows permeability ($\times 10^{-5} \text{ cm/s}$). The data points and curves indicate that as density increases, permeability decreases. The graph is divided into sections labeled Bad and Good, with the orange arrow indicating Low Density and the red arrow indicating High Permeability.
New 2016 VDOT Specs

SM-9.5 mixes (3/8” NMAS)
- 50 Design Gyrations
- 4% Design VTM (AV), 2%-5% Production VTM (AV)
- 16% Design/Production VMA
- F/A 0.7 – 1.3
- 23% Max #30 Sieve
- 58% Min #4 Sieve

SM-12.5 mixes (1/2” NMAS)
- 50 Design Gyrations
- 4% Design VTM (AV), 2%-5% Production VTM (AV)
- 15% Design/Production VMA
- F/A 0.7 – 1.3
- 23% Max #30 Sieve
- 58% Min #4 Sieve
Things To Consider

• Start with basics – look at the mix design specifications

• If a good mix is produced, then is it laid for success? The right treatment prescribed in the contract, the proper site preparation, etc.
Final Comments

- SCDOT and SCAPA must partner to address the durability issues
- Learn from other states and develop a few pilot projects with revised material specifications
- Simply adding binder or reducing design gyrations does not work
- Do not jump straight to a Lab Performance Test, get the basics right and verify with Lab Performance Tests (jury is still out on cracking)
- Then decide the next steps