Effect of Flat and Elongated Aggregate on SMA Performance

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Acknowledgements

- Sponsor- Georgia Department of Transportation
Outline

- Background - Why is the research needed?
- Objective - What will we do?
- Work Plan - How will mixes be evaluated?
- Results and Conclusions

Background

- Cost of SMA mix 20-80% higher than conventional dense-graded mix
  - High traffic volume routes
  - Night work with restricted hours
  - Higher asphalt binder demand
  - Special crushed aggregate
Special Crushed Aggregate

- Special crushing equipment
- Investment/benefit considerations
- High quality aggregates
  - European standards
    - L.A. wear ≤ 30
    - Flat and elongated (F & E) ≤ 20% at 3:1 ratio
  - To resist degradation from studded tires
  - May not be necessary for other countries

Previous Research

- NCAT Report 00-03
  - Abrasion value is influenced to some degree by particle shape
  - Significant breakdown on No. 4 (4.75 mm) sieve related to particle breakdown at 3:1 ratio
  - Concluded upper limit of F & E between 30-50 may be needed
Previous Research (Continued)

- Oduroh - Increases up to 40% F & E at 3:1 ratio did not adversely affect performance of Superpave mixes
- Barksdale - Related particle breakdown to both particle shape and L.A. abrasion loss

Barksdale Recommendation (1992)

<table>
<thead>
<tr>
<th>L.A. Abrasion % Loss</th>
<th>F &amp; E Limit (3:1 Ratio)</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 45</td>
<td>≤ 20</td>
</tr>
<tr>
<td>≤ 40</td>
<td>≤ 25</td>
</tr>
<tr>
<td>≤ 35</td>
<td>≤ 35</td>
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<tr>
<td>≤ 30</td>
<td>≤ 40</td>
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<tr>
<td>≤ 25</td>
<td>≤ 45</td>
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</table>
Objective

- Evaluate the performance of SMA mixes with different F & E aggregate
- Determine how critical this aggregate property is for SMA performance

Work Plan

- 5 aggregate sources
  - 3 produce SMA and non-SMA stone
  - 2 do not meet 20% at 3:1 Ratio
- Lab tests
  - F & E Comparison
  - Cantabro loss- cohesion/resistance to raveling
  - Degradation (100 gratings)
  - Rut testing- APA
  - Moisture susceptibility
### F & E Properties

<table>
<thead>
<tr>
<th>Quarry</th>
<th>Aggregate</th>
<th>% F &amp; E 5:1 (GDT 129)</th>
<th>% F &amp; E 3:1 (GDT 129)</th>
<th>% F &amp; E 3:1 (ASTM D4791)</th>
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<tbody>
<tr>
<td>A</td>
<td>SMA 7</td>
<td>0.5</td>
<td>19.7</td>
<td>8.4</td>
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<tr>
<td></td>
<td>7</td>
<td>1.4</td>
<td>25.5</td>
<td>17.3</td>
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<td></td>
<td>89</td>
<td>2.2</td>
<td>23.9</td>
<td>13.1</td>
</tr>
<tr>
<td>B</td>
<td>SMA 7</td>
<td>0.3</td>
<td>17.0</td>
<td>6.8</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>0.1</td>
<td>19.9</td>
<td>9.5</td>
</tr>
<tr>
<td></td>
<td>SMA 89</td>
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<td>18.2</td>
<td>7.0</td>
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<tr>
<td></td>
<td>89</td>
<td>0.0</td>
<td>19.2</td>
<td>10.2</td>
</tr>
<tr>
<td>C</td>
<td>SMA 7</td>
<td>0.0</td>
<td>15.5</td>
<td>9.1</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>0.0</td>
<td>23.3</td>
<td>15.7</td>
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<td></td>
<td>89</td>
<td>3.0</td>
<td>30.4</td>
<td>17.8</td>
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<tr>
<td>D</td>
<td>7</td>
<td>6.5</td>
<td>38.9</td>
<td>26.5</td>
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<td></td>
<td>89</td>
<td>3.8</td>
<td>20.7</td>
<td>20.9</td>
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<tr>
<td>E</td>
<td>7</td>
<td>6.2</td>
<td>43.6</td>
<td>31.5</td>
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<td></td>
<td>89</td>
<td>1.9</td>
<td>31.6</td>
<td>16.8</td>
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</tbody>
</table>

### Aggregate Degradation

% Breakdown Non-SMA Stone vs. % Breakdown SMA Stone

- Source A
- Source B
- Source C

Line of Equality
Degradation (Difference from Control)

Percent Passing

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<tr>
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<tbody>
<tr>
<td>No. 4</td>
<td>4.0</td>
<td>6.1</td>
<td>4.5</td>
<td>4.5</td>
<td>9.3</td>
<td>9.6</td>
<td>3.0</td>
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<tr>
<td>No. 8</td>
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<td>3.6</td>
<td>2.9</td>
<td>3.3</td>
<td>6.7</td>
<td>6.4</td>
<td>1.5</td>
<td>2.2</td>
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<tr>
<td>No. 200</td>
<td>0.0</td>
<td>0.6</td>
<td>0.0</td>
<td>0.3</td>
<td>0.6</td>
<td>0.5</td>
<td>0.1</td>
<td>0.3</td>
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Effect of F&E

![Graph showing the relationship between Composite F&E and Abrasion and Breakdown]
Mix Design Verification

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<td>Composite F&amp;E</td>
<td>15.6</td>
<td>20.0</td>
<td>13.9</td>
<td>15.9</td>
<td>14.2</td>
<td>19.5</td>
<td>28.2</td>
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<tr>
<td>L.A.</td>
<td>31</td>
<td>31</td>
<td>37</td>
<td>37</td>
<td>33</td>
<td>33</td>
<td>16</td>
<td>16</td>
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<tr>
<td>Opt. AC,%</td>
<td>6.4</td>
<td>6.2</td>
<td>6.5</td>
<td>6.2</td>
<td>6.6</td>
<td>6.6</td>
<td>7.1</td>
<td>8.3</td>
</tr>
<tr>
<td>VMA</td>
<td>18.2</td>
<td>18.0</td>
<td>18.5</td>
<td>17.7</td>
<td>18.6</td>
<td>18.5</td>
<td>19.8</td>
<td>21.5</td>
</tr>
</tbody>
</table>

Effect of F&E on VMA

\[ y = 0.1434x + 15.924 \]

\[ R^2 = 0.82435 \]
APA Rut Test (AASHTO T340)

- 64°C
- 100 lb load
- 100 psi hose pressure
- 5% air voids
- 8000 cycles
- 5 mm- maximum rut depth allowed
Rutting Results

\[ y = -0.018x + 1.6572 \]
\[ R^2 = 0.058 \]

Moisture Susceptibility

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<thead>
<tr>
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<tbody>
<tr>
<td>TS-Conditioned (psi)</td>
<td>88.3</td>
<td>89.9</td>
<td>78.3</td>
<td>92.6</td>
<td>85.1</td>
<td>84.7</td>
<td>76.4</td>
<td>77.1</td>
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<tr>
<td>TS-Control (psi)</td>
<td>79.4</td>
<td>104.8</td>
<td>72.5</td>
<td>93.7</td>
<td>78.8</td>
<td>77.6</td>
<td>85.2</td>
<td>86.4</td>
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<tr>
<td>TSR, % (≥ 80)</td>
<td>111.3</td>
<td>85.8</td>
<td>108.0</td>
<td>98.8</td>
<td>108.0</td>
<td>109.1</td>
<td>89.6</td>
<td>89.3</td>
</tr>
</tbody>
</table>

Moisture susceptibility
6.0% air voids
Loading rate- 0.065 inches/minute
Conclusions

- The 3:1 ratio was much more sensitive to F&E than 5:1.
- Previous recommendations of no more than 20% F&E based on a 3:1 ratio have been found to be unnecessarily restrictive.
- Aggregates with high F&E values may perform well if they have low abrasion loss.
- Aggregate breakdown on the No. 4 (4.75 mm) and No. 200 (0.075 mm) sieves is not dependent on F&E alone.
- Aggregate with high F&E aggregate particles generally have higher VMA properties and may require higher binder content.

Conclusions

- There is no correlation between rut depth and percent F&E.
- Generally, the tensile strength of SMA mixes is not adversely affected by F&E values.
Recommendations

- The maximum limit (≤ 20% F&E at a 3:1 ratio) that is a standard threshold used by most agencies for SMA aggregate should be reconsidered.
- Aggregates meeting Superpave F&E criteria specified in AASHTO M323 at a 5:1 ratio may be acceptable.
- Similar research is needed for quarry sources that may have both high L.A. abrasion loss and a high proportion of F & E aggregate particles to determine if such sources can also provide satisfactory performance.

Thank You