Why Adjusted AFT ?
5 Basic Options for % AC

• Specify a Minimum % AC
• **Specify a Minimum VMA**
  • Specify a Minimum $V_{be}$
  • Specify a Minimum AFT
• **Specify a Minimum Adjusted AFT**
Adjusted AFT and VMA are both intended to provide an adequate effective AC volume ($V_{be}$).

VMA is based on the Nominal Maximum Aggregate Size

AFT is based on the calculated Aggregate Surface Area (SA), which is basically an “Index”.
Why AFT instead of VMA?

There is little correlation between the nominal maximum aggregate size and overall gradation, or aggregate surface area (SA).

The Calculated “SA” represents a gradation similar to a Fineness Modulus.

“SA” can account for changes in Aggregate Specific Gravity.
• $V_{MA} = V_{be} + V_a$

• $AFT = V_{be}/SA$

• “SA” represents the aggregate gradation

• As “SA” increases, $V_{be}$ must also increase in order to maintain a specific $AFT$
• AFT, Aggregate SA and $V_{be}$ are independent of the degree of compaction at Design (i.e. the number of blows or gyrations)

• VMA and VFA are dependent on the degree of compaction at Design
The Primary Difference between Asphalt Pavement Mixture and Aggregate Base is ASPHALT CEMENT.
Inadequate

Asphalt Film Thickness (AFT) or Effective AC Volume ($V_{be}$) May Result in

“Stripping” or Raveling
Stripping on TH 12
Stripping on TH 10
Stripping on TH 101
More Stripping on TH 101
Stripping on TH 242
Stripping on TH 47
Stripping on TH 55
Stripping on TH 7
More Stripping on TH 7
Raveling on TH 12
More Raveling on TH 12
Raveling on Schmidt Lake Road
Raveling on TH 21
More Raveling on TH 21
Excessive

Asphalt Film Thickness (AFT) or Effective Asphalt Volume ($V_{be}$) may result in Rutting.
Rutting on TH 41
Rutting on TH 41
Rutting on TH 494

Edge of Bridge Shadow
Measures Tried to Provide Adequate Effective AC Volume

- Minimum Total Asphalt Cement Content
- Minimum Voids in Mineral Aggregate (VMA)
- Minimum Asphalt Film Thickness (AFT)
Minimum Total AC Content

Does Not Account for:

• Changes in AC Absorption

• Changes in Gradation or Aggregate Surface Area
Minimum VMA

- Accounts for Changes in AC Absorption
- Includes Both $V_{be}$ and Air Voids
- Based on Very Poor Correlation with Aggregate Surface Area
- Encourages the Addition of Sand
- VMA is dependent on Design Compaction
Minimum AFT Advantages

- Accounts for AC Absorption by using Effective AC Content

- Has a Direct Correlation with Aggregate Surface Area

- Can Account for Changes in Aggregate Specific Gravity
Minimum AFT
Problems

• “Normally” the Minimum Required Effective AC Volume ($V_{be}$) is Directly Proportional to the Aggregate Surface Area (This is probably not necessary).

• A Gradation is Required for Each AFT Calculation
MINIMUM VMA CRITERIA
(Based on 4% Design Air Voids)

ASPHALT INSTITUTE
MIX DESIGN (MS-2)

<table>
<thead>
<tr>
<th>Nominal Maximum Aggregate Size</th>
<th>Maximum Aggregate Size</th>
<th>Minimum % VMA</th>
</tr>
</thead>
<tbody>
<tr>
<td>25.0 mm (1&quot;)</td>
<td>1.5&quot;</td>
<td>12.0</td>
</tr>
<tr>
<td>19.0 mm (3/4&quot;)</td>
<td>1&quot;</td>
<td>13.0</td>
</tr>
<tr>
<td>12.5 mm (1/2&quot;)</td>
<td>3/4&quot;</td>
<td>14.0</td>
</tr>
<tr>
<td>9.5 mm (3/8&quot;)</td>
<td>1/2&quot;</td>
<td>15.0</td>
</tr>
<tr>
<td>4.75mm (#4)</td>
<td>3/8&quot;</td>
<td>17.0</td>
</tr>
</tbody>
</table>
Illustrations of Poor Correlation between Maximum Aggregate Size and Aggregate Gradation
Comparison of Spec. 2360, Gradations A & B Mixtures
(2001 Trial Mix Data)

Gradation B (Avg. + 1 SD)
Gradation B (Avg. - 1 SD)
Gradation A (Avg. + 1 SD)
Gradation A (Avg. - 1 SD)

Grad. B is 3/4" Max (Min VM A = 14.0)
Grad. A is 1/2" Max (Min VM A = 15.0)
COMPARISON OF SPEC. 2360, GRADATIONS B & C MIXTURES

(2001 Trial Mix Data)

Gradation C (Avg. + 1 SD)
Gradation C (Avg. - 1 SD)
Gradation B (Avg. + 1 SD)
Gradation B (Avg. - 1 SD)

Grad. C is 1" Max (Min VM A = 13.0)
Grad. B is 3/4" Max (Min VM A = 14.0)

PERCENT PASSING

SIEVE SIZE

#200 #100 #50 #30 #16 #8 #4
COMPARISON OF SPEC. 2350, GRADATIONS #3 & #5 MIXTURES
(2001 Trial Mix Data)

Gradation #3 (Avg. + 1 SD)
Gradation #3 (Avg. - 1 SD)
Gradation #5 (Avg. + 1 SD)
Gradation #5 (Avg. - 1 SD)

Grad. 3 is 3/4" Max (Min VMA = 14.0)
Grad. 5 is 3/8" Max (Min VMA = 15.0 or 17.0)
COMPARISON OF SPEC. 2350, GRADATIONS #3 & #4 MIXTURES
(2001 Trial Mix Data)

Gradation #3 (Avg. + 1 SD)
Gradation #3 (Avg. - 1 SD)
Gradation #4 (Avg. + 1 SD)
Gradation #4 (Avg. - 1 SD)

Grad. 3 is 3/4" Max (Min VMA = 14.0)
Grad. 4 is 1/2" Max (Min VMA = 15.0)
COMPARISON OF SPEC. 2350, GRADATIONS #2 & #3 MIXTURES
(2001 Trial Mix Data)

Gradation #2 (Avg. ± 1 SD)
Gradation #2 (Avg. ± 1 SD)
Gradation #3 (Avg. ± 1 SD)
Gradation #3 (Avg. ± 1 SD)

Grad. 2 is 1" Max (Min VM A = 13.0)
Grad. 3 is 3/4" Max (Min VM A = 14.0)
How is Aggregate Surface Area Calculated?

It is based on the Aggregate Gradation, and Surface Area Factors listed in the Asphalt Institutes MS-2 as part of the Hveem Design Method.
Based on the Asphalt Institutes MS-2

SA = Calculated Surface Area in SF/ Lb.

SA = 2 + .02a + .04b + 0.08c + .14d + .30e + .60f + 1.60g

Where:

a,b,c,d,e,f and g are % of total aggregate passing the #4, #8, #16, #30, #50, #100 and #200 sieves, respectively
Aggregate SA Adjustment

- The SA factors are generally based on an aggregate specific gravity ($G_{sb}$) of 2.650.

- Aggregates with higher $G_{sb}$’s will have less SA per pound than those with lower $G_{sb}$’s.

- The aggregate SA can be adjusted based on the minus #4 $G_{sb}$ as follows:

  \[
  \text{Adjusted SA} = \text{SA} \left( \frac{2.650}{-\#4 G_{sb}} \right)
  \]
## AGGREGATE SURFACE AREA VS. SIEVE SIZE
(Assuming Spherical Shape)

<table>
<thead>
<tr>
<th>Sieve Size #/ (mm)</th>
<th>Relative Surface Area (Per Unit Wt.)</th>
<th>Aggregate Surface Area (SF/Lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1&quot; (25)</td>
<td>1.0</td>
<td>0.44</td>
</tr>
<tr>
<td>3/4&quot; (19)</td>
<td>1.3</td>
<td>0.57</td>
</tr>
<tr>
<td>3/8&quot; (9.5)</td>
<td>2.6</td>
<td>1.13</td>
</tr>
<tr>
<td>#4 (4.75)</td>
<td>5.3</td>
<td>2.31</td>
</tr>
<tr>
<td>#8 (2.36)</td>
<td>11</td>
<td>4.77</td>
</tr>
<tr>
<td>#16 (1.18)</td>
<td>21</td>
<td>9.16</td>
</tr>
<tr>
<td>#30 (0.60)</td>
<td>42</td>
<td>18.31</td>
</tr>
<tr>
<td>#50 (0.30)</td>
<td>83</td>
<td>36.19</td>
</tr>
<tr>
<td>#100 (0.15)</td>
<td>167</td>
<td>72.81</td>
</tr>
<tr>
<td>#200 (0.075)</td>
<td>333</td>
<td>145.19</td>
</tr>
</tbody>
</table>

Assuming Spherical particles with a Specific Gravity = 2.65
The calculated aggregate SA is not exact,

but generally reasonably represents the gradation.
## SURFACE AREA CALCULATIONS

### 2001 TM Data Mix Type 2360 Grad. #B Avg. - 1 SD

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>% Passing</th>
<th>MS II</th>
<th>My Calculations</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/4&quot; (19mm)</td>
<td>100</td>
<td>0.02</td>
<td>0.006</td>
</tr>
<tr>
<td>3/8&quot; (9.5mm)</td>
<td>79</td>
<td>NA</td>
<td>0.011</td>
</tr>
<tr>
<td>#4 (4.75mm)</td>
<td>54</td>
<td>0.02</td>
<td>0.023</td>
</tr>
<tr>
<td>#8 (2.36mm)</td>
<td>38</td>
<td>0.04</td>
<td>0.048</td>
</tr>
<tr>
<td>#16 (1.18mm)</td>
<td>26</td>
<td>0.08</td>
<td>0.092</td>
</tr>
<tr>
<td>#30 (0.60mm)</td>
<td>17</td>
<td>0.14</td>
<td>0.183</td>
</tr>
<tr>
<td>#50 (0.30mm)</td>
<td>10</td>
<td>0.30</td>
<td>0.362</td>
</tr>
<tr>
<td>#100 (0.15mm)</td>
<td>4</td>
<td>0.60</td>
<td>0.728</td>
</tr>
<tr>
<td>#200 (0.075mm)</td>
<td>2.7</td>
<td>1.60</td>
<td>1.452</td>
</tr>
<tr>
<td>* (0.038mm)</td>
<td>1.8</td>
<td>NA</td>
<td>2.9</td>
</tr>
<tr>
<td>** (0.019mm)</td>
<td>1.1</td>
<td>NA</td>
<td>5.8</td>
</tr>
</tbody>
</table>

**MS II SA = 18.78**  
**My SA = 19.42**

* Assumes 65% of the Material Passing the 0.075mm Sieve Passes 0.038mm
** Assumes 65% of the Material Passing 0.038mm Passes 0.019mm

| #200 (0.075mm) | 2.7 | 1.60 | 4.32 | 1.3 | 1.452 | 1.89 |
| * (0.038mm)    | 1.9 | NA   | NA   | 0.8 | 2.9   | 2.35 |
| ** (0.019mm)   | 1.3 | NA   | NA   | 0.6 | 5.8   | 3.29 |

**MS II SA = 18.78**  
**My SA = 18.75**

* Assumes 70% of the Material Passing the 0.075mm Sieve Passes 0.038mm
** Assumes 70% of the Material Passing 0.038mm Passes 0.019mm
### SURFACE AREA CALCULATIONS

2001 TM Data | Mix Type | 2350 Grad. #5 | Avg. + 1 SD
--- | --- | --- | ---

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>% Passing</th>
<th>MS II SA</th>
<th>My Calculations</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Passing</td>
<td>SA Factor</td>
<td>SA (SF/Lb)</td>
<td>% Retained</td>
</tr>
<tr>
<td>3/4&quot; (19mm)</td>
<td>100</td>
<td>0.02</td>
<td>2.00</td>
</tr>
<tr>
<td>3/8&quot; (9.5mm)</td>
<td>100</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>#4 (4.75mm)</td>
<td>89</td>
<td>0.02</td>
<td>1.78</td>
</tr>
<tr>
<td>#8 (2.36mm)</td>
<td>72</td>
<td>0.04</td>
<td>2.88</td>
</tr>
<tr>
<td>#16 (1.18mm)</td>
<td>52</td>
<td>0.08</td>
<td>4.16</td>
</tr>
<tr>
<td>#30 (0.60mm)</td>
<td>35</td>
<td>0.14</td>
<td>4.90</td>
</tr>
<tr>
<td>#50 (0.30mm)</td>
<td>20</td>
<td>0.30</td>
<td>6.00</td>
</tr>
<tr>
<td>#100 (0.15mm)</td>
<td>10</td>
<td>0.60</td>
<td>6.00</td>
</tr>
<tr>
<td>#200 (0.075mm)</td>
<td>5.5</td>
<td>1.60</td>
<td>8.80</td>
</tr>
<tr>
<td>* (0.038mm)</td>
<td>3.6</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>** (0.019mm)</td>
<td>2.3</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

**MS II SA =** 36.52  
**My SA =** 38.09

* Assumes **65%** of the Material Passing the 0.075mm Sieve Passes **0.038mm**

**Assumes **65%** of the Material Passing 0.038mm Passes **0.019mm**

| #200 (0.075mm) | 5.5 | 1.60 | 8.80 | 4.5 | 1.452 | 6.53 |
| * (0.038mm) | 3.9 | NA | NA | 1.7 | 2.9 | 4.79 |
| ** (0.019mm) | 2.7 | NA | NA | 1.2 | 5.8 | 6.70 |

**MS II SA =** 36.52  
**My SA =** 36.74

* Assumes **70%** of the Material Passing the 0.075mm Sieve Passes **0.038mm**

**Assumes **70%** of the Material Passing 0.038mm Passes **0.019mm**
Examples of
Aggregate SA
vs
% Passing Various Sieves
SA vs. % Passing 3/4" Sieve
(2003 Project Data)

\[ R^2 = 0.035 \]
SA vs. % Passing 1/2" Sieve
(2003 Project Data)

$R^2 = 0.032$
There is virtually no correlation between the percent passing the \( \frac{3}{4}'' \) or \( \frac{1}{2}'' \) sieves and the Aggregate Surface Area (SA).
SA vs. % Passing #4 Sieve

(2004 Project Data)

R² = 0.257
SA vs. % Passing #8 Sieve

(2004 Project Data)

$R^2 = 0.424$
SA vs. % Passing #16 Sieve

(2004 Project Data)

\[ R^2 = 0.565 \]
SA vs. % Passing #30 Sieve
(2004 Project Data)

R² = 0.663
SA vs. % Passing #50 Sieve

(2004 Project Data)

$R^2 = 0.687$
SA vs. % Passing #100 Sieve

(2004 Project Data)

$R^2 = 0.715$
SA vs. % Passing #200 Sieve
(2004 Project Data)

$R^2 = 0.548$
Another Option besides “SA” that could have been used to Represent Aggregate Gradation would have been Fineness Modulus
Consider:

AGGREGATE SURFACE AREA "INDEX"
Aggregate Surface Area in SF/Lb.

ASPHALT FILM THICKNESS "INDEX"
Asphalt Film Thickness in Microns
Asphalt Film Thickness (AFT) is simply the:

Effective AC Volume ($V_{be}$) Divided by the Aggregate Surface Area (SA)
**ASPHALT FILM THICKNESS CALCULATION**

\[
AFT \text{ (in microns)} = \frac{P_{be} \times 4870}{100 \times P_s \times SA}
\]

**Where:**

- \(P_{be}\) = Effective Asphalt Content (% of Total Mixture Weight)
- \(P_s\) = Percent Aggregate in Mixture/100 (ie. Decimal)
- \(SA\) = Calculated Surface Area in SF/Lb.

\[
SA = 2 + 0.02a + 0.04b + 0.08c + 0.14d + 0.30e + 0.60f + 1.60g
\]

**Where:**

- \(a, b, c, d, e, f, g\) are % of total aggregate passing the #4, #8, #16, #30, #50, #100 and #200 sieves, respectively
Examples of

AFT

vs

% Passing Various Sieves
AFT vs. % Passing #4 Sieve

(2004 Projects)

R^2 = 0.168
AFT vs. % Passing #8 Sieve

(2004 Projects)

$R^2 = 0.219$
AFT vs. % Passing #16 Sieve

(2004 Projects)

R² = 0.283
AFT vs. % Passing #30 Sieve
(2004 Projects)

$R^2 = 0.388$
AFT vs. % Passing #50 Sieve

(2004 Projects)

\[ R^2 = 0.495 \]
AFT vs. % Passing #100 Sieve
(2004 Projects)

\[ R^2 = 0.660 \]
AFT vs. % Passing #200 Sieve
(2004 Projects)

\[ R^2 = 0.485 \]
Some Methods to Increase AFT:

• Reduce the % passing the #30, #50, #100 and/or #200 sieves
• Increase the amount of crushed material
• Waste the baghouse fines
• Completely redesign the mixture
The Primary Difference between Asphalt Pavement Mixture and Aggregate Base is ASPHALT CEMENT
## REDUCED PAY FACTORS FOR MIXTURE PRODUCTION FAILURES

<table>
<thead>
<tr>
<th>Item</th>
<th>Pay Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Individual</td>
</tr>
<tr>
<td>Gradation</td>
<td>95%</td>
</tr>
<tr>
<td>Coarse and Fine Aggregate Crushing</td>
<td>90%</td>
</tr>
<tr>
<td>VMA</td>
<td>85%</td>
</tr>
<tr>
<td>Asphalt Binder Content</td>
<td>85%</td>
</tr>
<tr>
<td>Production Air Voids (Isolated and Individual)</td>
<td>70%</td>
</tr>
<tr>
<td>Asphalt Film Thickness</td>
<td>No Current Requirement</td>
</tr>
</tbody>
</table>
Approximate AFT’s of some 1960’, 70’s and 80’s Projects

(Based on Mn/DOT Test Results)
APPROXIMATE AFT
1963 Thru 1965 Projects
2331 & 2341 Non Wear

Avg. AFT = 6.5 Microns
APPROXIMATE AFT
1963 Thru 1965 Projects
2351 Binder

Avg AFT = 11.1 Microns
APPROXIMATE AFT
1963 Thru 1965 Projects
Wear Mixtures

Avg AFT = 7.8 Microns
1978 TRIAL MIX AFT
(2331 Non Wear)

Avg. AFT = 6.7 Microns
1978 TRIAL MIX AFT
(2331 & 2341 Wear)

Avg. AFT = 9.3 Microns

Avg. 2361 AFT = 11.7 Microns
1980 PROJECT AFT
(Non Wear Mixtures)

Average AFT = 5.6 Microns
1980 PROJECT AFT
(2331 & 2341 Wear Mixtures)

Avg. 2331 & 2341 AFT = 6.8 Microns
Avg. 2361 AFT = 9.1 Microns
1982 PROJECT AFT
(Non Wear Mixtures)

Average AFT = 5.1 Microns
1982 PROJECT AFT
(2331 & 2341 Wear)

Avg. 2331 & 2341 Wear = 6.6 Microns
Avg. 2361 Wear = 11.3 Microns
1984 TRIAL MIX AFT
(2331 Non Wear)

Avg. AFT = 7.4 Microns
1984 TRIAL MIX AFT
(2331 & 2341 Wear)

Approximate AFT (Microns)

Project I.D.

Avg. AFT = 9.6 Microns
1986 TRIAL MIX AFT
(2331 Non Wear)

Avg. AFT = 7.8 Microns
1986 TRIAL MIX AFT
(2331 Shoulder Wear)

Avg. AFT = 9.3 Microns
1986 TRIAL MIX AFT
(2331 & 2341 Wear)

Avg. 2331 & 2341 AFT = 9.4 Microns

Avg. 2361 AFT = 13.9 Microns
## AVERAGE AFT

<table>
<thead>
<tr>
<th>YEAR</th>
<th>2331 &amp; 2341 NON WEAR</th>
<th>2331, 2341 &amp; 2351 WEAR</th>
<th>2351 NON WEAR</th>
<th>2361 WEAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1963-65</td>
<td>6.5</td>
<td>7.8</td>
<td>11.1</td>
<td>NA</td>
</tr>
<tr>
<td>1978</td>
<td>6.7</td>
<td>9.3</td>
<td>NA</td>
<td>11.7</td>
</tr>
<tr>
<td>1980</td>
<td>5.6</td>
<td>6.8</td>
<td>NA</td>
<td>9.1</td>
</tr>
<tr>
<td>1982</td>
<td>5.1</td>
<td>6.6</td>
<td>NA</td>
<td>11.3</td>
</tr>
<tr>
<td>1984</td>
<td>7.4</td>
<td>9.6</td>
<td>NA</td>
<td>?</td>
</tr>
<tr>
<td>1986</td>
<td>7.8</td>
<td>9.4</td>
<td>NA</td>
<td>13.9</td>
</tr>
</tbody>
</table>
Some Comments

concerning

VMA, AFT and $V_{be}$
Mn/DOT’s current minimum VMA requirements vary from 12.5% to 15.0%

Depending on max. aggregate size and percent passing #8 sieve.
The Sixth Edition of the Asphalt Institutes MS-2 also lists a Minimum VMA of 17%* for a Mixture with 3/8”Maximum Sized Aggregate

* 4% Design Air Voids
This results in a VMA Range of 4.5% (17.0 – 12.5) for our normally used Asphalt Mixture Gradations
# MINIMUM VMA CRITERIA

(Based on 4% Design Air Voids)

ASPHALT INSTITUTE
MIX DESIGN (MS-2)

<table>
<thead>
<tr>
<th>Nominal Maximum Aggregate Size</th>
<th>Maximum Aggregate Size</th>
<th>Minimum % VMA</th>
</tr>
</thead>
<tbody>
<tr>
<td>25.0 mm (1&quot;)</td>
<td>1.5&quot;</td>
<td>12.0</td>
</tr>
<tr>
<td>19.0 mm (3/4&quot;)</td>
<td>1&quot;</td>
<td>13.0</td>
</tr>
<tr>
<td>12.5 mm (1/2&quot;)</td>
<td>3/4&quot;</td>
<td>14.0</td>
</tr>
<tr>
<td>9.5 mm (3/8&quot;)</td>
<td>1/2&quot;</td>
<td>15.0</td>
</tr>
<tr>
<td>4.75mm (#4)</td>
<td>3/8&quot;</td>
<td>17.0</td>
</tr>
</tbody>
</table>
VMA includes both $V_{be}$ and $V_a$

As a result, in order to achieve the desired minimum $V_{be}$:

The minimum required VMA should vary with the $V_a$ during mix production
Example of VMA vs $V_{be}$ as $V_a$ Changes

- If $VMA = 14.0$ and $V_a = 4.0$; $V_{be} = 10.0\%$
- If $VMA = 14.0$ and $V_a = 5.0$; $V_{be} = 9.0\%$

- If you assume that a $V_{be}$ of 10% provides the desired amount of AC for a specific gradation, the mixture could have 10% less $V_{be}$ than desired and still fully meet the VMA criteria if the $V_a$ increases from 4.0 to 5.0%, while the VMA remains at 14.0\%.
In order to maintain an AFT of 8.0 Microns over our normal range of aggregate surface areas the V_{be} would have a Range of about 6.5%
AFT Spec. vs. $V_{be}$ Spec.

• A “normal” AFT spec. requires the $V_{be}$ to be directly proportional to the aggregate surface area (SA).

• An Effective AC Volume ($V_{be}$) spec. would allow the $V_{be}$ to be proportional, but not directly proportional, to the aggregate surface area. However, “Steps” would be required as the SA changed.
$V_{be}$ Vs. SA Vs. AFT
(Based on 2004 Test Data)

AFT = 10.0 Microns

AFT = 6.0 Microns
An "Adjusted" AFT Specification

• Allows the $V_{be}$ to have a Range of about 4.5%, to basically match current Asphalt Institute VMA criteria
• Eliminates the need for “steps” in the minimum $V_{be}$ required
• Allows both Individual and Moving Average Specification requirements

• Example: Adj. AFT = AFT + 0.06(SA-28)
Required $V_{be}$ Necessary to Provide an AFT, or Adjusted AFT, of 8.0 Microns
(Based on 2004 Project Test Data)

$V_{be}$ Required for AFT to Equal 8.0 Microns

$V_{be}$ Required for Adj. AFT to Equal 8.0 Microns Based on "Adj. AFT" = AFT + 0.06(SA-28)
Approximate $V_{be}$ Ranges:

- 4.5% for VMA Criteria
- 6.5% for “Normal” AFT
- 4.5% for “Adjusted” AFT
Some “Experts” believe that VMA combined with VFA and Fines/Effective AC is adequate for specifying the minimum $V_{be}$.

We’ve already discussed the problems with VMA. Now we’ll cover VFA and $P_{200}/P_{be}$.
VFA

VFA stands for the “voids filled with asphalt” and is the Percent $V_{be}$ as compared to the total Percent VMA.

If a mixture has a $V_{be}$ of 9.5% and a VMA of 14.0%, the VFA would be 68%.
VFA Criteria

- VFA criteria is usually based on Mixture Type or Traffic Level, and is listed as a range.

- VFA criteria is not based on the gradation: either maximum aggregate size or aggregate surface area

- Our VFA specs require between 65% and 78% for Wear, and between 70% and 83% for Non-Wear at Design
### MINIMUM VMA VS. AGGREGATE SURFACE AREA
(Mixtures with 8 Microns AC Film Thickness and 3% Air Voids)

<table>
<thead>
<tr>
<th>SA (SF/Lb.)</th>
<th>Aggregate SA (SF)</th>
<th>Min. Req. AC(_{eff}) Volume (gal/CF)</th>
<th>Min. Req. AC(_{eff}) Volume (CF/CF)</th>
<th>Min. VMA for AC(_{eff})</th>
<th>Minimum Total VMA for 3% Voids AC(<em>{eff}) and AC(</em>{eff})</th>
<th>% of VMA Which is AC(_{eff}) (VFA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>2256</td>
<td>0.443</td>
<td>0.059</td>
<td>5.9</td>
<td>8.9</td>
<td>66</td>
</tr>
<tr>
<td>20</td>
<td>2949</td>
<td>0.579</td>
<td>0.077</td>
<td>7.7</td>
<td>10.7</td>
<td>72</td>
</tr>
<tr>
<td>25</td>
<td>3612</td>
<td>0.709</td>
<td>0.095</td>
<td>9.5</td>
<td>12.5</td>
<td>76</td>
</tr>
<tr>
<td>30</td>
<td>4250</td>
<td>0.834</td>
<td>0.112</td>
<td>11.2</td>
<td>14.2</td>
<td>79</td>
</tr>
<tr>
<td>35</td>
<td>4865</td>
<td>0.955</td>
<td>0.128</td>
<td>12.8</td>
<td>15.8</td>
<td>81</td>
</tr>
<tr>
<td>40</td>
<td>5462</td>
<td>1.072</td>
<td>0.143</td>
<td>14.3</td>
<td>17.3</td>
<td>83</td>
</tr>
</tbody>
</table>

### MINIMUM VMA VS. AGGREGATE SURFACE AREA
(Mixtures with 8 Microns AC Film Thickness and 4% Air Voids)

<table>
<thead>
<tr>
<th>SA (SF/Lb.)</th>
<th>Aggregate SA (SF)</th>
<th>Min. Req. AC(_{eff}) Volume (gal/CF)</th>
<th>Min. Req. AC(_{eff}) Volume (CF/CF)</th>
<th>Min. VMA for AC(_{eff})</th>
<th>Minimum Total VMA for 4% Voids AC(<em>{eff}) and AC(</em>{eff})</th>
<th>% of VMA Which is AC(_{eff}) (VFA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>2234</td>
<td>0.439</td>
<td>0.059</td>
<td>5.9</td>
<td>9.9</td>
<td>59</td>
</tr>
<tr>
<td>20</td>
<td>2916</td>
<td>0.572</td>
<td>0.077</td>
<td>7.7</td>
<td>11.7</td>
<td>66</td>
</tr>
<tr>
<td>25</td>
<td>3574</td>
<td>0.702</td>
<td>0.094</td>
<td>9.4</td>
<td>13.4</td>
<td>70</td>
</tr>
<tr>
<td>30</td>
<td>4210</td>
<td>0.827</td>
<td>0.111</td>
<td>11.1</td>
<td>15.1</td>
<td>73</td>
</tr>
<tr>
<td>35</td>
<td>4819</td>
<td>0.946</td>
<td>0.127</td>
<td>12.7</td>
<td>16.7</td>
<td>76</td>
</tr>
<tr>
<td>40</td>
<td>5402</td>
<td>1.061</td>
<td>0.142</td>
<td>14.2</td>
<td>18.2</td>
<td>78</td>
</tr>
</tbody>
</table>
Fines to Effective Asphalt
\((P_{200}/P_{be})\)

- The \(P_{200}/P_{be}\) ratio may limit the \(P_{200}\), but it has little if any affect on the remaining sieves.

- In the SA calculation, the \(P_{200}\) generally accounts for only 20% to 30% of the Total calculated SA. 70% to 80% comes from the other sieves.
AFT vs. #200/P_{be}
(2004 Project Data)

- SP TL 2 thru 5 Max.
- LV & MV Wear Max.
- LV & MV Non Wear Max.

R^2 = 0.578
Summary of 2004 Project Data
AFT Vs. SA
Contractor Results, Except when OT
(2004 Project Data)

R² = 0.7282
AFT vs. VMA
(2004 Project Data)

$R^2 = 0.034$
Project Average AFT
Mixtures with 3.0% Air Void Design
(2004 Project Data)

Avg. AFT = 8.6 Microns
Avg. VMA = 14.7%
Avg. V_{be} = 11.6%
Project Average AFT
Mixtures with 3.5% Air Void Design
(2004 Project Data)

Avg. AFT = 8.6 Microns
Avg. VMA = 15.0%
Avg. Vbe = 11.5%
Project Average AFT
Mixtures with 4.0 Air Void Design
(2004 Project Data)

Avg. AFT = 8.3 Microns
Avg. VMA = 14.9%
Avg. Vbe = 11.1%
“Adjusted” AFT Specification

- $V_{be}$ does not have to be directly proportional to the Aggregate SA ($V_{be}$ range less than 6.5%)

- Allows “constant” minimum specification requirements (MA=4 of 8.0 & Indiv of 7.5, etc.) No “steps” required.

- No need for VMA, VFA, or upper limit on $P_{200}/P_{be}$. Must maintain $V_a$ requirements.
Wear Course AFT between 7.0 and 9.1

Surface Rating

Age, years

\[ y = -0.0034x^2 + 0.0026x + 4 \]

\[ R^2 = 0.5448 \]
Wear Course AFT less than 7.0

\[ y = -0.0182x^2 - 0.1051x + 4 \]

\[ R^2 = 0.8052 \]
Summary of the current Adjusted AFT Spec.
Mn/DOT’s Adjusted AFT specification is basically a compromise of “straight” AFT and VMA specifications.

Whereas the minimum required $V_{be}$ in a VMA spec is based on the Nominal Maximum aggregate size, the minimum required $V_{be}$ in our Adj. AFT spec is based on the calculated Aggregate SA “Index”
• The Contractor’s Trial Mix shall have a minimum Adjusted AFT of 8.5 microns.

• The minimum production Individual Adjusted AFT requirement is 7.5 microns.

• The minimum production Moving Average (n=4) Adjusted AFT requirement is 8.0 microns.
A gradation and Adjusted AFT calculation **are required** for each 1000 tons, or portion thereof,
or
at the same rate as the QC Mixture Property ($G_{mm}$ and $G_{mb}$) tests, with a **minimum of one per day**.
Aggregate SA Adjustment

Since aggregates with higher $G_{sb}$’s will have less SA per pound than those with lower $G_{sb}$’s, an Adjusted SA will be calculated as follows for aggregates with minus #4 aggregate $G_{sb}$’s less than 2.580, or greater than 2.700.

**Adjusted SA = SA*(2.650/-#4Gsb)**

There is currently no SA adjustment for aggregates with -#4 $G_{sb}$’s between 2.580 and 2.700.
• The **JMF limits** for the gradation sieves are the same as the **“Broad Band”** limits.

• These **“Broad Band”** limits apply to both Moving Average and Individual results.
- #8 Individual Sieve Tolerances:

#16 = 4%
#30 = 4%
#50 = 3%
#100 = 2%
#200 = 1.2%*

* Tolerance has been changed from Table 2360.4M
• Accurate Gradation results are very important, especially for the #30 thru #200 sieves, in order to meet the required test tolerances

• Hand Washing (rather than Agra-Wash) will be required if either gradation or calculated Adjusted AFT are Out of Tolerance
• The allowable Adjusted AFT calculation tolerance is 1.2 microns.

• If the Adjusted AFT calculation is confirmed to be out of tolerance, the Agency Adjusted AFT will be Equalized and used for both Individual and Moving Average calculations.
• Equalization of the Agency Adjusted AFT consists of increasing the original Agency value by 0.5 microns.

• This increased value will then be used for acceptance of the test result.
• The minimum **Individual** Adjusted AFT requirement is 7.5 microns.

• Material with less than 7.5, but equal to or greater than 7.0 microns, will receive **90%** pay.

• Material with less than 7.0, but greater than 6.0 microns, will receive **75%** pay.

• Material with 6.0 microns, or less, is subject to **removal** and replacement at the Contractor’s expense.
• The minimum **Moving Average** \( (n=4) \) Adjusted AFT requirement is 8.0 microns.

• Generally, all Material which contributed to a MA less than 8.0 microns will receive 80% pay. (Exception is Ind. Tests of 8.0 or greater)

• The **MA will not be calculated until the 6th test** after the beginning of mix production of a specific mixture. It will include Individual results of Tests 3, 4, 5 and 6.
• The Adjusted AFT Spec has usually led to mixtures with less -#200, and often more +#8, material.

• The Contractor can make an economic decision: Reduce AC content by using less and cleaner “sand”, or use less +#8 material and more AC.
Conclusion

Our Adjusted AFT Spec is basically a compromise between VMA and “straight” AFT criteria.

Instead of an approximate $V_{be}$ range of 4.5% being based on the Maximum Aggregate Size, it is based on the Aggregate SA “Index”.

Adjusted AFT is an “Index” that represents the $V_{be}$. As the SA increases, the $V_{be}$ must also increase in order to maintain a constant Adjusted AFT.
Density

Generally, the two most important factors in long term asphalt pavement performance are adequate (but not too much) asphalt cement and density.

Adjusted AFT will not do it alone!