# "R-2005A TS-2c"

## *Standard Recommended Practice for*

# Design Considerations when using Recycled Asphalt Shingles in New Hot Mix Asphalt

## 1. SCOPE

**This recommended practice provides guidance for designing new hot mix asphalt (HMA) which incorporates recycled asphalt shingles. Specific guidance includes design considerations, how to determine the shingle aggregate gradation, how to determine the virgin performance grade and percentage of the virgin asphalt binder and how to estimate the contribution of the shingle asphalt binder to the final blended binder.**

NOTE 1: Refer to "M-2005A TS-2c" Standard Specification For Use of Recycled Asphalt Shingle as an Additive in Hot Mix Asphalt for information specifying the use of recycled asphalt shingle in HMA.

## 2. REFERENCED DOCUMENTS

### 2.1. AASHTO Standards:

- AASHTO PP 2
- AASHTO PP 28
- AASHTO M-2005A TS-2c
- AASHTO M 320
- AASHTO MP 2,
- AASHTO TP 2
- AASHTO T 30
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### 2.2. ASTM Standards:

- ASTM D 228,

## 3. INTRODUCTION

3.1. Although the use of recycled asphalt shingle (RAS) has been used as an additive in hot mix asphalt in the United States for over 15 years, it remains a relatively new application. As a result there are design considerations that are not generally known to the specification user. Four separate areas are addressed by this recommended practice, with each elaborating on and providing recommendations relative to the following:

- Design Considerations When Using Recycled Asphalt Shingles in Hot Mix Asphalt

- Determining the Shingle Aggregate Gradation

- Determining the Virgin Performance Grade and Percentage of the Virgin Asphalt Binder in New Hot Mix Asphalt

- Determining the Shingle Asphalt Binder Availability Factor

## 4. Design Considerations When Using Recycled Asphalt Shingle in New Hot Mix Asphalt

4.1.1. The introduction of shingle aggregate from the recycled asphalt shingle will affect the gradation properties of the new hot mix asphalt. The designer must determine the particle size and fraction of shingle aggregate present and adjust the virgin aggregate composition, if necessary, to ensure that the new hot mix asphalt meets the appropriate gradation requirements.

4.1.2. The introduction of recycled asphalt shingle will affect virgin asphalt binder content requirements. The designer must determine the virgin asphalt binder content of the new hot mix asphalt as part of the volumetric design procedure.

4.1.3. During the production of the new hot mix asphalt, shingle asphalt binder present in the recycled asphalt shingle will mix with the virgin asphalt binder to produce a final blended binder. Since the properties of the shingle asphalt binder can be considerably different from those of virgin asphalt binder, if the quantity of shingle asphalt binder exceeds 0.75 percent by weight of the new hot mix asphalt, the properties (performance grade) of the final blended binder may be measurably different from the design performance grade of the binder as specified by the local jurisdiction. In addition, the size of recycled asphalt shingle can be expected to affect the fraction of shingle asphalt binder that contributes to the final blended binder. For example, material that is ground to a size passing a 12.5 mm (0.5 inch) sieve can be expected to release lower levels of available asphalt shingle binder (20 to 40 percent) than recycled asphalt shingle ground to a size passing a 4.75 mm (No. 4) sieve (as much as 95 percent available). The designer must be prepared to adjust the performance grade of virgin asphalt binder to compensate for this effect.

4.1.4. The release of shingle asphalt binder into the virgin asphalt binder can result in reduced virgin asphalt binder requirements. It is unlikely, however, that all of the shingle asphalt binder will dissolve and blend with the virgin asphalt binder. Particles of undissolved asphalt binder may act like aggregate particles that require more virgin asphalt binder to accomplish coating. Additionally, particles of shingle asphalt binder may absorb bituminous oils from the virgin asphalt binder. The fibrous material present in recycled asphalt shingle may also require additional virgin asphalt binder to accomplish coating. The location in a hot mix asphalt plant where recycled asphalt shingle is introduced into new hot mix asphalt can also affect the binder blending process. This point of introduction must minimize damage to the recycled asphalt shingle from excess heat and maximize the softening of shingle asphalt binder to facilitate the blending of the shingle asphalt binder with virgin asphalt binder.

## 5. Determining the Shingle Aggregate Gradation

5.1.1. Collect a representative sample of recycled asphalt shingle and proceed in accordance with AASHTO TP 2 to extract the shingle asphalt binder. The size of the sample should be such that the amount of aggregate material recovered will meet the size requirements of the gradation procedure. An alternate extraction method, when it is not necessary to retain the shingle asphalt binder, is provided in ASTM D 228, Sections 13 or 14.

5.1.2. To determine the shingle aggregate gradation, it is suggested that the shingle fiber present in the shingle be removed prior to testing the recovered aggregate in accordance with AASHTO T-30. Since the major portion of the shingle fiber will be retained on a 4.75 mm (No. 4) sieve, the fiber fabric can be removed by tweezers or other appropriate method prior to grading the shingle aggregate during the AASHTO T 30 test procedure.

## 6. Determining the Virgin Performance Grade and Percentage of the Virgin Asphalt Binder in the New Hot Mix Asphalt

6.1.1. Select the percentage of recycled asphalt shingle ($P_s$) to be introduced into the new hot mix asphalt.

6.1.2. Determine the percentage of shingle asphalt binder ($P_{sab}$) present in the recycled asphalt shingle in accordance with AASHTO TP 2 test procedures.

6.1.3. Determine the expected percentage of shingle asphalt binder ($P_{sb}$) present in the final blended binder with the use of the following equation:

$$P_{sb} = \frac{F(P_s)(P_{sab})}{(P_{fbb})}$$

Where:

$P_{sb}$ = percentage of shingle asphalt binder present in the final blended binder.
$P_s$ = percentage of recycled shingle asphalt in the new hot mix asphalt
$P_{sab}$ = percentage of shingle asphalt binder present in the recycled asphalt shingle determined in Section 6.1.2
$P_{fbb}$ = percentage of final blended binder present in the new hot mix asphalt
$F$ = shingle asphalt binder availability factor (determine using the procedure outlined in Section 7.1.9).

6.1.4. Establish the required performance grade (or critical temperature) for the virgin asphalt binder in accordance with AASHTO MP 2, Appendix X1, "Procedures for Developing a Blending Chart." This can be accomplished by constructing a blending chart and plotting the critical temperature of the shingle asphalt binder for 100 percent shingle asphalt binder and the value of $P_{sb}$ on the chart abscissa to determine the critical temperature of virgin asphalt binder that must be used in the new hot mix asphalt, or by utilizing the following equation, which is a mathematical representation of the blending chart:

$$T_{va} = T_{sb} - \frac{(T_{sb} - T_{fbb})}{(1 - P_{sb})}$$

Where:

$T_{va}$ = critical temperature of the virgin asphalt binder
$T_{sb}$ = critical temperature of the shingle asphalt binder
$T_{fbb}$ = critical temperature of the final blended binder
$P_{sb}$ = percentage of shingle asphalt binder present in the final blended binder

6.1.5. To make use of the above-referenced equation, $T_{sb}$ values for high, intermediate, and low critical temperatures for each of the defined properties in AASHTO M 320 must be determined by testing the extracted shingle asphalt binder from Section 6.1.2, above. The value for $T_{fbb}$ is established based on the climatic conditions where the new hot mix asphalt will be used, while the value for $P_{sb}$ is determined in Section 6.1.3. The equation may then be solved for $T_{va}$.

6.1.6. If the performance grade for virgin asphalt binder as determined in Section 6.1.4 is different from the grade used in Section 6.1.2, then an additional volumetric design for the new hot mix asphalt must be performed in accordance with AASHTO PP 28, or an equivalent method approved by the specifying jurisdiction, and a revised design binder content ($P_{var}$) in the new hot mix asphalt determined.

## 7. Estimating the Contribution of the Shingle Asphalt Binder to the Final Blended Binder in New Hot Mix Asphalt (Values of F)

7.1.1. When recycled asphalt shingle is added to new hot mix asphalt there is uncertainty as to the exact amount of asphalt binder that is released from the shingle asphalt binder to blend with the virgin asphalt binder. There are many factors that control the blending of these two binders. Perhaps the most significant factor is the size to which the recycled asphalt shingle is ground. The finer the grind the greater the amount of the contribution of binder from the recycled asphalt shingle to the final blended binder. But there are other factors also. These include the location in the manufacturing process where the recycled asphalt shingle is added to the new hot mix asphalt, the temperature of the aggregates, the temperature of the virgin asphalt binder, and the length of mixing time.

7.1.2. A calculated initial estimate of the percentage of asphalt binder $F_c$ that is released from the recycled asphalt shingle and blends with the virgin asphalt binder may be made by subtracting the difference between the design binder content of a virgin mix without recycled asphalt shingle ($P_{vav}$) and the design binder content of the new hot mix asphalt with recycled asphalt shingle ($P_{var}$), and dividing this value by the total available asphalt shingle binder in the new hot mix asphalt. Expressed mathematically

$$F_c = \frac{P_{vav} - P_{var}}{(P_s)(P_{sab})}$$

where $F_c$ = a calculated estimate of the shingle asphalt binder availability factor.

If $P_{vav} – P_{var} = \in$, then

$$F_c = \frac{\in}{(P_s)(P_{sab})}$$

The terms $P_s$ and $P_{sab}$ are defined in Section 6.1.3. This initial estimate will underestimate the value of $F_c$. A corrected value of F used in Section 6.1.3 is defined as follows:

$$F = \frac{1 + F_c}{2}$$

A discussion of the corrected value of F is presented in Section 7.1.9. More detailed descriptive instructions, which outline the steps in this procedure, are as follows:

7.1.3. Perform a volumetric mix design on the new hot mix asphalt combination that includes all of the components of the mixture except for the recycled asphalt shingle in accordance with the procedures set forth in AASHTO PP 28. Select the design aggregate structure and prepare replicate mixtures in accordance with Section 10.1 of AASHTO PP 28. Condition the mixtures according to AASHTO PP 2. Determine the design binder content ($P_{vav}$).

7.1.4. Perform a second volumetric mix design procedure with the same combination of materials but including the recycled asphalt shingle in the percentage desired for the new hot mix asphalt. The recycled asphalt shingle should be added at ambient temperature to the heated aggregate materials just prior to the addition of the heated virgin asphalt binder. Condition the mixtures according to AASHTO PP2. Determine the design binder content ($P_{var}$).

7.1.5. Subtract the optimum asphalt content of the recycled asphalt shingle mixture ($P_{var}$) from the optimum asphalt content of the virgin mixture ($P_{vav}$). If the value of $\in$, which represents the value of $P_{vav} – P_{var}$, so determined is positive, then the shingle asphalt binder is contributing to the final blended binder. If the value of $\in$ is negative, then coating recycled asphalt binder particles and absorption of virgin asphalt binder by recycled asphalt shingle particles resulting from the introduction of the recycled asphalt shingle is exceeding the amount of asphalt shingle binder contributing to the final blended binder. Additional virgin binder will then be required.

7.1.6. Multiply the percentage of asphalt binder in the recycled asphalt shingle ($P_{sab}$) by the percentage of recycled asphalt shingle added to the mixture ($P_s$). This value represents the total available shingle asphalt binder expressed as a fraction or percentage of the new hot mix asphalt.

7.1.7. Divide the value determined in Section 7.1.5 by the product of $(P_s)(P_{sab})$ determined in Section 7.1.6

7.1.8. Determine the value of F to be used in Section 6.1.3 by taking the arithmetic average of the value of $1 + F_c$ or $(1 + F_c)/2$. A description of the basis for this approach is presented in Section 7.1.9.

7.1.9. Theoretically, the value of F can be represented by the equation

$$F_c = \frac{P_{vav} - P_{var}}{(P_s)(P_{sab})}$$

presented in Section 7.1.2. There are practical limitations, however, to this approach for estimating the value of F. These limitations are inherent in the assumption that $\in$ is the quantity of shingle asphalt binder that is contributing to the final blended binder. This is because the value of $\in$ is dependent on at least three factors, which include:

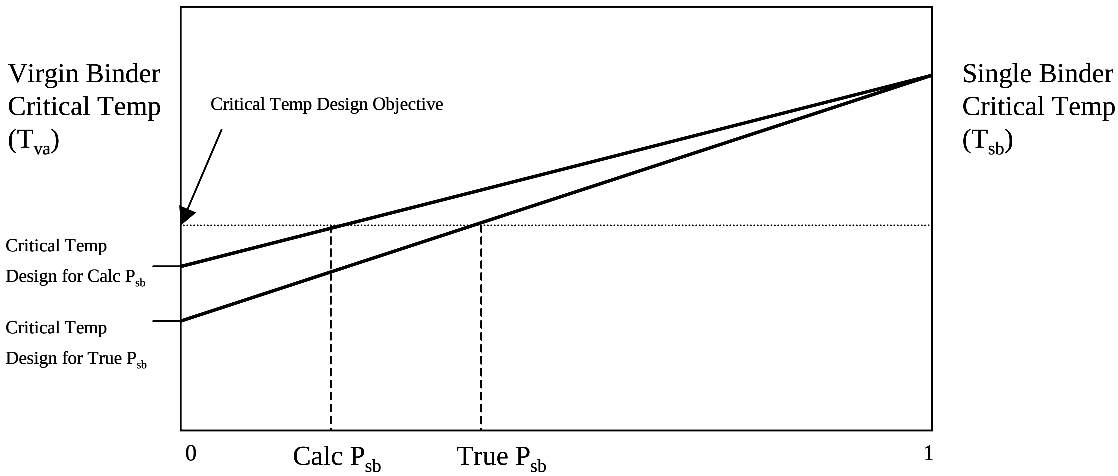
- The amount of shingle asphalt binder released into the mix

- Minus the additional absorption due to the recycled asphalt shingle present in the mix

- Minus the additional existing coating requirements due to the recycled asphalt shingle present in the mix.

As a result, the calculated value of F ($\in/(P_s)(P_{sab})$) will always be less than the true value of F, and the critical design temperature of the virgin asphalt will always be overestimated. This is illustrated more clearly in the hypothetical recycled asphalt shingle blending chart shown below.

**Recycled Asphalt Shingle**
**Hypothetical Blending Chart**




Percentage of Shingle Asphalt Binder in the Final Blended Binder ($P_{sb}$)

In the blending it can be observed that since the calculated value of $P_{sb}$ will always be less than the true value, the calculated critical temperature will always be higher than the true critical temperature. In the design (selection of critical temperature/performance grade of the virgin binder) this must be taken into account otherwise a harder asphalt will always be chosen.

Since the maximum value of F is theoretically equal to 1, the true value of F can be expected to lie between the value of $F_c$ and 1, or expressed mathematically, $F_c < F < 1$. As a result, the best approximation of F can be expressed by the following equation:

$$F = \frac{1 + F_c}{2}$$

This value of F is used as input to calculate $P_{sb}$ in Section 6.1.3.