

## APPENDIX H

### **Superpave Design Guidelines for Using Hot-Mix Recycled Asphalt Pavement and Recycled Asphalt Shingles**

#### **Recycling Hot-Mix Asphalt and Recycling Manufacturer Waste Asphalt Roofing Shingles General Guidelines**

Producing quality hot-recycled asphalt pavement or producing quality asphalt pavement containing recycled manufacturer waste asphalt roofing shingles is most successful when “best practices” are followed. Today, through many years of experience and technological improvements using Recycled Asphalt Pavement (RAP) and experience starting in the mid-1990’s using Recycled Asphalt Shingles (RAS), recommended practices and procedures can be found in numerous publications regarding use of RAP and RAS. To assist new or less experienced personnel involved in the review, testing, design or production of hot-recycled asphalt mixtures, several comprehensive references are provided herein. By becoming familiar with such best practices, one should be more able to avoid potential problems affecting quality; more effectively address recognized existing problems affecting quality, and provide better assurance of consistent quality hot-mixed asphalt being produced cost-effectively. Recommended publications are referenced below and the publication may be obtained by contacting the publishers directly as noted.

“Recycling Hot Mix Asphalt Pavements,” Informational Series (IS) 123, Revised 1/2007, National Asphalt Pavement Association, NAPA Building, 5100 Forbes Blvd., Lanham, MD 20706-4407. Tel: (301-731-4748). This publication is available for purchase on the Internet at <http://www.hotmix.org> and following the link for “Online Store”.

“Recommended Use of Reclaimed Asphalt Pavement in the Superpave Mix Design Method: Technician’s Manual,” NCHRP Report 452, 2001, Transportation Research Board, National Research Council, Business Office, 500 Fifth Street N.W., Washington D.C. 20001. Tel: (202-334-3213); or email [TRBSales@nas.edu](mailto:TRBSales@nas.edu). This publication is also available on the Internet at <http://www.trb.org> and following the links for “Online Documents” and “NCHRP Project Reports”.

“Designing HMA Mixtures with High RAP Content, A Practical Guide”, Quality Improvement Series (QIS) 124, Printed 3/2007, National Asphalt Pavement Association, NAPA Building, 5100 Forbes Blvd., Lanham, MD 20706-4407. Tel: (303) 731-4748. This publication is available for purchase on the Internet at <http://www.hotmix.org> and following the link for “Online Store”.

“Waste Asphalt Shingles-Uses in HMA, State-of-the-Practice”, Special Report (SR) 179, 12/1996, National Asphalt Pavement Association, NAPA Building, 5100 Forbes Blvd., Lanham, MD 20706-4413. This publication is available for purchase on the Internet at <http://www.hotmix.org> and following the link for “Online Store”.

**TIER 1 DESIGN PROCEDURE  
(MIXTURES CONTAINING UP TO AND INCLUDING 15% RAP OR  
MIXTURES CONTAINING 5% RAS)**

**1. Sampling and Preparation (See Note 1)**

- a. Obtain 5 to 10 representative samples of the reclaimed asphalt pavement (RAP) material or milled material or obtain 5 to 10 representative samples of the manufacturer waste recycled asphalt shingles (RAS) from different locations in the stockpile using the mini-stockpile method. The number of increments selected, should be based on the estimated variability and size of the existing stockpile. The RAP or RAS material to be sampled must be representative of the RAP or RAS product used in production (i.e. The RAP is to be crushed, broken or screened the same as would be entered into the mix. The RAS is to be shredded, screened and perhaps blended with virgin aggregate the same as would be entered into the mix.). When RAP or RAS consists of large quantities from different sources, it is recommended to keep stockpiles separated and identified by source. However, with proper management, uniform RAP can be produced using crushing and screening operations, and uniform RAS can be produced using shredding, screening and perhaps blending operations, to process RAP and RAS coming from different sources. Each sample should consist of at least 30 lbs (14 kg) of RAP or 2 lbs. ( $\approx$  1 kg) of RAS.

**Note 1** - A recommended “best practice” for assuring representative sampling of a stockpile is to randomly sample the pile as it is constructed.

After an initial stockpile is established and representative samples analyzed for composition, additional RAP or RAS may be incorporated into the stockpile if the plant’s QC plan satisfactorily addresses the management and frequency of additional testing to ensure uniform RAP or RAS composition on a continuous basis.

**Note 2** – A recommended “best practice” for stockpiling RAS that has been processed (shredded) from full-size manufacturer waste asphalt roofing shingles to the specified 100% passing the 12.5 mm (1/2 inch) sieve is to either blend the processed RAS with a virgin aggregate or store the processed RAS under roof to prevent the processed RAS from conglomerating as a result of storing out in the open under direct sunlight. A recommended “best practice” for blending processed shingles with virgin aggregate is to blend the processed shingles with a fine aggregate at a 50:50 blend and then add the 50:50 blend at 10% by weight of the HMA mixture to obtain the specified 5% of RAS by weight of the total mixture.

- b. Break up the RAP or RAS into small pieces similar to the AASHTO T 209 sample preparation procedure.
  - c. Scalp the RAP or RAS over the same size sieve being used during production for the mix being designed.
  - d. Dry all samples to a constant mass at 50° C. Do not overheat.
2. **RAP or RAS Gradation and Asphalt Content (n=5 to 10)**
- a. Determine the RAP or RAS asphalt content using PTM No. 757 Section 5 or PTM No. 702 (use a specific gravity of 1.030 for the asphalt cement). PTM No. 702 is the referee method if results are questionable or greater accuracy and reliability are desired.
  - b. Determine the aggregate gradation using PTM No. 757 or PTM No. 739.
  - c. Average the test results (n=5 to 10) for asphalt content and gradation. Use the average values for design.
3. **Determination of the RAP or RAS Aggregate Bulk Specific Gravity**
- a. Determine the effective specific gravity of the RAP or RAS using the following procedure and use as the bulk specific gravity for the mix design.
    - Combine the remaining material from the original samples (n=5 to 10) mixing thoroughly as stated in AASHTO T 248.
    - Quarter the combined material in accordance with AASHTO T 248. There will be four samples after combining and quartering.
    - Split each quarter according to AASHTO T 248 to obtain the correct sample mass required for a maximum specific gravity test using AASHTO T 209.
    - Determine the maximum specific gravity ( $G_{mm}$ ) of each sample (n=4) using AASHTO T 209 as modified in Appendix I herein. Before performing the Gmm test on RAP or RAS, it is important that the RAP or RAS is prepared as follows:
      - 1. Dry the test sample to constant mass in a forced draft oven at  $110 \pm 5^{\circ}\text{C}$  ( $230 \pm 9^{\circ}\text{F}$ ).
      - 2. Break up the sample similar to a standard Gmm sample.
      - 3. Mix the RAP or RAS sample thoroughly to allow the old RAP or RAS binder to coat the uncoated aggregate particles.

**Note 3** – Determining Gmm of RAS may be a problem and it may be best to use the RAS as a blend with fine aggregate (50:50 blend) and then determine the Gmm on the blend. The blend could then be added to the HMA mixture at 10% by weight of the total mix. As an alternative, the HMA Producer may request the shingle manufacturer to provide the aggregate Gsb and the asphalt binder Gb and use these values for the RAS.

- Determine the effective specific gravity ( $G_{se}$ ) for each sample using the following formula:

Assume:

$$G_b = 1.030$$

$$P_b = \text{Average Percent Asphalt of (n=5 to 10) samples}$$

$$G_{mm} = \text{Maximum Specific Gravity}$$

$$G_{se} = \frac{(100 - P_b)}{\left( \frac{100}{G_{mm}} \right) - \left( \frac{P_b}{G_b} \right)} = G_{sb}$$

- Average the  $G_{se}$  of the four quarters. Use this value as the  $G_{sb}$  for the mix design.

#### 4. Combined Bulk Specific Gravity of Aggregate

- Calculate the combined aggregate bulk specific gravity (RAP or RAS aggregate and virgin aggregate) using the  $G_{se}$  of the RAP or RAS as the  $G_{sb}$ . Use only the aggregate percentage of the RAP or RAS.

Example 1: 10 % RAP with 6.0% asphalt based on the 10 samples tested and averaged, the aggregate contribution is 9.4% and the asphalt contribution is 0.6% of the total mix.

Example 2: 5% RAS with 20% asphalt content based on the 10 samples tested and averaged, the aggregate contribution is 4.0% and the asphalt contribution is 1.0% of the total mix.)

#### 5. Preparation of Mixture Specimens

- Heat the mixture containing the RAP or RAS and virgin aggregate to the mixture temperature. Weigh the RAP or RAS as a completed mass or as sieve size fractions and add to the virgin aggregate. Heat the combined virgin

aggregate and RAP or RAS to the required mixing temperature in accordance with AASHTO T 312. The mixture should not be held at the mixing temperature for more than one hour. Calculate the weight of virgin asphalt to be batched (the weight of asphalt required at the individual asphalt content minus the weight of asphalt included in the RAP or RAS) and add to the heated aggregate and RAP or RAS.

- b. After laboratory mixing and prior to compaction, short-term aging is required the same as for a virgin mixture. (AASHTO T 209 as modified in Appendix I herein).

#### 6. **Apparent Specific Gravity and Absorption of RAP or RAS Material**

- a. Use the  $G_{se}$  calculated for the RAP or RAS as the apparent specific gravity ( $G_{sa}$ ) and assume 0% absorption for the RAP or RAS material (See Note 3).

#### 7. **Consensus Properties**

- a. Use only the consensus properties of the virgin aggregate. Consensus properties (AASHTO M 323 Table 5) are waived on the RAP or RAS aggregate, except Crush count requirements on the coarse aggregate will be required for RAP designs  $\geq 30$  million ESALS to assure crush requirements are met, unless mix is a base course. (See AASHTO R 35 Subsection 8.3 Notes 9 and 10).

#### 8. **Mix Design**

- a. A  $\leq 15\%$  RAP mix design or a 5% RAS mix design is formulated based on an approved virgin mix design and similar in composition (asphalt content and gradation) to the virgin design. A one-point design (See Note 4) may be sufficient for submission of the mix design for review, if the following occurs. The resulting air void content of the RAP and virgin blend or the RAS and virgin blend shall be  $4\% \pm 0.1\%$ . If the air void content is between 3.5% and 3.9%, or 4.1% and 4.5%, for the initial trial, then adjust the asphalt content accordingly in order to obtain the 4.0% air void content. If a  $4.0\% \pm 0.1\%$  air void content can be achieved by adjusting the asphalt content and the RAP or RAS mixture meets all the requirements in Chapter 2A (excluding Table 5. Superpave Aggregate Consensus Property Requirements), the one-point mix design may be submitted for approval. However, if the air void content is less than 3.5% or greater than 4.5% (based on initial testing at the optimum asphalt content of the virgin mix design) then a complete mix design produced in accordance with Chapter 2A is required.
- b. After optimum asphalt content has been determined, perform moisture sensitivity testing as required in Chapter 2A.

<p><b>Note 4</b> - A minimum of 3 volumetric specimens at estimated target A.C. to verify optimum A.C. for the mix is acceptable in lieu of 3 trial blends.</p>
---

9. **Design Submittal**

- a. In accordance with Publication 408, submit to the District Materials Engineer/Manager the following:

RAP or RAS Mix Design Information:

- Table 1 (RAP or RAS) showing the gradations, asphalt contents and averages.
- TR 448 Completed and Signed.
- Volumetric Testing Summary.
- Moisture Sensitivity Testing Summary.

Virgin Mix Design Information (Mix Used as Basis for RAP or RAS Design):

- TR 448 of previously completed, reviewed and signed virgin design.
- Moisture Sensitivity Testing Summary of previously completed, reviewed and signed virgin mix design.

TABLE 1. RECYCLED ASPHALT PAVEMENT OR RECYCLED ASPHALT SHINGLES MIX DESIGN DATA

Sieve Size	(Check One) RAP <input type="checkbox"/> or RAS <input type="checkbox"/> Grading and AC Content										Average RAP/RAS Gradation & AC Content	Combined Grading	Proposed JMF
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10			
2" (50mm)													
1½" (37.5mm)													
1" (25mm)													
¾" (19mm)													
½" (12.5mm)													
⅜" (9.5mm)													
#4 (4.75mm)													
#8 (2.36mm)													
#16 (1.18mm)													
#30 (0.600mm)													
#50 (0.300mm)													
#100 (0.150mm)													
#200 (0.075mm)													
Asphalt Content													

SR & Section #		PG Binder Supplier		MTD Use Only	
Contract No. (CMS or ECMS)		Alternate PG Binder Supplier		Recommended Virgin PG Binder Grade	
Design PG Binder Grade Required		Alternate PG Binder Supplier			
% RAP or RAS, Total Mix				% RAP (>15%)	
Estimated Asphalt Content, Total Mix		RAP or RAS Stockpile #			

Notes:

Technician \_\_\_\_\_ Date \_\_\_\_\_

**TIER 2 DESIGN PROCEDURE**  
**(MIXTURES CONTAINING GREATER THAN 15% RAP or**  
**MIXTURES CONTAINING 5% OR MORE RAP AND 5% RAS)**

1. **Sampling and Preparation (See Note 1, page H - 1)**
  - a. Obtain 5 to 10 representative samples of the reclaimed asphalt pavement (RAP) material or milled material from different locations in the stockpile using the mini-stockpile method. If combining  $\geq 5\%$  RAP with 5% manufacturer waste recycled asphalt shingles (RAS), obtain 5 to 10 representative samples of the processed RAS from different locations in the stockpile using the mini-stockpile method. The number of increments selected, should be based on the estimated variability and size of the existing stockpile. The RAP and, if used, RAS, material that is to be sampled must be representative of the RAP and RAS product used in production (i.e., The RAP is to be crushed, broken, and screened the same as would be entered into the mix. The RAS is to be shredded, screened and perhaps blended with virgin aggregate the same as would be entered into the mix.). When RAP or RAS consists of large quantities from different sources, it is recommended to keep stockpiles separated and identified by source. However, with proper management, uniform RAP can be produced using crushing and screening operations, and uniform RAS can be produced using shredding, screening and perhaps blending with virgin aggregate operations, to process RAP and RAS coming from different sources. Each sample should consist of at least 60 lbs. (27 kg) of RAP and if used, 4 lbs. ( $\approx 2$  kg) of RAS.
  - b. Break up the RAP and if used, RAS (keeping it separated from the RAP) into small pieces similar to the AASHTO T 209 sampled preparation procedure.
  - c. Scalp the RAP and if used, RAS over the same size sieve used during production for the mix being designed.
  - d. Split each sample of the RAP and if used, RAS into two portions keeping the RAP and RAS materials separated. Identify both portions of each sample (ex., RAP 1A, RAP 1B, and, if used, RAS 1A, RAS 1B).
  - e. Save a split sample of at least 30 lbs. (14 kg) of RAP and, if used, at least 2 lbs. ( $\approx 1$  kg) of the RAS to send to the Materials and Testing Division.
  - f. Retain the other split samples at the plant for testing and designing the HMA mixture containing RAP or the HMA mixture containing both RAP and RAS. (See Note 5)



**Note 5** - When a design is anticipated to incorporate more than 20% RAP (>20%), or anticipated to incorporate greater than or equal to 10% RAP and 5% RAS, it is recommended that the mix design process required by the producer commence well in advance of the anticipated need for the proposed design, due to the potential length of time that may be required to achieve an approved mix design.

2. **RAP and If Used, RAS Gradation and Asphalt Content (n=5 to 10)**

- a. Follow the procedure beginning at Section 1.d of Tier 1 Design procedure and continue following the procedure in Section 2, with the following exceptions: The RAP asphalt content must be determined using PTM No. 702 if >20% RAP is used. PTM No. 702 must be used to determine asphalt content when using 10% or more RAP and 5% RAS.

3. **PG Binder Grade Evaluation**

- a. Complete the information required in Table 1. Submit the split samples of RAP, the split samples of RAS (if used), 2 quarts of P.G. binder specified for mix application, TR 448 for the virgin mix design used as a basis for the RAP design or for the combined RAP and RAS design, proposed blend and JMF for the recycled design, and the completed Table 1 to the MTD for evaluation. If the design incorporates >20% RAP or incorporates both RAP and RAS, submit additional samples of P.G. binder that is one grade softer than the specified application.
- b. The MTD will evaluate the aged asphalt in the RAP and if used, RAS, after asphalt binder recovery, and will recommend the grade of virgin asphalt cement for recycling utilizing the procedure outlined in Figure 1 and additional criteria as deemed appropriate. When >20% RAP will be incorporated in a mix, or when both RAP and RAS will be incorporated in the mix, additional analysis will typically include: more thorough evaluation of recovered RAP and RAS (if used) binder properties, relative proportions of required virgin to RAP binder or, to RAP and RAS binder, estimated asphalt film thickness calculated for the proposed mix, more detailed evaluation of long-term aging effects on both volumetric mixture properties and moisture sensitivity, and finally, a statistical evaluation of recycled material component variability based on plant QC records.

4. **Determination of the RAP and RAS (If Used), Aggregate Bulk Specific Gravity**

- a. Follow the procedure in Section 3 of Tier 1 Design Procedure.

5. **Combined Bulk Specific Gravity of Aggregate**

- a. Follow the procedure in Section 4 of Tier 1 Design Procedure.

**6. Preparation of Mixture Specimen**

- a. Follow the procedure in Section 5 of Tier 1 Design Procedure, however, note the following recommendations. Reduce the RAP by hand sieving over a 4.75 mm (No. 4) and a 2.36 mm (No. 8) sieve, resulting in the following three size fractions; the minus 2.36 mm (No. 8) sieve, the minus 4.75 mm (No. 4) sieve retained on the 2.36 mm (No. 8) sieve, and the plus 4.75 mm (No. 4) sieve material. This method can significantly reduce the potential for non-uniform or inconsistent mix composition of completed mix specimens, which can occur when using higher percentages of RAP. If RAS is included and not pre-blended with virgin fine aggregate, combine with the minus 2.36 mm (No. 8) sieve RAP material. (See Note 3 of Tier 1.)

**7. Apparent Specific Gravity and Absorption of RAP or RAS Material**

- a. Follow the procedure in Section 6 of Tier 1 Design Procedure.

**8. Consensus Properties**

- a. Consensus properties (AASHTO M 323, Table 5) must be determined on the RAP aggregate and mathematically combined with the virgin aggregate consensus properties in proper proportions or the combined blend of RAP aggregate and virgin aggregate in accordance with the requirements in AASHTO R 35 (See Chapter 2A, Subsection 6.9 modification to Note 6). The consensus properties on the aggregate blend using either method must meet or exceed the required consensus properties for the ESAL range the mix is intended for except as modified in AASHTO R 35 Subsection 8.3 Notes 9 and 10 and AASHTO M 323, Subsection 6.6, for RAP or RAS sand equivalent. Assume RAS aggregate consensus properties are negligible unless combined with a virgin fine aggregate as described in Note 3 of Tier 1. In this case, determine consensus properties of the blended RAS aggregate and fine aggregate. PTM No. 757 cannot be used to obtain the aggregate portion of the RAP used for the consensus property testing. PTM No. 702 is an approved method of obtaining the RAP aggregate fraction.

**9. Mix Design**

- a. A >15% RAP mix design or, a combined RAP and RAS mix design, is to be formulated based on an approved virgin mix design and similar in composition (asphalt content and gradation) to the virgin mix design. A >15% RAP mix design or, a combined RAP and RAS mix design, requires additional work to evaluate the affect of the RAP or combined RAP and RAS on the mixture volumetric properties and moisture sensitivity. Use Chapter 2A to develop the RAP or combined RAP and RAS mix design (Complete Design Procedure).

**10. Design Submittal**

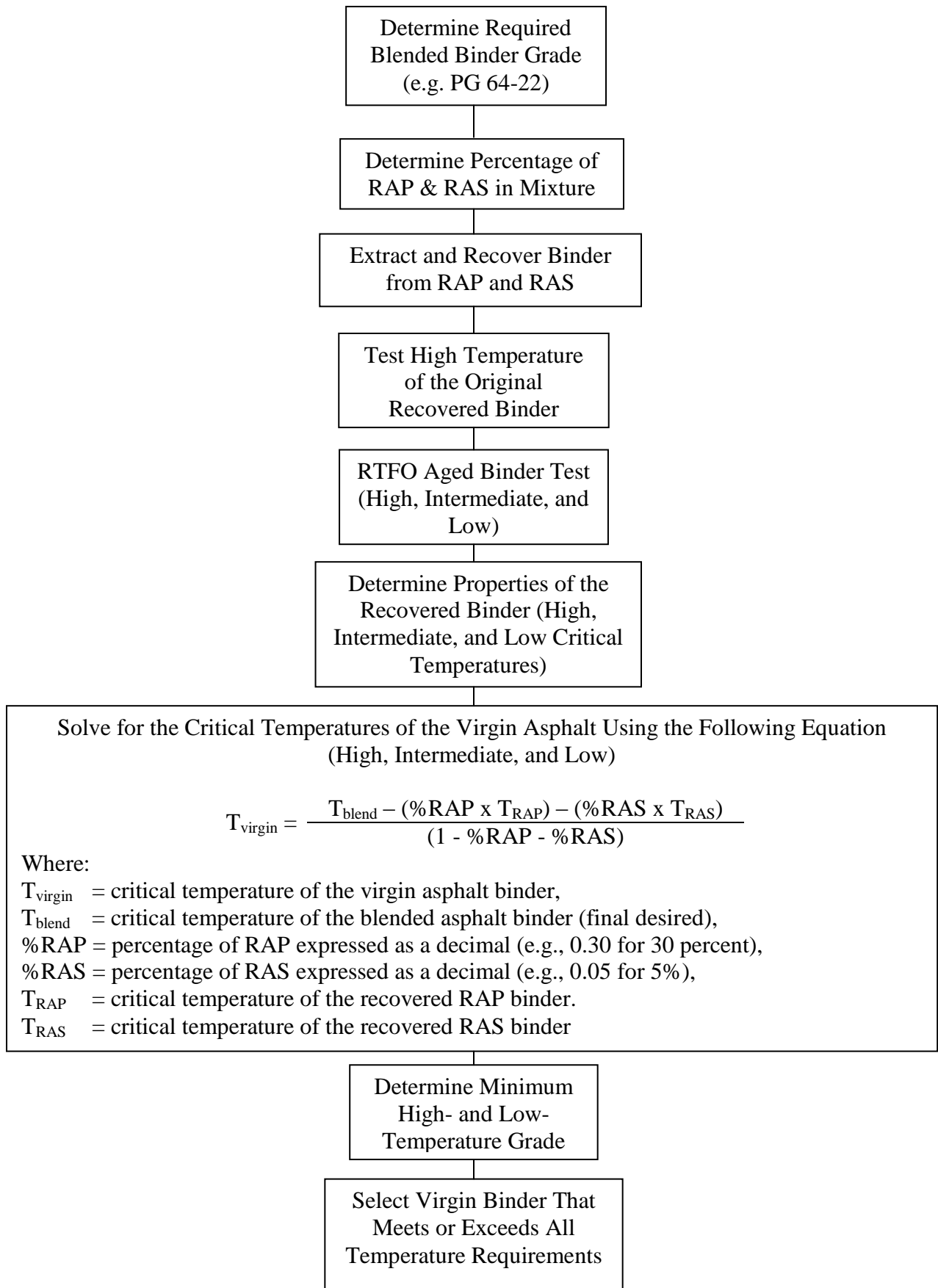
- a. In accordance with Publication 408, submit to the District Materials Engineer/Manager the following:

RAP Mix Design or Combined RAP and RAS Mix Design Information:

- Table 1 showing the gradations, asphalt contents and averages.
- TR 448 Completed and Signed by Producer.
- Volumetric Testing Summary.
- Moisture Sensitivity Testing Summary.

Virgin Mix Design Information (Mix Used as Basis for Tier 2 Design):

- TR 448 of previously completed, reviewed and signed virgin mix design.
  - Moisture Sensitivity Testing Summary of previously completed, reviewed and signed virgin mix design.
- b. If requested by the District Materials Engineer/Manager, the MTD will provide testing and analysis of the proposed design, with recommendations. When >20% RAP will be incorporated in a mix or, when 10% or more RAP and 5% RAS will be incorporated in a mix, additional analysis will typically include: evaluation of mix volumetric properties and moisture sensitivity, following simulated long-term aging of specimens and a statistical evaluation of recycled material component variability based on plant QC records.



*Figure 1. Method A: Blending at known RAP and, if used, RAS Content (virgin binder grade unknown)*