

**DEPARTMENT OF TRANSPORTATION**  
**DIVISION OF ENGINEERING SERVICES**  
 Transportation Laboratory  
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**METHOD OF TEST FOR COMBINING GRADATIONS FOR HOT MIX ASPHALT (HMA)  
 USING RECLAIMED ASPHALT PAVEMENT (RAP) AND/OR  
 RECLAIMED ASPHALT SHINGLES (RAS)**

**A. SCOPE**

This test method contains the procedures for combining gradations using Reclaimed Asphalt Pavement (RAP) and/or Reclaimed Asphalt Shingles (RAS) combined with virgin aggregate and virgin asphalt binder. California Test 384 applies to Hot Mix Asphalt (HMA) mixtures containing up to 25 % RAP aggregate and/or up to 5 % RAS.

**B. REFERENCES**

- |                     |                                                                                                    |
|---------------------|----------------------------------------------------------------------------------------------------|
| California Test 125 | — Sampling Highway Materials and Products Used In The Roadway Structural Sections                  |
| AASHTO M 92         | — Standard Specification of Wire-Cloth Sieves For Testing Purposes                                 |
| AASHTO T 30         | — Standard Method of Test for Mechanical Analysis of Extracted Aggregate                           |
| AASHTO R 47         | — Standard Practice for Reducing Samples of HMA to Testing Size                                    |
| AASHTO T 84         | — Standard Method of Test for Specific Gravity and Absorption of Fine Aggregate                    |
| AASHTO T 85         | — Standard Method of Test for Specific Gravity and Absorption of Coarse Aggregate                  |
| AASHTO T 164        | — Standard Method of Test for Quantitative Extraction of Asphalt Binder from HMA                   |
| AASHTO T 201        | — Standard Method of Test for Kinematic Viscosity of Asphalts (bitumens)                           |
| AASHTO T 209        | — Standard Method of Test for Theoretical Maximum Specific Gravity (Gmm) and Density of HMA        |
| AASHTO T 308        | — Standard Method of Test for Determining the Asphalt Binder Content of HMA by the Ignition Method |
| AASHTO PP 78        | — Standard Practice for Design Considerations When Using RAS in Asphalt Mixtures                   |
| ASTM D2172          | — Standard Test Methods for Quantitative Extraction of Bitumen From Bituminous Paving Mixtures     |

MS-2 "Mix Design Methods for Asphalt Concrete and Other Hot Mix Types," and Superpave Series No.2 (SP-2) "Superpave Mix Design" provide in-depth procedures for preparing HMA using RAP and/or RAS for mix design and the determination of a job mix formula (JMF).

**C. APPARATUS**

1. Ovens: Oven(s) with free circulation of air for heating aggregates, asphalt binder, mixing bowl, and other equipment to within 3°F of the required lab mixing temperature.

2. Balance: balance or scale accurate to 0.1 g and having a minimum capacity of 5 kg.
3. Sample Splitters: Riffle-type splitter having individual chutes approximately 50% larger than the maximum size aggregate in the lab-mixed and field-mixed HMA. Optional: rotating pan type splitter for all lab-mixed and field-mixed HMA.
4. Sieves: Woven-wire cloth sieves of 3 in., 2 ½ in., 2 in., 1 ½ in., 1 in., ¾ in., ½ in., ⅜ in., ¼ in., No. 4, No. 8, No. 16, No. 30, No. 50, No. 100, and No. 200 designations with square openings conforming to AASHTO Designation M 92. Each sieve must be visually inspected for bent or distorted wires after each use. Replace any damaged or nonconforming sieves.
5. Sieve Shaker: Any mechanical sieve-shaking device that accomplishes the same thoroughness of sieving as the hand-sieving procedure described in AASHTO T 30 Section 7. It is essential that the sieve shaker be designed so that its motion includes a bumping or bouncing action sufficient to keep the aggregate particles in motion on the surface of the sieves.

#### D. SAMPLING PROCEDURE

##### 1. RAP SAMPLING

Sample RAP in accordance with California Test 125, Appendix A

- a. For the mix design:
  - (1) Take a minimum of 3 separate, representative samples.
  - (2) Each sample will be a minimum of 40 lb.
  - (3) When sampling from a stockpile, refer to California Test 125, Appendix A.G.
- b. For Production:
  - (1) Batch Plant: Refer to California Test 125, Appendix A.A.1.
  - (2) Continuous Mixing Plant: Refer to California Test 125, Appendix A.B.1.

##### 2. RAS SAMPLING

Sample RAS from the fractionated stockpile. Refer to California Test 125 Appendix A.G. for procedure.

- a. For the mix design:
  - (1) Take a minimum of 3 separate representative samples.
  - (2) Each sample must be a minimum of 10 lb.
- b. For Production:
  - (1) Batch Plant: Refer to CT 125, Appendix A.A.1
  - (2) Continuous Mixing Plant: Refer to CT 125, Appendix A.B.1

#### E. RAP/RAS EVALUATION PROCEDURE

Unless otherwise stated, the following procedures apply to RAP and/or RAS

1. For combined RAP and/or RAP/RAS combinations, separate into coarse and fine fractions.
2. Prepare each sample separately for evaluation.
3. Separate particles by hand so that the particles of the fine

- aggregate portion pass the  $\frac{3}{8}$  in. sieve. Care must be taken to avoid fracturing the aggregate.
4. Samples must be prepared in accordance with AASHTO R 47. Split or quarter each sample into representative portions for ASTM D 2172/ AASHTO T 164, AASHTO T 308, and AASHTO T 209 testing. After the required test samples have been prepared, combine the remaining RAP and/or RAS material for subsequent splitting into representative mix design test samples.
  5. Determine the asphalt binder content of each sample using ASTM 2172 /AASHTO T 164 (3 minimum). Calculate and report the individual and average asphalt binder content. Perform a sieve analysis on each sample of recovered aggregate in accordance with AASHTO T 30 (3 minimum). Calculate and report the individual and average gradation. Calculate bulk specific gravity of recovered aggregate using SP-2 for RAP or AASHTO PP 78 for RAS.
  6. Burn asphalt from each sample in accordance with AASHTO T 308 for aggregate gradation (3 minimum). Calculate and record the individual and average asphalt binder content. Perform a sieve analysis on each sample of recovered aggregate in accordance with AASHTO T 30 (3 minimum). Calculate and record the individual and average gradations.
  7. Determine a correlation factor for each sieve to be used for gradation testing during production. The correlation factor for each sieve must be determined by taking the average gradation of the ASTM D 2172/ AASHTO T 164 samples minus the average gradation of the AASHTO T 308 samples.
  8. Determine the theoretical maximum specific gravity (Rice) of each sample in accordance with AASHTO T 209 (3 minimum). Calculate and record the individual and average values.
  9. If RAS or any combination of RAS is used, evaluate the binder recovered in step E.5 in accordance with AASHTO PP 78.

The above procedures are summarized in Table 1 below:

**Table 1 - RAP/RAS Evaluation**

Tests	Sample			Description
	1	2	3	
ASTM D 2172/AASHTO T 164	X	X	X	Record individual and average asphalt contents to 0.1%
AASHTO T 30 from extraction	X	X	X	Record individual and average gradation results for each sieve.
AASHTO T 308	X	X	X	Record individual and average asphalt contents to 0.1% (for information only).
AASHTO T 30 from ignition oven	X	X	X	Record individual and average gradation results for each sieve.
AASHTO T 209	X	X	X	Record individual and average results.
Determine Aggregate Gradation Correlation Factor	X			Record average gradation of ASTM D2172/ AASHTO T 164 minus average gradation of AASHTO T 308

**F. MIX DESIGN PROCEDURE**

Unless otherwise stated, the following procedures apply to RAP and/or RAS.

1. Determine the percentage that will be used in the mix design (maximum 25% RAP and/or RAS in the aggregate blend. RAS is not to exceed 5 %).
2. Determine the combined gradation of the HMA mixture based on proposed proportions of RAP and/or RAS and virgin aggregate to be used in accordance with Section G.1.b. of this test method.
3. Calculate batch weights for each ingredient in the mixture using the provided batching sheet.

Note 1: When using RAP and/or RAS in HMA mix designs, the aggregate gradations and total asphalt content are altered slightly from original batch percentages due to the asphalt contained in the RAP and/or RAS.

If using blending sand with RAS, the blending sand must be included in the final gradation.

4. RAP and/or RAS shall be oven dried to a constant mass in accordance with AASHTO T 209 Section 9.2., except the temperature must not exceed 100°F.
5. Prepare and test specimens (virgin aggregate, RAP and/or RAS, and virgin asphalt binder) in accordance with AASHTO T 312 except as follows:
  - a. If lime treatment (anti-strip) is specified, only the virgin aggregate must be treated. Treating the RAP and/or RAS with lime is not allowed.
  - b. Virgin aggregate must be heated to 20°F above mixing temperature<sup>2</sup> and RAP and/or RAS must be heated to 230°F for a maximum of 2 hours. RAP and/or RAS must not be reheated.
  - c. Add the proper amount of virgin aggregate to the mixing bowl and then add the proper amount of RAP and/or RAS. Dry mix for a minimum of 10 seconds. Add the proper amount of virgin asphalt binder and proceed with wet mixing. The first batch shall be considered a butter batch and discarded.
  - d. Use AASHTO T 209 to measure theoretical maximum specific gravity (Rice).

Note 2: Mixing temperature is the range of temperature where the unaged asphalt binder has a kinematic viscosity of  $170 \pm 20$  centistokes measured in accordance with AASHTO T 201.

## **G. PRODUCTION AND JOB MIX FORMULA (JMF) VERIFICATION PROCEDURE**

1. During production, sample and test per Section 39 of the Standard Specifications:
  - a. Asphalt Content – When developing a correction factor for asphalt content, per AASHTO T308, include the proposed portion of RAP and/or RAS. A new correction factor will not be required unless the RAP and/or RAS proportion changes by more than 5 % from the JMF Samples for determining asphalt content must be taken in accordance with California Test 125, Appendix B.
  - b. Aggregate Gradation – When determining the combined gradation, burn off the RAP and/or RAS sample in accordance with AASHTO T308. Report the asphalt content of the RAP and/or RAS sample to 0.1% (for

information only). Perform a sieve analysis on recovered aggregate in accordance with AASHTO T30. Add the correlation factor established in Section E.7. Report the actual gradation, the correlation factor, and the corrected gradation for each sieve size. Mathematically combine the virgin and corrected RAP and/or RAS aggregate gradations at the correct proportions to obtain the combined gradation.

Note 3: California Test 384 Form can be found at the following link:

<[http://www.dot.ca.gov/hq/esc/ctms/CT\\_ChooseVersion.html#384](http://www.dot.ca.gov/hq/esc/ctms/CT_ChooseVersion.html#384)>

## **H. HEALTH AND SAFETY**

It is the responsibility of the user of this test method to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. Prior to handling, testing or disposing of any materials, testers must be knowledgeable about safe laboratory practices, hazards and exposure, chemical procurement and storage, and personal protective apparel and equipment.

Caltrans Laboratory Safety Manual is available at:

[http://www.dot.ca.gov/hq/esc/ctms/pdf/lab\\_safety\\_manual.pdf](http://www.dot.ca.gov/hq/esc/ctms/pdf/lab_safety_manual.pdf)

**End of Text  
(California Test 384 contains 5 pages)**