

**DEPARTMENT OF TRANSPORTATION**

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**METHOD OF TEST FOR PREPERATION OF HMA FOR TEST SPECIMENS****A. SCOPE**

This test method describes the procedure for determining the preparation of laboratory-mixed and field-mixed hot mix asphalt (HMA) specimens. This test method also describes a procedure for the compaction of laboratory-mixed and field-mixed HMA by means of a California Kneading Compactor that imparts a kneading action. This procedure applies to laboratory-mixed and field-mixed HMA containing aggregate up to 1 in. maximum size.

The procedure is presented in two parts:

- Part 1. Preparation of lab-mixed and field-mixed HMA samples.
- Part 2. Compaction of lab-mixed and field-mixed HMA using the California Kneading Compactor.

Appendices are included as follows:

- Appendix A Preparation of lab-mixed and field-mixed HMA test specimens containing reclaimed asphalt pavement (RAP).
- Appendix B Preparation of lab-mixed and field-mixed HMA test specimens containing asphalt binder with liquid anti-strip.
- Appendix C Preparation of lab-mixed and field-mixed HMA test specimens containing damp aggregate treated with dry lime.
- Appendix D Preparation of lab-mixed and field-mixed HMA test specimens containing aggregate treated with lime slurry.

More complete descriptions of the procedures needed to prepare lab-mixed HMA samples for mix design and the determination of a job-mix formula (JMF) can be found in the Asphalt Institute MS-2 "Mix Design Methods for Asphalt Concrete and Other Hot-Mix Types", Superpave Series No. 2 (SP-2) "Superpave Mix Design", California Test 367, and California Test 368.

**PART 1. PREPERATION OF LAB-MIXED AND FIELD-MIXED HMA SAMPLES**

## 1A. REFERENCES

CT 101	Operation and Calibration of the Mechanical Compactor
CT 104	Operation and Calibration of the Electronically Controlled Compactor
CT 105	Calculations Pertaining to Gradings and Specific Gravities
CT 125	Sampling Highway Materials and Products Used in the Roadway Structural Sections
CT 202	Sieve Analysis of Fine and Coarse Aggregates
CT 206	Specific Gravity and Absorption of Coarse Aggregate
CT 207	Specific Gravity and Absorption of Fine Aggregate
CT 367	Optimum Bitumen Content (OBC) for HMA Types A, B, and C, and Rubberized HMA (Type G)
CT 368	Optimum Bitumen Content (OBC) for Open Graded Friction Course
AASHTO T201	Kinematic Viscosity of Asphalts (Bitumens)
AASHTO T245	Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus
ASTM D3549	Thickness or Height of Compacted Bituminous Paving Mixture Specimens

## 1B. APPARATUS

1. Ovens:
  - a. Ovens 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.
  - b. An oven with free circulation of air capable of maintaining a temperature of 140°F ± 3°F or 295°F ± 3°F for curing lab-mixed HMA.
  - c. Oven(s) with free circulation of air for heating field-mixed HMA samples to within 3°F of the required temperature (Section 1D.).
2. Balance: a balance or scale accurate to 0.1 g and having a minimum capacity of 5 kg.
3. Sample Splitters:
  - a. Riffle-type splitter having individual chutes approximately 50% larger than the maximum size aggregate in the lab-mixed and field-mixed HMA.

- b.** Optional rotating pan type splitter for all lab-mixed and field-mixed HMA.
- 4. Metal Pans: pans having a surface area of 75 to 100 in.<sup>2</sup>, and approximately 1 in. deep.
- 5. Thermometers: thermometers or temperature probes having metal stems with a minimum range of 100 to 400°F, accurate to 3°F or less.
- 6. Sample Mixing Apparatus: suitable equipment for mixing the aggregate and asphalt binder.
  - a.** Suitable equipment for hand mixing consists of a sand bath on the surface of a hot plate to minimize localized overheating.
  - b.** Suitable equipment for mechanical mixing consists of any type of mechanical mixer that can be maintained at the required mixing temperature. Mixing equipment must produce a well-coated, homogeneous mixture of the required amount, and from which essentially all of the batch can be recovered.

### **1C. PREPERATION OF LAB-MIXED HMA SPCIMENS**

- 1. Aggregate
  - a.** Sample aggregate in accordance with California Test 125.
  - b.** For mix design (per California Test 367 or others) and other purposes as required, perform a sieve analysis on individual coarse aggregate samples and a washed sieve analysis on individual fine aggregate samples in accordance with California Test 202. Discard fine aggregate samples after the washed sieve analysis.
  - c.** Determine specific gravity and absorption of the aggregate in accordance with California Test 206 and California Test 207. If there is a difference in specific gravity of 0.2 or more between the coarse and fine parts of different aggregate blends, compute the blend of aggregate required to produce a combined gradation that conforms to specified requirements modified in accordance with California Test 105.
  - d.** Separate each of the combined aggregate samples on the coarse and fine aggregate sieves in accordance with California Test 202. Use the sieves and pan appropriate for the gradations required for the mix specified.

**NOTE:** Use aggregates as received. Do not wash aggregates to be used for preparing lab-mixed HMA for specimens. In the case of coated aggregates, separate by hand if the aggregates are coated to prevent removal of these coatings.

For a combined aggregate sample, split out no more than 10 kg. at a time before separating. For individual bin or stockpile samples, combine no more than 10 kg. at a time at the proposed proportions before separating.

- e. Batch the aggregate. The cumulative weight for the required batch is derived by simple computation. An example of this computation for an aggregate batch weight of 1200 g follows.

Sieve Size	Percent Passing	Individual Weight	Cumulative Weight
1 in.	100	0.0	0.0
3/4 in.	89	132.0	132.0
1/2 in.	78	132.0	264.0
3/8 in.	73	60.0	324.0
No. 4	67	72.0	396.0
No. 8	51	192.0	588.0
Pan	0	612.0	1200.0

Passing	Retained	1200 g Batch Weight
1 in.	3/4 in.	$(100 - 89) \times 12 = 132.0$
3/4 in.	1/2 in.	$(100 - 78) \times 12 = 264.0$
1/2 in.	3/8 in.	$(100 - 73) \times 12 = 324.0$
3/8 in.	No. 4	$(100 - 67) \times 12 = 396.0$
No. 4	No. 8	$(100 - 51) \times 12 = 588.0$
No. 8	Pan	$(100 - 0) \times 12 = 1200.0$

Note: Up to 1.5% fine aggregate or mineral fillers may be added to the batch. This will not be included in pre-mixing gradation calculations. If added, please note any additional materials in the comment section of CEM-3512.

## 2. Asphalt Binder

- a. Obtain samples of the asphalt binder that will be used on the project.
- b. For hot mix design (in accordance with California Test 367), prepare at least 1 sample for each combination of aggregate and binder content. Use at least 4 binder contents in 0.50% increments for the development of the proposed JMF and the determination of OBC. The Approximate Binder Content (ABC), the ABC - 0.50%, the ABC + 0.50%, and the ABC + 1.00% are the most commonly used 4 binder contents.

Once the OBC has been determined, prepare 3 samples separately at the proposed JMF and test for compliance.

- c. Report binder content as a percentage by weight of total mix. An example of computing binder content as a percentage by weight of total mix and asphalt binder batch weights follows:

The total weight of hot mix is expressed as:

$$W_{Mix} = W_{Asph} + W_{Agg}$$

[1]

Where:  $W_{Mix}$  = Weight of hot mix asphalt, in grams (g)

$W_{Asph}$  = Weight of asphalt binder, in grams (g)

$W_{Agg}$  = Weight of aggregate, in grams (g)

The percentage of asphalt binder is:

$$P_{Asph} = \left( \frac{W_{Asph}}{W_{Mix}} \right) \times 100$$

[2]

Where:  $P_{Asph}$  = Binder percentage (binder content) by weight of total mix

By rearranging equations [1] and [2]. The weight of asphalt binder required for a batch can be determined as follows:

$$W_{Asph} = \frac{W_{Agg} \times P_{Asph}}{1 - P_{Asph}}$$

[3]

Example: Determine the asphalt binder batch weight at a binder content of 5% (by weight of total mix) with an aggregate batch weight of 1200 g.

Step 1 – Use equation [3]:

$$W_{\text{Asph}} = \frac{1200 \times 0.05}{1 - 0.05} = 63.2$$

Step 2 – Using equation [1], the total weight of hot mix asphalt is:

$$W_{\text{Mix}} = W_{\text{Asph}} + W_{\text{Agg}} = 63.2 + 1200 = 1263.2g$$

Check: To check the binder percentage by weight of total mix substitute the values obtained in Steps 1 and 2 into equation [2]:

$$P_{\text{Asph}} = \frac{63.2}{1263.2} \times 100 = 5.0\%$$

### 3. Mixing and Curing

- a. The lab mixing temperatures for the various asphalt binder types are:

Asphalt Binder Type	Lab Mixing Temperature
Neat, unmodified (PG__ - __)	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.
Polymer Modified (PG__ - __PM)	Asphalt supplier's recommended range.
PG__ - __TR	Asphalt supplier's recommended range.
Asphalt Rubber Binder (ARB)	325° to 375°F $\pm 3^\circ\text{F}$ .
Asphalt Binder for OGFC	As specified in California Test 368.

- b. Heat the aggregate to the lab mixing temperature (how much?).
- c. Heat the asphalt binder to the lab mixing temperature, and in no instance exceed 380°F. Do not hold asphalt binder at the lab mixing temperature for more than 2 hours before using. Do not reheat asphalt binder more than 2 times.

- d. Place the mixing bowl in the oven or on the sand bath and heat to a temperature not exceeding 50°F above the lab mixing temperature and not exceeding 380°F. Charge the mixing bowl with heated aggregates and dry mix thoroughly. Form a crater in the dry blended aggregate. Remove the asphalt binder from the oven and stir the asphalt binder thoroughly until uniform. Pour the required amount of asphalt binder into the mixture in accordance with the calculated batch weights. At this point the temperature of the aggregate and asphalt binder must be within the limits of the lab mixing temperature (Section 1C.3.a).

**NOTE:** Before lab mixing, prepare 1 mixture at the lowest binder content to butter the mixing bowl. Discard this batch.

- e. Mix the aggregate and asphalt binder, preferably with a mechanical mixer, or by hand with a trowel or spoon as quickly and thoroughly as possible, to yield a mixture where all particles are coated. The length of mixing time varies with the type of material, but two to three minutes is generally sufficient.
- f. When mixing is completed, transfer the mixture to a metal pan. Cure at a temperature of 140°F ± 3°F in an oven for 15 to 18 hr.

An alternate procedure, when the combined aggregate absorption is less than 2.0% as determined in accordance with California Test 206 and California Test 207, is to cure the mixture at a temperature of 295°F ± 3°F in an oven for 2 to 3 hr.

**NOTE:** When transferring the mixture to a suitable pan, the mixing bowl must be scraped in order to transfer the mixture to within ± 0.1% of the mixture's initial total batch weight.

- g. After curing, the mixture is then ready for testing.

#### **1D. PREPERATION OF FIELD-MIXED HMA (LOOSE MIX) SPECIMENS**

Field-mixed HMA can be heated for workability a maximum of 2 times, including heating for compaction, to the appropriate temperature as listed below (and as used in Section 2C.3.). Heat the field-mixed HMA for 2 to 3 hr. Do not heat field-mixed HMA more than 3 hr. After heating, the mixture is then ready for testing.

<b>Asphalt Binder Type</b>	<b>Field-Mixed HMA Temperature (Maximum)</b>	<b>OGFC Temperature (Maximum)</b>
Neat, unmodified (PG__ - __)	235°F ± 3°F	235°F ± 3°F
Polymer Modified (PG__ - __PM)	235°F ± 3°F	235°F ± 3°F
PG__ - __TR	235°F ± 3°F	235°F ± 3°F
Asphalt Rubber Binder (ARB)	305°F ± 3°F	305°F ± 3°F

## 1E. REPORTING

The following information should be included when reporting the test results:

- Mix type (identified as Lab-mixed or Field-mixed HMA)
- Asphalt binder type and content
- Individual and composite aggregate gradation
- Aggregate gradation plot on the FHWA 0.45th power chart
- Additives (if used): Type, percentage and method of incorporation
- Lab-mixed HMA mixing temperature, curing time and temperature, or
- Field-mixed HMA heating time and temperature

## PART 2. COMPACTION OF LAB-MIXED AND FIELD-MIXED HMA USING THE CALIFORNIA KNEADING COMPACTOR

### 2A. REFERENCES

CT 101	Operation and Calibration of the Mechanical Compactor
CT 104	Operation and Calibration of the Electronically Controlled Compactor
CT 308	Method of Test for Determining Bulk Specific Gravity and Density of Compacted Hot Mix Asphalt
CT 366	Method of Test for Stabilometer Value
AASHTO T245	Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus
ASTM D3549	Thickness or Height of Compacted Bituminous Paving Mixture Specimens
ANSI B46.1	Surface Texture

### 2B. APPARATUS



1. California Kneading Compactor: use a compactor designed to consolidate the material by a series of individual or roving “kneading action” impressions made by a compactor foot. The compactor must be capable of exerting a force of 500 psi under the compactor foot and must be operated and calibrated in accordance with California Test 101 or California Test 104.
2. Compactor Foot: a ram having a face shaped as a sector of a 4 in. diameter circle as shown in California Test 101 and California Test 104 and having an area of approximately 3.2 in<sup>2</sup>.

The temperature of the compactor foot must be maintained at the compaction temperature by means of a variable transformer controlling the foot's heater.

3. Mold Holder: a mold holder placed into position on the California Kneading Compactor and used to center the 4 in. mold and hold it securely in position during compaction.
4. Molds: molds of 4 in.  $\pm$  0.005 in. inside diameter and 5 in.  $\pm$  0.10 in. height with steel walls that are at least 0.235 in. thick at room temperature (77°F  $\pm$  9°F). Molds must be hardened to at least a Rockwell hardness of C48. The initial inside finish of the molds must have a root mean square (rms) of 1.60  $\mu$  m or smoother in accordance with ANSI B 46.1.
5. Solid Rubber Specimen: a specimen of approximately 4 in. diameter by 2½ in. height designed to fit in the mold for warming-up the California Kneading Compactor.

**NOTE:** A handful of rags stuffed into the mold is a suitable alternative.

6. Paper Disks: heavy paper disks of approximately 4 in. diameter designed to fit in the mold.
7. Metal Disks: metal disks of approximately 4 in. diameter designed to fit in the mold.

**NOTE:** The base plate used in AASHTO T 245 is a suitable disk.

8. Metal Feeder Trough: a feeder trough 4 in. wide and 16 in. long with a paddle that is shaped to fit the trough.
9. Rod: a round, straight steel rod with a diameter of ¾ in.  $\pm$  1/16 in. and length of at least 16 in. One or both ends of the tamping rod must be rounded to a hemispherical tip of the same diameter as the rod.
10. Mechanical Spader (optional): designed to prevent segregation of coarse and fine material or the formation of rock pockets in the test

specimen by introducing the mixture into the compaction mold from an endless belt, at the same time imparting a spading action with four mechanically operated bullet-nosed steel rods that are ½ in. diameter and 23 in. long.

11. Shim: a ¼ in. thick steel shim approximately ¾ in. wide and 2½ in. long.
12. Steel Followers: two steel followers with a flat surface 3.985 in. ± 0.005 in. in diameter; one 5.5 in. ± 0.25 in. in height, the other 1.575 in. ± 0.25 in. in height.
13. Compression Testing Machine: a compression testing machine having a minimum capacity of 50,000 lb and capable of maintaining the specified loading rate (see Section 2C.14.).
14. Specimen Extractor: a steel device in the form of a disk with a diameter not less than 3.95 in. and ½ in. thick for extracting the compacted specimen from the mold.
15. Ovens:
  - a. Oven(s) with free circulation of air for heating samples and/or equipment to the required temperature(s).
  - b. An oven with free circulation of air capable of maintaining a temperature of 235°F ± 3°F and 305°F ± 3°F for heating lab-mixed and field-mixed HMA samples prior to compaction.
  - c. An oven with free circulation of air capable of maintaining a temperature of 140°F ± 3°F for lab-mixed and field-mixed HMA compacted specimens.
16. Balance: a balance or scale having a minimum capacity of 5 kg, accurate to 0.1 g.

## **2C. COMPACTION OF LAB-MIXED AND FIELD-MIXED HMA**

1. Prepare lab-mixed and/or field-mixed HMA in accordance with California Test 304, Part 1.

**NOTE:** Normally, 1200 g of dry aggregate is sufficient for the stabilometer specimen. However, if the specific gravity of the aggregate is 2.80 or higher, 1300 g may be required. Three compacted specimens are required for the stabilometer testing per California Test 366, and other test methods may also require multiple compacted specimens.

2. Warm-up the California Kneading Compactor by running it through at least 1 complete cycle (20 tamping blows at 250 psi followed by 150

tamping blows at 500 psi) using the solid rubber specimen or suitable alternative.

3. Use one of the following specified temperatures when compacting the lab-mixed and/or field-mixed HMA:

<b>Asphalt Binder Type</b>	<b>Compaction Temperature</b>
Neat, unmodified (PG__ - __)	235°F ± 3°F
Polymer Modified (PG__ - __PM)	235°F ± 3°F
PG__ - __TR	235°F ± 3°F
Asphalt Rubber Binder (ARB)	305°F ± 3°F

4. Place the appropriate quantity of lab-mixed and/or field-mixed HMA in a metal pan and heat to the compaction temperature in an oven for 2 to 3 hr. Do not heat the HMA mixture for more than 3 hr.
5. Preheat the compactor foot, mold holder (one time only), molds, feeder trough, and rod to the compaction temperature.
6. Place the mold in position in the mold holder and insert a 4 in. diameter paper disk into the mold on top of the mold holder base.
7. Place a steel shim under the edge of the mold adjacent to the portion of the mold holder that extends up into the mold. Tighten the tightening screw on the mold holder.

**NOTE:** The maximum time allowed to perform Steps 7 through 9, from removal of the mixture from the oven to starting the compactor, is 1 min. This is necessary to prevent cooling of the sample.

8. Thoroughly mix and disperse the heated mixture in the heated feeder trough. Spread the mixture on the trough to ensure uniformity when transferring to the mold. Use the paddle to push half of the mixture into the mold. Rod this portion of the mixture 20 times in the center of the mass and 20 times around the edge with the heated rod. Push the remainder of the mixture into the mold and repeat the rodding procedure, just penetrating the first lift.

**NOTE:** The Mechanical Spader is suitable alternative for placing the mixture into the mold.

9. Place the mold holder containing the mixture and the mold into position in the California Kneading Compactor.

10. Start the compactor and adjust the air pressure to a point where 250 psi will be exerted by the compactor foot.
11. Apply approximately 25 tamping blows at 250 psi to accomplish a semi-compacted condition of the mixture so it will not be unduly disturbed when the 500 psi load is applied. The exact number of blows to accomplish the semi-compaction is determined by observation and may vary between 20 and 50 depending upon the type of HMA.
12. After semi-compaction has been accomplished, remove the shim and release the mold-tightening screw sufficiently to allow approximately 1/8 in. side movement of the mold during the compaction stroke. Increase the compactor foot pressure to 500 psi and apply 150 tamping blows to complete the compaction.
13. After compaction in the California Kneading Compactor, place the mold and the compacted specimen upright (tamp side up) on a metal disc and place the assembly in an oven at 140°F ± 3°F for the following range of curing time prior to applying the static leveling off load:

<b>Asphalt Binder Type</b>	<b>Curing Time in Oven</b>
Neat, unmodified (PG__ - __)	1½ to 3 hr
Polymer Modified (PG__ - __PM)	1½ to 3 hr
PG__ - __TR	1½ to 3 hr
Asphalt Rubber Binder (ARB)	2 to 3 hr

14. Remove the compacted specimen from the oven and place a 4 in. diameter paper disk on the compacted specimen. Apply a 12,600 lb leveling-off load to the specimen in a compression testing machine. Use a testing machine head or platen speed of 0.25 in./min. Apply the load by the double plunger method in which a free-fitting metal plunger is placed on the top and bottom of the compacted specimen.

**NOTE:** If the compression testing machine has a spherically seated type of upper head, use the proper shims to lock it in such a manner that the contact face is fixed firmly in a horizontal plane.

15. Return the compacted specimens for stabilometer tests (and still contained in the mold) to the 140°F ± 3°F oven for 15 min to 2 hr to retain temperature for testing in accordance with California Test 366.

**NOTE:** Stabilometer test specimens are also used to obtain the bulk specific gravity in accordance with California Test 308, unless there is a

dispute about the bulk specific gravity test result. For dispute resolution, compacted specimens must also be made, without stabilometer testing, to determine the bulk specific gravity.

16. Cool the compacted specimens not used for stabilometer and bulk specific gravity testing to room temperature (77°F ± 9°F) before removing the specimens from the mold by means of a specimen extractor. Measure the height of each compacted specimen at room temperature in accordance with ASTM D 3549 to the nearest 0.01 in. and record the measurement. The compacted specimens are then ready for any other testing.
17. Compacted lab-mixed or field-mixed specimens must be 2.5 in. ± 0.05 in. in height. Compacted specimens for mix design must be 2.5 in. ± 0.10 in. in height.

**NOTE:** To determine the required amount of lab-mixed or field-mixed HMA needed to produce a 2.5 in. compacted specimen, it is generally desirable to prepare a trial specimen. For mix designs, the trial specimen should be prepared prior to preparing all the batches. If the trial specimen height falls outside of the height limits, the amount of lab-mixed or field-mixed HMA used for the specimen may be adjusted as follows:

$$\text{Adjusted HMA Weight} = \frac{2.5 \times \text{Weight of HMA}}{\text{Specimen height obtained}}$$

## **2D. REPORTING**

The following information should be included when reporting the test results:

- Mix type (identified as lab-mixed or field-mixed HMA)
- Binder type and content
- Compaction temperature
- Curing time and curing temperature (for the stabilometer and bulk specific gravity specimens)
- Compacted specimen height

## **B. 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)

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**(California Test 304 contains 22 pages)**

# APPENDIX A

## METHOD OF PREPARATION OF LAB-MIXED AND FIELD-MIXED HMA TEST SPECIMENS CONTAINING RECYCLED ASPHALT PAVEMENT (RAP)

### A. SCOPE

This appendix includes modifications that must be made to California Test 304 when preparing test specimens of lab-mixed and field-mixed HMA containing RAP.

### B. REFERENCED DOCUMENTS

CT 201	Soil and Aggregate Sample Preparation
CT 226	Determination of Moisture Content by Oven Drying
CT 309	Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures
CT 382	Determination of Asphalt Content of Bituminous Mixtures by the Ignition Method
ASTM D2172	Quantitative Extraction of Bitumen from Bituminous Paving Mixtures

### C. PREPERATION OF LAB-MIXED HMA SPECIMENS

Prior to preparing specimens of lab-mixed HMA that contain RAP, the following procedures must be followed:

1. Sample RAP in accordance with California Test 125.

**NOTE:** Sample a minimum of 3 separate representative samples of RAP and split each sample into 2 equal parts.

2. Prepare each RAP sample separately for evaluation under California Test 201.

Split or quarter each RAP sample into representative portions for ASTM D 2172, California Test 309 and California Test 382 testing.

### Size of Sample

HMA Aggregate Size	ASTM D2172 <sup>a</sup>	CT 309 <sup>b</sup>	CT 382 <sup>c</sup>
	Minimum Weight of Sample, g		
2 in.	--	6000	--
1 1/2 in.	4000	4000	4000
1 in.	3000	2500	3000
3/4 in.	2000	2000	2000
1/2 in.	1500	1500	1500
3/8 in.	1000	1000	1200
No. 4	500	500	1200

<sup>a</sup> ASTM D 2172 is used to determine the asphalt binder content in RAP and RAP gradation for calculating batch weights.

<sup>b</sup> California Test 309 is used to calculate the effective specific gravity of the RAP aggregate.

<sup>c</sup> California Test 382 is compared with ASTM D 2172 to determine a RAP gradation correlation factor.

3. Determine the binder content of each RAP sample in accordance with ASTM D 2172, Method B (3 minimum). Calculate and report the individual and average binder content. Perform a sieve analysis on each sample of recovered aggregate in accordance with California Test 202, Appendix A (3 minimum). Calculate and report the individual and average gradation.
  4. Determine the RAP percentage that will be used in the mix design.
  5. Determine the combined gradation of the lab-mixed HMA mixture based on the proposed proportions of RAP and virgin aggregate to be used.
  6. Calculate batch weights for each ingredient in the mixture using the information from ASTM D 2172 and the attached "Worksheet for Computing Laboratory Batch Weights for lab-mixed HMA Mixtures Containing RAP" (Figure A1).
- NOTE:** Other batch worksheets may be used as long as the same information is provided.
7. Oven-dry RAP to a constant weight in accordance with California Test 226, except that the temperature must not exceed 100°F.
  8. Add moisture-free RAP on top of aggregate in the amount needed for a batch and proceed with the lab-mixed HMA specimen preparation (Section 1C.3.).



# D. PREPERATION OF FIELD-MIXED HMA (LOOSE MIX) SPECIMENS

There are no modifications.

Worksheet for Computing Laboratory Batch Weights for HMA Mixtures Containing RAP

Date: \_\_\_\_\_ Mix Type: \_\_\_\_\_ Prepared By: \_\_\_\_\_ EXAMPLE for CT 304

% RAP in HMA (15% Max.)	10
Asphalt Content of RAP <sup>1</sup>	5.7
% Hydrated Lime for Coarse Aggregate <sup>2</sup>	0.5
% Hydrated Lime for Fine Aggregate <sup>2</sup>	0.5
% Total Hydrated Lime in Aggregate mixture <sup>3</sup>	1.0

**1** - yellow cell denotes a required input.

<sup>1</sup> By weight of total mix. Use average from ASTM D 2172.

<sup>2</sup> This percentage is based on the weight of new virgin aggregate plus hydrated lime

<sup>3</sup> This percentage is based on the weight of total aggregate including RAP aggregate;

however, RAP aggregates are not treated with hydrated lime.

Table 1: Batch Weights for Virgin Aggregate, RAP, New Asphalt Binder, and Hydrated Lime

Parameter \ Sample Number	1	2	3	4	5
Desired Total Asphalt Content of Mix, % by wt. of mix	4.3	4.8	5.3	5.8	6.3
Desired Hot Mix Sample Weight, g	1200	1200	1200	1200	1200
Weight of total Aggregate, g	1148	1142	1136	1130	1124
New Asphalt, % by wt. of mix	4.3	4.8	5.3	5.8	6.3
Weight of New Asphalt to be Added, g	51.6	57.6	63.6	69.6	75.6
RAP, % by wt. of aggregate	0.0	0.0	0.0	0.0	0.0
Weight of RAP to be Added, g	0	0	0	0	0
Weight of Asphalt from RAP, g	0	0	0	0	0
New Aggregate, %	100	100	100	100	100
Weight of Virgin Aggregate + Hy. Lime, g	1148	1142	1136	1130	1124
Weight of Hydrated Lime for Coarse Aggregate, g	0	0	0	0	0
Weight of Hydrated Lime for Fine Aggregate, g	0	0	0	0	0
Weight of Virgin Aggregate, g	1148	1142	1136	1130	1124
Check	1200	1200	1200	1200	1200

Table 2: Combined Gradation Summary

AGGREGATE: % of Blend of Blend w/o RAP % of Blend w/ RAP or Lime	3/4"		1 1/2"		3/8"		Rock Dust		Natural Sand		Crushed Sand		Hydrated Lime		Blend *		
	% Passing	% of Blend	% Passing	% of Blend	% Passing	% of Blend	% Passing	% of Blend	% Passing	% of Blend	% Passing	% of Blend	% Passing	% of Blend	% Passing	% of Blend	
1 1/2"	100.0	10.0	100.0	28.0	100.0	28.0	20.0	20.0	100.0	10.0	0.0	0.0	100.0	1.0	100.0	100.0	
1"	100.0	10.0	100.0	28.0	100.0	28.0	20.0	20.0	100.0	10.0	0.0	0.0	100.0	1.0	100.0	100.0	
3/4"	100.0	10.0	100.0	28.0	100.0	28.0	20.0	20.0	100.0	10.0	0.0	0.0	100.0	1.0	100.0	100.0	
1/2"	100.0	10.0	93.9	28.3	100.0	28.0	20.0	20.0	100.0	10.0	0.0	0.0	100.0	1.0	97.9	79.09	
No. 4	85.0	8.5	2.0	0.1	4.3	1.2	47.3	12.2	19.2	9.8	0.0	0.0	100.0	1.0	75.7	68.88	
No. 8	66.0	6.6	1.0	0.1	3.0	0.8	8.7	17.7	80.6	8.1	0.0	0.0	100.0	1.0	52.4	45.85	
No. 16	52.0	5.2	1.0	0.1	3.0	0.8	4.0	1.0	68.1	13.2	6.3	0.0	60.0	1.0	36.4	31.53	
No. 30	39.0	3.9	1.0	0.1	3.0	0.8	3.0	0.8	48.6	9.7	43.3	4.3	0.0	60.0	0.8	27.8	24.60
No. 50	28.0	2.8	1.0	0.1	2.0	0.5	31.0	8.8	21.8	2.2	20.0	2.0	0.0	60.0	0.8	20.4	14.50
No. 100	18.0	1.8	1.0	0.1	2.0	0.5	20.0	4.0	7.2	0.7	0.0	0.0	60.0	0.8	13.2	9.21	
No. 200	10.8	1.1	1.0	0.1	1.0	0.3	13.8	2.7	3.3	0.3	0.0	0.0	60.0	0.8	7.8	6.78	
* Must = 100%																	5.2

Table 3: Batch Weights Needed for Each Individual Sieve

Sample Fraction	1		2		3		4		5	
	RAP	Cumula	RAP	Cumula	RAP	Cumula	RAP	Cumula	RAP	Cumula
1 1/2" - 1"	0	0	0	0	0	0	0	0	0	0
1" - 3/4"	0	0	0	0	0	0	0	0	0	0
3/4" - 1/2"	0	0	0	0	0	0	0	0	0	0
1/2" - 3/8"	0	0	0	0	0	0	0	0	0	0
3/8" - No. 4	13	0	13	0	0	0	0	0	0	0
No. 4 - No. 8	13	0	26	0	0	0	0	0	0	0
No. 8 - Pan	50	0	76	0	0	0	0	0	0	0
Lime	0	1224	0	0	0	0	0	0	0	0
Asphalt	0	1124	2425	0	0	0	0	0	0	0

FIGURE 1A. Example worksheet for Computing Laboratory Batch Weights for HMA Containing RAP

## **APPENDIX B**

### **METHOD OF PREPARATION OF LAB-MIXED AND FIELD-MIXED HMA TEST SPECIMENS CONTAINING ASPHALT BINDER TREATED WITH LIQUID ANTISTRIP**

#### **A. SCOPE**

This appendix includes modifications that must be made to California Test 304 when preparing test specimens of lab-mixed and field-mixed HMA containing asphalt binder treated with liquid anti-strip.

#### **B. PREPERATION OF LAB-MIXED HMA SPECIMENS**

1. Heat the asphalt binder to be used in the lab-mixed HMA to the appropriate lab mixing temperature (Section 1C.3.a.).
2. Weigh out a sufficient quantity of asphalt binder into a tared metal container and determine the weight to the nearest 0.1 g.
3. Under a fume hood, slowly stir the required amount of room-temperature (77°F ± 9°F) liquid anti-strip into the required weight of heated asphalt binder.

**NOTE:** If the liquid anti-strip is too viscous at room temperature, it may be warmed to the liquid anti-strip producer's recommended temperature and thoroughly stirred prior to adding it to the asphalt binder.

4. Use a stirring rod to blend the liquid anti-strip and asphalt binder together for a minimum of 2 min.
5. Maintain the treated asphalt binder at the lab mixing temperature specified until it is used.

**NOTE:** Discard the treated asphalt binder if it is not used the same day it is prepared, or if it is allowed to cool so that it requires reheating.

6. Proceed with the lab-mixed HMA specimen preparation (Section 1C.3.).

#### **C. PREPERATION OF FIELD-MIXED HMA (LOOSE MIX) SPECIMENS**

There are no modifications.

## **APPENDIX C**

### **METHOD OF PREPARATION OF LAB-MIXED AND FIELD-MIXED HMA TEST SPECIMENS CONTAINING DAMP AGGREGATE TREATED WITH DRY LIME**

#### **A. SCOPE**

This appendix includes modifications that must be made to California Test 304 when preparing lab-mixed and field-mixed HMA test specimens containing damp aggregate treated with dry hydrated lime.

#### **B. REFERENCED DOCUMENTS**

CT 226                      Determination of Moisture Content by Oven Drying

#### **C. PREPERATION OF LAB-MIXED HMA SPECIMENS**

##### 1. Aggregate Treated with Lime Without Marination

- a.** Before adding lime, place the combined dry aggregate batch in a mixing bowl and add 2 % water by dry weight of aggregate.

Mix the aggregate with water for 1 to 2 min, then add the required proportion of hydrated lime and continue mixing for 2 to 3 additional minutes.

NOTE: Add more moisture, if necessary, to assure complete coating of aggregate particles in lime.

- b.** After mixing, oven-dry the lime-treated aggregate to a constant weight in accordance with California Test 226, except that the temperature must be the specified lab mixing temperature (Section 1C.3.a.).

NOTE: If fine particles or lime residue stick to the pan after drying, use a short-bristle brush to remove the material and recombine it with the rest of the lime-treated aggregate.

- c.** Proceed with the lab-mixed HMA specimen preparation.

##### 2. Aggregate Treated with Lime and Marinated

- a.** Batch coarse and fine aggregate fractions separately.
- b.** Oven-dry the coarse and fine aggregate fractions in accordance with California Test 226, and then cool to room temperature (77°F ± 9°F).

- c. Add 1 % water by dry weight of coarse aggregate to the coarse fraction and add 2 % water by dry weight of fine aggregate to the fine fraction.
- d. Mix each coarse and fine fraction with the water for 1 to 2 min, then add the required proportion of hydrated lime to each coarse and fine fraction, and then continue mixing each fraction for 2 to 3 additional minutes.

NOTE: Add more moisture to the coarse and fine fraction, if necessary, to achieve complete coating of aggregate particles in lime.

- e. Marinate the coarse and fine fractions separately in air-tight plastic containers for 24 to 96 hr.
- f. In a mixing bowl, combine the marinated aggregate fractions and mix the composite blend thoroughly with a trowel or spoon. Break up any clumps.
- g. Transfer the lime-treated marinated aggregate to a pan and oven-dry to a constant weight under California Test 226, except that the temperature must be the specified lab mixing temperature (Section 1C.3.a.).

**NOTE:** If fine particles or lime residue stick to the pan after drying, use a short-bristle brush to remove the material and recombine it with the rest of the lime-treated marinated aggregate.

- h. Proceed with lab-mixed HMA specimen preparation (Section 1C.3.).

#### **D. PREPERATION OF FIELD-MIXED HMA (LOOSE MIX) SPECIMENS**

There are no modifications.

## **APPENDIX D**

### **METHOD OF PREPARATION OF LAB-MIXED AND FIELD-MIXED HMA TEST SPECIMENS CONTAINING AGGREGATE TREATED WITH LIME SLURRY**

#### **A. SCOPE**

This appendix contains modifications that must be made to California Test 304 when preparing lab-mixed and field-mixed HMA test specimens containing aggregate treated with hydrated lime slurry.

#### **B. PREPERATION OF LAB-MIXED HMA SPECIMENS**

1. Batch coarse and fine aggregate fractions separately.
2. Oven dry the coarse and fine aggregate fractions in accordance with California Test 226 and allow them to cool to room temperature (77°F ± 9°F).
3. Add 1 % water by dry weight of aggregate to the respective coarse and fine aggregate fractions and place the fractions in separate air-tight plastic containers to retain moisture while preparing the lime slurry.
4. Determine the weight of lime required (by dry weight of aggregate) to provide the required lime content of each coarse and fine aggregate fraction. Mix 1 part lime to 2 parts water. Break up any clumps in the lime slurry.
5. Separately, add the required amount of lime slurry to each coarse and fine aggregate fraction. In separate mixing bowls, use a trowel or spoon to thoroughly mix the slurry with each moisture-conditioned coarse and fine aggregate fraction. Stir each fraction for a minimum of 3 min.
6. Marinate the coarse and fine fractions separately in air-tight plastic containers for 24 to 96 hr.
7. In a mixing bowl, combine the marinated aggregate fractions and mix the composite blend thoroughly with a trowel or spoon. Break up any clumps.
8. Transfer the lime-treated, marinated aggregate to a pan and oven dry to a constant weight in accordance with California Test 226, except that the temperature must be the specified lab mixing temperature (Section 1C.3.a.).

**NOTE:** If fine particles or lime residue stick to the pan after drying, use a short-bristle brush to remove the material and recombine it with the rest of the lime-treated marinated aggregate.

9. Proceed with the lab-mixed HMA specimen preparation (Section 1C.3.).

**C. PREPERATION OF FIELD-MIXED HMA (LOOSE MIX) SPECIMENS**

There are no modifications.