METHOD OF TEST FOR OPTIMUM BINDER CONTENT (OBC) FOR HMA TYPE A, B, C, AND RHMA-G

A. SCOPE

This test method describes the procedure to determine the optimum binder content (OBC) by total weight of mix at design air voids for hot mix asphalt (HMA) Type A, B, C and rubberized hot mix asphalt gap-graded (RHMA-G) specimens compacted using the California Kneading Compactor.

This test method also contains the following appendices:

Appendix A  Definitions and Equations for Volumetric Relationships
Appendix B  Determining Optimum Binder Content for HMA Containing up to 15 % Reclaimed Asphalt Pavement
Appendix C  Calculations for Converting Between By Dry Weight of Aggregate and By Total Weight of Mix
Appendix D  Sample Mix Design and Job-Mix Formula Report

B. REFERENCES

CT 106  Definitions of Terms Relating to Specific Gravity
CT 202  Sieve Analysis of Coarse and Fine Aggregate
CT 206  Specific Gravity and Absorption of Coarse Aggregate
CT 207  Specific Gravity and Absorption of Fine Aggregate
CT 208  Apparent Specific Gravity of Fine Aggregate
CT 304  Preparation of Hot Mix Asphalt for Test Specimens
CT 308  Specific Gravity of Compacted HMA Specimens
CT 309  Theoretical Maximum Specific Gravity and Density of Hot Mix Asphalt
C. DETERMINING OPTIMUM BINDER CONTENT

SPECIAL NOTE: Prior to the issuance of this California Test 367 (dated November 2010) binder content, etc. were calculated based on dry weight of aggregate. Beginning with the issuance of this test method, binder content, etc. are calculated based on total weight of mixture. Appendix C contains examples of converting from by dry weight of aggregate to by total weight of mix and from total weight of mix to by dry weight of aggregate.

To determine OBC fabricate HMA briquettes with various binder contents, test the briquettes for stability and air voids content, evaluate their volumetric properties (Appendix A), and choose the binder content that will provide a mix that meets the specifications. An approximate binder content (ABC) is selected to start the process.

ABC selection may be made based on prior experience with the proposed aggregate or use the ABC values in Table 1:

### TABLE 1

**Recommended ABC for Hot Mix Asphalt Aggregate Size**

<table>
<thead>
<tr>
<th>HMA Aggregate Size</th>
<th>Recommended ABC by Total Weight of Mix ¹ ²</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 1/2 in</td>
<td>4.00%</td>
</tr>
<tr>
<td>1.0 in</td>
<td>4.50%</td>
</tr>
<tr>
<td>3/4 in</td>
<td>5.00%</td>
</tr>
<tr>
<td>1/2 in</td>
<td>5.50%</td>
</tr>
<tr>
<td>3/8 in</td>
<td>6.00%</td>
</tr>
<tr>
<td>No. 4</td>
<td>6.50%</td>
</tr>
</tbody>
</table>

¹ For all RHMA-G mixes use 7.50% by total weight of mix
² All binder contents are for mixes without reclaimed asphalt pavement (RAP). See Appendix B for mixes that include RAP.

1. Select 4 trial binder contents: ABC — 0.50%, ABC, ABC + 0.50%, and ABC + 1.00%.
NOTE: 0.50% interval is recommended, smaller intervals may be used for sensitive mixes.

2. Fabricate 1 briquette at each trial binder content in accordance with California Test 304. Determine the stability value of each briquette in accordance with California Test 366 and the bulk specific gravity ($G_{mb}$) of each briquette in accordance with California Test 308, Method A.

3. Determine the theoretical maximum specific gravity ($G_{mm}$) and unit weight of the HMA in accordance with California Test 309. Use the $G_{mm}$ result for each trial binder content to calculate the corresponding effective specific gravity ($G_{se}$) of the aggregate. Because $G_{se}$ is considered constant, use the $G_{se}$ results at the 4 trial binder contents to determine the average $G_{se}$, and use this average as the $G_{se}$ value in subsequent calculations.

4. Determine the air voids content at each trial binder content. Trial binder contents should result in air voids contents that encompass the specified design air voids. If the trial binder contents do not encompass the specified design air voids, select additional trial binder contents to encompass design air voids. Repeat Steps 1 through 4 at additional trial binder contents. Do not extrapolate to determine binder content at design air voids content.

5. Calculate other volumetric parameters (Appendix A and Appendix C).

6. Plot the following:
   - binder vs. air voids content
   - binder content vs. stability
   - binder content vs. voids in mineral aggregate, VMA
   - binder content vs. voids filled with asphalt, VFA
   - binder content vs. bulk specific gravity, $G_{mb}$
   - binder content vs. max theoretical maximum density (unit weight)
   - binder content vs. dust proportion, DP

7. Select the OBC at the specified design air voids content meeting the stability, VMA, VFA, and DP requirements.

8. Fabricate and test 3 briquettes at the selected OBC to verify compliance with the project specifications. If the volumetric properties do not meet the specification requirements, the mix design process must be repeated until the specification requirements are met.

D. REPORTING OF RESULTS
Report the HMA mix design and job-mix formula (JMF) information on Form CEM-3512.

For JMF Verification report the information on Form CEM-3513.

For JMF Renewal report the information on Form CEM-3514.

Forms are available at:

https://dot.ca.gov/programs/construction/forms

E. 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.

Refer to the Safety Manual for your laboratory.

Caltrans Laboratory Safety Manual is available at:


End of Text
(California Test 367 contains 35 pages)
APPENDIX A

DEFINITIONS AND EQUATIONS FOR VOLUMETRIC RELATIONSHIPS

A. SCOPE

This appendix describes the definition and equations necessary to compute the volumetric relationships of an HMA mixture.

B. VOLUMETRIC PROPERTIES OF HMA

Mix design is a volumetric process, but weights are much easier to measure and control in the laboratory than volumes. Calculations are based on weight-volume relationships of compacted mixture specimens.

Figure 1 depicts the volumetric relationships:

Where:

- \( V_a \) = Volume of air voids, percent
- \( V_b \) = Total volume of asphalt binder, percent
- \( V_{ba} \) = Volume of absorbed asphalt binder, percent
- \( V_{FVA} \) = Volume of voids filled with asphalt binder, percent
- \( V_{VMA} \) = Volume of voids in mineral aggregate, percent
- \( V_{mb} \) = Bulk volume of compacted mix
- \( V_{mm} \) = Voidless volume of paving mix
- \( V_{sb} \) = Bulk volume of mineral aggregate (for bulk specific gravity)

![Figure 1. Weight-Volume Relationships in Compacted HMA](image-url)
$V_{se} = \text{Effective volume of mineral aggregate (for effective specific gravity)}$

The differences between bulk, apparent, and effective specific gravities are that they are based on different volumes. The volume for bulk specific gravity (dry) is the largest and includes the volume of the aggregate and of surface and interior voids (permeable and impermeable). The volume for effective specific gravity excludes the voids that are filled with asphalt binder. Apparent specific gravity considers only the impermeable volume (smallest).

The volumetric calculations herein can be used in conjunction with any method of HMA volumetric mix design, including Hveem and Superpave among others.

**Notation**

A widely used, consistent system of notation has been developed by The Asphalt Institute and established as a national standard. This system is used in this document and here are the keys to understanding it.

"P" stands for the percentage of any component by total weight of mix and subscripts identify which component:
- "b" stands for binder,
- "m" stands for mix, and
- "s" stands for stone, i.e. aggregate.

"G" stands for specific gravity and two subscripts are used as identifiers:
- The first subscript identifies the material:
  - "b" stands for binder,
  - "m" stands for mix, and
  - "s" stands for stone, i.e. aggregate
- The second subscript identifies which type specific gravity is being used:
  - "a" stands for apparent,
  - "b" stands for bulk,
  - "e" stands for effective, and
  - "m" stands for theoretical maximum specific gravity

Examples: $G_{sb} = \text{Bulk specific gravity of the aggregate}$
$G_{mb} = \text{Bulk specific gravity of the mixture}$
$G_{mm} = \text{Theoretical maximum specific gravity of the mixture}$

**C. EQUATIONS AND DEFINITIONS FOR VOLUMETRIC CALCULATIONS**
SPECIAL NOTE: Prior to the issuance of this California Test 367 (dated October 2010) binder content, etc. were calculated based on dry weight of aggregate. Beginning with the issuance of this test method, binder content, etc. are calculated based on total weight of mixture.

Appendix C contains examples of converting from by dry weight of aggregate to by total weight of mix and from by total weight of mix to by dry weight of aggregate.

1. **Theoretical Maximum Specific Gravity**

The theoretical maximum specific gravity ($G_{mm}$) is determined on HMA samples that include admixture (if it will be used in the mix) in accordance with California Test 309. Theoretical maximum specific gravity is determined for the 4 trial binder contents (ABC — 0.50%, ABC, ABC + 0.50%, and ABC + 1.00%).

Theoretical maximum specific gravity can be calculated for other binder contents (Equation A3) using the effective specific gravity of the aggregate-admixture blend ($G_{se}$).

Theoretical maximum density (unit weight) is $G_{mm} \times 62.245$ lb/ft$^3$ (the density of water at 77°F).

2. **Effective Specific Gravity of Aggregate-Admixture Blend, $G_{se}$**

Effective specific gravity of the aggregate-admixture blend ($G_{se}$) is considered constant regardless of binder content. $G_{se}$ is calculated as follows:

$$G_{se} = \frac{100 - P_b}{100} \frac{P_b}{G_{mm} - G_b}$$

(A1)

Where: 

- $G_{se}$ = Effective specific gravity of the aggregate-admixture blend, to the nearest 0.001
- $P_b$ = Binder content at which the theoretical maximum specific gravity test was performed, as percent by total weight of mix to the nearest 0.01
- $G_{mm}$ = Theoretical maximum specific gravity of the HMA at binder content ($P_b$), to the nearest 0.001
Gb = Specific gravity of the asphalt binder, to the nearest 0.001

During the mix design, calculate Gse for each of the 4 trial binder contents and average. Use this average as the Gse value in subsequent calculations.

3. **Bulk Specific Gravity of Aggregate-Admixture Blend, Gsb**

Bulk specific gravity of aggregate-admixture blend (Gsb) is considered constant regardless of binder content. Gsb is calculated as follows:

\[
G_{sb} = \frac{P_1 G_1 + P_2 G_2 + \cdots + P_n G_n}{P_1 + P_2 + \cdots + P_n}
\]

(A2)

Where:
- \( G_{sb} \) = Bulk specific gravity of the aggregate-admixture blend, to the nearest 0.001
- \( P_1, P_2, P_n \) = Individual percentages of aggregate, including fine aggregate, coarse aggregate and supplemental fines (if used), by total weight of mix to the nearest 0.1. (Total = 100.0%)
- \( G_1, G_2, G_n \) = Individual bulk specific gravities of aggregate components, including fine aggregate, coarse aggregate and supplemental fines (if used), to the nearest 0.001

During the mix design, calculate Gsb for each of the 4 trial binder contents and average. Use this average as the Gsb value in subsequent calculations.

4. **Theoretical Maximum Specific Gravity for Different Binder Contents, Gmm**

**NOTE:** This equation for Gmm may be used only for determining Gmm of additional mixtures when it requires more than 4 trial asphalt binders to develop air voids contents that encompass the specified design air voids. For all other circumstances, determine Gmm in accordance with California Test 309.

Theoretical maximum specific gravity of the HMA at binder content (Pb) by WTM is simply solving the Gse equation for Gmm instead, as follows:

\[
G_{mm} = \frac{100}{\frac{P_s}{G_{se}} + \frac{P_b}{Gb}}
\]
Where: $G_{mm} =$ Theoretical maximum specific gravity of the HMA at binder content ($P_b$), to the nearest 0.001

$P_s =$ Aggregate content, as percent by total weight of mix to the nearest 0.1 (except $P_{200} -$ to the nearest 0.01) ($P_s = 100 - P_b$)

$P_b =$ Trial binder content, as percent by total weight of mix to the nearest 0.01

$G_{se} =$ Effective specific gravity of the aggregate-admixture blend, to the nearest 0.001

$G_b =$ Specific gravity of the asphalt binder, to the nearest 0.001

5. **Percent Absorbed Asphalt Binder, $P_{ba}$**

Percent absorbed asphalt binder ($P_{ba}$) is calculated as follows:

$$P_{ba} = 100 \frac{G_{se} - G_{sb}}{G_{sb}(G_{se})} G_b$$

(A4)

Where: $P_{ba} =$ Absorbed asphalt binder, as percent by dry weight of aggregate to the nearest 0.01

$G_{se} =$ Effective specific gravity of the aggregate-admixture blend, to the nearest 0.001

$G_{sb} =$ Bulk specific gravity of the aggregate-admixture blend, to the nearest 0.001

$G_b =$ Specific gravity of the asphalt binder, to the nearest 0.001

6. **Effective Binder Content of the Mixture, $P_{be}$**

Effective binder content of the mixture ($P_{be}$) is calculated as follows:

$$P_{be} = P_b - \left(\frac{P_{ba}}{100}\right) P_s$$

(A5)

Where: $P_{be} =$ Effective binder content of the mixture (free asphalt binder not absorbed), as percent by total weight of mix to the nearest 0.01
\( P_b = \) Binder content, as percent by total weight of mix to the nearest 0.01
\( P_{ba} = \) Absorbed asphalt binder, as percent by total weight of mix to the nearest 0.01
\( P_s = \) Aggregate content, as percent by total weight of mix to the nearest 0.1 (except \( P_{200} \) – to the nearest 0.01) \( (P_s = 100 - P_b) \)

### 7. Percent Effective Asphalt Binder Volume, \( V_{be} \)

Percent effective asphalt binder volume of the mixture (\( V_{be} \)) is calculated as follows:

\[
V_{be} = \frac{P_{be} \times G_{mb}}{G_b}
\]

(A6)

Where:

- \( V_{be} = \) Effective asphalt binder volume, as percent of bulk volume to the nearest 0.1
- \( P_{be} = \) Effective asphalt binder content of the mixture (free asphalt binder not absorbed), as percent by total weight of mix to the nearest 0.01
- \( G_{mb} = \) Bulk specific gravity of compacted mixture, to the nearest 0.001
- \( G_b = \) Specific gravity of the asphalt binder, to the nearest 0.001

### 8. Percent Voids in Mineral Aggregate (VMA) in Compacted Mixture, VMA

Voids in Mineral Aggregate (VMA) is the void space between the aggregate particles in a compacted paving mixture that includes the air voids and the effective binder content, expressed as a percentage of the total mixture volume. Where mixture composition is determined as percent by total weight of mix, the following equation applies:

\[
VMA = 100 - \frac{G_{mb} P_s}{G_{sb}}
\]

(A7)

Where:

- \( VMA = \) Voids in the mineral aggregate, as percent of bulk volume to the nearest 0.1
G_{sb} = Bulk specific gravity of the aggregate-admixture blend, to the nearest 0.001
G_{mb} = Bulk specific gravity of compacted mixture, to the nearest 0.001
P_s = Aggregate content, as percent by total weight of mix to the nearest 0.1 (except P_{200} – to the nearest 0.01) \( P_s = 100 - P_b \)

9. Percent Air Voids in Compacted Mixture, \( V_a \)

Air voids are the spaces between coated aggregate particles that are not filled with asphalt binder. The calculated \( G_{mm} \) values for the respective binder contents are used to determine the corresponding air voids contents of the compacted specimens at each binder content level as follows.

\[
V_a = 100 - \left( \frac{G_{mm} - G_{mb}}{G_{mm}} \right)
\]  
(A8)

Where: \( V_a = \) Volume of effective air voids in the compacted mixture, as percent of total volume to the nearest 0.1
\( G_{mm} = \) Theoretical maximum specific gravity of the HMA at binder content \( (P_b) \), to the nearest 0.001
\( G_{mb} = \) Bulk specific gravity of compacted mixture, to the nearest 0.001

10. Percent Voids Filled with Asphalt in Compacted Mixture, \( VFA \)

VFA is the percentage of the VMA (void space between the aggregate particles) that is filled with asphalt binder. VFA is calculated as follows:

\[
VFA = \frac{100(VMA - V_a)}{VMA}
\]  
(A9)

Where: \( VFA = \) Voids filled with asphalt binder, percent of VMA to the nearest 0.1
\( VMA = \) Voids in the mineral aggregate, as percent of bulk volume to the nearest 0.1
\( V_a = \) Volume of effective air voids in the compacted mixture, as percent of total volume to the nearest 0.1
11. Dust Proportion in the Compacted Mixture, DP

Dust proportion (DP) is the ratio of weight of dust (percentage passing #200 sieve) to the effective binder content in the mixture. DP is calculated as follows:

\[
DP = \frac{P_{200}}{P_{be}}
\]

(A10)

Where:

- DP = Ratio of percentage passing #200 sieve to the effective binder content, by total weight of mix to the nearest 0.01
- \(P_{200}\) = Percentage passing #200 sieve by dry weight of aggregate, to the nearest 0.01
- \(P_{be}\) = Effective binder content, as percent by total weight of mix to the nearest 0.01
APPENDIX B

DETERMINING OPTIMUM BINDER CONTENT (OBC) FOR HMA CONTAINING UP TO 15% RECLAIMED ASPHALT PAVEMENT (RAP)

A. SCOPE

This appendix describes the modifications that must be made to the method for determining OBC described in California Test 367 and to the basic volumetric calculations in Appendix A when preparing HMA containing up to 15% RAP by dry weight of aggregate.

B. REFERENCES

ASTM D 2172 Quantitative Extraction of Bitumen from Bituminous Paving Mixtures

C. HMA MIX CONTAINING RAP PREPARATION AND DETERMINATION OF THE PROPERTIES

Sample and prepare the RAP and HMA mix containing RAP as follows:

1. Prepare virgin aggregate and RAP blend in accordance with California Test 304.
2. Select the ABC and the other 3 trial binder contents to be used with the selected aggregate gradation, based on experience with the subject materials and/or the values recommended in Table 1 of California Test 367.
3. Determine the amount of virgin asphalt binder (by total weight of mix) to add for each trial by subtracting the asphalt binder in the proposed portion of RAP from the total asphalt binder of each trial.
4. Mix, compact, and test briquettes at the selected trial binder contents and perform volumetric calculations as specified in Section D.
5. Select an OBC that provides an HMA mixture that conforms to specifications.

D. VOLUMETRIC CALCULATIONS USING RAP

The binder content, gradation, and theoretical maximum specific gravity of the RAP are used to calculate the volumetric properties by total weight of the RAP and of the HMA containing the RAP. This section presents the modifications to the volumetric calculations to account for the RAP using example data shown in Table B-1.
### TABLE B-1

**Example Mix Design Containing RAP**  
(Design Air Voids Content = 4.0 %)

<table>
<thead>
<tr>
<th>Component</th>
<th>Bulk Specific Gravity</th>
<th>By Dry Weight of Aggregate (Percent)</th>
<th>By Total Weight of Mix (Percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proposed total asphalt binder, $P_b$</td>
<td>$G_b = 1.020 \text{ }^1$</td>
<td>5.82</td>
<td>5.50</td>
</tr>
<tr>
<td>Asphalt binder in RAP, $P_{br}$ (From ASTM D 2172)</td>
<td>$G_{br} = 1.020 \text{ }^2$</td>
<td>5.70</td>
<td>5.39</td>
</tr>
<tr>
<td>Virgin asphalt binder to be added</td>
<td>$G_b = 1.020 \text{ }^2$</td>
<td>5.25 $^3$</td>
<td>4.99</td>
</tr>
<tr>
<td>RAP, $P_r$</td>
<td>Calculate $G_{ser}$</td>
<td>10.0</td>
<td>9.5</td>
</tr>
<tr>
<td>Virgin coarse aggregate, $P_1$ (retained No. 4 sieve)</td>
<td>$G_1 = 2.720$</td>
<td>49.8</td>
<td>47.1</td>
</tr>
<tr>
<td>Virgin fine aggregate, $P_2$ (passing No. 4 sieve)</td>
<td>$G_2 = 2.700$</td>
<td>39.2</td>
<td>37.0</td>
</tr>
<tr>
<td>Supplemental fines, $P_3$ $^4$</td>
<td>$G_3 = 2.380$</td>
<td>1.0</td>
<td>0.9</td>
</tr>
<tr>
<td>Compacted mixture</td>
<td>$G_{mb} = 2.440$</td>
<td><strong>California Test 308A</strong></td>
<td></td>
</tr>
<tr>
<td>Loose mixture</td>
<td>$G_{mm} = 2.542$</td>
<td><strong>California Test 309</strong></td>
<td></td>
</tr>
</tbody>
</table>

---

1 Value should be available from asphalt supplier  
2 Assumed values which may be used if no test results are available  
3 Calculated: 5.82% - (5.70% x 10%) = 5.25%  
4 May include lime, baghouse fines, or other mineral filler
TABLE B-2

Example Aggregate Blend

<table>
<thead>
<tr>
<th>Percent of Blend</th>
<th>RAP</th>
<th>Virgin Aggregate</th>
<th>Supplemental Fine</th>
<th>Blend</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.0</td>
<td>89.0</td>
<td>1.0</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Percent Passing</th>
<th>Percent Passing</th>
<th>Percent Passing</th>
<th>Percent Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Passing Used</td>
<td>Passing Used</td>
<td>Passing Used</td>
<td></td>
</tr>
<tr>
<td>1”</td>
<td>100.0 10.0</td>
<td>100.0 89.0</td>
<td>100.0 1.0</td>
<td>100.0</td>
</tr>
<tr>
<td>3/4”</td>
<td>100.0 10.0</td>
<td>100.0 89.0</td>
<td>100.0 1.0</td>
<td>100.0</td>
</tr>
<tr>
<td>1/2”</td>
<td>100.0 10.0</td>
<td>97.5 86.8</td>
<td>100.0 1.0</td>
<td>97.8</td>
</tr>
<tr>
<td>3/8”</td>
<td>100.0 10.0</td>
<td>72.7 64.7</td>
<td>100.0 1.0</td>
<td>75.7</td>
</tr>
<tr>
<td>#4</td>
<td>83.0 8.3</td>
<td>44.0 39.2</td>
<td>100.0 1.0</td>
<td>48.5</td>
</tr>
<tr>
<td>#8</td>
<td>66.0 6.6</td>
<td>32.3 28.7</td>
<td>100.0 1.0</td>
<td>36.3</td>
</tr>
<tr>
<td>#16</td>
<td>52.0 5.2</td>
<td>23.7 21.1</td>
<td>100.0 1.0</td>
<td>27.3</td>
</tr>
<tr>
<td>#30</td>
<td>39.0 3.9</td>
<td>17.1 15.2</td>
<td>100.0 1.0</td>
<td>20.1</td>
</tr>
<tr>
<td>#50</td>
<td>26.0 2.6</td>
<td>10.3 9.2</td>
<td>100.0 1.0</td>
<td>12.8</td>
</tr>
<tr>
<td>#100</td>
<td>16.0 1.6</td>
<td>5.4 4.8</td>
<td>100.0 1.0</td>
<td>7.4</td>
</tr>
<tr>
<td>#200</td>
<td>10.00 1.00</td>
<td>3.30 2.90</td>
<td>90.00 0.90</td>
<td>4.80</td>
</tr>
</tbody>
</table>
The following calculations illustrate the procedures to determine the percentages of RAP (Pr), virgin binder content (Pbv), virgin coarse aggregate (P1), virgin fine aggregate (P2), and supplemental fines (P3) by total weight of mix:

\[ P_r = P_s \times P_{sr} = (100\% - 5.50\%) \times 10\% = 94.50\% \times 10\% = 9.5\% \]

(B1)

\[ P_{bv} = P_b - P_{br} = 5.50\% - (5.39\% \times 9.5\%) = 4.99\% \]

(B2)

Where:  
- \( P_r \) = RAP, as percent by total weight of mix to the nearest 0.1  
- \( P_s \) = Aggregate content, as percent by total weight of mix to the nearest 0.1 (except \( P_{200} \) – to the nearest 0.01) \((P_s = 100 - P_b)\)  
- \( P_{sr} \) = RAP in gradation blend chart, as percent by total weight of mix to the nearest 0.1  
- \( P_b \) = Total binder content, as percent by total weight of mix to the nearest 0.01 \((P_b = P_{br} + P_{bv})\)  
- \( P_{br} \) = Binder content of RAP, as percent by total weight of mix to the nearest 0.01  
- \( P_{bv} \) = Virgin binder content, as percent by total weight of mix to the nearest 0.01

**NOTE:** When developing an aggregate blend including both RAP and virgin aggregates, current industry practices considers asphalt binder in the RAP as part of the aggregate in the calculation as illustrated in Table B-2.

\[ P_1 = P_s \times P_{sv} \times \% \text{ retained on #4} = 94.50\% \times 85.0\% \times 56.0\% = 45.0\% \]

(B3)

\[ P_2 = P_s \times P_{sv} \times \% \text{ passing #4} = 94.50\% \times 85.0\% \times 44.0\% = 35.3\% \]

(B4)

\[ P_3 = P_s \times P_{ss} = 94.5\% \times 1.0\% = 0.9\% \]

(B5)

Where:  
- \( P_s \) = Total aggregate, as percent by total weight of mix to the nearest 0.1
1. **Effective Specific Gravity of RAP Aggregate, \( G_{ser} \)**

One of the primary differences in the volumetric calculations when RAP is used is that the effective specific gravity is used to approximate the bulk specific gravity (\( G_{sb} \)) of the RAP aggregate. Use the binder content of the RAP determined in accordance with ASTM D 2172 and the theoretical maximum specific gravity of the RAP determined in accordance with California Test 309 to calculate the effective specific gravity of the RAP aggregate.

**NOTE:** Test 3 samples in accordance with California Test 309 and use the average of the results as \( G_{mmr} \) in the following calculations.

**Given:**

\[
G_{mm} = 2.542 \text{ (average of 4 California Test 309 results for trial binder contents)}
\]

\[
G_{mmr} = 2.533 \text{ (average of 3 California Test 309 results)}
\]

\[
G_b \text{ and } G_{br} = 1.020
\]

\[
\begin{align*}
G_{ser} &= \frac{100 - P_{br}}{G_{mmr} - G_{br}} = \frac{100 - 5.39}{2.533 - 1.020} = 2.767
\end{align*}
\]

\[(B6)\]

**Where:**

\( G_{ser} \) = Effective specific gravity of the RAP aggregate, to the nearest 0.001

\( G_{mmr} \) = Theoretical maximum specific gravity of the RAP mix at binder content \( P_{br} \), by total weight of mix to the nearest 0.001

\( P_{br} \) = RAP binder content at which the theoretical maximum specific gravity test was performed, as percent by total weight of mix to the nearest 0.01
\[ G_{br} = \text{Specific gravity of the RAP asphalt binder, to the nearest 0.001} \]

2. **Bulk Specific Gravity of the Virgin Aggregate and RAP Blend, } G_{sb}\]

To calculate the bulk specific gravity of the blend of virgin aggregate and RAP, treat the RAP as another aggregate. Use the percentage of RAP and the \( G_{ser} \) for the RAP for the bulk specific gravity of the RAP aggregate as follows:

\[
G_{sb} = \frac{P_1 + P_2 + \cdots + P_r}{\frac{P_1}{G_1} + \frac{P_2}{G_2} + \cdots + \frac{P_r}{G_{ser}}} = \frac{47.1 + 37.0 + 0.9 + 9.5}{\frac{47.1}{2.720} + \frac{37.0}{2.700} + \frac{0.9}{2.380} + \frac{9.5}{2.767}} = 2.712
\]

\[(B7)\]

Where:

\( G_{sb} = \text{Bulk specific gravity of the blend of virgin aggregate and RAP, to the nearest 0.001} \)

\( P_1 = \text{Virgin coarse aggregate, as percent by total weight of mix to the nearest 0.1} \)

\( P_2 = \text{Virgin fine aggregate, as percent by total weight of mix to the nearest 0.1} \)

\( P_3 = \text{Hydrated lime, as percent by total weight of mix to the nearest 0.1} \)

\( P_r = \text{RAP, as percent by total weight of mix to the nearest 0.1} \)

\( G_1 = \text{Bulk specific gravity of the virgin coarse aggregate, to the nearest 0.001} \)

\( G_2 = \text{Bulk specific gravity of the virgin fine aggregate, to the nearest 0.001} \)

\( G_3 = \text{Bulk specific gravity of the hydrated lime, to the nearest 0.001} \)

\( G_{ser} = \text{Effective specific gravity of the RAP aggregate, to the nearest 0.001} \)

The rest of the volumetric calculations are based on the properties of the HMA mix including the RAP and are the same as presented in Section D of this test method.

3. **Theoretical Maximum Specific Gravity of HMA and RAP Mix, } G_{mm}\]

Perform California Test 309 on the trial HMA mixture(s) of blended virgin aggregate and RAP. \( G_{mm} \) must be determined at each of the trial binder contents (ABC — 0.50%, ABC, ABC + 0.50%, and ABC + 1.00%). Once the
average effective specific gravity of the blend (G_{se}) is determined for the 4 trial binder contents, all other G_{mm} can be calculated using:

$$\frac{G_{mm}}{G_{se}} = \frac{P_s}{G_{se}} + \frac{P_b}{G_b}$$

\hspace{1cm} (B8)

Where:
- \(G_{mm}\) = Theoretical maximum specific gravity of the HMA at binder content \(P_b\), to the nearest 0.001
- \(P_s\) = Aggregate content, as percent by total weight of mix to the nearest 0.1 (except \(P_{200}\) – to the nearest 0.01) \((P_s = 100 - P_b)\)
- \(P_b\) = Trial binder content, as percent by total weight of mix to the nearest 0.01
- \(G_{se}\) = Effective specific gravity (average) of the aggregate-admixture blend, to the nearest 0.001
- \(G_b\) = Specific gravity of the asphalt binder, to the nearest 0.001

4. **Effective Specific Gravity of Virgin Aggregate and RAP Blend, G_{se}**

The effective specific gravity of the virgin aggregate and RAP blend (G_{se}) is calculated from the G_{mm} determined for the HMA and RAP blend at binder content \(P_b\) using:

$$G_{se} = \frac{100\% - P_b}{G_{mm}} - \frac{100\% - 5.50\%}{2.542 - 1.020} = 2.784$$

\hspace{1cm} (B9)

Where:
- \(G_{se}\) = Effective specific gravity of the virgin aggregate and RAP blend to the nearest 0.001
- \(G_{mm}\) = Theoretical maximum specific gravity of the HMA and RAP mix at binder content \(P_b\), by total weight of mix to the nearest 0.001

**NOTE:** Perform California Test 309 at the 4 trial binder contents (ABC − 0.50 %, ABC, ABC + 0.50 %, and ABC + 1.00 %), calculate \(G_{se}\) for each trial binder content; and use the average of the \(G_{se}\) values in the calculations.

\(P_b\) = Binder content, as percent by total weight of mix to the nearest 0.01
NOTE: Binder content at which California Test 309 was performed which includes both the virgin and RAP asphalt binder (Pb at ABR = 5.50 % for this example)

Gb = Specific gravity of the asphalt binder, to the nearest 0.001

5. Absorbed Asphalt Binder, Pba

The percent absorbed asphalt binder is calculated using the Gsb value for the blend of virgin aggregate and RAP, and the corresponding Gse value (or average thereof) calculated using:

\[
P_{ba} = 100\% \left( \frac{G_{se} - G_{sb}}{G_{se}(G_{sb})} \right) G_{b} = 100\% \left( \frac{2.784 - 2.712}{2.784(2.712)} \right) 1.020 = 0.97\%
\]

(B10)

Where:

- Pba = Absorbed asphalt binder, as percent by total weight of the HMA mix to the nearest 0.01
- Gse = Effective specific gravity of the virgin aggregate and RAP blend, to the nearest 0.001
- Gsb = Bulk specific gravity of the virgin aggregate and RAP blend, to the nearest 0.001
- Gb = Specific gravity of the asphalt binder, to the nearest 0.001

6. Effective Binder Content of the HMA with RAP Mix, Pbe

\[
P_{be} = P_{b} - (P_{ba} \times P_{s}) = 5.50\% - (0.97\% \times 94.50\%) = 4.58\%
\]

(B11)

Where:

- Pbe = Effective binder content of the mixture, as percent by total weight of mix to the nearest 0.01 (free asphalt binder not absorbed)
- Pb = Binder content, as percent by total weight of mix to the nearest 0.01
- Pba = Absorbed asphalt binder, as percent by total weight of mix to the nearest 0.01
- Ps = Aggregate content, as percent by total weight of mix to the nearest 0.01

7. Effective Asphalt Binder Volume of the HMA with RAP Mix, Vbe
\[
V_{be} = \frac{P_{be}(G_{mb})}{G_{b}} = \frac{4.58\%(2.440)}{1.020} = 10.96\%
\]

(B12)

Where:
- \( V_{be} \) = Effective asphalt binder volume, as percent of bulk volume to the nearest 0.01%
- \( P_{be} \) = Effective binder content of the HMA mix (free asphalt binder not absorbed), as percent by total weight of mix to the nearest 0.01%
- \( G_{mb} \) = Bulk specific gravity of compacted mixture, to the nearest 0.001
- \( G_{b} \) = Specific gravity of the asphalt binder to the nearest 0.001

8. **Voids in the Mineral Aggregate in Compacted HMA with RAP Mix, VMA**

\[
V_{be} = \frac{P_{be}(G_{mb})}{G_{b}} = \frac{4.58\%(2.440)}{1.020} = 10.96\%
\]

(B13)

Where:
- \( V_{be} \) = Effective asphalt binder volume, as percent of bulk volume to the nearest 0.01%
- \( P_{be} \) = Effective binder content of the HMA mix (free asphalt binder not absorbed), as percent by total weight of mix to the nearest 0.01%
- \( G_{mb} \) = Bulk specific gravity of compacted mixture, to the nearest 0.001
- \( G_{b} \) = Specific gravity of the asphalt binder to the nearest 0.001

9. **Percent Air Voids (\( V_{a} \)) in Compacted HMA with RAP Mix, \( V_{a} \)**

\[
V_{a} = 100\% \left( \frac{G_{mm} - G_{mb}}{G_{mm}} \right) = 100\% \left( \frac{2.542 - 2.440}{2.542} \right) = 4.0\%
\]

(B14)

Where:
- \( V_{a} \) = Volume of effective air voids in the compacted mixture, percent of total volume to the nearest 0.1%
- \( G_{mm} \) = Theoretical maximum specific gravity of the HMA mix at binder content \( P_{b} \), by total weight of mix to the nearest 0.001
\[ G_{mb} = \text{Bulk specific gravity of compacted mixture, to the nearest 0.001} \]

10. **Voids Filled with Asphalt in Compacted HMA with RAP Mix, VFA**

\[ VFA = \frac{100\%(VMA - V_{b})}{VMA} = \frac{100\%(15.0\% - 4.0\%)}{15.0\%} = 73\% \]  

(B15)

Where:  
VFA = Voids filled with asphalt binder, as percent of VMA to the nearest 0.1  
VMA = Voids in the mineral aggregate, as percent of bulk volume to the nearest 0.1  
\( V_{b} \) = Bulk specific gravity of compacted mixture, to the nearest 0.001

11. **Dust Proportion in the HMA with RAP Mix, DP**

\[ DP = \frac{P_{200}}{P_{be}} = \frac{4.80\%}{4.58\%} = 1.05 \]  

(B16)

Where:  
DP = Dust Proportion, to the nearest 0.01  
P_{200} = Aggregate passing the No. 200 sieve, as percent by total weight of mix to the nearest 0.0 (\( P_{200} = 4.80\% \) for this example)  
P_{be} = Effective binder content of the HMA mix (free asphalt binder not absorbed), as percent by total weight of mix to the nearest 0.01
APPENDIX C

CALCULATIONS FOR CONVERTING BETWEEN BY DRY WEIGHT OF AGGREGATE AND BY TOTAL WEIGHT OF MIX

A. SCOPE

The volumetric calculations in this test method (California Test 367) are primarily based on proportions of the asphalt binder and aggregate components by total weight of the HMA mixture (by total weight of mix) rather than proportions by dry weight of aggregate.

This Appendix C provides examples of converting from by dry weight of aggregate to by total weight of mix and from by total weight of mix to by dry weight of aggregate.

1. Converting From Proportioning By Dry Weight of Aggregate to By Total Weight of Mix

Example 1: Convert binder content and coarse and fine aggregate fractions from percentages by dry weight of aggregate to percentages by total weight of mix using the data in Table C-1. This example uses weights of the mix components, because 100 g is the total weight of aggregate, the percentages by dry weight of aggregate may be substituted for weights.

Assume: Total weight of the combined aggregates is 100.0 g.

TABLE C-1

Converting from by Dry Weight of Aggregate to by Total Weight of Mix

<table>
<thead>
<tr>
<th>Material</th>
<th>(Given) By Dry Weight of Aggregate (Percent)</th>
<th>(Computed) By Total Weight of Mix (Percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt Binder 1</td>
<td>5.15</td>
<td>4.90</td>
</tr>
<tr>
<td>Coarse Aggregate (Retained on No. 4 sieve)</td>
<td>56.9</td>
<td>54.1</td>
</tr>
<tr>
<td>Fine Aggregate (Passing No. 4 sieve) 2</td>
<td>43.1</td>
<td>41.0</td>
</tr>
<tr>
<td>Supplemental Fines 2</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

1 Calculate and report to the nearest 0.01%
2. May include lime, bag house fines, or other mineral filler

**Compute total weight of mix by dry weight of aggregate:**

\[
\text{Total weight of mix} = \text{Total aggregate weight} + \text{Asphalt binder weight}
\]

\[
= 100.0g + (0.0515 \times 100g)
\]

\[
= 100.0g + 5.15g
\]

\[
= 105.15g
\]

**Compute binder content by total weight of mix:**

\[
\% \text{ asphalt} = \frac{5.15}{105.15} \times 100\%
\]

\[
= 4.90\%
\]

**Compute percent of coarse aggregate by total weight of mix:**

\[
\% \text{ coarse aggregate} = \frac{\text{coarse aggregate weight (by dry weight of aggregate)}}{\text{total weight of mix}} \times 100\%
\]

\[
= \frac{0.569 \times 100g}{105.15g} \times 100\%
\]

\[
= 54.1\%
\]

**Compute percent of fine aggregate by total weight of mix:**

\[
\% \text{ fine aggregate} = \frac{\text{fine aggregate weight (by dry weight of aggregate)}}{\text{total weight of mix}} \times 100\%
\]

\[
= \frac{43.1g}{105.15g} \times 100\%
\]

\[
= 41.0\%
\]

**Check:**

\[
100\% \text{ of total weight of mix} = 4.90\% (\text{binder}) + 54.1\% (\text{coarse}) + 41.0\% (\text{fine})
\]

\[
= 100\%
\]
Example 2: Convert binder content and coarse and fine aggregate fractions from percentages by total weight of mix to percentages by dry weight of aggregate using the data in Table C-2. This example uses weights of the mix components, but their percentages by dry weight of aggregate may be substituted for weights.

Assume: Total weight of the combined aggregates is 100.0 g.

TABLE C-2

Converting from by Dry Weight of Aggregate to by Total weight of mix

<table>
<thead>
<tr>
<th>Material</th>
<th>(Computed) By Total Weight of Mix (Percent)</th>
<th>(Given) By Dry Weight of Aggregate (Percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt Binder ¹</td>
<td>4.90</td>
<td>5.15</td>
</tr>
<tr>
<td>Coarse Aggregate (Retained on No. 4 sieve)</td>
<td>54.1</td>
<td>54.1</td>
</tr>
<tr>
<td>Fine Aggregate (Passing No. 4 sieve)</td>
<td>41.0</td>
<td>41.0</td>
</tr>
<tr>
<td>Supplemental Fines ²</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

¹ Calculate and report to the nearest 0.01%
² May include lime, bag house fines, or other mineral filler

Compute total weight of aggregate:

\[
total \ weight \ of \ aggregate = (0.541 \times 100.0g) + (0.410 \times 100.0g) + (0 \times 100g)
\]

\[
= 54.1g + 41.0g + 0g
\]

\[
= 95.1g
\]

Or

\[
100.0g - 4.90g = 95.1g
\]

Compute total weight of mix:

\[
total \ weight \ of \ mix = total \ aggregate \ weight + asphalt \ binder \ weight
\]

\[
= 95.1g + (0.0490 \times 100.0g)
\]

\[
= 95.1g + 4.90g
\]
Computer binder content by dry weight of aggregate:

\[
\text{binder content} = \frac{\text{asphalt binder weight (by DWA)}}{\text{dry aggregate weight}} \times 100\%
\]

\[
= \frac{0.0490 \times 100g}{95.1g} \times 100\%
\]

\[
= 4.90\%
\]

Computer percent coarse aggregate by dry weight of aggregate:

\[
\% \text{ coarse aggregate} = \frac{\text{coarse aggregate weight (by total weight of mix)}}{\text{total weight of aggregate}} \times 100\%
\]

\[
= \frac{0.541 \times 100g}{95.1g} \times 100\%
\]

\[
= 56.9\%
\]

Compute percent fine aggregate by total weight of mix:

\[
\% \text{ fine aggregate} = \frac{\text{fine aggregate weight (by total weight of mix)}}{\text{total weight of aggregate}} \times 100\%
\]

\[
= \frac{0.410g \times 100g}{95.1g} \times 100\%
\]

\[
= 43.1\%
\]

Check:

\[
100\% \text{ of aggregate} = 56.9\% \text{ (coarse)} + 43.1\% \text{ (fine)}
\]

\[
= 100\%
\]
APPENDIX D

SAMPLE MIX DESIGN AND JOB-MIX FORMULA REPORT

A. SCOPE

This Appendix provides a sample mix design and job-mix formula (JMF) report that would be developed for the HMA mix. Mix design and job-mix formula (JMF) information is summarized on Form CEM-3512.

The mix design volumetric relationships are solved using the data given in Table D-1.

TABLE D-1

Converting from by Dry Weight of Aggregate to by Total Weight of Mix

<table>
<thead>
<tr>
<th>Material</th>
<th>By Dry Weight of Aggregate (Percent)</th>
<th>By Total Weight of Mix (Percent)</th>
<th>Specific Gravity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt Binder(^{1})</td>
<td>5.26 (^{1})</td>
<td>5.00 (^{1})</td>
<td>(G_{b} = 1.025)</td>
</tr>
<tr>
<td>Coarse Aggregate (Retained on No. 4 sieve)</td>
<td>39.5</td>
<td>37.5</td>
<td>(G_{1} = 2.754)</td>
</tr>
<tr>
<td>Fine Aggregate (Passing No. 4 sieve)</td>
<td>60.5</td>
<td>57.5</td>
<td>(G_{2} = 2.665)</td>
</tr>
<tr>
<td>Supplemental Fines (^{2})</td>
<td>0</td>
<td>0</td>
<td>(G_{3} = 2.455)</td>
</tr>
<tr>
<td>HMA Briquette</td>
<td>Bulk Specific Gravity, (G_{mb} = 2.384)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loose HMA</td>
<td>Theoretical maximum specific gravity, (G_{mm} = 2.563)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^{1}\) Calculate and report to the nearest 0.01%
\(^{2}\) May include lime, bag house fines, or other mineral filler

Note: Passing No. 200 sieve \((P_{200}) = 5.1\%

1. Theoretical Maximum Specific Gravity
The theoretical maximum specific gravity is determined in accordance with California Test 309 for all 4 trial binder contents, and for this example is given as:

\[ G_{mb} = 2.384 \]
\[ G_{mm} = 2.563 \]

2. **Effective Specific Gravity of Aggregate-Admixture Blend (\( G_{se} \))**

\[ G_{se} = \frac{100 - P_b}{100 \cdot \frac{P_b}{G_{mm}} - \frac{P_b}{G_b}} = \frac{100 - 5.00}{100 \cdot \frac{5.00}{2.563} - \frac{5.00}{1.025}} = 2.783 \]

3. **Bulk Specific Gravity of Aggregate-Admixture Blend (\( G_{sb} \))**

\[ G_{sb} = \frac{P_1 + P_2 + \ldots + P_n}{\frac{P_1}{G_1} + \frac{P_2}{G_2} + \ldots + \frac{P_n}{G_n}} = \frac{37.5 + 57.5}{\frac{37.5}{2.754} + \frac{57.5}{2.665}} = 2.702 \]

4. **Theoretical Maximum Specific Gravity for Different Binder Contents**

\[ G_{mm} = \frac{100}{\frac{G_s}{G_{se}} + \frac{P_b}{G_b}} = \frac{100}{\frac{95.0}{2.783} + \frac{5.0}{1.025}} = 2.563 \]

5. **Percent Absorbed Asphalt Binder**

\[ P_{ba} = 100 \frac{G_{se} - G_{sb}}{G_{sb}(G_{se})} G_b = 100 \times \left( \frac{2.783 - 2.703}{2.703 \times 2.783} \right) \times 1.025 = 1.09 \]

6. **Effective Binder Content of the Mixture**

\[ P_{be} = P_b - \left( \frac{P_{ba}}{100} \right) P_s = 5.00 - \left( \frac{1.09}{100} \right) \times 95.0 = 3.97 \]

7. **Percent Effective Asphalt Binder Volume**

\[ V_{be} = \frac{P_{be} \times G_{mb}}{G_b} = \frac{3.97 \times 2.384}{1.025} = 9.2 \]

8. **Calculating Percent Voids in Mineral Aggregate (VMA) in Compacted Mixture**

\[ VMA = 100 - \frac{G_{mb} P_s}{G_{sb}} = 100 - \frac{2.384 \times 95.0}{2.703} = 16.2 \]

9. **Calculating Percent Air Voids (Air Voids Content, \( V_a \)) in Compacted Mixture**
\[ V_a = 100 \left( \frac{G_{mm} - G_{mb}}{G_{mm}} \right) = 100 \left( \frac{2.563 - 2.384}{2.563} \right) = 7.0 \]

10. Calculating Percent Voids Filled with Asphalt (VFA) in Compacted Mixture

\[ VFA = \frac{100(VMA - V_a)}{VMA} = \frac{100(16.2 - 7.0)}{16.2} = 56.9 \]

11. Calculating Dust Proportion (DP) in the Compacted Mixture

\[ DP = \frac{P_{200}}{P_{be}} = \frac{5.1}{3.97} = 1.28 \]

Figure D-1 that follows is an example of the documentation for this mix design.
FIGURE D-1. Example of Mix Design and Documentation
FIGURE D-1 (continued). Example of Mix Design and Documentation
**FIGURE D-1 (continued). Example of Mix Design and Documentation**

<table>
<thead>
<tr>
<th>Aggregate Quality ¹</th>
<th>Quality Characteristic/Property</th>
<th>Test Method</th>
<th>Test Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crushed particles, coarse aggregate</td>
<td>Retained on No. 4 sieve</td>
<td>CT 205</td>
<td>96</td>
</tr>
<tr>
<td>One fractured face (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crushed particles, coarse aggregate</td>
<td>Retained on No. 4 sieve</td>
<td>CT 205</td>
<td>88</td>
</tr>
<tr>
<td>Two fractured faces (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crushed particles, fine aggregate</td>
<td>Passing No. 4 sieve and retained on No. 8 sieve</td>
<td>CT 205</td>
<td>93</td>
</tr>
<tr>
<td>One fractured face (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Los Angeles Rattler, Loss at 100 Rev. (%)</td>
<td></td>
<td>CT 211</td>
<td>6</td>
</tr>
<tr>
<td>Los Angeles Rattler, Loss at 500 Rev. (%)</td>
<td></td>
<td>CT 211</td>
<td>19</td>
</tr>
<tr>
<td>Sand equivalent</td>
<td></td>
<td>CT 217</td>
<td>67 70 68 Average 68</td>
</tr>
<tr>
<td>Fine aggregate angularity (%)</td>
<td></td>
<td>CT 234</td>
<td>52</td>
</tr>
<tr>
<td>Flat and elongated particles (% by mass at 3:1)</td>
<td></td>
<td>CT 235</td>
<td>N/A</td>
</tr>
<tr>
<td>Flat and elongated particles (% by mass at 5:1)</td>
<td></td>
<td>CT 235</td>
<td>2</td>
</tr>
<tr>
<td>Plasticity Index</td>
<td></td>
<td>CT 204</td>
<td>NP</td>
</tr>
<tr>
<td>Sodium sulfate soundness</td>
<td></td>
<td>CT 214</td>
<td>N/A</td>
</tr>
<tr>
<td>Cleanness Value, Cᵥ</td>
<td></td>
<td>CT 227</td>
<td>N/A</td>
</tr>
<tr>
<td>Fine aggregate Durability Index, D₁</td>
<td></td>
<td>CT 229</td>
<td>N/A</td>
</tr>
<tr>
<td>Coarse aggregate Durability Index, D₂</td>
<td></td>
<td>CT 229</td>
<td>N/A</td>
</tr>
<tr>
<td>Bulk specific gravity (oven dry) of coarse aggregate, G₀</td>
<td></td>
<td>CT 206</td>
<td>2.754</td>
</tr>
<tr>
<td>Absorption of coarse aggregate</td>
<td></td>
<td>CT 206</td>
<td>0.7 %</td>
</tr>
<tr>
<td>Bulk specific gravity (SSD) of fine aggregate</td>
<td></td>
<td>CT 207</td>
<td>2.711</td>
</tr>
<tr>
<td>Bulk specific gravity (oven dry) of fine aggregate, G₁</td>
<td></td>
<td>CT 207</td>
<td>2.665</td>
</tr>
<tr>
<td>Apparent specific gravity of supplemental fines, Gₛᵣ</td>
<td></td>
<td>CT 208</td>
<td>2.455</td>
</tr>
<tr>
<td>Absorption of fine aggregate</td>
<td></td>
<td>CT 207</td>
<td>1.7 %</td>
</tr>
<tr>
<td>Bulk specific gravity of the aggregate blend, Gₒ₂</td>
<td></td>
<td>CT 367</td>
<td>2.699</td>
</tr>
</tbody>
</table>

Note:
¹ Aggregate must comply with the quality specifications before it is treated with lime.
### FIGURE D-1 (continued). Example of Mix Design and Documentation

<table>
<thead>
<tr>
<th>Quality Characteristic</th>
<th>Test Method</th>
<th>Test Result</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt binder content (%) (JMF TV)</td>
<td>CT 367</td>
<td>5.80</td>
<td></td>
</tr>
<tr>
<td>Briquette bulk specific gravity, G&lt;sub&gt;mb&lt;/sub&gt;</td>
<td>CT 308 (Method A)</td>
<td>2.426, 2.430, 2.431</td>
<td>2.429</td>
</tr>
<tr>
<td>Maximum specific gravity</td>
<td>CT 309</td>
<td>2.538</td>
<td></td>
</tr>
<tr>
<td>Air voids content, V&lt;sub&gt;a&lt;/sub&gt; (%)</td>
<td>CT 367</td>
<td>4.4, 4.3, 4.2</td>
<td>4.3</td>
</tr>
<tr>
<td>Voids in mineral aggregate, VMA (%)</td>
<td>CT 367</td>
<td>15.5, 15.3, 15.2</td>
<td>15.3</td>
</tr>
<tr>
<td>Effective specific gravity of RAP aggregate</td>
<td>CT 367</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Voids filled with asphalt, VFA (%)</td>
<td>CT 367</td>
<td>71.4, 72.2, 72.4</td>
<td>72.0</td>
</tr>
<tr>
<td>Dust proportion, DP</td>
<td>CT 367</td>
<td>1.09</td>
<td></td>
</tr>
<tr>
<td>Effective specific gravity of aggregate</td>
<td>CT 367</td>
<td>2.792</td>
<td></td>
</tr>
<tr>
<td>Stabilometer value</td>
<td>CT 366</td>
<td>44, 41, 43</td>
<td>43</td>
</tr>
<tr>
<td>Modified stabilometer value</td>
<td>CT 366</td>
<td>Average N/A</td>
<td></td>
</tr>
<tr>
<td>Surface abrasion (%)</td>
<td>CT 360</td>
<td>Average N/A</td>
<td></td>
</tr>
<tr>
<td>Tensile strength ratio (TSR) untreated&lt;sup&gt;2&lt;/sup&gt;</td>
<td>CT 371</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Tensile strength ratio (TSR) treated&lt;sup&gt;2&lt;/sup&gt;</td>
<td>CT 371</td>
<td>N/A</td>
<td></td>
</tr>
</tbody>
</table>

<sup>1</sup> For mix design, prepare 3 briquettes separately at the proposed JMF and test for compliance. Report the average of 3 tests. Prepare new briquettes and test if the range of stability for the 3 briquettes is more than 12 points.<br><sup>2</sup> Attach Figure 1 from CT 371.
FIGURE D-1 (continued). Example of Mix Design and Documentation
FIGURE D-1 (continued). Example of Mix Design and Documentation