# DESIGN OF ASPHALTIC CONCRETE FRICTION COURSE

## (An Arizona Method)

1. **SCOPE**

1.1 This test method provides a standard methodology to be used for the development of an asphaltic concrete friction coarse mix design. It includes a means of determining the density and design binder content.

1.2 This test method may involve hazardous material, operations, or equipment. This test method does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user to consult and establish appropriate safety and health practices and determine the applicability of any regulatory limitations prior to use.

1.3 See Appendix A1 of the Materials Testing Manual for information regarding the procedure to be used for rounding numbers to the required degree of accuracy.

1.4 A listing of subsequent Sections and Figures in this procedure is given below:

## 2. TEST METHODS AND APPARATUS

2.1 This test method is used in conjunction with the test methods listed below. The required apparatus is shown in the individual test methods, as appropriate. This test method also requires specific apparatus for the draindown and unit weight procedure, as listed in Subsection 2.5. Requirements for the frequency of equipment calibration and verification are found in Appendix A3 of the Materials Testing Manual.

2.2

| | |
|---|---|
| ARIZ 201 | Sieving of Coarse and Fine Graded Soils and Aggregates |
| ARIZ 205 | Composite Grading |
| ARIZ 210 | Specific Gravity and Absorption of Coarse Aggregate |
| ARIZ 211 | Specific Gravity and Absorption of Fine Aggregate |
| ARIZ 212 | Percentage of Fractured Coarse Aggregate Particles |
| ARIZ 233 | Flakiness Index of Coarse Aggregate |
| ARIZ 238 | Percent Carbonates in Aggregate |
| ARIZ 242 | Sand Equivalent Test for Mineral Aggregate for Asphaltic Concrete Friction Course |
| ARIZ 248 | Alternate Procedures for Sieving of Coarse and Fine Graded Soils and Aggregates |
| ARIZ 251 | Combined Coarse and Fine Specific Gravity and Absorption |
| ARIZ 714 | Sieving of Granulated Rubber |
| ARIZ 806 | Maximum Theoretical Specific Gravity of Laboratory Prepared Bituminous Mixtures (Rice Test) |

2.3 AASHTO T 96 Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine

AASHTO T 176 Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test

AASHTO T 228 Specific Gravity of Semi-Solid Bituminous Materials

**Note:** Perform testing by AASHTO T 228 at 77 °F.

AASHTO M 231 Weighing Devices Used in the Testing Materials

AASHTO T 316 Viscosity Determination of Asphalt Binder Using Rotational Viscometer

2.4 ASTM D 7741 Measurement of Apparent Viscosity of Asphalt-Rubber or Other Asphalt Binders by Using a Rotational Hand Held Viscometer

2.5 Apparatus for Draindown and Unit Weight Procedure

2.5.1 Oven – An oven capable of maintaining constant temperatures between 220 and 335 °F.

2.5.2 Compression Testing Machine – A testing machine conforming to the requirements of AASHTO T 167.

2.5.3 Molds – Molding cylinders, and top and bottom molding plungers; the cylinders shall be 4.000 ± 0.005 inches inside diameter by approximately 6 inches in height. The top and bottom plungers shall be 3.985 ± 0.005 inches in diameter, the bottom plunger shall be approximately 2 inches in height and the top plunger shall be approximately 6 inches in height. A baseplate approximately 8”x 8” shall be provided to hold the mold and plunger assembly.

**Note:** Identify the molding cylinders and record the tare weight to the nearest 0.1 gram, and the inside diameter recorded to the nearest 0.001 inch. Check the tare weight and inside diameter of the cylinders periodically to assure they have not changed due to use.

2.5.4 Support Bars – Steel bars to hold the mold cylinder one inch above the baseplate during the molding operation.

2.5.5 A balance or scale capable of measuring the maximum weight to be determined and conforming to the requirements of AASHTO M 231, except the readability and sensitivity of any balance or scale utilized shall be at least 0.1 gram.

2.5.6 Hot Plate – Capable of maintaining a temperature of up to 325 ± 5 °F.

2.5.7 Miscellaneous mixing bowls, spoons, spatulas, scoops, pans, etc.

2.5.8 Thermometers – Dial type with glass face, or digital, capable of reading to the nearest 1 °F with a range of 50 to at least 350 °F.

2.5.9 1,000 ml Glass Beakers.

2.5.10 Glass Plate or Watch Glass large enough to cover Glass Beaker.

## 3. MATERIALS

3.1 Mineral Aggregate – The mineral aggregate used in the design shall be produced material from the source(s) for the project.

3.1.1 The composited gradation of the aggregate without admixture, and the composited gradation of the aggregate-mineral admixture blend shall comply with the grading limits of the specifications.

3.1.2 The composited mineral aggregate shall conform to the requirements of the specifications for Combined Bulk Oven Dry Specific Gravity (ARIZ 251), Combined Water Absorption (ARIZ 251), Sand Equivalent (ARIZ 242), Fractured Coarse Aggregate Particles (ARIZ 212), Flakiness Index (ARIZ 233), Percent Carbonates (ARIZ 238), and Abrasion (AASHTO T 96) when applicable.

3.2 Bituminous Material – The bituminous material used in the design shall be an asphalt binder, conforming to the requirements of Section 1005 of the specifications, which is to be used in the production of the asphaltic concrete. The specific gravity of the asphalt binder shall be determined in accordance with AASHTO T 228 (at 77 °F).

3.3 Mineral Admixture – Mineral admixture is required. The mineral admixture used in the design shall be the same type of material from the same supplier to be used in production of friction course. The mineral admixture shall conform to the requirements of the specifications.

**Note:** The mineral admixture used for mix design testing should be stored in an airtight container and be no older than 3 months.

3.4 Crumb Rubber Asphalt (CRA) – The Crumb Rubber Asphalt shall be tested and conform to the specifications of ADOT Specifications Section 1009.

3.5 Crumb Rubber – The crumb rubber shall be tested for sieve analysis in accordance with ARIZ 714. It shall conform to ADOT Specifications Sections 414 & 1009.

## 4. DETERMINATION OF COMPOSITE GRADATION

4.1 Perform a coarse and a fine sieve analysis for the aggregate from each stockpile in accordance with ARIZ 201. The fine sieve sample size may be reduced if the minimum of 500 grams is not obtained from coarse sieving, or if there is insufficient material for performing other desired tests which utilizes the Minus No. 4 Material.

4.2 Compare the Percent Pass No. 8 from the Sieve Analysis to the actual Percent Pass No. 8 as follows:

4.2.1 The Minus No. 4 Material from each stockpile is separated into Retained No. 8 Material and Minus No. 8 Material, and the weights for each recorded.

4.2.2 Determine the actual Percent Pass No. 8 by dividing the weight of Minus No. 8 Material by the combined total weight of the Plus No. 8 and Minus No. 8 Material that was determined in Subsection 4.2.1.

4.2.3 Multiply this value by the Percent Pass No. 4 from the sieve analysis. Record the result to the nearest whole percent. This is the actual Percent Pass No. 8.

4.2.4 Compare the actual Percent Pass No. 8 to the Percent Pass No. 8 from the sieve analysis. If the difference between the two results is greater than 4.0%, a new fine sieve analysis must be performed. If the difference between the two results is still greater than 4.0% after performing a new fine sieve analysis, adjust the fine sieve analysis by multiplying the Percent Pass for each sieve smaller than the No. 8 sieve by a factor obtained by dividing the actual Percent Pass No. 8 by the Percent Pass No. 8 from the sieve analysis.

4.3 Determine the mineral aggregate composite in accordance with ARIZ 205. This is used to establish the mix design gradation which is then compared to the specifications. If the gradation falls outside of the specification band, the stockpile percentages will be adjusted until the composite is within the band. (An example is given in Figure 1 & 2).

**Note:** Adjustments of stockpile percentages greater than 5% for any stockpile should not be made without the agreement of the supplier in writing.

4.4 The aggregate-mineral admixture blend composite is determined by adjusting the mineral aggregate composite (Percent Passing) for mineral admixture by performing the calculation for each sieve:

$$\left(\begin{array}{c}\text{\% Pass} \\ \text{Each Sieve} \\ \text{[Adjusted for} \\ \text{Mineral Admixture]}\end{array}\right) = \frac{\left(\begin{array}{c}\text{\% Pass Each Sieve in} \\ \text{the Aggregate Composite}\end{array}\right) + \left(\begin{array}{c}\text{\% Mineral} \\ \text{Admixture}\end{array}\right)}{(100) + (\text{\% Mineral Admixture})} \times 100$$

4.5 The composited gradation of the aggregate and the composited gradation of the aggregate-mineral admixture blend shall be shown on the design report, along with the percentage of each material.

4.6 The design gradation is adjusted for Minus No. 200 Material adhering to the coarse aggregate by washing a composited sample of Plus No. 4 Material in accordance with ARIZ 248, alternate #5 (Referee Method). Figure 3 gives an illustration of the calculations and the adjustment to the Minus No. 200 Material from washing.

If adjustments to the gradation are necessary due to the increase in Minus No. 200 Material, a maximum of a one percent change may be made for the Percent Retained on No. 200. If the adjusted Percent Pass No. 200 results in a greater amount of change, wash a composited sample as specified in ARIZ 248 Section 5 (Alternate #4) to determine the actual design gradation.

**Note:** It is recommended that the composited dust correction sample be tested before additional mix design testing is performed to assure that the design gradation meets governing specifications.

## 5. PREPARING SAMPLES FOR MIX DESIGNS USING STOCKPILE MATERIAL

5.1 Representative aggregate samples for each test are prepared utilizing the information from the composite for individual size fractions for No. 8 sieve size and larger from each stockpile; and the Minus No. 8 Material from each stockpile.

**Note:** Aggregate retained on the No. 8 and larger sized sieves may be weighed up by hand for each size fraction. The individual Minus No. 8 Materials may be obtained by first splitting each Minus No. 8 Material into pans of adequate size to hold approximately 1500 grams of material, and then using the split portions for weighing up samples by stirring and scooping out the required amount with a small scoop.

5.2 Table 1 shows the aggregate sample sizes, the number of samples required for each test listed, and which samples include mineral admixture. The aggregate weight shown for Maximum Theoretical Specific Gravity will provide three Rice test specimens. An example weigh-up sheet is shown in Figure 4.

| Table 1 | | |
|---|---|---|
| **Sample Type** | **Sample Size** | **No. of Samples** |
| Coarse Aggregate Specific Gravity/ Absorption (ARIZ 210) | Required grams of Mineral Aggregate as determined by the Nominal Maximum Aggregate Size [Excludes mineral admixture] | 2 |
| Fine Aggregate Specific Gravity/ Absorption (ARIZ 211) | 1200 grams of Mineral Aggregate [Excludes mineral admixture] | 2 |
| Dust (ARIZ 248) | 1000 grams Refer to Figure 4. [Excludes mineral admixture] | 1 |
| Sand Equivalent (ARIZ 242) | 500 to 750 grams of Mineral Aggregate [Excludes mineral admixture] | 1 |
| Fractured Coarse Aggregate Particles (ARIZ 212) | Required grams of Mineral Aggregate as determined by test method [Excludes mineral admixture] | 1 |
| Flakiness Index (ARIZ 233) | #¼” Sieve 200g<br>#4 Sieve 100g<br>#8 Sieve 50g<br>[Excludes mineral admixture] | 1<br>1<br>1 |
| Percent Carbonates (ARIZ 238) | 300 grams of Mineral Aggregate [Excludes mineral admixture] | 1 |
| Abrasion (AASHTO T 96) | 5000 grams of Mineral Aggregate as per test method for grading type [Excludes mineral admixture] | 1 |
| Maximum Theoretical Specific Gravity (Rice Test) (ARIZ 806, as modified in Section 11) | 3030 grams of Mineral Aggregate [Includes mineral admixture] | 1 [Yields 3 test specimens] |
| Draindown | 960 grams Refer to Section 10. [Includes mineral admixture] | 3 |
| Bulk Unit Weight | 960 grams Refer to Section 11. [Includes mineral admixture] | 3 |

| | | |
|---|---|---|
| Minus No. 8<br>Make-Up<br>Material | An adequate amount<br>(normally 600 grams) of<br>Mineral Aggregate<br>[Excludes mineral admixture] | 1 |

## 6. AGGREGATE SPECIFIC GRAVITIES AND ABSORPTION

6.1 Determine the bulk oven dry (OD) specific gravity, bulk saturated surface dry (SSD) specific gravity, apparent specific gravity, and absorption of the fine and coarse mineral aggregates in accordance with Arizona Test Method 211 and Arizona Test Method 210.

**Note:** Two samples of both the fine aggregate and coarse aggregate are to be tested and the results must not exceed the maximum range as listed below in Table 2. Additional samples are to be run as necessary until results fall within these ranges.

| **Table 2** | |
|---|---|
| **Fine Specific Gravity** | **Acceptable Range of 2 Results** |
| Bulk Sp. Gr.(OD) | 0.032 |
| Bulk Sp. Gr.(SSD) | 0.027 |
| Apparent Sp. Gr. | 0.027 |
| Absorption, % | 0.31 |
| **Coarse Specific Gravity** | **Acceptable Range of 2 Results** |
| Bulk Sp. Gr.(OD) | 0.250 |
| Bulk Sp. Gr.(SSD) | 0.020 |
| Apparent Sp. Gr. | 0.020 |
| Absorption, % | 0.25 |

6.2 The individual averages for the fine and coarse specific gravities are then utilized in calculating the final combined specific gravities.

6.3 The combined bulk (OD) specific gravity, bulk saturated surface dry (SSD) specific gravity, apparent specific gravity, and combined absorption for the coarse and fine mineral aggregates are calculated by the following:

$$\begin{bmatrix} \text{Combined} \\ \text{Bulk (OD)} \\ \text{Specific Gravity} \end{bmatrix} = \frac{100}{\frac{P_c}{G_c} + \frac{P_f}{G_f}}$$

Where: $P_c$ and $P_f$ = Percent of Coarse Aggregate (Plus No. 8) from the composite and Percent of Fine Aggregate (Minus No. 8), respectively. (Use the nearest whole percent in calculations.).

$G_c$ and $G_f$ = Specific gravity of coarse and fine aggregate respectively.

$$\text{Example :} \begin{bmatrix} P_c = 86 \\ P_f = 14 \\ G_c\,(\text{OD}) = 2.741 \\ G_f\ (\text{OD}) = 2.704 \end{bmatrix}$$

$$\begin{bmatrix} \text{Combined} \\ \text{Bulk (OD)} \\ \text{Specific Gravity} \end{bmatrix} = \frac{100}{\frac{86}{2.741} + \frac{14}{2.704}} = 2.736$$

$$\text{Example :} \begin{bmatrix} \text{Combined Bulk (SSD) Specific Gravity} = 2.798 \\ \text{Combined Bulk (OD) Specific Gravity} = 2.736 \end{bmatrix}$$

$$(\text{Combined \% Absorption}) = \frac{(2.798) - (2.736)}{(2.736)} \text{ x } 100 = 2.27\%$$

6.4 The combined aggregate bulk specific gravity (OD) must be adjusted for admixture ($G_{sb}$ adj). The calculations for this are as follows:

$$G_{sb\,adj} = \frac{100 + P_{admix}}{\frac{100}{G_{sb}} + \frac{P_{admix}}{G_{admix}}}$$

Where: $P_{admix}$ = Percent of Mineral Admixture, by weight of the mineral aggregate (typically 1.0%)

$G_{sb}$ = Combined Bulk OD Specific Gravity

$G_{admix}$ = Specific Gravity of Mineral Admixture
Type I or II Cement = 3.14
Type IP Cement = 3.00
Hydrated Lime = 2.20

$$\text{Example}: \begin{bmatrix} P_{admix} = 1.0\% \\ G_{sb} = 2.736 \\ G_{admix} = 3.14 \end{bmatrix}$$

$$G_{sb\,adj} = \frac{100 + 1.0}{\frac{100}{2.736} + \frac{1.0}{3.14}} = 2.739$$

**7. ASPHALT MIXTURES TESTING TEMPERATURE REQUIREMENTS**

7.1 Maximum Theoretical Specific Gravity (ARIZ 806), Draindown Determination, and Bulk Density Determination of friction course must be performed to complete the development of a mix design. Mix and cure samples for these tests at the temperatures specified below in Table 3. The Engineer will specify the laboratory mixing and curing temperatures for all the binders not listed in Table 3.

**Table 3**

| Asphalt Binder Type | Mixing Temperature | Curing Temperature for Rice and Draindown Test | Curing and Compaction Temperature for Unit Weight |
|---|---|---|---|
| CRA | 325 ± 5 °F | 325 ± 10 °F | 230 ± 5 °F |
| ALL PG’s & TR+ | 300 ± 5 °F | 300 ± 10 °F | 230 ± 5 °F |

**8. DETERMINATION OF MAXIMUM THEORETICAL SPECIFIC GRAVITY (with mineral admixture)**

8.1 Determine the maximum theoretical specific gravity ($G_{mm}$) of the friction course mixture in accordance with ARIZ 806 and the temperature guidelines specified in Section 7. For design purposes the binder content will be 4.0% by weight of total mix.

**Note:** The final binder content selected for a friction course design is typically much higher than the 4.0% mandated above. However, using high asphalt percentages in conjunction with open-graded mixes often results in erroneous values when performing ARIZ 806. Occasionally, 4.0% binder does not provide an adequate asphalt film coating on the aggregate which results in a negative asphalt absorption calculation. If this happens, increase the percent of binder in increments of 0.5% until satisfactory test results are obtained.

8.2 Calculate the Effective Specific Gravity of the Aggregate/Admixture (Gse) using the following formula:

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

Where:

$G_{se}$ = Effective specific gravity of the combined aggregate and mineral admixture.

$P_b$ = Asphalt binder content at which the Rice test was performed (Rice $P_b$).

$G_{mm}$ = Measured maximum theoretical specific gravity of the mix at Rice $P_b$.

$G_b$ = Specific gravity of the asphalt binder.

$$\text{Example}: \begin{bmatrix} P_b = 4.0 \\ G_{mm} = 2.628 \\ G_b = 1.034 \end{bmatrix}$$

$$G_{se} = \frac{100 - 4.0}{\frac{100}{2.628} - \frac{4.0}{1.034}} = 2.808$$

8.3 Calculate the percent asphalt absorption ($P_{ba}$) by the following:

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

Where:

| | | | |
|---|---|---|---|
| | $P_{ba}$ | = | Absorbed asphalt, percent by total weight of mix. |
| | $G_{se}$ | = | Effective specific gravity of the combined aggregate and mineral admixture. |
| | $G_{sb}$ | = | Bulk oven dry specific gravity of the combined aggregate and mineral admixture. |
| | $G_b$ | = | Specific gravity of the asphalt binder. |

$$\text{Example}: \begin{bmatrix} Gse = 2.808 \\ Gsb = 2.739 \\ Gb = 1.034 \end{bmatrix}$$

$$P_{ba} = \left( \frac{2.808 - 2.739}{2.808 \text{ x } 2.739} \right) \text{x } 1.034 \text{ x } 100 = 0.93$$

Report the asphalt absorption to the nearest 0.01%.

## 9. DETERMINATION OF DESIGN ASPHALT CONTENT

9.1 Design binder content is based on the binder draindown procedure as described in Section 10. The target percent of binder draindown is 0.25% and the intent is to determine a percent of binder as close as possible to the target draindown percent without exceeding it.

**Note:** Often draindown tests for AR-ACFC will indicate a design binder content that is over 10%. It is current ADOT practice not to issue a friction course design over 9.9%, regardless of what draindown test results indicate.

9.2 An initial binder percent for draindown testing is calculated using one of the two following formulas:

**For ACFC and ACFC Special mixes:**

$$\text{ACFC Binder Content} = (0.20)(W) + \left(\frac{(61+P)}{5}\right)\left(\frac{1}{C}\right) + 0.1$$

| | | | |
|---|---|---|---|
| Where: | W | = | Percent Water Absorption |
| | P | = | Percent Pass #8 |
| | C | = | Combined Bulk OD Specific Gravity |

Example: W = 2.27
P = 14
C = 2.736

$$\text{ACFC Binder Content} = (0.20)(2.27) + \left(\frac{(61+14)}{5}\right)\left(\frac{1}{2.736}\right) + 0.1 = 6.0\%$$

**For AR-ACFC mixes:**

$$\text{AR ACFC Binder Content} = [(0.80)(W) + 8.6]\left(\frac{2.620}{C}\right)$$

| | | | |
|---|---|---|---|
| Where: | W | = | Percent Water Absorption |
| | C | = | Combined Bulk OD Specific Gravity |

Example: W = 2.27
C = 2.736

$$\text{AR ACFC Binder Content} = [(0.80)(2.27) + 8.6]\left(\frac{2.620}{2.736}\right) = 10.0\%$$

**Note:** The equations above are used to give an initial binder content value only. This binder content will need to be adjusted based on the actual draindown test results. A minimum of three draindown tests will be run for the mix design; one at the design asphalt content, one at approximately 0.2% below the design content, and one at approximately 0.2% above the design content. Refer to Subsection 9.1.

## 10. DRAINDOWN DETERMINATION

10.1 Prepare a composited aggregate-admixture sample of approximately 960 grams and dry the sample to a constant weight.

10.2 Heat the composited sample, binder, metal mixing bowl, spoons, and scrapers to the temperature specified in Section 7. Determine the weight of a 1,000 milliliter glass beaker. Record the weight to the nearest 0.1 gram.

10.3 Once the binder and aggregate have reached the proper mixing temperature remove the mixing bowl from the oven and apply a light coat of aerosol based vegetable oil to the inner surface, and wipe any excess with a towel. Place the mixing bowl on a balance and zero the balance. Carefully add the heated aggregate into the mixing bowl. Determine the weight of the aggregate and, if needed, add Minus No. 8 Make-Up Material (See Table 1) to the sample to bring the weight back to 960 grams.

10.4 Create a small crater in the center of the aggregate and add the heated binder to the sample until the total weight of mix is reached.

**Note:** The total weight of mix is calculated by the following formula:

$$\text{Total Weight of Mix} = \frac{\text{Wt. of Composited Aggregate (with Admixture)} \times 100}{100 - P_b}$$

Where: $P_b$ = Asphalt Binder Content

10.5 Place the mixing bowl on a hot plate and quickly and thoroughly hand mix the sample using a heated spoon. Transfer the sample into the glass beaker taking care to transfer as much of the mixture as possible. Use a scraper to remove mix material adhering to the bowl and spoon, and transfer it into the beaker.

10.6 Weigh and record the weight of the beaker and mixture to the nearest 0.1 gram. Place a glass plate or watch glass over the sample and return it to the oven at mix temperature for 1 hour ± 10 minutes.

10.7 Determine the weight of a sample pan and record the weight to the nearest 0.1 gram.

10.8 After the 1 hour curing, remove the glass beaker from the oven and remove the glass plate or watch glass. Flip the beaker over and quickly empty the asphalt mixture into the sample pan. This must be done without shaking or tapping the glass beaker, nor allowing the beaker to drain for an extended time.

10.9 Place the beaker and the pan containing the sample in front of a fan and cool to room temperature. Weigh the beaker with the asphalt residue. Then determine the final weight of the pan and asphalt mixture. Record these values to the nearest 0.1 grams.

10.10 Determine the percent draindown by the following equation:

$$\text{Percent Draindown} = \frac{(C - A) \times 100}{(C - A) + (D - B)}$$

| Where: | | | |
|---|---|---|---|
| | A | = | Weight of Glass Beaker |
| | B | = | Weight of Sample Pan |
| | C | = | Final Weight of Beaker and Mixture Residue |
| | D | = | Final Weight of Pan and Mixture |

Report the draindown value to the nearest 0.01%. An example of the calculations is shown in Figure 5.

## 11. BULK DENSITY DETERMINATION

11.1 Prepare a minimum of three composited aggregate-admixture samples of approximately 960 grams each and dry the samples to a constant weight.

11.2 Heat the composited samples, asphalt binder, metal mixing bowl, and spoons to the temperature specified in Section 7.

11.3 Once the binder and aggregate have reached the proper mixing temperature, remove the mixing bowl from the oven and apply a light coat of aerosol based vegetable oil to the inner surface, and wipe any excess with a towel. Place the mixing bowl on a balance and zero the balance. Carefully add the heated aggregate into the mixing bowl. Determine the weight of the aggregate and add Minus No. 8 Make-Up Material to the sample to bring the weight back to 960 grams.

11.4 Create a small crater in the center of the aggregate sample and add enough asphalt binder to the sample to bring the asphalt content up to the design binder content that was determined in Section 10.

11.5 Place the mixing bowl on a hot plate and quickly and thoroughly mix the sample using a heated spoon.

11.6 Place the mixed sample into a 230 ± 5 °F oven until a constant temperature is attained (approximately 1 hour). Also place a calibrated mold, bottom, and a top plunger in the oven.

11.7 Repeat steps 11.3 through 11.6 for the remaining two samples.

11.8 Remove the bottom plunger and mold cylinder from oven, place mold assembly on baseplate (bottom plunger in place with mold cylinder supported on the two steel bars). Apply a light coat of aerosol based vegetable oil to the mold and bottom plunger, and wipe any excess with a towel. Place all of the mixture into molding cylinder and spade mixture vigorously with heated flat metal spatula (approximately 1" wide and 8" long, stiff enough to penetrate the entire layer of material), 15 times around the edge of the mold and 10 times at random into the mixture, penetrating the mixture to the bottom of the mold. Smooth the surface of the mix to a slightly rounded shape.

11.9 Apply a light coat of aerosol based vegetable oil to the upper plunger, and wipe any excess with a towel. Place the upper plunger (which has been preheated) on the sample and compress the mixture under an initial load of 150 psi, to set it against the sides of the mold. Remove the support bars to permit full double-plunger action. Apply the load to the mixture at a rate of 0.2 inches per minute until a load of 2,000 psi is reached. Hold the load at 2,000 ± 100 psi for 2 minutes.

11.10 After compaction, the top plunger is removed, leaving the bottom plunger in place to support the specimen until the sample has cooled sufficiently to be handled safely with bare hands.

**Note:** Cooling may be achieved by the use of a 77 °F air bath or, if more rapid cooling is desired, fans may be used.

11.11 Repeat the procedure as described in Subsections 11.8 through 11.10 above, for the other two samples.

11.12 After the specimens have cooled, remove the bottom plunger and determine the weight of each mold with specimen to the nearest 0.1 gram. The weight of each specimen is calculated by subtracting the weight of the corresponding mold cylinder.

11.13 While the specimens are still in the molds, the heights of each of the three specimens are determined to the nearest 0.001 inch.

11.14 The inside diameters of the molds used for each of the three specimens is recorded to the nearest 0.001 inch.

11.15 The bulk density is determined for each specimen by the following:

$$\text{Bulk Density} = \frac{\text{Weight of Specimen (grams)}}{(d/2)^2\,(h)\,(50.86)} \text{ X } 62.3$$

Where: d = Inside Diameter of Mold (inches)
h = Height of Specimen (inches)

Report the densities to the nearest 0.1 lbs./cu.ft.

$$\text{Example}: \begin{bmatrix} \text{Weight of Specimen} = 1002.7 \text{ grams} \\ \text{Inside Diameter of Mold} = 4.002 \text{ inches} \\ \text{Height of Specimen} = 2.489 \text{ inches} \end{bmatrix}$$

$$\text{Bulk Density} = \frac{1002.7}{(4/2)^2 x (2.489) x (50.86)} \text{ X } 62.3 = 123.2 \text{ lbs./cu. ft.}$$

**Note:** The range of densities between all 3 samples shall not differ by more than 2.0 lbs./cu.ft. If this density requirement is not met, discard the entire set of specimens and prepare a new set of specimens.

11.16 The average bulk density of the three specimens is determined and recorded to the nearest 0.1 lbs./cu.ft.

## 12. EXAMPLE AND REPORT

12.1 Report the test results and data obtained on the appropriate form. Liberal use of the remarks area to clarify and/or emphasize any element of the design is strongly recommended. Information required in the mix design report is shown in the items listed below.

12.2 Name of the testing organization and the signature of the mix design engineer responsible for the mix design.

12.3 Aggregate:

- Source and identification
- Individual stockpile gradations
- Aggregate blend proportions and composite gradation, with and without mineral admixture
- Fine and coarse aggregate bulk (OD) specific gravity, bulk (SSD) specific gravity, and absorption
- Combined aggregate bulk (OD) specific gravity
- Combined aggregate absorption
- LA Abrasion at both 100 and 500 revolutions
- Sand Equivalent
- Fractured Coarse Aggregate Particles (percent with two fractured faces)
- Carbonates

12.4 Mineral Admixture:

- Type and source
- Percentage used
- Specific gravity

12.5 Combined Mineral Aggregate and Mineral Admixture:

- Combined bulk (OD) specific gravity (with admix)

12.6 CRA Binder Design for AR-ACFC only (from supplier), including:

- Source and grade of base asphalt cement
- Source and type of crumb rubber
- Crumb rubber gradation
- Proportions of asphalt cement and crumb rubber
- Percentage of crumb rubber, by weight of asphalt cement
- CRA binder properties, in compliance with Section 1009 of the ADOT Specifications

- CRA binder specific gravity at 77° F

12.7 Asphalt Cement for ACFC, ACFC Special, and AR-ACFC mixes:

- Source and grade of asphalt cement
- Asphalt cement properties, in compliance with Section 1005 of the ADOT Specifications
- Asphalt cement specific gravity at 77 °F

12.8 Maximum Theoretical Specific Gravity of Asphaltic Mix:

- The binder content at which the Rice test was performed
- Calculated maximum theoretical specific gravity ($G_{mm}$) and density (pcf) at the binder and mineral admixture content at which the Rice was performed
- Effective specific gravity of the combined aggregate and mineral admixture ($G_{se}$)

12.9 Asphaltic Mix Properties:

- Design binder content
- Bulk density (pcf)
- Asphalt absorption

12.10 Mix Design Summary:

- An example of a mix design summary report is shown in Figure 6

**Arizona Department of Transportation**
ARIZONA TEST METHOD 814

Initial Composite Gradation

Project Number: XM122 01X Design: 15-09015 Type: 407 SPECIAL

% Admix: 1.0 % Dust: N/A

| Material | 3/8" Coarse | 3/8" Fine | W.C.F. | Composite | | Specifications for 407 Special | |
|---|---|---|---|---|---|---|---|
| Lab # | 2015-00119 | 2015-00118 | 2015-00120 | | | | |
| % Used | 42 | 42 | 16 | Without Admix | With Admix | Without Admix | With Admix |
| Sieve # | | | | | | | |
| | Gradation Percent Passing | | | | | | |
| 1 1/2" | 100 | 100 | 100 | 100.0 | 100.0 | | |
| 1" | 100 | 100 | 100 | 100.0 | 100.0 | | |
| 3/4" | 100 | 100 | 100 | 100.0 | 100.0 | | |
| 1/2" | 100 | 100 | 100 | 100.0 | 100.0 | | |
| 3/8" | 100 | 100 | 100 | 100.0 | 100.0 | 100 | 100 |
| 1/4" | 50 | 62 | 100 | 63.0 | 63.4 | | |
| #4 | 15 | 27 | 100 | *33.6 | *34.3 | 35 - 55 | 36 - 55 |
| #8 | 3 | 3 | 63 | 12.6 | 13.5 | 9 - 14 | 10 - 15 |
| #10 | 2 | 2 | 57 | 10.8 | 11.7 | | |
| #16 | 2 | 2 | 40 | 8.1 | 9.0 | | |
| #30 | 1 | 1 | 23 | 4.5 | 5.5 | | |
| #40 | 1 | 1 | 18 | 3.7 | 4.7 | | |
| #50 | 1 | 1 | 14 | 3.1 | 4.0 | | |
| #100 | 1 | 1 | 7 | 2.0 | 2.9 | | |
| #200 | 0.6 | 0.7 | 4.0 | 1.2 | 2.2 | 0.0 - 2.0 | 1.0 - 3.0 |

* Stockpile composite out of specification

**FIGURE 1**

**Arizona Department of Transportation**
ARIZONA TEST METHOD 814

Adjusted Composite Gradation

Project Number: XM122 01X Design: 15-09015 Type: 407 Special

% Admix: 1.0 % Dust: N/A

| Material | 3/8" Coarse | 3/8" Fine | W.C.F. | Composite | | Specifications for 407 Special | |
|---|---|---|---|---|---|---|---|
| Lab # | 2015-00119 | 2015-00118 | 2015-00120 | | | | |
| % Used | 40 | 42 | 18 | Without Admix | With Admix | Without Admix | With Admix |
| Sieve Size | Gradation Percent Passing | | | | | | |
| 1 1/2" | 100 | 100 | 100 | 100.0 | 100.0 | | |
| 1" | 100 | 100 | 100 | 100.0 | 100.0 | | |
| 3/4" | 100 | 100 | 100 | 100.0 | 100.0 | | |
| 1/2" | 100 | 100 | 100 | 100.0 | 100.0 | | |
| 3/8" | 100 | 100 | 100 | 100.0 | 100.0 | 100 | 100 |
| 1/4" | 50 | 62 | 100 | 64.0 | 64.4 | | |
| #4 | 15 | 27 | 100 | 35.3 | 36.0 | 35 - 55 | 36 - 55 |
| #8 | 3 | 3 | 63 | 13.8 | 14.7 | 9 - 14 | 10 - 15 |
| #10 | 2 | 2 | 57 | 11.9 | 12.8 | | |
| #16 | 2 | 2 | 40 | 8.8 | 9.7 | | |
| #30 | 1 | 1 | 23 | 5.0 | 5.9 | | |
| #40 | 1 | 1 | 18 | 4.1 | 5.0 | | |
| #50 | 1 | 1 | 14 | 3.3 | 4.3 | | |
| #100 | 1 | 1 | 7 | 2.1 | 3.1 | | |
| #200 | 0.6 | 0.7 | 4.0 | 1.3 | 2.2 | 0.0 - 2.0 | 1.0 - 3.0 |

**FIGURE 2**

Arizona Department of Transportation
**ARIZONA TEST METHOD 814**

**Determination Of Percent Pass No. 200 On Coarse Aggregate
And Total Percent Pass No. 200 In Composite
Using Arizona 248 Alternate Procedures for Sieving of
Coarse and Fine Graded Soils and Aggregates Alternate #5**

Lab #: 15-09015 Project #: XM122 01X Date: 08/19/2015

| | |
|---|---|
| O D Weight of Unwashed Plus No. 4 = | 993.9 |
| O D Weight of Washed Plus No. 4 = | 990.9 |

Calculate the "% Pass No. 200 on the Coarse Aggregate" by the following, and record result to the nearest 0.01%

$$\frac{(\text{O D Weight of Unwashed Plus No. 4}) - (\text{O D Weight of Washed Plus No. 4})}{\text{O D Weight Unwashed Plus No. 4}} \times 100 =$$

$$\frac{(993.9) - (990.9)}{993.9} \times 100 =$$

0.30 % Pass No. 200 on Coarse Aggregate

Calculate Total Percent Pass No. 200 in Sample by the following, and record to the nearest 0.1 %:

$$\begin{pmatrix}\text{Total \% Pass}\\ \text{No. 200 in Sample}\end{pmatrix} = \begin{pmatrix}\text{\% Pass No. 200}\\ \text{from fine Sieving}\end{pmatrix} + \frac{\left(100 - \begin{pmatrix}\text{\% Pass}\\ \text{No. 4}\end{pmatrix}\right) \times \begin{pmatrix}\text{\% Pass No. 200}\\ \text{Coarse Agg}\end{pmatrix}}{100}$$

$$\text{Total \% Pass No. 200 in Sample} = (1.3) + \frac{(100 - (35.34)) \times (0.30)}{100}$$

= 1.5 % Total Pass #200

**FIGURE 3**

Arizona Department of Transportation

**ARIZONA TEST METHOD 814**

Weigh UP Sheet

| Material | 3/8" Coarse | 3/8" Fine | WCF |
|---|---|---|---|
| Percent | 40 | 42 | 18 |

| Material | Sieve Size | Accum. % Ret. | Rice (3030 g) | Bulk Unit Wt. (960 g) | Dust (1000 g) | Coarse Specific Gravity [Plus #8] (2000 g) | Fractured Faces [Plus # 8] (300 g) | Abrasion (5000 g) | Percent Carbonates [Plus # 4] (300 g) | Drain Down (960 g) | Flakiness Index (200 gr., 100 gr., & 50 g) | Sand Equivalent [Minus #8] (600 g) | Fine Specific Gravity [Minus #8] (1200 g) | Make-up Material [Minus #8] (600 g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of Sets | | | 1 | 3 | 1 | 2 | 1 | 1 | 1 | 3 | 1 | 1 | 2 | 1 |
| 3/8" Coarse | 1/4" | 20 | 600 | 190 | 309 | 464 | 69 | 1390 | 92 | 190 | | | | |
| 3/8" Coarse | # 4 | 34 | 1020 | 323 | 772 | 788 | 118 | 2610 | 157 | 323 | | | | |
| 3/8" Fine | 1/4" | 50 | 1498 | 474 | 1000 | 1159 | 173 | 3720 | 231 | 474 | | | | |
| 3/8" Fine | # 4 | 64.7 | 1939 | 614 | | 4500 | 225 | 5000 | 300 | 614 | | | | |
| 3/8" Coarse | # 8 | 69.5 | 2083 | 659 | | 1611 | 241 | | | 659 | | | | |
| 3/8" Fine | # 8 | 79.5 | 2386 | 755 | | 1845 | 276 | | | 755 | | | | |
| WCF | # 8 | 86.2 | 2586 | 818 | | 2000 | 300 | | | 818 | | | | |
| 3/8" Coarse | - # 8 | 87.4 | 2622 | 830 | | | | | | 830 | | 52 | 104 | 52 |
| 3/8" Fine | - # 8 | 88.7 | 2659 | 842 | | | | | | 842 | | 106 | 213 | 106 |
| WCF | - # 8 | 100 | 3000 | 950 | | | | | | 950 | | 600 | 1200 | 600 |
| Admix | | 101 | 3030 | 960 | | | | | | 960 | | | | |

| | | |
|---|---|---|
| 3/8" Coarse | 1/4" | 111 |
| 3/8" Fine | 1/4" | 200 |
| 3/8" Coarse | # 4 | 48 |
| 3/8" Coarse | # 4 | 100 |
| 3/8" Fine | # 8 | 11 |
| 3/8" Fine | # 8 | 34 |
| WCF | # 8 | 50 |

**FIGURE 4**

Arizona Department of Transportation
**Arizona Test Method 814**

## A.C.F.C. DESIGN WORKSHEET

Lab.No.: 15-09015 Tracs.No.: XM122 01X Date: 08/21/2015

### BULK DENSITY EQUATION:

$$BD = \frac{(\text{Weight of Specimen})}{((d/2)^2\ (\text{Height of Specimen})\ (50.86))} \times 62.3$$

| % Binder | Mold Spec.# | (d/2)² | Height Of Spec. | Wt.of Spec / Mold | Wt.of Mold | Wt. of Spec. | Sp. Gr. | Bulk Dens. | Avg.Sp. Gr. | Avg. Bulk Dens. |
|---|---|---|---|---|---|---|---|---|---|---|
| 6.4 | 1 | 4 | 2.339 | 3563.8 | 2543.3 | 1020.5 | 2.145 | 133.6 | 2.136 | 133.1 |
| | 8 | 4 | 2.353 | 3615.1 | 2595.6 | 1019.5 | 2.13 | 132.7 | | |
| | 4 | 4 | 2.352 | 3607.5 | 2586.8 | 1020.7 | 2.133 | 132.9 | | |

### BINDER DRAIN DOWN TEST

% Binder: 6.4

$$\text{Percent Draindown} = \frac{(C - A) \times 100}{(C - A) + (D - B)}$$

A= Wt. of Beaker: 402.0

C = Wt. of Beaker (After) : 404.5

B = Wt. of Pan : 213.6

D = Wt. of Pan & Binder: 1213.3

$$\text{Percent Drain Down} = \frac{(404.5 - 402.0) \times 100}{(404.5 - 402.0) + (1213.3 - 213.6)} = 0.25\ \%$$

**FIGURE 5**

**ARIZONA DEPARTMENT OF TRANSPORTATION**
**CONSTRUCTION MATERIALS GROUP**

407 Special ACFC Mix Design    Lab # 2015-09015    Date: 8/19/2015

## This design meets ADOT specifications

Tracs #: XM12201X    Project #: 011-D(211)T    Project Name: I 11– VULTURE FLAT TI
Resident Engineer: Doe, John    Contractor: Easy Contracting, Inc..

**General Design Information**

lab # 2015-16030    PG Grade PG70-22 TR+    PG Source Acme Asphalt    PG Specific Gravity 1.034

Admixture Type TYPE II DRY    Design % 1.0    Admix Source Sugarville Products    Admix Specific Gravity 3.140

Total number of stockpiles: 3

Aggregate:

| | lab # | Description | Site # | Design % |
|---|---|---|---|---|
| 1. | 2015-00119 | 3/8`` Coarse Agg | CM 9888 | 40 |
| 2. | 2015-00118 | 3/8`` Fine Agg | CM 9888 | 42 |
| 3. | 2015-00120 | W.C.F. | CM 9888 | 18 |
| 4. | | | | |
| 5. | | | | |
| 6. | | | | |
| 7. | | | | |
| | | | Total | 100 % |

**Composite Gradation**

| Sieve # | Specification band % passing min | Specification band % passing max | Gradation w/o admix % passing | Gradation w/ admix % passing | Field Target Band % passing min | Field Target Band % passing max |
|---|---|---|---|---|---|---|
| 1 1/2" | | | 100 | 100 | | |
| 1 " | | | 100 | 100 | | |
| 3/4" | | | 100 | 100 | | |
| 1/2" | | | 100 | 100 | | |
| 3/8" | 100 | | 100 | 100 | | |
| 1/4" | | | 64 | 64 | | |
| #4 | 35 | 55 | 35 | 36 | | |
| #8 | 9 | 14 | 14 | 15 | | |
| #10 | | | 12 | 13 | | |
| #16 | | | 9 | 10 | | |
| #30 | | | 5 | 6 | | |
| #40 | | | 4 | 5 | | |
| #50 | | | 3 | 4 | | |
| #100 | | | 2 | 3 | | |
| #200 | 0.0 | 2.0 | 1.5 | 2.5 | | |

**Composite Aggregate Properties**

| Property | Test Value | min | max |
|---|---|---|---|
| L.A. Abrasion % at 100 revolutions (AASHTO T96) | 4 | | 9 |
| L.A. Abrasion % at 500 revolutions (AASHTO T96) | 17 | | 40 |
| Sand Equivalent (AZ 242) | 74 | 55 | |
| Two Fractured Faces, % (AZ 212) | 99 | 85 | |
| Flakiness Index, % (AZ 233) | 21 | | 25 |
| Carbonates, % (AZ 238) | 2.0 | | 20 |
| Combined O.D. Specific Gravity (AZ 210) | 2.736 | 2.35 | 2.85 |
| Corrected Combined O.D. Specific gravity (with admix) | 2.739 | | |
| Combined Water Absorption, % (AZ 814) | 2.27 | | 2.50 |

**Calculated Mix Properties Results**

| Description | Design Values | Specification Limits |
|---|---|---|
| Design Binder Content | 6.4 | |
| Bulk Density pcf | 133.1 | |
| Asphalt Absorption % | 0.93 | < 1.0 |

**FIGURE 6**

| Stockpile Gradations | | | |
|---|---|---|---|
| | 2015-00119 | 2015-00118 | 2015-00120 |
| sieve # | 3/8`` Coarse Agg | 3/8`` Fine Agg | W.C.F. |
| 1 1/2" | 100 | 100 | 100 |
| 1 " | 100 | 100 | 100 |
| 3/4" | 100 | 100 | 100 |
| 1/2" | 100 | 100 | 100 |
| 3/8" | 100 | 100 | 100 |
| 1/4" | 50 | 62 | 100 |
| #4 | 15 | 27 | 100 |
| #8 | 3 | 3 | 63 |
| #10 | 2 | 2 | 57 |
| #16 | 2 | 2 | 40 |
| #30 | 1 | 1 | 23 |
| #40 | 1 | 1 | 18 |
| #50 | 1 | 1 | 14 |
| #100 | 1 | 1 | 7 |
| #200 | 0.6 | 0.7 | 4.0 |

**Laboratory Aggregate Specific Gravity Test Results**

| Type | O.D. Sp. Gr. | SSD SP. Gr. | Water Absorption % | Tested On |
|---|---|---|---|---|
| Fine (AZ 211) | 2.704 | 2.773 | 2.57 | -#8 |
| Coarse (AZ 210) | 2.741 | 2.802 | 2.23 | +#8 |

**Laboratory Rice Data (AZ 806)**

| % Asphalt | Maximum Specific Gravity | Maximum Density - pcf | Effective Specific Gravity |
|---|---|---|---|
| 4.00 | 2.628 | 163.7 | 2.808 |

This design has been prepared and submitted under the direction of:

Lab Supervisior: Bossman, Joe    Bituminous Engineer Engineer, Ima

Remarks:

Designed approved by: ____________________

**FIGURE 6 (continued)**