Test Procedure for

MIXTURE DESIGN PROCEDURE FOR CRUMB RUBBER MODIFIED ASPHALTIC CONCRETE

TxDOT Designation: Tex-232-F

Effective Date: August 1999

1. SCOPE

1.1 Use this procedure to determine the proper proportions of approved aggregates and rubber-asphalt blend which, when combined, will produce a mixture that will satisfy the specification requirements. Typical examples for design are provided.

1.2 The values given in parentheses (if provided) are not standard and may not be exact mathematical conversions. Use each system of units separately. Combining values from the two systems may result in nonconformance with the standard.

2. DEFINITIONS

2.1 *Binder*—a blend of asphalt and ground rubber.

3. APPARATUS

3.1 *Apparatus listed in the following test methods:*

- Tex-200-F
- Tex-201-F
- Tex-202-F
- Tex-205-F
- Tex-206-F
- Tex-207-F
- Tex-227-F.

PART I—DETERMINING OPTIMUM GRADATION

4. PROCEDURE

4.1 Obtain representative samples of each processed aggregate proposed for use in accordance with Tex-221-F. Approximately 45 kg (100 lb.) of each aggregate stockpile will be required.

4.2 Dry the aggregate in an oven at a temperature between 38 and 150°C (100 and 302°F).

4.3 Obtain the average gradation of each proposed aggregate stockpile in accordance with Tex-200-F, Part II. Use samples taken from several locations in the stockpile and average the results. When this is not possible, quarter aggregate samples received in the laboratory to use for the sieve analysis.

4.4 Determine the 24-hour water absorption and specific gravity of each size of each aggregate in accordance with Tex-201-F and Tex-202-F.

Note 1—Normally, specific gravities are not determined for size fractions consisting of less than 15% of the individual aggregate. Assign smaller size fractions of the water absorption and specific gravity of the next adjacent size fraction for which values were determined.

4.5 Calculate the initial desired combined gradation from the gradations of the stockpiles proposed for use.

4.5.1 As a guideline, keep a ratio of 1.5–2.0 between the two coarsest sieves on which aggregate is retained. Use this initial gradation only to determine aggregate grading factors.

4.5.2 In Table 1 the initial gradation has a coarse to fine aggregate ratio of 80/20 and a 1.67 ratio between the two coarsest sieves.

4.6 Prepare 5000 g batches with 4.0% asphalt for each of the coarse-to-fine aggregate ratios. (See Section 5.) Follow Tex-205-F.

4.7 Mold three samples of mix from each of the batches in accordance with Tex-206-F.

4.8 Determine the bulk specific gravity of each of the compacted specimens in accordance with Tex-207-F.

4.9 Determine the theoretical maximum specific gravity of each of the batches in accordance with Tex-227-F.

4.10 Calculate the density of each of the molded specimens in accordance with Tex-207-F.

4.11 Plot the average volumetric proportion of total retained on the 2.00 mm (No. 10) sieve for each set of molded specimens versus their average density. (See Figure 1.)

4.12 Pick the point that gives the maximum density on the curve in Figure 1.

4.12.1 Draw a line from the peak down to where it intersects the x-axis and read the total volume of + 2.00 mm (No. 10). (See example in Figure 1.)

4.12.2 The optimum density occurs at a density of 97.3% and a volume of 66.0% retained on the 2.00 mm (No. 10) sieve.

4.13 Add 2.5% to the total volume retained on the 2.00 mm (No. 10) sieve. This value will be the new target used in Part II. (See example in Figure 1.) The new target gradation will be 68.5% by volume retained on the 2.00 mm (No. 10) sieve.

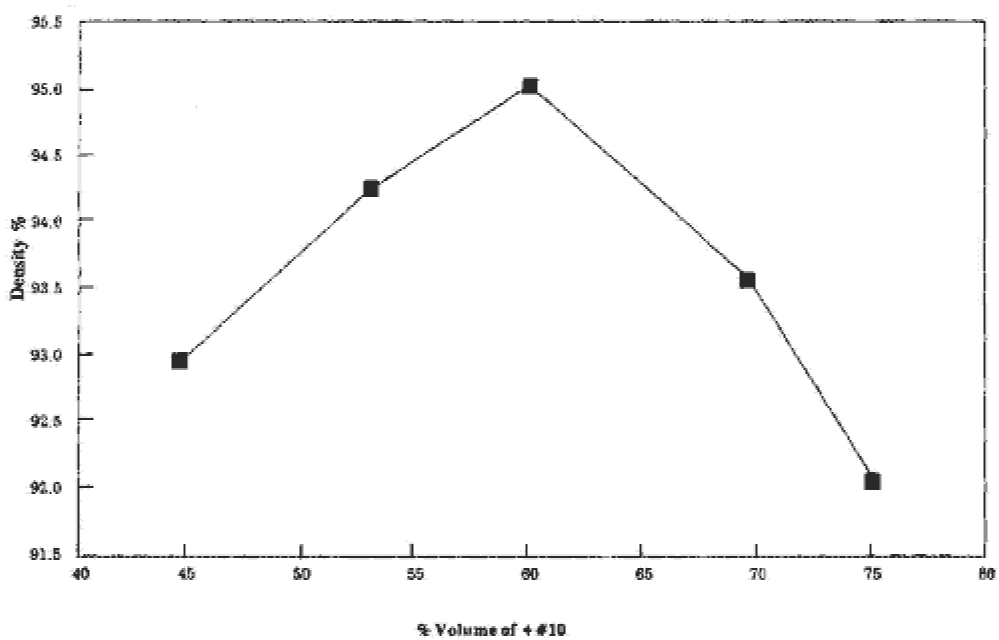

Figure 1—Density vs. Volume + No. 10

5. CALCULATIONS

5.1 Determine grading factors for coarse aggregate:

$$Grading\ \ factor = \frac{individual\ \%\ retained\ on\ each\ sieve}{total\ \%\ retained\ on\ 2.00\ mm\ (No.10)\ sieve}$$

5.1.1 *Example from Table 1:*

5.1.1.1 The amount passing the 9.5 mm (3/8 in.) and retained on 4.75 mm (No. 4) sieve = 50%. The total retained on the 2.00 mm (No. 10) sieve = 80%.

5.1.1.2 The grading factor = 50/80 = 0.625 for the 9.5 mm - 4.75 mm (3/8 in.- 4.75 mm (No. 4)) fraction.

5.2 Determine grading factors for fine aggregate:

$$Grading\ \ factor = \frac{individual\ \%\ retained\ on\ each\ sieve}{total\ \%\ \ passing\ 2.00\ mm\ (No.10) - 6.0\%}$$

5.2.1 *Example from Table 1:*

5.2.2 The amount passing the 2.00 mm (No. 10) sieve and retained on the 425 µm (No. 40) sieve = 10% and the total % passing the 2.00 mm (No. 10) sieve = 20%.

5.2.3 The grading factor = 10/(20-6) = 0.714 for the 2.00 mm- 425 µm (No.10-no. 40) size fraction.

5.3 Calculate combined gradations for coarse-to-fine aggregate ratios of 60/40, 65/35, 70/30, 75/25, 80/20, and 85/15. Use the grading factors determined in Sections 4.2 and 4.3 to keep the same aggregate proportions.

5.3.1 *Example from Table 1:*

5.3.1.1 For a coarse-to-fine aggregate ratio of 60/40, the % passing the 9.5 mm (3/8 in.) sieve and retained on the 4.75 mm (No. 4) sieve will be (0.625)(60%) = 37.5%. The % passing the 2.00 mm (No. 10) and retained on the 425 µm (No. 40) will be (.714)(34%) = 24.2%.

5.4 Calculate volume of total retained on the 2.00 mm (No. 10) sieve for each set of molded specimens:

$$\%V_{2.00\,mm(+No.10)} = (V_{2.00\,mm(+No.10)} / V_s)\,x\,100$$

Where:

$V_{2.00\ mm\ (+10)} = W_{2.00\ mm\ (+No.\ 10)} / G_{2.00\ mm\ (+No.\ 10)}$ = Volume of aggregate retained on 2.00 mm (No. 10) sieve

V_s = Volume of molded specimen = W_s/G_s

W_s = Weight of dry molded specimen, Tex-207-F

W_{ar} = Weight of binder in molded specimen

$W_{-2.00\ mm\ (-10)}$ = Weight of aggregate passing 2.00 mm (No. 10) sieve

$W_{2.00\ (+10)}$ = Weight of aggregate retained on 2.00 mm (No. 10) sieve

V_{air} = Volume of air

V_{ar} = Volume of binder = W_{ar}/G_{ar}

$VMA = V_{air} + V_{ar}$

$V_{-2.00\ mm\ (-10)} = W_{-2.00\ mm\ (-No.\ 10)}/G_{-2.00\ mm\ (-No.\ 10)}$ = Volume of aggregate passing 2.00 mm (No. 10) sieve

G_s = Bulk specific gravity of molded specimen, Tex-207-F

$G_{2.00\ mm\ (+10)}$ = Bulk specific gravity of aggregate retained on 2.00 mm (No. 10) sieve, Tex-201-F

$G_{-2.00\ mm\ (-10)}$ = Specific gravity of aggregate passing 2.00 mm (No. 10) sieve, Tex-201-F and Tex-202-F

G_{ar} = Specific gravity of binder at 20°C (68°F).

5.5 Figure 2 shows a graphical representation of components of a molded specimen.

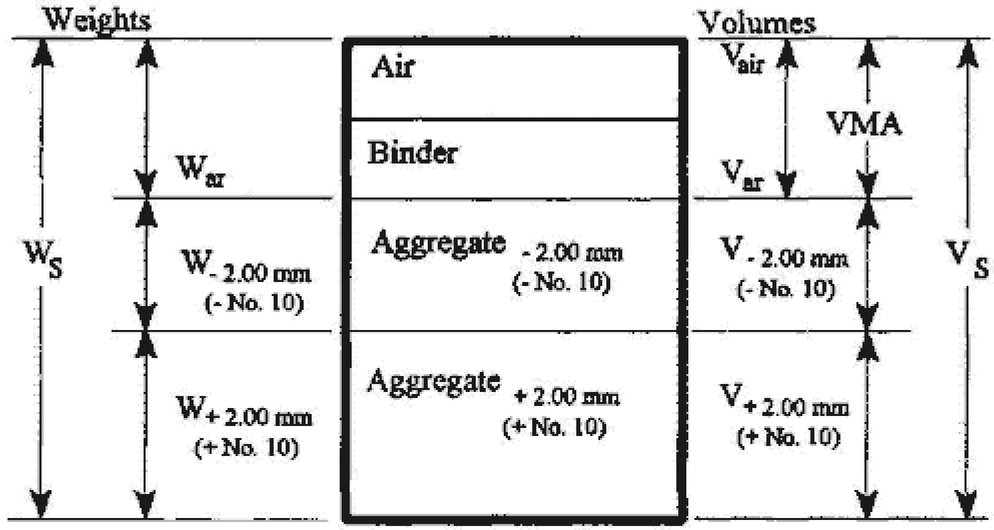

Figure 2—Volumetric Analysis of Molded Specimens.

Note 2—The sum of the volumetric proportions ($V_{2.00\ mm\ (+No.\ 10)}$ + $V_{-2.00\ mm\ (-No.\ 10)}$ + V_{ar} + V_{air}) may not total 100%, caused by errors in determining aggregate specific gravity. Check errors greater than ± 3%.

Table 1—Trial Gradations

Sieve Size	Initial Gradation	Grading Factor	% Retained on 2.00 mm (No. 10)/% Passing 2.00 mm (No. 10)					
			60/40	65/35	70/30	75/25	80/20	85/15
12.5–9.5 mm (1/2–3/8 in.)	0							
9.5–4.75 mm (3/8 in.–4.75 mm [No.4])	50.0	50/80 = 0.625	37.5	40.6	43.8	46.9	50.0	53.1
4.75–2.00 mm (No. 4–10)	30.0	30/80 = 0.375	22.5	24.4	26.3	28.1	30.0	31.9
2.00 mm–425µm (No. 10–40)	10.0	10/(20 - 6) =0.714	24.2	20.8	17.1	13.6	10.0	6.4
425–180 µm (No. 40–80)	2.0	2/(20 - 6) = 0.143	4.9	4.1	3.4	2.7	2.0	1.3
180 µm (No. 80)–No. 200	2.0	2/(20 - 6) = 0.143	4.9	4.1	3.4	2.7	2.0	1.3
Pass No. 200	6.0	N/A	6.0	6.0	6.0	6.0	6.0	6.0
TOTAL	100.0		100.0	100.0	100.0	100.0	100.0	100.0

PART II—DETERMINING OPTIMUM ASPHALT CONTENT

6. PROCEDURE

6.1 Weigh enough aggregate, asphalt, and crumb rubber to make a 5000 g batch of mix using the stockpile percentages in Section 7.5. Use the binder content determined in Table 2.

6.2 Heat the aggregate to a minimum temperature of 190°C (375°F).

6.3 Heat the asphalt and crumb rubber to 190°C (375°F).

6.4 Blend thoroughly and place in the 190°C (375°F) oven for approximately 30 minutes.

6.5 Stir thoroughly and leave the blend for another 30 minutes at the same temperature.

6.6 Remove from the oven at the end of 1 hour and measure the viscosity using a Haake viscometer.

6.6.1 If the viscosity meets the required specification, proceed to Section 6.7.

6.6.2 If the viscosity is below the minimum requirement, stir the binder thoroughly and return it to the 190°C (375°F) oven for 30-minute increments until it reaches a satisfactory viscosity.

6.7 Thoroughly stir the heated binder and add the appropriate amount to the heated aggregate.

6.8 Mix with a mechanical mixer in accordance with Tex-205-F.

6.9 Weigh three separate 1000 g samples of the mix for molding. Save the remaining mix for determining the theoretical maximum specific gravity.

6.10 Cure all four samples in an oven preheated to 121°C (250 ± 5°F) for two hours.

6.11 Mold the three 1000 g specimens in accordance with Tex-206-F. Heights must be 50.8 ± 2.5 mm (2 ± 0.1 in.)

6.12 Leave the samples in the molds until they are cool to the touch.

6.13 Determine the maximum specific gravity in accordance with Tex-227-F.

6.14 Determine the bulk specific gravity and relative density of molded specimens in accordance with Tex-207-F.

6.15 Calculate the density of the molded specimens using the theoretical maximum specific gravity determined in accordance with Tex-227-F.

6.16 If the molded density is equal to 97 ± 0.2%, determine the creep properties of the mixture in accordance with Tex-231-F.

6.17 If the density is greater than 97.2%, perform the procedure in Section 8. If the molded density is less than 96.8%, perform the procedure in Section 10.

7. CALCULATIONS

7.1 Determine the first estimated volume of air, asphalt, and - 2.00 mm (- No. 10) aggregate:

$$V_{+2.00\ mm\,(+No.10)} + V_{-2.00\ mm\,(-No.10)} + V_{ar} + V_{air} = 100\%$$

7.1.1 From Part I:

$$V + 2.00\ \ mm\ \left(+\ No.10\right) = 68.5\%$$

Where:

V_{air} = 3% (as set in the specification)

VMA = minimum 20 (as set in the specification)

V_{ar} = VMA - V_{air} =20-3=17% minimum

$V_{-200mm(-No.\ 10)}$ = 100% -68.5%-17%-3%=11.5%.

7.2 Calculate the combined aggregate gravities from the bulk gravities of individual sizes. For the example proportions determined in Section 7.1, the following gravities are calculated:

$$G_{b+2.00\ mm\,(+No.10)} = 2.565, G_{b-2.00\ mm\,(-No.10)} = 2.678$$

7.2.1 The gravity of the binder (G_{ar}) is 1.02.

7.3 Calculate the weight of each of the volumes determined in Section 7.1 by multiplying the volume times its gravity.

7.3.1 Assume the total volume of the molded specimen to be 100 mL (3.5 fl. oz.)

7.3.2 For the proportions determined in Calculation No. 1, the weight of the + 2.00 mm (No. 10) portion of the aggregate is:

$$68.5 \times 2.565 = 175.7g$$

7.3.3 Refer to Table 2 for the weight conversions of the other components. The total weight of a 100 mL (3.5 fl. oz.) molded specimen using these aggregates is 223.8 g.

7.4 Calculate the percent by weight of total mix of each of the components calculated in Section 7.3 by dividing the component weight by the total molded specimen weight. For the weights determined, the percent by weight retained on the 2.00 mm (No. 10) sieve is:

$$\left(175.7 \big/ 223.8\right) x\ 100 = 78.5$$

7.5 Calculate the percentages of each stockpile necessary to obtain the total weight percentages of +2.00 mm (+No. 10), -2.00 mm (-No. 10), and binder calculated in Table 2.

Table 2—Ratios of Volume to Weight in % of Total

	Volume	Weight (g)	% of Total
Retained 2.00 mm (No.10)	68.5 mL (2.3 fl. oz.)	68.5 × 2.565 = 175.7 g	175.7/223.8 × 100 = 78.5%
Passing 2.00 mm (No. 10)	11.5 mL (0.4 fl. oz.)	11.5 × 2.678 = 30.8 g	30.8/223.8 × 100 = 13.8%
Binder	17.0 mL (0.6 fl. oz.)	17.0 × 1.02 = 17.3 g	17.3/223.8 × 100 = 7.7%
Air	3.0 mL (0.11 fl. oz)		
TOTAL	100.0 mL (3.5 fl. oz.)	223.8 g	100.0 %

8. MOLDED DENSITY GREATER THAN 97.2%

8.1 Add 5.0% to the total volume retained on the 2.00 mm (No. 10) sieve.

8.2 Subtract 5.0% from the volume passing the 2.00 mm (No.10) sieve.

8.3 Determine new batch proportions in Section 9. Calculate new weight proportions as shown in Table 3.

8.4 Mix a 5000 g batch using mix proportions determined in Section 9 and Table 3.

8.5 Repeat Sections 6.1 through 6.15.

8.6 Plot density versus volume retained on the 2.00 mm (No. 10) sieve on the same graph with the first set of molds made in Part II (See Figure 3 for example).

8.7 Interpolate to find the volume retained on the 2.00 mm (No.10) sieve where the density equals 97.0%.

8.8 Mix and mold a set of specimens at the interpolated +2.00 mm (+No. 10) volume from Section 8.7.

8.9 Test for creep properties in accordance with Tex-231-F.

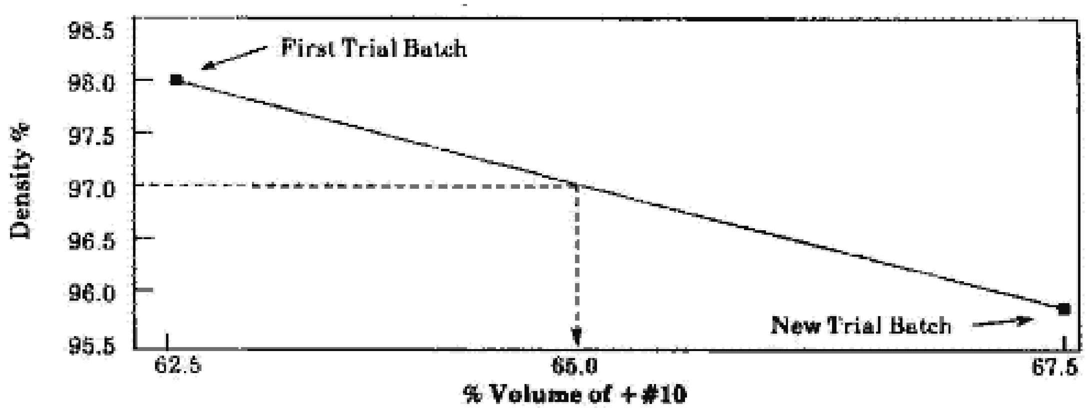

Figure 3—Density vs. Volume of #10 (Example)

9. CALCULATIONS

9.1 Determine new batch proportions:

- Volume retained on 2.00 mm (No. 10) = 68.5 + 5.0 = 73.5%
- Volume passing 2.00 mm (No. 10) = 11.5 - 5.0 = 6.5%
- Volume of binder = 17.0%
- Volume of air = 3.0%.

9.2 Calculate new weight proportions in this ratio table:

Table 3—Mix Ratios if Molded Density is Greater than 97.2%

	Volume	Weight	Mix Proportion
Retained 2.00 mm (No. 10)	73.5 mL (2.5 fl. oz.)	73.5 × 2.565 = 188.5 g	(188.5/223.2) × 100 = 84.4%
Passing 2.00 mm (No. 10)	6.5 mL (0.22 fl. oz.)	6.5 × 2.678 = 17.4 g	(17.4/223.2) × 100 = 7.8 %
Binder	17.0 mL (0.6 fl. oz.)	17.0 × 1.02 = 17.3 g	(17.3/233.2) × 100 = 7.8 %
Air	3.0 mL (0.11 fl. oz.)	-	-
TOTAL	100.0 mL (3.5 fl. oz.)	223.2 g	100.0%

10. MOLDED DENSITY LESS THAN 96.8%

10.1 Add 2.0% to the volume of the binder.

10.2 Subtract 2.0% from the volume passing the 2.00 mm (No. 10) sieve.

10.3 Use data from Section 11 and Table 4 to calculate new weight proportions.

10.4 Mix a 5000 g batch using the proportions determined in Section 11 and Table 4.

10.5 Repeat Sections 6.1 through 6.15.

10.6 Plot density versus percent volume of binder for the initial binder content and the second binder content. (See Figure 4 for an example.)

10.7 Interpolate to find the volume of binder at a density of 97.0%.

10.8 Mix and mold a set of specimens at the interpolated binder content from Section 10.7. Determine creep properties in accordance with Tex-231-F.

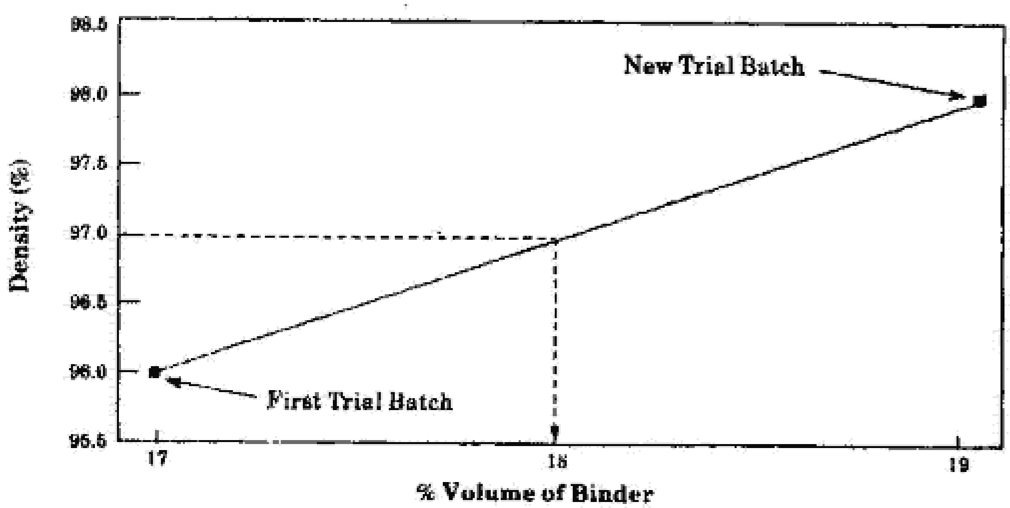

Figure 4—Density vs. Volume of Binder

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11. CALCULATIONS

11.1 Determine new trial batch proportions as shown by this example:

- Volume retained on 2.00 mm (No. 10) sieve = 68.5 %
- Volume passing 2.00 mm (No. 10) sieve = 11.5 - 2.0 = 9.5 %
- Volume of binder = 17.0 + 2.0 = 19.0 %
- Volume of air = 3.0 %.

11.2 Calculate new weight proportions in accordance with Table 4.

Table 4—Mix Ratios if Molded Density is Less than 96.8%

	Volume	Weight	Total Mix Proportion
Retained 2.00 mm (No.10)	68.5 mL (2.3 fl. oz.)	68.5 × 2.565 = 175.7 g	(175.7/220.5) × 100 = 79.7%
Passing 2.00 mm (No. 10)	9.5 mL (0.32 fl. oz.)	9.5 × 2.678 = 25.4 g	(25.4/220.5) × 100 = 11.5%
Binder	19.0 mL (0.64 fl. oz.)	19.0 × 1.02 = 19.4 g	(19.4/220.5) × 100 = 8.8%
Air	3.0 mL (0.11 fl. oz.)		
Total	100.0 mL (3.5 fl. oz.)	220.5 g	100.0%