Recommend Approval: Assistant Division Chief 1/28/13 Date Division Chief 1/25/13 Date	Maryland Department of Transportation State Highway Administration Office of Materials Technology MARYLAND STANDARD METHOD OF TESTS	
Approved: Director 02/01/13 Date	**MIX DESIGN PROCEDURE FOR OPEN GRADED FRICTION COURSE**	**MSMT 409**

SCOPE:

This procedure is used to determine the design asphalt content, optimum mixing temperature, and resistance to the effects of water on Open Graded Friction Course (OGFC). The procedure uses aggregate and mixture properties to produce an open graded mix design. The mix design is based on aggregate voids, air voids and moisture susceptibility.

REFERENCE DOCUMENTS:

D 4791	Standard Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate
D 5821	Standard Test Method for Determining the Percentage of Fractured Particles in Coarse Aggregate
M 320	Performance Graded Asphalt Binder
M 323	Standard Specification for Superpave Volumetric Mix Design
M 325	Stone Matrix Asphalt
T 2	Sampling of Aggregates
T 11	Materials Finer than 75 µm (No. 200) Sieve in Mineral Aggregates by Washing
T 19	Bulk Density ("Unit Weight") and Voids in Aggregate
T 27	Sieve Analysis of Fine and Coarse Aggregates
T 85	Specific Gravity and Absorption of Coarse Aggregates
T 96	Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
T 209	Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures
T 283	Resistance of Compacted Hot Mix Asphalt (HMA) to Moisture-Induced Damage
T 304	Uncompacted Void Content of Fine Aggregate
T 305	Determination of Draindown Characteristics in Uncompacted Asphalt Mixtures

T 312 Method for Preparing and Determining the Density of Hot Mix Asphalt (HMA) Specimens by Means of the SHRP Gyratory Compactor

T 331 Bulk Specific Gravity and Density of Compacted Hot Mix Asphalt (HMA) Using Automatic Vacuum Sealing Method

National Asphalt Pavement Association, IS Series 115: **Design, Construction, and Maintenance of Open Graded Asphalt Friction Courses**, May 2002

TERMINOLOGY:

Open Graded Friction Course (OGFC) – a hot mix asphalt surface mixture used to increase skid resistance and reduce hydroplaning in wet weather. This mixture provides a free draining layer that permits surface water to migrate through the surface to the edge of the pavement.

Air Voids (Va) – the total volume of air pockets between the coated aggregate articles throughout the compacted mixture.

Voids In Coarse Aggregate (VCA) – the volume between the coarse aggregate particles.

MATERIAL REQUIREMENTS:

Select asphalt binder, aggregate, mineral filler, and stabilizing additives that meet the following:

Aggregates - meeting the requirements of 901 and M325.

Asphalt Binder – meeting the requirements of M320 for the appropriate climate and traffic loading conditions. Elastomer modification is required. Any other modification shall as be approved by the Administration.

Stabilizing Additive – cellulose or mineral fibers to prevent drain down during transport and placement of the mix.

PROCEDURE:

TRIAL GRADATION SELECTION

1. Prepare trial gradation meeting the desired specification range. Prepare three trial blends:

    a) one near the coarse side of the gradation band
    b) one near the fine side of the gradation band
    c) one near the middle of the gradation band

2. Determine the voids of the dry-rodded coarse aggregate fraction (VCA_{DRC}) for each of the trial blends Using T19. The coarse aggregate is defined as the aggregate fraction retained on the 4.75 mm sieve. Calculate the VCA_{DRC} as follows:

$$VCA_{DRC} = \frac{G_{ca}Y_w - Y_s}{G_{ca}Y_w} \times 100$$

Where:

G_{ca} = bulk specific gravity of the coarse aggregate (T 85)

Y_s = unit weight of the coarse aggregate fraction in the dry-rodded condition (kg/m^3) (T 19)

Y_w = unit weight of water (998 kg/m^3)

TRIAL BINDER SELECTION

1. Select an estimated asphalt content for each trial gradation based on the combined aggregate bulk specific gravity as shown in Table 1 or Optional Estimated Percent Binder.

TABLE 1

Trial Asphalt Content Selection	
Combined Aggregate Bulk Specific Gravity	Trial Asphalt Content Based on Mass, %
2.45	6.7
2.50	6.6
2.55	6.5
2.60	6.3
2.65	6.2
2.70	6.1
2.75	6.0
2.80	5.9
2.85	5.8
2.90	5.7
2.95	5.6
3.00	5.5

OPTIONAL ESTIMATED PERCENT BINDER

1. Obtain two representative samples of the material passing the 9.5 mm sieve and retained on the No 4 sieve; each weighing approximately 105 g.

2. Dry the samples to a constant weight in a 230 F oven and allow to cool to room temperature.

3. Weigh 100.0 g of the material and place in the metal funnel.

4. Place a stopper in the funnel outlet and fill with SAE No 10 oil until the aggregate is completely immersed.

5. After 5 minutes, remove the stopper and allow the oil to drain for 2 minutes.

6. Place the funnel containing the aggregate in an oven maintained at 140 F for 15 minutes of additional draining.

7. Remove the sample from the funnel, cool to room temperature and weigh to the nearest 0.1 g and record.

8. Repeat steps 3 through 7 for the second sample.

CALCULATIONS:

1. Calculate the percent oil retained for each sample as follows:

$$R = \frac{B - A}{A} x100$$

where:

R = percent oil retained,
A = weight of sample before test, and
B = weight of sample after test.

2. Using the average percent oil retained from the two samples, calculate the corrected oil retained as follows:

$$RC = \frac{GA}{2.65} xR$$

where:

R = corrected percent oil retained, and
GA = weight of sample after test.

3. Using the corrected percent oil retained, determine the surface constant (Kc) from Table 2.

4. Calculate the estimated design asphalt content as follows:

$$EAC = \frac{2.65}{GA} x(2.0Kc + 4.0)$$

where:

EAC = estimated design asphalt content,
GA = weight of sample after test, and
Kc = surface constant.

TABLE 2

DETERMINATION OF SURFACE CONSTANT Kc							
Corrected % Oil	**Kc**	**Corrected % Oil**	**Kc**	**Corrected % Oil**	**Kc**	**Corrected % Oil**	**Kc**
0.1	0.1	2.6	1.2	5.1	2.2	7.6	3.1
0.2	0.1	2.7	1.2	5.2	2.2	7.7	3.1
0.3	0.2	2.8	1.2	5.3	2.2	7.8	3.2
0.4	0.2	2.9	1.3	5.4	2.3	7.9	3.2
0.5	0.3	3.0	1.3	5.5	2.3	8.0	3.2
0.6	0.3	3.1	1.4	5.6	2.3	8.1	3.3
0.7	0.4	3.2	1.4	5.7	2.4	8.2	3.3
0.8	0.4	3.3	1.4	5.8	2.4	8.3	3.4
0.9	0.4	3.4	1.5	5.9	2.5	8.4	3.4
1.0	0.5	3.5	1.5	6.0	2.5	8.5	3.4
1.1	0.5	3.6	1.6	6.1	2.5	8.6	3.5
1.2	0.6	3.7	1.6	6.2	2.6	8.7	3.5
1.3	0.6	3.8	1.6	6.3	2.6	8.8	3.5
1.4	0.7	3.9	1.7	6.4	2.6	8.9	3.6
1.5	0.7	4.0	1.7	6.5	2.7	9.0	3.6
1.6	0.7	4.1	1.8	6.6	2.7	9.1	3.6
1.7	0.8	4.2	1.8	6.7	2.8	9.2	3.7
1.8	0.8	4.3	1.8	6.8	2.8	9.3	3.7
1.9	0.9	4.4	1.9	6.9	2.8	9.4	3.8
2.0	0.9	4.5	1.9	7.0	2.9	9.5	3.8
2.1	1.0	4.6	2.0	7.1	2.9	9.6	3.8
2.2	1.0	4.7	2.0	7.2	2.9	9.7	3.9
2.3	1.0	4.8	2.0	7.3	3.0	9.8	3.9
2.4	1.1	4.9	2.1	7.4	3.0	9.9	3.9
2.5	1.1	5.0	2.1	7.5	3.1	10.0	4.0

TRIAL MIX DESIGN

1. Fabricate samples according to Sample Preparation.
2. Compare VCA_{mix} to VCA_{DRC} for each trial gradation.
3. Select the trial design gradation with the finest gradation that meets the minimum air void requirements and where the trial gradation VCA_{mix} is equal to or less than VCA_{DRC}.

OPTIMUM ASPHALT CONTENT SELECTION

1. Using the selected design gradation, prepare three batches at the estimated design asphalt content, plus and minus 0.5 percent asphalt.

2. Fabricate samples according to Sample Preparation.

3. Conduct drain down test according to T 305 on loose mix at a temperature of 27 F higher than the design production temperature.

4. Select the optimum design asphalt content using the following criteria:

    a) Air Voids ≥ 18%
    b) VCA_{mix} is equal to or less than VCA_{DRC}
    c) Draindown ≤ 0.3%

SAMPLE PREPARATION

1. Prepare the aggregate per T 27 and separate into the following fractions:

    a) 19.0 to 12.5 mm
    b) 12.5 to 9.5 mm
    c) 9.5 to 4.75 mm
    d) 4.75 to 2.36 mm
    e) Passing 2.36 mm

2. The mixing and compaction temperature should be based on the asphalt modifier manufacturer's guidelines.

3. For each blend, prepare three samples and place into an oven at the mixing temperature. Adjust the aggregate mass after mixing with asphalt to provide compacted specimens with a height of 115 ± 5 mm.

4. Heat the asphalt binder to the mixing temperature.

5. Combine the aggregate and asphalt binder at the selected asphalt content for each sample and mix until thoroughly coated. Include fibers if used.

6. After mixing, age the loose mix for 2 hour per R30.

7. Compact two specimens at 50 gyrations for each of the trial batches.

8. Allow the specimens to cool in the mold a minimum of 10 minutes before extrusion.

9. Determine the bulk specific gravity of the compacted specimens per T 331.

10. Geometric measurements may be used to determine the bulk specific gravity of the compacted specimens as follows:

$$G_{mb} = 1000 \times \left[\frac{SampleMass}{\frac{3.1416 \times D^2}{4} \times t} \right]$$

where:

G_{mb} = bulk specific gravity of compacted specimen,
D = diameter of sample based on dimensional measurements in mm, and
t = thickness of sample based on dimensional measurements in mm.

11. Determine the VCA_{mix} for each of the specimens as follows:

$$VCA_{mix} = 100 - \left[\frac{G_{mb}}{G_{CA}} \times P_{CA} \right]$$

where:

VCA_{mix} = total voids mix,
G_{mb} = bulk specific gravity of compacted specimen,
G_{CA} = bulk specific gravity of coarse aggregate, and
P_{CA} = percent coarse aggregate in mix.

12. Determine the maximum specific gravity per T 209 using the remaining sample from each trial batch.

MOISTURE SUSCEPTIBILITY EVALUATION

1. Test the final mix for moisture susceptibility per T 283, with the following exceptions:

   a) Compact using 50 gyrations.
   b) Apply partial vacuum of 26 inches of Hg for 10 minutes.
   c) Use five freeze/thaw cycles.
   d) Keep specimens submerged in water during the freeze cycles.

2. Retained tensile strength shall be ≥ 80%.

REPORT:

1. Information on the materials used including source and properties for: aggregate, asphalt binder, and stabilizing additive.

2. The results of the trial gradation determination.

3. The optimum gradation and asphalt binder content.

4. The volumetric properties and drain down at optimum asphalt binder content.

5. The moisture susceptibility results.