

SUPPLEMENTAL TEST PROCEDURES FOR HMAC AND EAC

CITED IN:

“Contractor Mix Design Guidelines for Asphalt Concrete”

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ODOT Test Method 303-03

Method of Test for

**RESISTANCE TO DEFORMATION OF BITUMINOUS MIXTURES
BY MEANS OF HVEEM STABILOMETER**
(Mod. AASHTO Designation T 246)

SCOPE

- 1.0 This test determines the resistance to deformation of compacted bituminous mixtures using the Hveem Stabilometer. The Hveem stabilometer measures lateral pressure developed from applying a vertical load.

APPARATUS

- 2.1 Stabilometer – The Hveem Stabilometer is a triaxial testing device per AASHTO T-246. See Fig. 1. Refer to California Method No. 902 for details on the mechanics of the Hveem Stabilometer including the installation and calibration of the neoprene diaphragm. Calibrate the neoprene diaphragm when it is installed and at least annually after installation. For at least 2 hours prior to adjusting the stabilometer or testing specimens, keep the stabilometer and follower at a temperature of 77 ± 9 °F (25 ± 5 °C).
- 2.2 Calibration Cylinder – A hollow metal cylinder 4 ± 0.005 in. (101.6 ± 0.13 mm) outside diameter by 5.5 in. (140 mm) high for calibration purposes.
- 2.3 Follower – One metal follower 3.985 in (101.2 mm). in diameter by 5.5 in. (140 mm) high. (Fig. 2)
- 2.4 Testing Machine – A compression testing machine having a minimum capacity of 10,000 lb (44.5 Kn).
- 2.5 Oven – An oven capable of maintaining a temperature of 140 ± 5 ° F (60 ± 3 ° C)
- 2.6 Oven – An oven capable of maintaining a temperature of 230 ± 5 ° F (110 ± 3 ° C)

ADJUSTMENT OF STABILOMETER

- 3.1 Adjust the displacement of the stabilometer immediately prior to testing samples by the following:

- 3.1.1 Adjust the bronze nut on the adjustable stage so that the top of the stage is 3.5 in. (89 mm.) below the visible top of the neoprene diaphragm. Place the metal calibration cylinder in the stabilometer.
 - 3.1.2 Turn the pump to a pressure of exactly 5 psi (34.5 kPa). When setting the gauge pressure to 5 psi (34.5 kPa), always drop the pressure 2-4 psi (14-18 kPa) below 5psi (34.5 kPa), then bring the pressure back up to 5psi (34.5 kPa) and gently tap the dial to remove slack in the dial indicator gear.
 - 3.1.3 Adjust the turns indicator dial to zero. Turn the pump handle at approximately two turns per second until the stabilometer reads 100 psi (689 kPa). The turns indicator dial should then read 2.00 ± 0.05 turns. If it does not, the air in the cell must be adjusted by means of the needle valve and the displacement measurement must be repeated after each air change until the proper number of turns is obtained. Release the horizontal pressure and remove the cylinder. The stabilometer is now ready for testing specimens.
- 3.2 Adjust the testing machine to give a constant movement of 0.05 in (1.3 mm) per minute with no load applied. Operate hydraulic machines for several minutes until the oil warms sufficiently to maintain a constant speed.

SAMPLE PREPARATION

FIRST COMPACTION

- 4.1 Mix the samples and immediately compact the test specimens as specified in AASHTO T-247 with the following exceptions. Do not allow the sample temperature to drop below the compaction temperature range. Use the compaction temperature recommended by the asphalt supplier instead of the standard temperature designated in AASHTO T-247. Begin the “leveling off load” immediately after the 150 blow compaction procedure. Omit the 1.5 hr. heating period.
- 4.2 Fabricate test specimens to an overall height between 2.4 and 2.6 in (61 mm and 65 mm.). If the sample height falls outside this range, correct the stability value according to Figure 4.
- 4.3 Remove the samples from the molds. Measure the sample height to the nearest 0.01 in. If the test will not be completed in one day, this is an acceptable point at which to suspend the test. When the test is to continue, put the specimens on a flat surface and place them in an oven set at $140 \pm 5^\circ$ F ($60 \pm 3^\circ$ C). Hold the test specimens at that temperature for 3 to 4 hours. After the heating period, proceed to Section 5.1.

SECOND COMPACTION

- 4.4 After completing the testing in Section 5.7, roll the samples between two solid surfaces, such as a tabletop and a rigid board to return the samples to approximately cylindrical shape. Then invert the samples and return them to their molds with the side that was tamped during first compaction facing down. This is another acceptable point at which to suspend the test until the next workday. When the test is to continue, place the samples in an oven heated to 230° F \pm 9 F (110° C \pm 5°C.) Hold the test specimens at that temperature for 4 to 6 hours.
- 4.5 After the heating period, recompact the samples following the procedure in AASHTO T-247, Sections 4.2-4.4 at 500 psi tamping pressure. Do not apply the preliminary 20 blows described in Section 4.2 of AASHTO T-247 during the recompaction process.
- 4.6 Following recompaction do not apply a leveling load. Remove the samples from the molds and measure the heights to the nearest millimeter. Bring the specimens to 140 \pm 5° F (60 \pm 3° C) , holding them at that temperature according to Section 4.3, until just before placing the specimens in the stabilometer.
- 4.7 Retest the samples for stability according to Sections 5.1 – 5.8. Test the samples in a position inverted from the first stability test. If the sample height after recompaction is not 2.4 – 2.6 inches (61-65 millimeters), adjust the stability value according to figure 4.

TEST PROCEDURE

- 5.1 Immediately prior to testing the compacted specimens, adjust the stabilometer according to Section 3.1. Do not remove the specimens from the oven until the stabilometer is adjusted.
- 5.2 Place a 4 in. (100 mm) manila paper disk in the stabilometer. Back out the displacement crank sufficiently to avoid friction between the rubber diaphragm and the specimen when placing the sample into the stabilometer. Place the sample into the stabilometer and place a second manila paper disk on top of the sample. Be sure that the specimen is straight with the recently tamped end facing up and firmly seated level on the base. Place the metal follower on top of the sample.
- 5.3 Complete the testing rapidly to minimize cooling of the test specimen.
- 5.4 Adjust the pump to give a gauge pressure of exactly 5 psi (34.5 kPa). See 3.1.2. If the testing machine has a spherically seated type of upper head, remove the locking shims from the upper head prior to performing the stabilometer test.
- 5.5 Start vertical movement of the testing machine platen at the speed of 0.05 in (1.3 mm.) per minute and record the stabilometer gauge readings when the vertical applied loads

are 5000 and 6000 lbs (22.3 and 26.7 kN.) total load. The gauge reading at 5000 lbs. load will be used in the calculation in 6.1.

- 5.6 Stop vertical loading exactly at 6000 lb (26.7 kN) and immediately reduce the load to 1000 lbs (4.45 kN).
- 5.7 Turn the displacement pump to indicate a reduced horizontal pressure of exactly 5 psi (34.5 kPa) according to Section 3.1.2. This will result in a further reduction in the vertical load reading, which is normal, and no compensation is made. Set the turns displacement indicator dial to zero. Turn pump handle at approximately two turns per second until the stabilometer gauge reads 100 psi (689 kPa). During this operation the vertical load registered on the testing machine will increase and in some cases exceed the initial 1000 lb (4.45 kN.) load. As before, this change in vertical load reading is normal and no adjustment or compensation is required.
- 5.8 Record the number of turns indicated on the dial as the displacement, D_i , of the specimen. The turns indicator dial reads in 0.001 in. (0.004 mm) divisions and each 0.1 in. (0.4 mm) equals one turn. Thus, a reading of 0.250 in. (6.63 mm) indicates that 2.50 turns were made with the displacement pump. This measurement is known as turns displacement of the specimen.

CALCULATION

- 6.1 Calculation of stabilometer values.

$$S = \frac{22.2}{\frac{P_h D_i}{P_v - P_h} + 0.222}$$

Where:

P_v = vertical pressure in psi, typically 400 psi (2760 kPa). This reading corresponds to a 5000 lb. load for a 4 inch sample.

P_h = horizontal pressure (stabilometer reading in psi).
 P_h taken at the instant P_v is 400 psi (2760 kPa).

D_i = turns displacement of specimen.

REPORTING RESULTS

- 7.1 Report the results of the stabilometer tests for first and second compaction, as the nearest whole number.

CHART FOR CORRECTING STABILOMETER VALUES
TO SPECIMEN HEIGHT OF 64 mm

Height correction should be made using
the table and chart below.

Example: Overall height of 69mm:
select correction curve "B". Stabilometer
value uncorrected = 35
Stabilometer value corrected = 38.

Overall Specimen Ht.	Correction Curve
71mm to 76mm	A
66mm to 70mm	B
61mm to 65mm	C
56mm to 60mm	D
51mm to 55mm	E

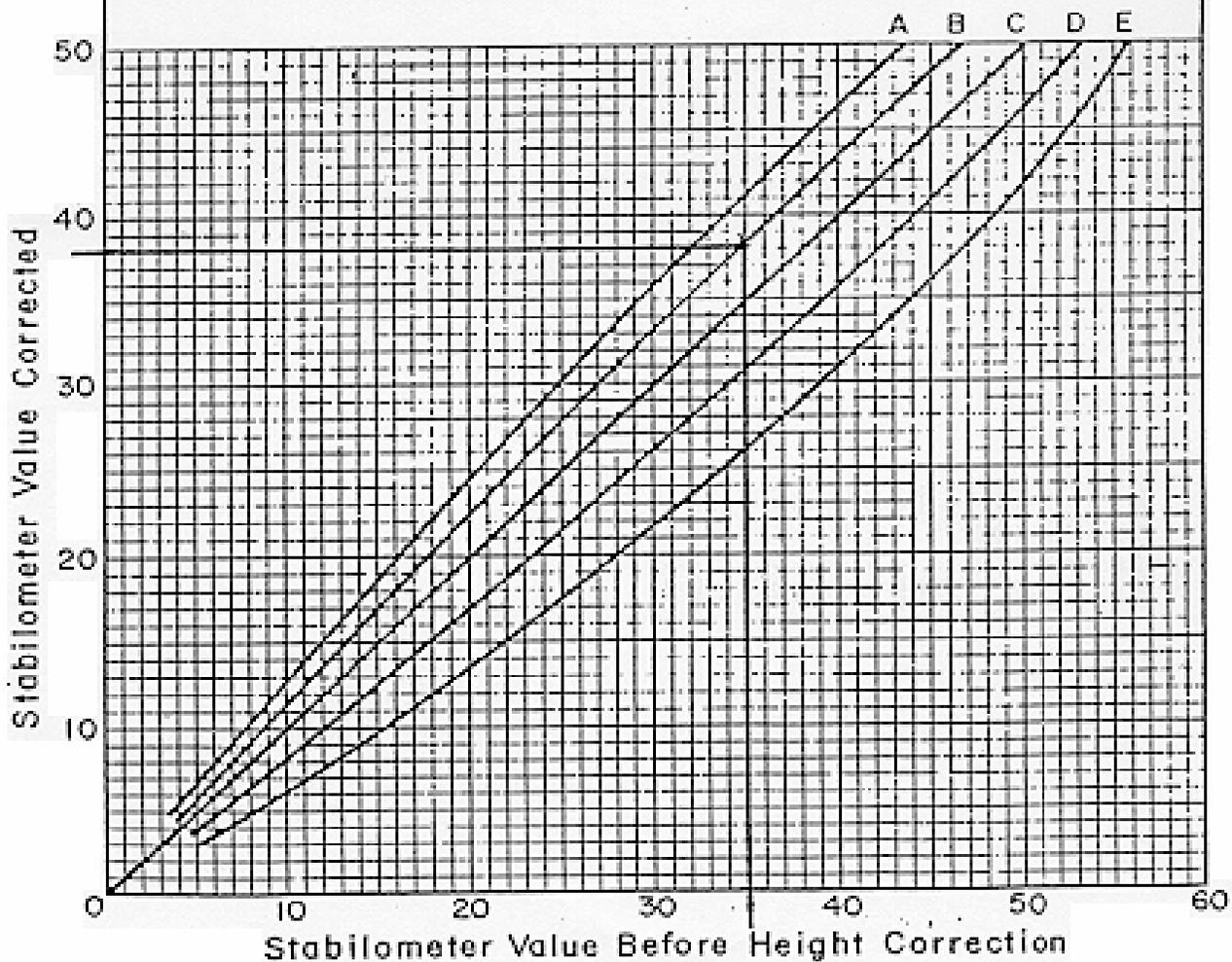
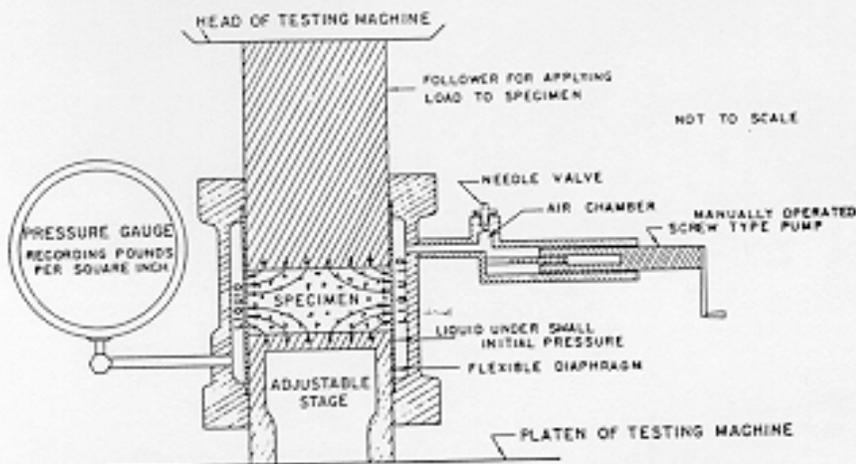


FIGURE 4

DIAGRAMATIC SKETCH OF THE HVEEM STABILOMETER



NOTE: Specimen given lateral support by flexible side wall which transmits horizontal pressure to liquid. Magnitude of pressure may be read on gauge.

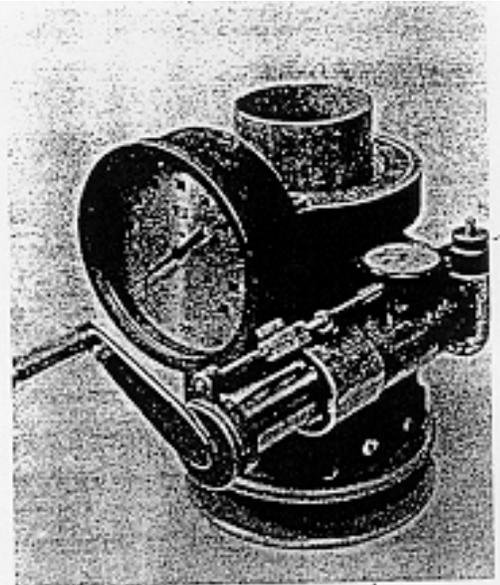
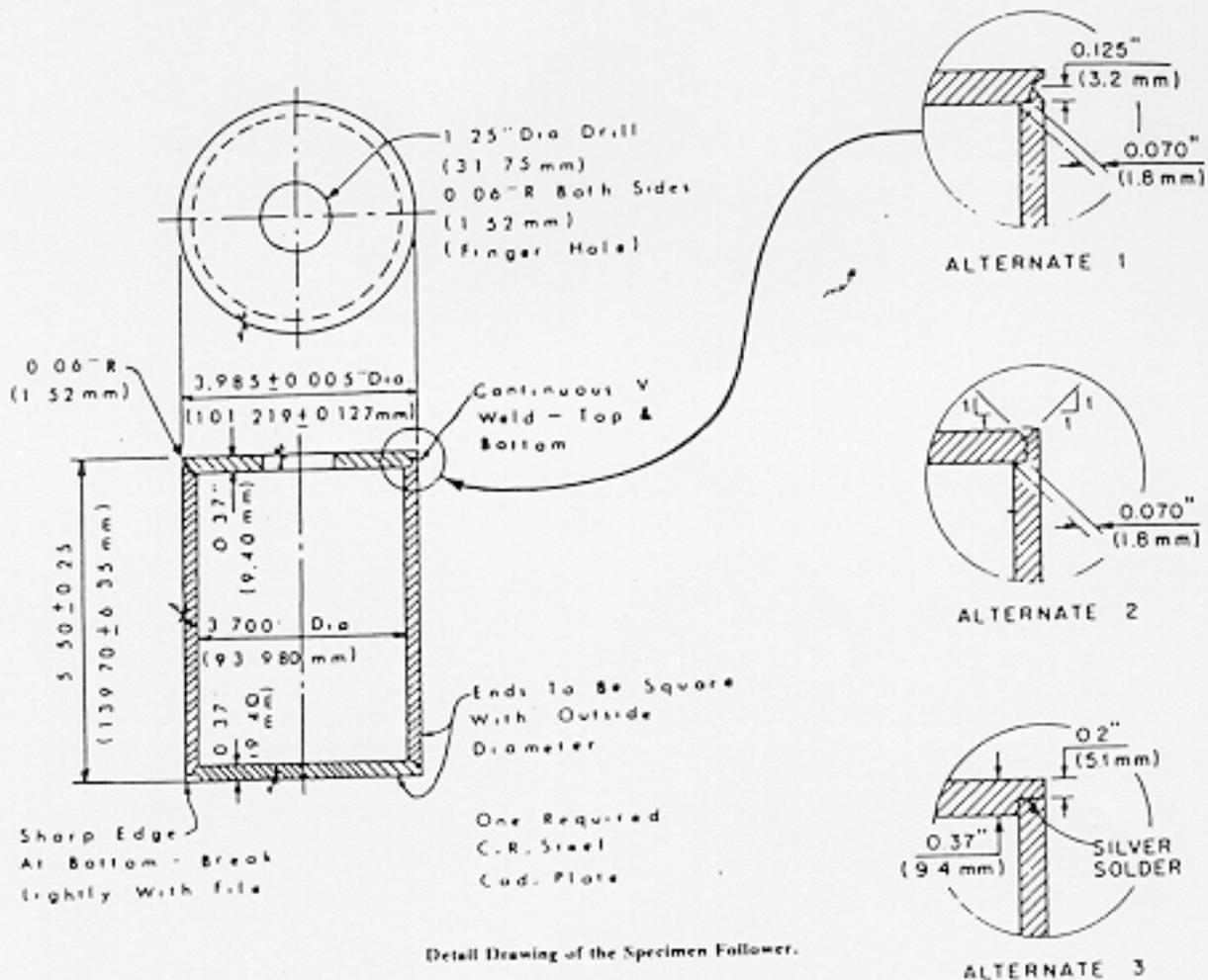


FIGURE 1



MATERIALS LABORATORY
ODOT Test Method 313-04

Method of Test for
**COMPRESSIVE STRENGTH AND MIX DESIGN
OF EMULSIFIED ASPHALT MIXTURES**

(Modified AASHTO Designation T 165 & 167)

SCOPE

- 1.1 This method of test for compacted Emulsified Asphalt Concrete (EAC) mixtures of the cold-mixed, cold laid type for use in pavement surfaces and base courses is intended to evaluate the asphalt-aggregate compatibility in the mixture. It employs the relative compressive strength of conditioned versus unconditioned test specimens. Mixtures with compatible materials will generally have a compressive strength ratio of 40 or more.

APPARATUS

- 2.1 Steel compaction mold -- 4.0 in (101.6 mm.) inside diameter, 4.5 in (114 mm.) outside diameter and 7.0 in (178 mm.) height.

Mold holder, funnel, plunger and mixing bowls approximately 3 quart capacity.

- 2.2 Testing Machine - The testing machine may be of any type of sufficient capacity that will provide a range of accurately controllable rates of vertical deformation. Since the rate of vertical deformation for the compression test is specified as 0.05 in (1.3 mm.) per minute per 1 in (25 mm.) of specimen height, and it may be necessary to test specimens ranging in size from 2 x 2 in (50 x 50 mm.) to perhaps 8 x 8 in (200 x 200 mm.), in order to maintain the specified minimum ratio of specimen diameter to particle size, the testing machine should have a range of controlled speeds covering at least 0.1 in (2.5 mm.) per minute for 2 in (50 mm.) specimens to 0.4 in (10 mm.) per minute for 8 in (200 mm.) specimens.

For central control laboratory installations, the testing machine shall conform to the requirements of section 14 of the Methods of Verification of Testing Machines (AASHTO T67). The testing machine shall be equipped with two steel bearing blocks with hardened faces, one is spherically seated and the other plain. The spherically seated block shall be mounted to bear on the upper surface of the test specimen and the plain block shall rest on the platen of the testing machine to form a seat for the specimen. The bearing faces of the plates shall have a diameter slightly greater than that of the largest specimens to be tested.

The bearing faces, when new, shall not depart from a true plane by more than 0.0005 in (0.013 mm.) at any point and shall be maintained within a permissible variation limit of 0.001 in (0.025 mm.). In the spherically seated block, the center of the sphere shall coincide with the bearing face. The movable portion of this block shall be held closely in the spherical seal, but the design shall be such that the bearing face can be rotated freely and tilted through small angles in any direction.

- 2.3 Air Bath - The air bath shall be capable of either manual or automatic control for storing the specimens at $77 \pm 1^\circ \text{ F}$ ($25 \pm 0.5^\circ \text{ C}$) immediately prior to making the compression test.
- 2.4 Balance - A balance having a capacity of 2000 grams or more and a sensitivity of 0.1 g for weighing the ingredients of the mixture shall be provided.
- 2.5 Glass or plexiglass plates for use under the specimens while being cured; 4.5 in (114 mm.) square by 0.25 in (6 mm.) thick. One of these plates shall be kept under each of the specimens during the immersion period and during subsequent handling, except when weighing and testing, in order to prevent breakage or distortion of the specimens.
- 2.6 Containers approximately 5 in (125 mm.) by 5 in (125 mm.) by 6 in (150 mm.) high to surround the test specimens in the conditioning bath, described in section 2.7.
- 2.7 One or more automatically controlled water baths shall be provided for immersing the "B" specimens. The baths shall be of sufficient size to permit total immersion of the test specimens. They shall be so designed and equipped as to permit accurate and uniform control of the immersion temperature within plus or minus 1.8° F (1° C). They shall be constructed of or lined with copper, stainless steel, or other non-reactive material.

PREPARATION OF TEST MIXTURES

- 3.1 In preparing aggregates for making mixtures, a sieve analysis shall be made on each aggregate involved. All coarse aggregates shall be separated individually and recombined in the necessary quantities with the fine aggregates to meet the formula under study.
 - 3.1.1 Obtain test gradation from average field gradations.
 - 3.1.2 Set up worksheets, recording project information and design gradation.
 - 3.1.3 Test specimens will normally be 1700 grams per sample. This weight will normally make cylinders 4.0 in (102 mm.) in diameter and 4.0 ± 0.1 in (102 \pm 2.5 mm.) in height. The size of the test specimens has an influence on the

results of the compressive strength test. Therefore, if the known specific gravity or unit weight of the aggregate indicates an excessive variation in height, a correction must be determined. Fabricate and measure asphalt coated compacted sample to determine the required correction to the batch weights.

- 3.1.4 Screen and separate aggregate in sizes dictated by the design gradation.
- 3.1.5 Weigh out a minimum of eight samples using the gradation described in section 3.1.2.
- 3.2 Emulsion contents, expressed as percents of the dry aggregate weight, shall be 5.0, 6.0, 7.0 and 8.0%.

Example showing calculation for weight of emulsion at 5.5% of oven dry aggregate when the aggregate weight is 1720 grams:

$$\text{Weight required: } \frac{(\text{Dry Agg.}) (\% \text{ Emulsion})}{100}$$
$$\frac{(1720 \text{ gr.}) (5.5)}{100} = 94.6 \text{ grams}$$

Two specimens shall be made at each emulsion content. One series shall be designated as “A” specimens and will be tested for compressive strength. These will serve as control or “dry” specimens. The other series, designated as “B” specimens, will be tested “wet” as described in Section 7.

- 3.3 An initial batch shall be mixed for the purpose of “buttering the mixing bowl. This batch shall be emptied after mixing and the sides of the bowl shall be cleaned of mixture residue by scraping with a small limber spatula but shall not be wiped with cloth or cleaned with solvent, except when a change is to be made in the binder or at the end of a run.
- 3.4 Place the aggregate in the mixing bowl. Add clean water to the aggregate in increments of 0.5% of dry aggregate weight. After adding each increment, mix thoroughly by hand. Repeat until the surface of the aggregate is thoroughly moistened and very little free water is present.
- 3.5 Add the pre-determined amount of emulsion to the moistened aggregate. Stir 2 to 3 minutes or until complete aggregate coating is achieved. If mix becomes stiff before aggregate is completely coated, terminate the mixing.

- 3.6 Evenly spread the mixture in a large flat bottomed pan, 2 x 9 x 13 in (50 x 230 x 330 mm.) and cure at room temperature for 24 to 72 hours. Additional curing time will be required if any “unbroken” emulsion remains in the box. Stir the sample after each 24 hour increment of curing.
- 3.7 When curing is completed, observe and record the percent of coated aggregate.
- 3.8 Repeat steps 3.4 - 3.7 for each sample required.

MOLDING

- 4.1 Place approximately one-half of the mixture in the mold. The mixture shall be spaded vigorously twenty-five times with a flat bladed spatula with fifteen blows being delivered around the inside of the mold to reduce honeycomb. The remaining half of the mixture shall then be quickly transferred to the mold and similar spading action repeated. The spatula should penetrate the mixture as deeply as possible. The top of the mixture should be slightly rounded or cone-shaped to aid in firm seating of the upper plunger.
- 4.2 In order to place a leveling preload on the specimen, proceed as follows:
 - 4.2.1 Place the mold/mold holder assembly with shims in place, on the bottom platen of compression testing machines.
 - 4.2.2 Place shims in the upper platen to prevent tilting under load.
 - 4.2.3 Place the upper plunger on the specimen and exert an initial leveling load of 150 psi (1034 kPa) which shall be held for 15-20 seconds, and which will set the mixture against the sides of the mold.
- 4.3 The compressive load will be placed as follows:
 - 4.3.1 Remove the shims from the mold/mold holder assembly.
 - 4.3.2 Apply the full molding load of 37800 lbs (168 KN) or 3000 psi (20,685 kPa) at a rate which will produce full load in 0.5 minutes. Hold the load an additional 2 minutes to complete the molding.

INITIAL CURING

- 5.1 Place the specimens, still in the molds, onto glass or plexiglass plates in trays and cure for 24 hours in an oven at 140° F (60° C).

- 5.2 Cool the specimens in air at room temperature for a period of 2 hours, after which the specimen shall be ejected from the mold while employing a smooth, uniform rate of travel. Determine the Bulk Specific Gravity.

BULK SPECIFIC GRAVITY DETERMINATION

- 6.1 Determine the Bulk Specific Gravity of each specimen by the Geometric Method and calculations as follows:

$$\text{SPECIFIC GRAVITY (GEOMETRIC)} = \frac{1273W}{HD^2}$$

Where:

W = dry weight in grams

H = Height of sample in millimeters (average of 4 measurements)

D = Diameter of sample in millimeters (average of 4 measurements)

Explanation of constants in formula:

$$\frac{\frac{W(\text{gr})}{\frac{\pi D^2(\text{mm}^2)}{4} \cdot H(\text{mm}) \cdot \frac{1(\text{cm}^3)}{1000(\text{mm}^3)}}}{(gr)} \times \frac{1(\text{cm}^3)}{(gr)} = \frac{W \cdot 4 \cdot 1000}{HD^2 \pi} = \frac{1273W}{HD^2}$$

A simplified version which assumes a nominal 4 in (102 mm.) diameter results in this formula:

$$\frac{0.1233W}{H}$$

FINAL CURING

- 7.1 Divide the “8” specimens into groups “A” & “B”. For each pair of samples at a given emulsion content, assign the sample with higher Bulk Specific Gravity to the “B” group.
- 7.2 The “A” specimens will be brought to test temperature, 77° F (25° C), by storing in the air bath at this temperature for 24 hours before testing.

- 7.3 The “B” specimens will be placed in a water bath at $140 \pm 1.8^\circ \text{ F}$ ($60 \pm 1^\circ \text{ C}$) for a period of 24 hours.
- 7.4 After 24 hours of curing, place the “B” specimens in a water bath at $77 \pm 2^\circ \text{ F}$ ($25 \pm 1^\circ \text{ C}$) for 2 hours.
- 7.5 Be sure to use the appropriate water baths marked either “Lime Treated” or “No Lime”.

COMPRESSION TEST

- 8.1 After all curing and temperature stabilization is complete, test the specimens in axial compression without lateral support at a uniform rate of vertical deformation of 0.05 in (1.3 mm.) per minute per 1 in (25 mm) of height (0.2 in [5.1 mm] per minute for specimens 4 in. [102 mm] in height).

THEORETICAL MAXIMUM SPECIFIC GRAVITY

- 9.1 After compression testing described in 8.1 of ODOT TM 313, perform maximum specific gravity tests (Gmm) per AASHTO T-209, as described in the ODOT Manual of Field Test Procedures (MFTP) on the dry conditioned samples labeled group “A”. However, the sample size will be smaller than specified in T 209.

CALCULATION

- 10.1 The numerical index of resistance of bituminous mixtures to the detrimental effect of water shall be expressed as the percent of the original strength that is retained after the immersion period. It shall be calculated as follows:

$$\text{Index of retained strength} = \frac{S_2}{S_1} \times 100$$

Where:

S1 = Compressive Strength of dry specimens (“A” specimens) in psi.

S2 = Compressive Strength of immersed specimens (“B” specimens) in psi.

DESIGN CRITERIA

- 11.1 EAC is designed based on three parameters: air voids, percent asphalt coating, and Index of Retained Strength (IRS). The gradation is controlled by the broadband specification only. The design criteria are:

AIR VOIDS (Va)	15 - 30 %
PERCENT COATING	90 % minimum
IRS	40 recommended minimum

DESIGN EMULSION CONTENT

- 12.1 The emulsion content target is an estimated starting point, which may be field adjusted at the direction of the Project Manager. The recommended emulsion content should be the lowest emulsion content at which all the criteria are met, but no lower than 5 percent by weight of dry aggregate.

- 12.2 Sometimes, the minimum IRS value cannot be achieved at any emulsion content or at a very high emulsion content. This can be an indication of several different materials problems. The most common one is incompatibility of the aggregate and emulsion. A solution often employed in this situation is to change grades or brands of emulsion to improve compatibility.

REPORT

- 13.1.1 The report shall include the following:
 - 13.1.1 The Bulk Specific Gravity of the specimens.
 - 13.1.2 The compressive strength in pounds per square inch, determined by dividing the maximum vertical load obtained during deformation at the rate specified in section 8 by the original cross-sectional area of the test specimen.
 - 13.1.3 The nominal height and diameter of the test specimens.
 - 13.1.4 The Index of Retained Strength (IRS) for each emulsion content calculated to the nearest integer as calculated in section 10.1.
 - 13.1.5 The air void content (Va) of each dry specimen based on specific gravities determined in Sections 6.1 and 9.1.
 - 11.1.6 Recommended emulsion content as a percent of the dry weight of aggregate.

MATERIALS LABORATORY
ODOT Test Method 316-95

Method of Test for
ADDING ANTI-STRIP ADDITIVES, LIME, or
LATEX POLYMER TO MIX DESIGN SAMPLES

SCOPE

- 1.1 Lime or latex polymer treated aggregate, and/or liquid anti-strip additives in the asphalt may be required to reduce the moisture sensitivity of hot asphalt mixtures. This method describes the procedure for lime or latex polymer treating aggregate in laboratory mixed samples and for adding liquid anti-strip additives to laboratory samples of asphalt.

APPARATUS

- 2.1 An electronic balance with a capacity of at least 1200 grams and sensitive and accurate to 0.1 gram.
- 2.2 Pans, bowls, cans, stirring implements, brushes and other miscellaneous equipment.
- 2.3 Heating oven capable of maintaining a constant temperature in the 140 to 360 degrees F range.

ADDING LIME TO THE SAMPLES

- 3.1 Lime should not be added to the samples until the night before the samples will be mixed with asphalt or sooner.
- 3.2 After batching out aggregate test samples to the proper test size, add the correct mass of dry lime to the aggregate samples. For RAP mixes, the mass of lime should be based on the mass of virgin aggregate only. The correct portion of lime should already have been stored in a closed tin and placed with the aggregate sample.
- 3.3 Using a spoon or spatula, thoroughly stir the lime into the dry aggregate sample.
- 3.4 Add sufficient water to thoroughly wet all the aggregate.
- 3.5 Stir the lime, aggregate and water thoroughly. This should take about five minutes per sample. All the described operations should be done in the container that will go into the oven. Transferring material to different containers may result in a loss of fine material.
- 3.6 Do everything possible to retain all fine material. Spatulas and brushes may be needed to clean the fine material from the implements.

- 3.7 Place the wetted sample of aggregate and lime into the drying oven until the samples are completely dry. Set the oven to the temperature at which the aggregate will be held for mixing.
- 3.8 After the samples are thoroughly dry, proceed with mixing in the normal manner.

ADDING LIQUID ANTI-STRIP ADDITIVES TO MIX DESIGN SAMPLES

- 4.1 Heat sufficient quantities of neat asphalt to make all samples necessary. Samples should be heated to approximately mixing temperatures. This should be done by the procedures normally used for mix preparation.
- 4.2 Heat anti-strip samples to between 110 and 140 degrees F. Read the manufacturer's literature to make sure these temperatures are appropriate.
- 4.3 Obtain a clean mixing/pouring can to combine asphalt and additive into. Tare this can and weigh into it sufficient asphalt to mix test samples.
- 4.4 Calculate the proper amount of liquid anti-strip to be added. Example:

$$0.25\% \text{ anti-strip} \times 850 \text{ grams of asphalt} = 2.1 \text{ grams anti-strip}$$

(The percentage of anti-strip is based on the neat asphalt weight alone.)

- 4.5 Weigh the anti-strip additive into the mix/pour can to the nearest 0.1 gram. Be very cautious with this addition because once it's poured in it is part of the sample.

It is helpful to use a small spoon or stirring rod to introduce the anti-strip into the mix/pour can.

- 4.6 Stir the combined sample thoroughly and replace it in the heating oven until proper mix temperature is reestablished. Be sure to keep the treated sample covered loosely in the oven. If it is uncovered, the volatile additive will escape. If it is covered tightly, the contents may erupt when opened and spill out.
- 4.7 Each time, before weighing the treated asphalt into a mix sample, stir thoroughly again. This is very important.
- 4.8 If you run out of asphalt, repeat the process to treat new samples of asphalt.

ADDING LATEX POLYMER TO MIX DESIGN AGGREGATE SAMPLES

- 5.1 Follow the recommendations of the latex polymer manufacturer when adding this material to mix design aggregate samples.

MATERIALS LABORATORY
ODOT Test Method 318-04

Method of Test for
OPEN GRADED HOT MIX DESIGNS

SCOPE

- 1.1 This test method covers the procedures developed by ODOT for designing open graded hot mixes. The open graded mix design guidelines are found in Section 7 of the CONTRACTOR MIX DESIGN GUIDELINES for ASPHALT CONCRETE. Protocols and procedures for ½” (12.5 mm) and ¾” (19 mm) Open Graded hot mixes are found on pages 17-20, and protocols and procedures for ¾” (19 mm) Asphalt Treated Permeable Base (ATPB) are found on page 21 of this Test Method. Draindown charts are found on pages 22-26.

APPARATUS

- 2.1 Molds used in the testing described in 4.1.2 shall be approximately 5 in. (125 mm) minimum length and approximately 4 in. (102 mm) in diameter. Plungers and other apparatus shall generally conform to equipment described in AASHTO T-167.

PREPARING TEST SPECIMENS

- 3.1 Prepare two compacted Gmb specimens and one draindown sample at 4.5%, 5.5%, and 6.5% asphalt content by weight of total mix for each aggregate gradation. Prepare Gmm samples at 4.5% and 5.5% asphalt content. If lime or liquid antistripping is required, add them according to ODOT TM-316.
- 3.2 Heating Temperature.
- 3.2.1 Heat asphalt cement to 0-36° F (0 - 20° C) above the mixing temperature described in 4.1.1.
- 3.2.2 Heat all aggregates, mixing bowls, molds, and plungers to 0- 72° F (0 - 40° C) above the mixing temperature described in 4.1.1.
- 4.1 Preparation of Mixtures.
- 4.1.1 Weigh into one pan for each batch, the size fractions of each aggregate required to produce three batches for Gmb testing (approximately 3200 - 4000 grams each), three 1000 gm batches for draindown samples and two 2000 gm batches for Gmm samples (eight total batches). An alternate procedure is to batch individual samples to the appropriate mass for each specimen. Place each pan in

an oven and heat to the specified temperature. Charge the heated and buttered mixing bowl with the heated aggregate and dry mix thoroughly with a large spoon. Weigh in the required amount of preheated asphalt for each batch. Allow the mixture to come to the desired mixing temperature corresponding to 800 ± 100 cST on the asphalt temperature / viscosity curve prior to mixing. After one minute of mechanical mixing, all mixes will be quickly hand mixed with a large heated spoon to remove mix from the sides of the bowl. Continue mechanical mixing for another one minute period. Cover the mixing bowl and place in a convection oven heated to a temperature $20 - 35^{\circ}$ F ($12 - 20^{\circ}$ C) above the appropriate compaction temperature for a period of 90 ± 10 minutes. The appropriate compaction temperature is the temperature on the asphalt temperature / viscosity curve corresponding to 1400 ± 200 cST. Do not cure the draindown samples. See Section 6 for the Draindown procedure. After the curing period, remix the mixture by hand before making the test specimens.

4.1.2 Heat the compaction molds and plungers in an oven to the required compaction temperature. Place a paper disc in the bottom of a mold and transfer sufficient mixture to form specimens $4 \pm 0.5''$ (100 ± 12 mm) in height. Insert a calibrated metal stem thermometer to check compaction temperature. Do not allow the thermometer to touch the mold. Spade the mixture with a heated spatula 15 times to reduce voids at the side of the mold. Form the surface of the mix to a slightly mounded shape and cover with a paper disc.

4.2 Compaction of Specimen

4.2.1 Place the charged mold assembly in the compactor. With the top and bottom plungers loosely in place, and the mold temporarily supported on two steel bars, compress the sample under an initial load of about 150 psi (1 Mpa) to set the mixture against the sides of the mold. Hold this load for 15-20 seconds. Remove the support bars to permit full double plunger action and apply the entire molding load of 3000 psi (20.7 Mpa) at a rate that will produce the full load in 30 seconds. Hold the full load for 2 additional minutes.

4.2.2 After compaction, allow the specimens to cool in the mold on their base plate in front of a fan for a minimum of 20 minutes and until they are cool to the touch. Do not try to remove the paper disk until the specimens have cooled (if removal of the disk damages the specimens leave the paper disk attached to the specimen). Leave the specimens in the mold for volume measurements.

DETERMINATION OF UNIT WEIGHT OF COMPACTED ASPHALT SPECIMENS

5.1 Determine specimen bulk specific gravity (G_{mb}) using AASHTO T269. Calculate the geometric G_{mb} value to three decimal places. Do NOT divide the calculated density by 0.99707 to determine bulk specific gravity. Assume the factor is 1.0.

PROCEDURE FOR DETERMINATION OF MAXIMUM SPECIFIC GRAVITY

- 6.1 Determine the theoretical maximum specific gravity (G_{mm}) of the mixture according to AASHTO T209 procedure found in the ODOT Manual of Field Test Procedures, with the following exceptions. Condition the G_{mm} samples in the same manner as the compacted samples. Test a minimum of one sample at a minimum of two asphalt contents. The effective specific gravity of the mix (G_{se}), calculated from the G_{mm} tests must be within 0.012. Calculate an average G_{se} for all samples with G_{se} values within 0.012. Using the average G_{se}, recalculate all G_{mm} values for all subsequent calculations.

DRAINDOWN EVALUATION

- 7.1 Place each draindown sample of the mixture evenly in an 8" by 8" (200 mm by 200 mm) Pyrex dish. Store in a convection oven set at 320° ± 5 F (160° ± 3 C) for a period of 60 ± 2 minutes. Remove the dishes from the oven, cool in front of a fan for 45 minutes or longer and invert the Pyrex dish and mixture. Evaluate the percent draindown by comparing the bottom of the dishes to standard charts on pages 22-26 of this document.
- 7.2 As an alternate to 7.1, the NCAT draindown procedure may be used. If the NCAT procedure is used, the maximum draindown allowed at the design asphalt content is 0.3% of the mass of the mix. The NCAT draindown procedure is described in AASHTO T 305-97.

OPEN GRADED MIX DESIGN CALCULATIONS

- 8.1 Calculate V_a, VMA, and VFA using the equations in ODOT TM 330-04, Section 10.5.1.

CHOOSING THE OPEN GRADED DESIGN ASPHALT CONTENT

- 9.1 Plot the test results for bulk specific gravity (G_{mb}), air voids, Draindown and VFA versus asphalt content.
- 9.2 The design asphalt content reported to the nearest 0.1 percent shall be the percent asphalt determined from the ODOT draindown test as near the center of the specified range as possible and at which the air voids and VFA meet the specification requirements.
- 9.3 If the NCAT draindown procedure is used, the design asphalt content reported to the nearest 0.1 percent shall be the percent asphalt at the highest draindown percentage not exceeding 0.3% that is within the specified range for air voids and VFA.

OPEN GRADED MIX DESIGN REPORT

- 10.1 Submit a mixture design report including the following information:
 - 10.1.1 Gradation of the final blend.
 - 10.1.2 Final asphalt content chosen.
 - 10.1.3 Brand, grade, specific gravity @ 77/77 (25/25) and 60/60 (15.6/15.6), mixing and compaction temperatures for the asphalt used in testing. Identify any antistrip additives in the asphalt.
 - 10.1.4 Test results determined at 4.5%, 5.5%, and 6.5% asphalt for the mixture voids, VMA, VFA, and draindown.
 - 10.1.5 Worksheets for mixture bulk specific gravity (Gmb), mixture maximum gravity (Gmm), and aggregate specific gravity (Gsb) for each aggregate component.
- 10.2 Provide the TSR data from a surrogate dense graded mixture. If a dense graded JMF has been prepared for the same material sources in the last year, the results for the most recent TSR may be applied to the open graded mixture. If not, prepare TSR samples for a dense graded mix using the equivalent top size stone and materials from the same sources, which will represent the open graded mix.

3/4" (19 MM) ASPHALT TREATED PERMEABLE BASE (ATPB)

11.1 For ATPB mix, the only parameter measured is percent asphalt coating by visual evaluation. Prepare and evaluate the mix based on the following procedure.

11.1.1 Prepare three mix samples according to Sections 4.1.1 and 7.1 as if the samples were for the draindown test, WITH TWO EXCEPTIONS. The mix samples are prepared at 2.5%, 3.0 %, and 3.5 % asphalt content and after placing the samples in the Pyrex dishes they are not cured in an oven, but are allowed to cool.

11.1.2 By visual inspection, estimate the percent of the mass of the mix that is fully coated. Record this percentage for each sample.

Evaluation

11.2 The design asphalt content is defined as the percentage of asphalt to the nearest 0.1% at which the mix is judged to be 90% coated. If all three samples are judged to be above 90% coating, then 2.5% is the design asphalt content.

Report

11.3 JMF: Show to the nearest whole percent except for the No. 200 (0.075 mm) sieve and asphalt cement, which shall be recorded to the nearest 0.1 percent.

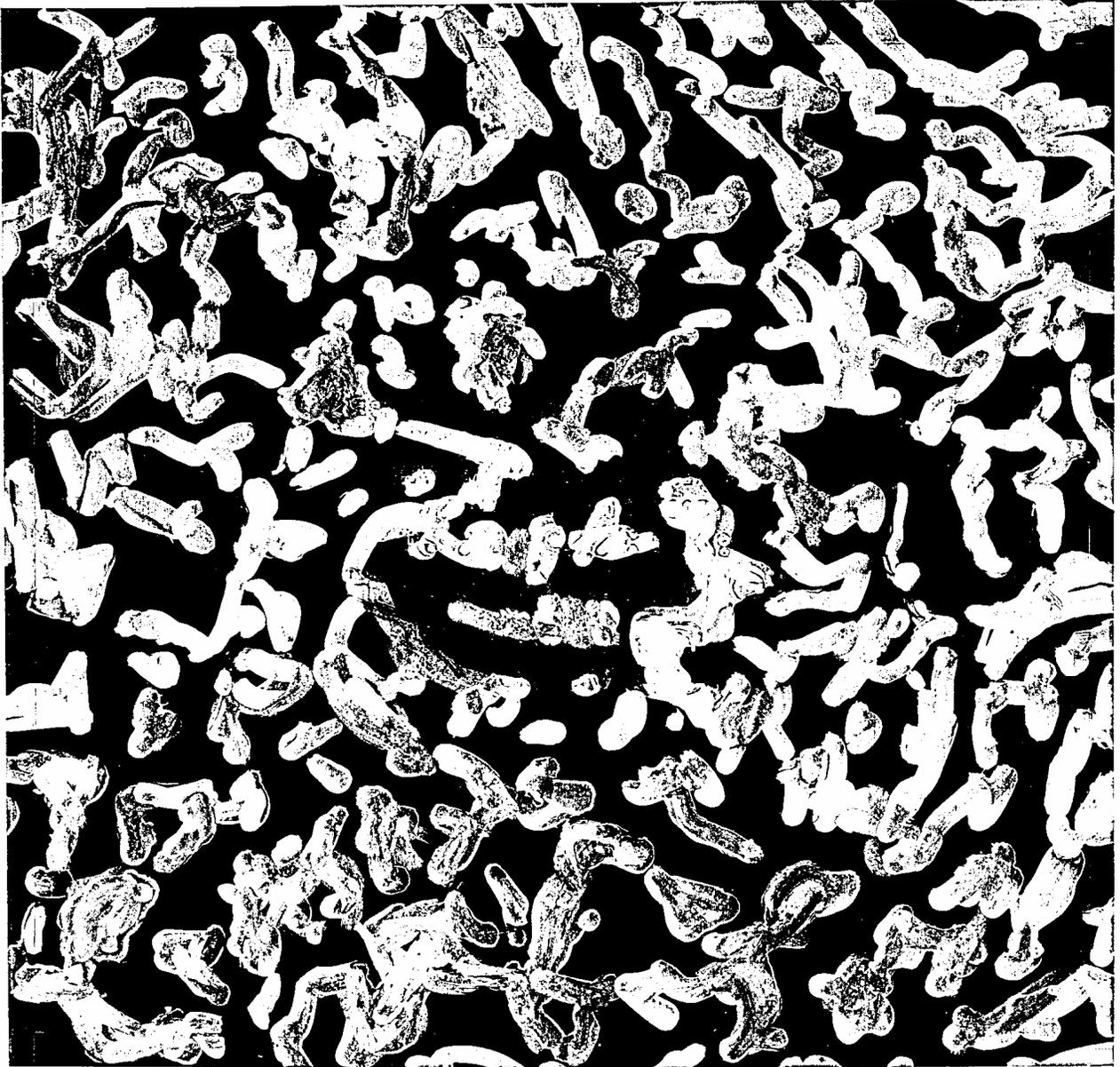
Aggregate gradation:

<u>Sieve</u>	<u>Percent Passing</u>
1" (25 mm)	
3/4" (19 mm)	
1/2" (12.5 mm)	
3/8" (9.5 mm)	
No. 4 (4.75 mm)	
No. 8 (2.36 mm)	
No. 30 (0.60 mm)	
No. 200 (0.075 mm)	

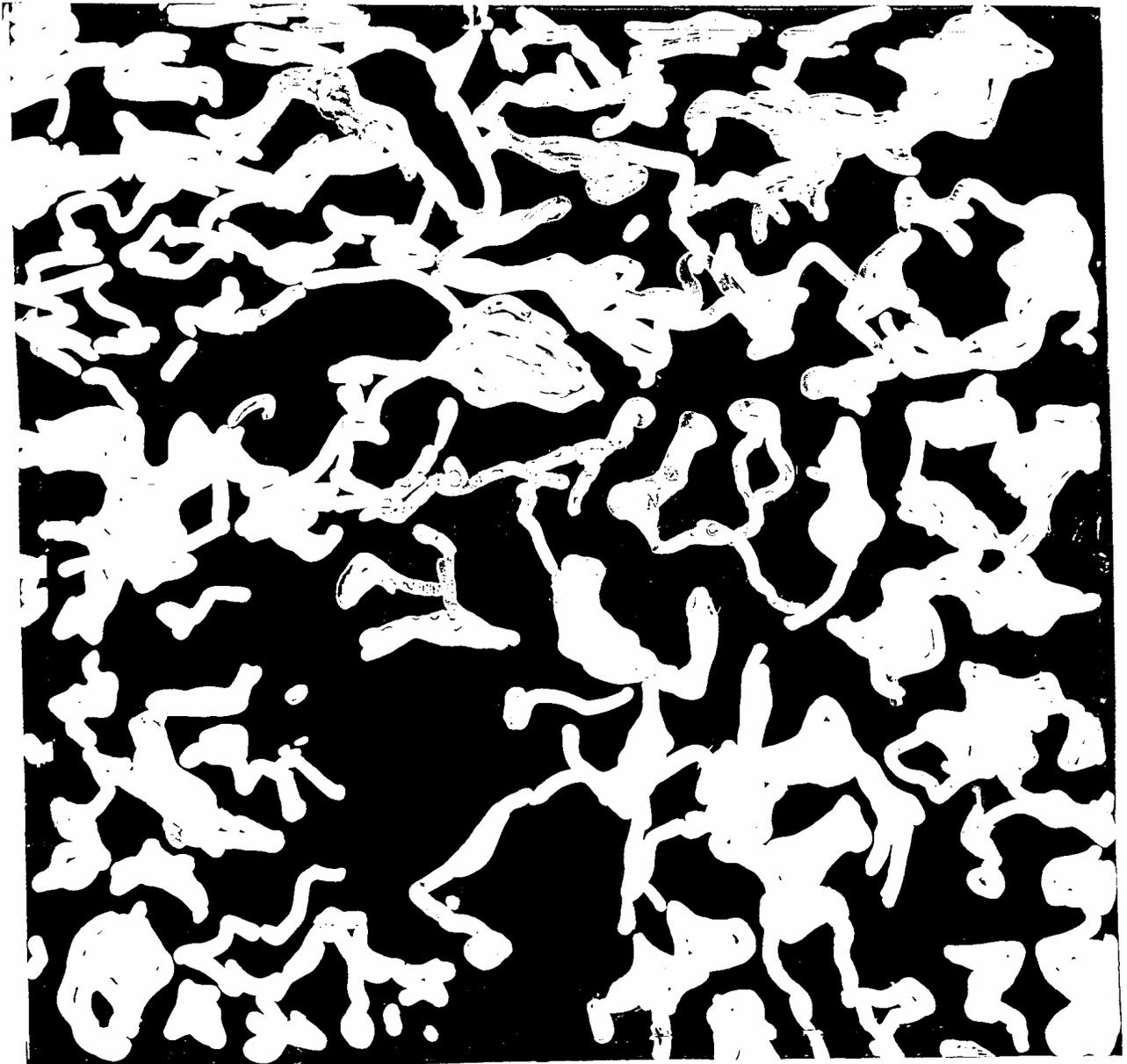
Target asphalt content, percent

Percent coating at each asphalt content

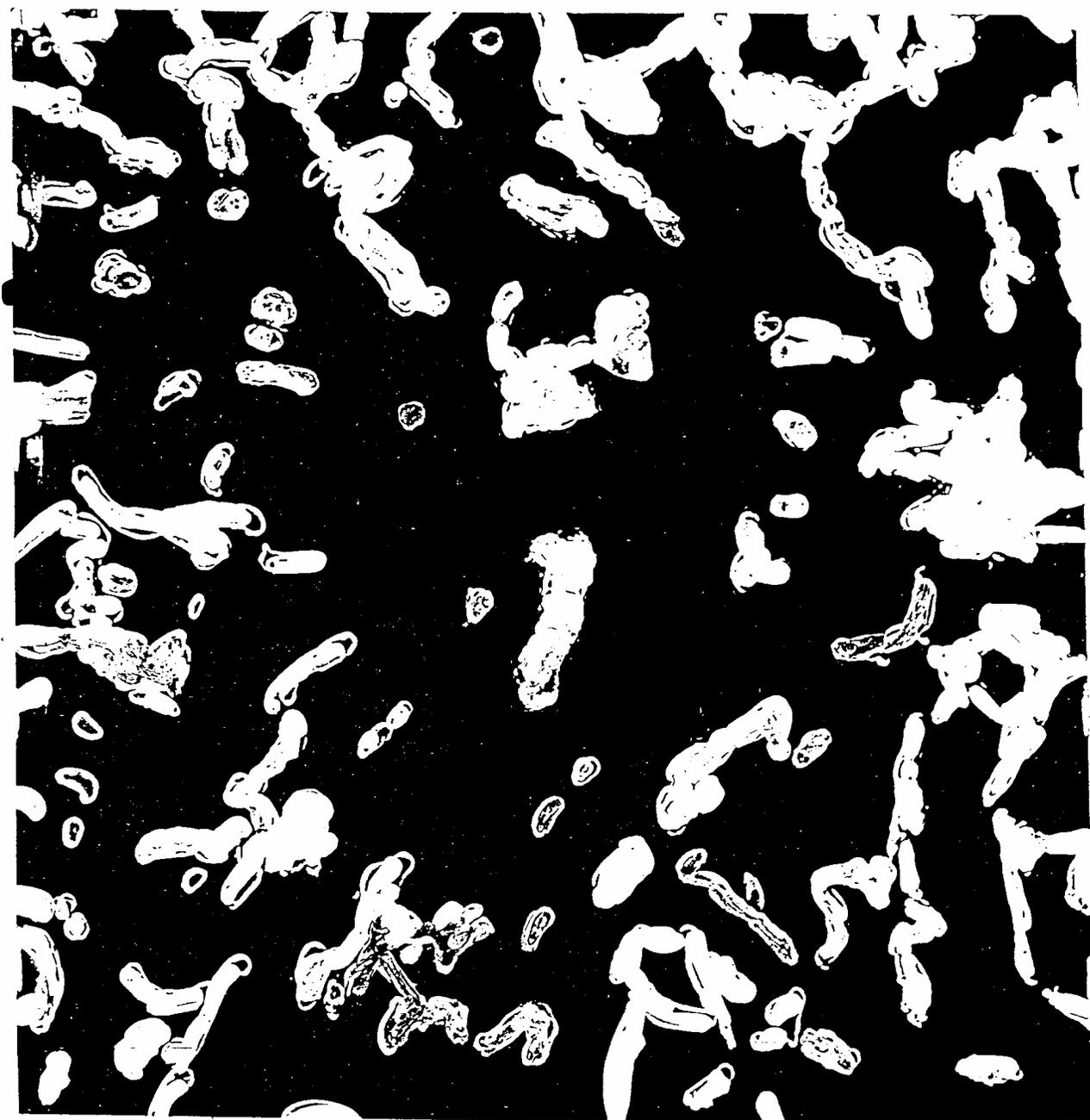
DRAINDOWN CHARTS FOR ODOT TM 318



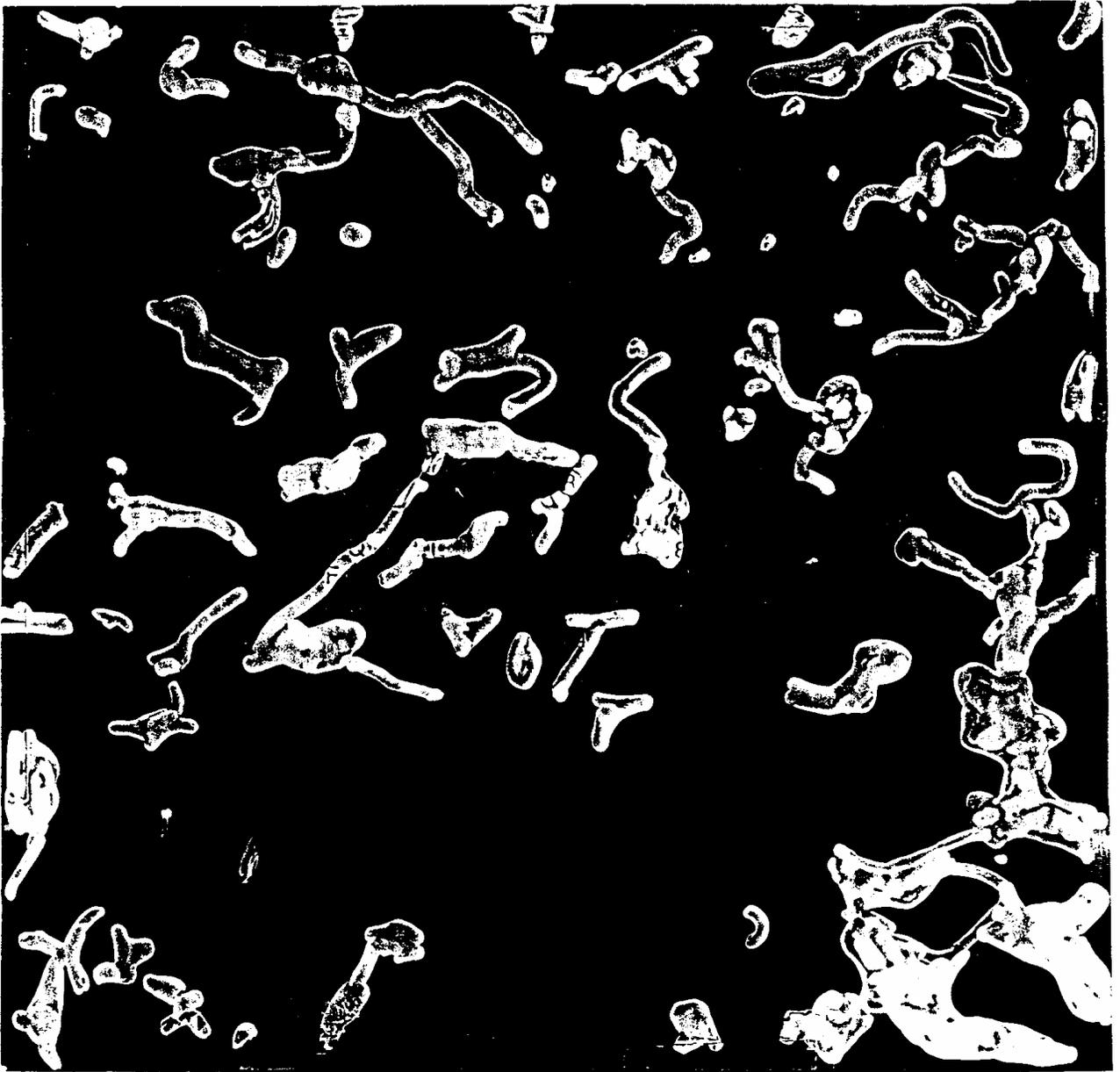
50 %



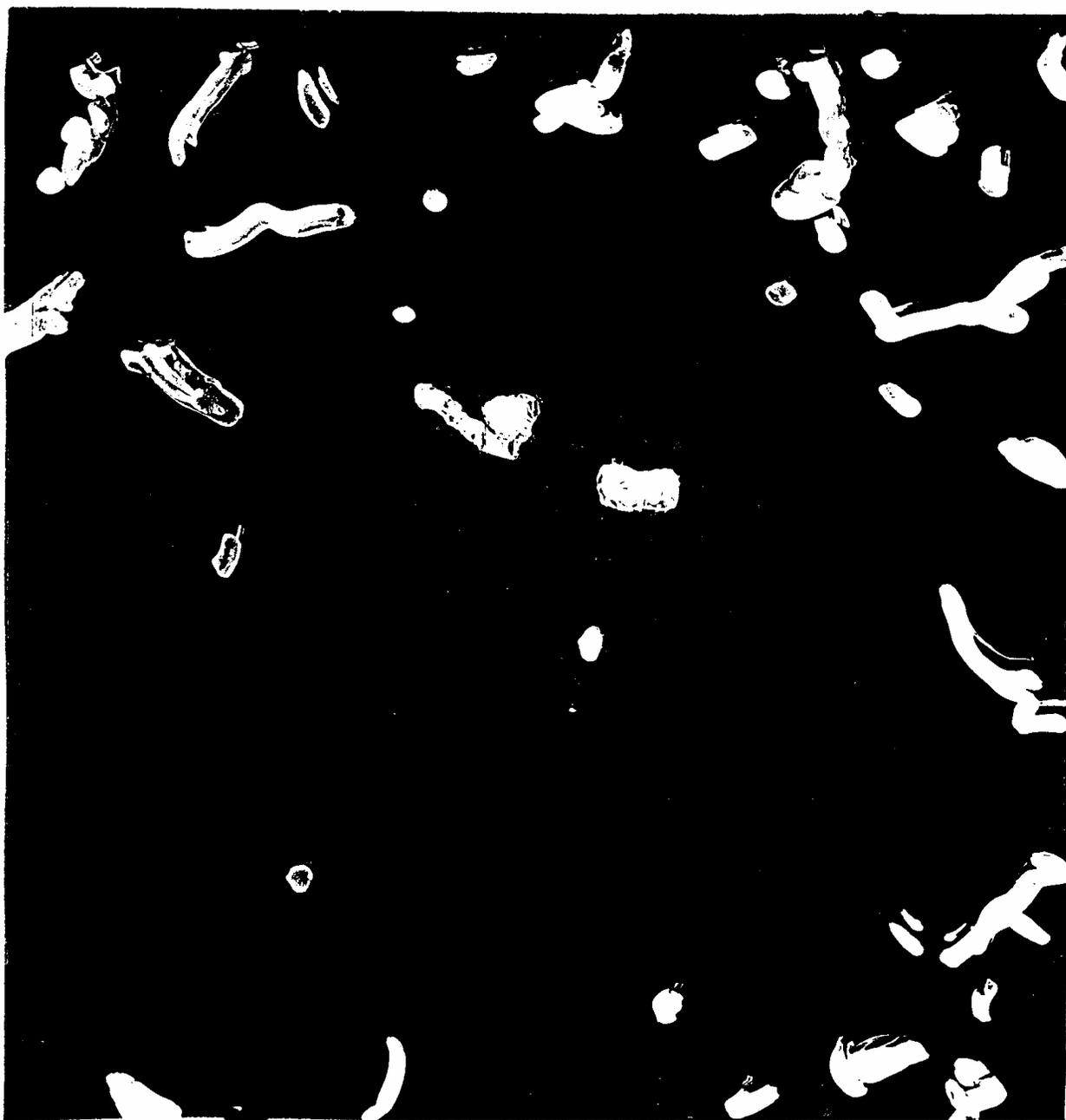
60 %



70 %



80 %



90 %

Standard Practice for
Superpave Volumetric Mix Design
For Dense Graded HMAC
ODOT TM 330-04

(A Modification of AASHTO R35-04)

1. SCOPE

- 1.1. This standard for mix design evaluation uses aggregate and mixture properties to produce a hot-mix asphalt (HMA) job-mix formula. The mix design is based on the volumetric properties of the HMA in terms of the air voids, voids in the mineral aggregate (VMA), and voids filled with asphalt (VFA).
- 1.2. This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this procedure to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. REFERENCED DOCUMENTS

2.1 AASHTO Standards:

- M320, Performance-Graded Asphalt Binder
- M323, Superpave Volumetric Mix Design
- R30, Mixture Conditioning of Hot-Mix Asphalt (HMA)
- T 2, Sampling of Aggregates
- T 11, Materials Finer Than 75- μ m (No. 200) Sieve in Mineral Aggregates by Washing
- T 27, Sieve Analysis of Fine and Coarse Aggregates
- T 84, Specific Gravity and Absorption of Fine Aggregate
- T 85, Specific Gravity and Absorption of Coarse Aggregate
- T 100, Specific Gravity of Soils
- T 166, Bulk Specific Gravity of Compacted Asphalt Mixtures Using Saturated Surface-Dry Specimens
- T 209, Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures
- T 228, Specific Gravity of Semi-Solid Bituminous Materials
- T 248, Reducing Samples of Aggregate to Testing Size
- T 275, Bulk Specific Gravity of Compacted Bituminous Mixtures Using Paraffin Coated Specimens

- T 283, Resistance of Compacted Asphalt Mixture to Moisture-Induced damage
- T 312, Preparing and Determining the Density of Hot-Mix Asphalt (HMA) Specimens by Means of the Superpave Gyratory Compactor

2.2. Asphalt Institute Standards:

- MS-2, Mix Design Methods for Asphalt Concrete and Other Hot-Mix Types
- SP-2, Superpave Mix Design

2.3 ODOT Standards

- Manual of Field Test Procedures – ODOT TM 326 Preparation of Field Compacted Gyratory Specimens
- Supplemental Test Procedures for HMAC and EAC
- 2002 Oregon Standard Specifications for Construction

3. TERMINOLOGY

3.1. *HMAC* – hot-mix asphalt concrete.

3.2 *Design ESALs* – design equivalent (18,000 lb.) single-axle loads.

3.2.1 *Discussion* – design ESALs are the anticipated project traffic level expected on the design lane over a 20-year period. For pavements designed for more or less than 20 years, determine the design ESALs for 20 years when using this standard.

3.3 *Air voids (Va)* – the total volume of the small pockets of air between the coated aggregate particles throughout a compacted paving mixture, expressed as a percent of the bulk volume of the compacted paving mixture (Note 1).

NOTE 1 – Term defined in Asphalt Institute Manual MS-2, Mix Design Methods for Asphalt Concrete and Other Hot-Mix Types.

3.4 *Void in the mineral aggregate (VMA)* – the volume of the intergranular void space between the aggregate particles of a compacted paving mixture that includes the air voids in the effective binder content, expressed as a percent of the total volume of the specimen (Note 1).

3.5 *Absorbed binder volume (Vba)* – the volume of binder absorbed into the aggregate (equal to the difference in aggregate volume when calculated with the bulk specific gravity and effective specific gravity).

3.6 *Binder content (Pb)* – The percent by mass of binder in the total mixture including binder and aggregate.

- 3.7 *Effective binder volume (Vbe)* – The volume of binder which is not absorbed into the aggregate.
- 3.8 *Voids filled with asphalt (VFA)* – the percentage of the voids in the mineral aggregate (VMA) filled with binder (the effective binder volume divided by the VMA).
- 3.9 *Dust-to-binder ratio (P200/Pbe)* – by mass, ratio between percent passing the No. 200 (0.075 mm) sieve (P200) and the effective binder content (Pbe).
- 3.10 *Nominal maximum aggregate size* – one size larger than the first sieve that retains more than 10 percent aggregate (Note 2).

NOTE 2 - The definitions given in Sections 3.10 and 3.11 apply to Superpave mixes only and differ from the definitions published in other AASHTO standards.

- 3.11 *Maximum aggregate size* – one size larger than the nominal maximum aggregate size (Note 2).
- 3.12 *Reclaimed asphalt pavement (RAP)* – removed and/or processed pavement materials containing asphalt binder and aggregate.
- 3.13 *Primary Control Sieve (PCS)* – The sieve defining the break point between fine and coarse-graded mixtures for each nominal maximum aggregate size.

4. SUMMARY OF THE PRACTICE

- 4.1 *Materials Selection* – Binder, aggregate and RAP stockpiles are selected that meet the environmental and traffic requirements applicable to the paving project. The bulk specific gravity of all aggregates proposed for blending and the specific gravity of the binder are determined.
- 4.2 *Design Aggregate Structure (Stage 1)* – At least three trial aggregate blend gradations from selected aggregate stockpiles are blended. For each trial gradation, an initial trial binder content is determined, and at least two specimens are compacted in accordance with T 312. A design aggregate structure and an estimated design binder content are selected on the basis of satisfactory conformance of a trial gradation meeting the requirements given in Section 745.13 of the ODOT Specifications for Va, VMA, VFA, dust-to-binder ratio at N_{design} , and relative density at N_{initial} . **Stage 1 is optional for projects under Spec. Section 00744.**
- 4.3 *Design Binder Content Selection* – Replicate specimens are compacted in accordance with T 312 at the estimated design binder content and at the estimated design binder content ± 0.5 percent and $+ 1.0$ percent. As an alternate procedure, prepare four sets of replicate specimens, two sets above and two sets below the estimated design binder content. The design binder content is selected on the basis of satisfactory conformance

with the requirements of Specification Section 745.13 for Va, VMA, VFA, and dust-to-binder ratio at N_{design} , and the relative density at N_{initial} .

- 4.4 *Evaluating Moisture Susceptibility* (Stage 3) – The moisture susceptibility of the design aggregate structure is evaluated at the design binder content according to AASTHO T 283 as modified in the ODOT Manual of Field Test Procedures.

5. SIGNIFICANCE AND USE

- 5.1 The procedure described in this practice is used to produce HMAC that satisfies Superpave HMAC volumetric mix design requirements.

6. PREPARING AGGREGATE TRIAL BLEND GRADATIONS

- 6.1 Obtain the binder specified in the Contract bid items.
- 6.2 Determine the specific gravity at 77 F (25 C) of the binder according to T 228, or obtain the specific gravity from the manufacturer.
- 6.3 Obtain samples of aggregates proposed for use on the project from the aggregate stockpiles in accordance with T2. Obtain crushing records for each stockpile produced per Section 745.10(f) of the ODOT Specifications.

NOTE 3 - Each stockpile usually contains a given size of an aggregate fraction. Most projects employ three to five stockpiles to generate a combined gradation conforming to the job-mix formula and M323.

- 6.4 Reduce the samples of aggregate fractions according to T 248 to samples of the size specified in T 27.
- 6.5 Wash and grade each aggregate sample according to T 11 and T 27.
- 6.6 Determine the bulk and apparent specific gravity for each coarse and fine aggregate fraction in accordance with T 85 and T 84, respectively, and determine the specific gravity of the mineral filler in accordance with T 100. Mechanical devices approved by AASHTO may be used to determine fine aggregate specific gravity.
- 6.7 Blend the aggregate fractions using Equation 1:

$$P = Aa + Bb + Cc, \text{ etc.} \quad (1)$$

Where:

P = Percentage of material passing a given sieve for the combined aggregates A, B, C, etc.;

A, B, C, etc. = Percentage of material passing a given sieve for aggregates A, B, C, etc.; and

a, b, c, etc. = Decimal proportions of aggregates A, B, C, etc. used in the combinations, and where the total = 1.00.

6.8 Prepare a minimum of three trial aggregate blends and confirm per AASHTO T27/T11 that each trial blend meets gradation controls in ODOT Specification Section 745.12. Gradation control is based on four control sieve sizes: the sieve for the maximum aggregate size, the sieve for the nominal maximum aggregate size, the No. 4, or No. 8 sieve, and the No. 200 sieve. The difference between the three trial blends must be a minimum of **3 percent** passing the No. 8 (2.36 mm) sieve. If aggregate from two or more sources will be used in the mix, be certain to use the aggregate from each source in the proper proportions when blending trial samples.

If lime treated aggregate is required by the Contract, add lime according to ODOT TM 316. If bag house fines will be incorporated into the mix, it is advisable to include the bag house fines, in approximately the anticipated proportions, into the trial blends.

NOTE: When batching test samples, account for the difference of the pass 0.075 mm material between AASHTO T27/T11 test results. The final reported gradation of the sample must be based on AASHTO T 27/T 11.

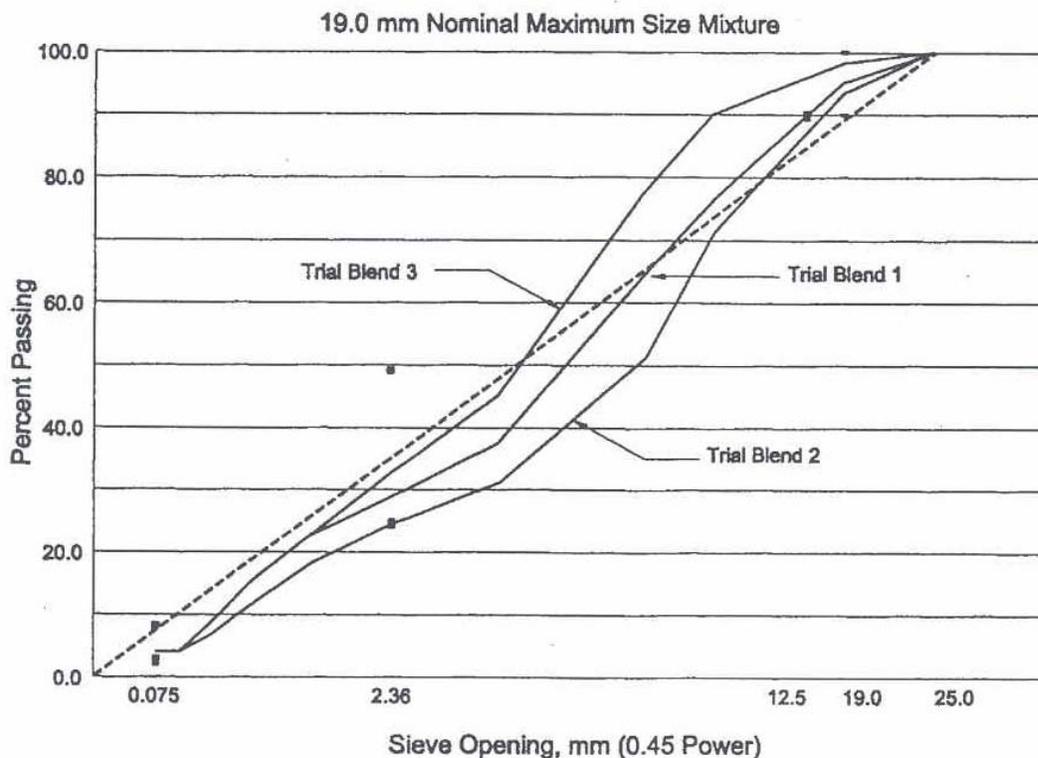


Figure 1 – Evaluation of the Gradations of Three Trial Blends (Example)

7. DETERMINING AN INITIAL TRIAL BINDER CONTENT FOR EACH TRIAL AGGREGATE GRADATION

Designers can either use their experience with the materials or the procedure given in Appendix A1, AASHTO R35-04 to determine an initial trial binder content for each trial aggregate blend gradation.

NOTE 4 – When using RAP, the initial trial asphalt content should be reduced by an amount equal to that provided by the RAP.

8. COMPACTING SPECIMENS OF EACH TRIAL GRADATION

- 8.1 Prepare replicate mixtures (Note 5) at the initial trial binder content for each of the chosen trial aggregate trial blend gradations. **Trial blends are optional for mixes specified under Section 00744.** Binder contents may be unique to each trial blend or the same binder content for all trial blends. Refer to ODOT Specification Section 745.13 for the proper number of gyrations for the specified level of HMAC. These gyrations are designated “ N_{design} ”.

NOTE 5 – At least two replicate specimens are required, but three or more may be prepared if desired. Average the test results. Generally, 4500 to 4700 g of aggregate is sufficient for each compacted specimen with a height of 110 to 120 mm for aggregates with combined bulk specific gravities of 2.55 to 2.70, respectively.

- 8.2 Condition the mixtures according to R 30, Section 1 – 7.1.4, and compact the specimens to N_{design} gyrations in accordance with ODOT TM 326. Record the specimen height to the nearest 0.1 mm after each revolution.
- 8.3 Determine the bulk specific gravity (G_{mb}) of each of the compacted specimens in accordance with T 166 or T 275 as appropriate.
- 8.4 Determine the theoretical maximum specific gravity (G_{mm}) according to T 209 of separate samples representing each of these combinations that have been mixed and conditioned to the same extent as the compacted specimens. Use the “dryback” procedures in T 209 for the trial blends, if there is no HMAC experience with the aggregate source or if asphalt absorption has exceeded 1.5% in previous mix designs.

9. EVALUATING COMPACTED TRIAL MIXTURES

- 9.1 Determine the volumetric requirements for the trial mixtures in accordance with ODOT Specification Section 745.13. When calculating the percent of G_{mm} at N_{initial} in Section 9.3.5, N_{initial} is at 7 gyrations for level 2 mix, 8 gyrations for level 3 mix, and 9 gyrations for level 4 mix.

If the “dryback” procedure was used per Section 8.4, calculate P_{ba} with both the “dryback” and standard procedure. If the standard procedure results in a P_{ba} of 1.5% or

greater, use the “dryback” results for all calculation. Note on the mix design report that the “dryback” procedure was used.

9.2 Calculate V_a and VMA at N_{design} for each trial mixture using Equations 2 and 3:

$$V_a = 100 \times (G_{\text{mm}} - G_{\text{mb}}) / G_{\text{mm}} \quad (2)$$

$$\text{VMA} = 100 - (G_{\text{mb}} \times P_s / G_{\text{sb}}) \quad (3)$$

Where:

G_{mb} = bulk specific gravity of the extruded specimen;
 G_{mm} = theoretical maximum specific gravity of the mixture
 P_s = percent of aggregate in the mix (100-Pb); and
 G_{sb} = bulk specific gravity of the combined aggregate.

NOTE 6 – Although the initial trial binder content was estimated for a design air void content of 4.0 percent, the actual air void content of the compacted specimen is unlikely to be exactly 4.0 percent. Therefore, the change in binder content needed to obtain a 4.0 percent air void content, and the change in VMA caused by this change in binder content, is estimated. These calculations permit the evaluation of VMA and VFA of each trial aggregate gradation at the same design air void content, 4.0 percent.

9.3 Estimate the volumetric properties at 4.0 percent air voids for each compacted specimen.

9.3.1 Determine the difference in average air void content at N_{design} (ΔV_a) of each aggregate trial blend from the design level of 4.0 percent using Equation 4:

$$\Delta V_a = 4.0 - V_{a \text{ trial}} \quad (4)$$

where:

$V_{a \text{ trial}}$ = air void content of the aggregate trial blend at N_{design} gyrations.

9.3.2 Estimate the change in binder content (ΔP_b) needed to change the air void content to 4.0 percent using Equation 5.

$$\Delta P_b = -0.4 (\Delta V_a) \quad (5)$$

9.3.3 Estimate the change in VMA (ΔVMA) caused by the change in the air void content (ΔV_a) determined in Section 9.3.1 for each trial aggregate blend gradation, using Equation 6 or 7.

$$\Delta \text{VMA} = 0.2 (\Delta V_a) \text{ if } V_a > 4.0 \quad (6)$$

$$\Delta \text{VMA} = 0.1 (\Delta V_a) \text{ if } V_a < 4.0 \quad (7)$$

NOTE 7 – A change in binder content affects the VMA through a change in the bulk specific gravity of the compacted specimen (G_{mb}).

- 9.3.4 Calculate the VMA for each aggregate trial blend at N_{design} gyrations and 4.0 percent air voids using Equation 8.

$$VMA_{4.0} = VMA_{trial} + \Delta VMA \quad (8)$$

where:

$VMA_{4.0}$ = VMA estimated at a design air void content of 4.0 percent; and

VMA_{trial} = VMA determined at the initial trial binder content.

- 9.3.5 Using the values of ΔV_a determined in Section 9.3.1 and Equation 9, estimate the relative density of each specimen at $N_{initial}$, when the design air void content is adjusted to 4.0 percent at N_{design} :

$$\%G_{mm,initial} = 100 \times (G_{mb}h_{des} / G_{mm}h_i) - \Delta V_a \quad (9)$$

where:

$\%G_{mm,initial}$ = relative density at $N_{initial}$ gyrations at the adjusted design binder content;

h_{des} = height of the specimen after N_{design} gyrations, from the Superpave gyratory compactor, mm; and

h_i = height of the specimen after $N_{initial}$ gyrations, from the Superpave gyratory compactor, mm

- 9.3.6 Estimate the percent of effective binder ($P_{be\ 4.0}$) and calculate the dust-to-binder ratio (P_{200} / P_{be}) for each trial blend using Equations 10 and 11:

$$P_{be\ 4.0} = - (P_{s\ 4.0} \times G_b) \frac{(G_{se} - G_{sb})}{(G_{se} \times G_{sb})} + P_{b\ 4.0} \quad (10)$$

where:

$P_{be\ 4.0}$ = estimated effective binder content @ 4.0 V_a
 $P_{s\ 4.0}$ = aggregate content (100- $P_{b\ 4.0}$),
 G_b = specific gravity of the binder,
 G_{se} = effective specific gravity of the aggregate,
 G_{sb} = bulk specific gravity of the combined aggregate, and
 $P_{b\ 4.0}$ = estimated binder content.

$$P_{200}/P_{be} = P_{200 \text{ trial}} / P_{be 4.0} \quad (11)$$

where:

P_{200} = percent passing the No. 200 (0.075 mm) sieve.

NOTE 8 – If removal of passing No. 200 material at the paving plant is anticipated, use the actual percentage of passing No. 200 material included in test samples to calculate dust to asphalt ratio.

- 9.3.7 Compare the estimated volumetric properties from each trial aggregate blend gradation at the adjusted design binder content with the criteria specified in the ODOT Specification Section 745.13. Choose the trial aggregate blend gradation that best satisfies the volumetric criteria.

Generally, the best trial blend to choose is the blend that is near the center of the VFA specification range and approximately 1% above the minimum VMA at 4.0% voids. The chosen blend should also be safely below the maximum allowed dust to effective asphalt ratio. If all volumetric properties are satisfactory for more than one blend, then the blend requiring the lowest percentage of asphalt is desirable for economic reasons.

Table 2 – Selection of a Design Aggregate Structure (Example)

Volumetric Property	Trial Mixture (19.0-mm Nominal Maximum Aggregate) 20-Year Project Design ESALs = 5 million			Criteria
	1	2	3	
	At the Initial Trial Binder Content			
P_b (trial)	4.4	4.4	4.4	
% $G_{mm(2.0)}$ (trial)	88.1	87.8	87.1	
% $G_{mm(7.5)}$ (trial)	95.9	95.3	94.7	
V_a at N_{design}	4.1	4.7	5.3	4.0
VMA _{trial}	12.9	13.4	13.9	
Adjustments to Reach Design Binder Content ($V_a = 4.0\%$ at N_{design})				
ΔV_a	-0.1	-0.7	-1.3	
ΔP_b	0.0	0.3	0.5	
ΔVMA	0.0	-0.1	-0.3	
At the Estimated Design Binder Content ($V_a = 4.0\%$ at N_{design})				
Estimated P_b (design)	4.4	4.7	4.9	
VMA (design)	12.9	13.3	13.6	> 13.0
% $G_{mm(2.0)}$ (design)	88.2	89.5	88.4	< 89.0

Notes:

- The top portion of this table presents measured densities and volumetric properties for specimens prepared for each aggregate trial blend.
- None of the specimens had an air void content of exactly 4.0 percent. Therefore, the procedures described in Section 9 must be applied to: (1) estimate the design binder content at which $V_a = 4.0$ percent, and (2) obtain adjusted VMA and relative density values at this estimated binder content.

3. The middle portion of this table presents the change in binder content (ΔP_b) and VMA (ΔVMA) that occurs when the air void content (V_a) is adjusted to 4.0 percent for each trial aggregate blend gradation.
4. A comparison of the VMA and densities at the estimated design binder content to the criteria in the last column shows that trial aggregate blend gradation No. 1 does not have sufficient VMA (12.9 percent versus a requirement of >13.0 percent). Trial blend No. 2 exceeds the criterion for relative density at $N_{initial}$ gyrations (89.6 percent versus requirement of ≤ 89.0 percent). Trial blend No. 3 meets the requirements for relative density and VMA and, in this example, is selected as the design aggregate structure.

10. SELECTING THE DESIGN BINDER CONTENT

- 10.1 Prepare replicate mixtures (Note 8) containing the selected design aggregate structure at each of the following four binder contents: (1) the estimated design binder content, P_b (design); (2) 0.5 percent below P_b (design); (3) 0.5 percent above P_b (design); and (4) 1.0 percent above P_b (design). As an alternate procedure, prepare four sets of replicate samples, two sets above and two sets below the estimated design asphalt content, P_b (design).
 - 10.1.1 At the same time the samples in 10.1 are batched to determine the Design Binder Content, batch an additional sample of the selected blend. Verify the accuracy of the blend gradation by testing this additional sample according to AASHTO T11 and T 27. Report the test results with the mix design data. For RAP mixes, remove the asphalt from the appropriate mass of RAP by incineration or solvent extraction and add the uncoated RAP aggregate to the virgin aggregate prior to gradation testing. Alternately, a test sample of mix including RAP can be incinerated or extracted with solvent to obtain an aggregate sample for gradation verification.
 - 10.1.2 Use the number of gyrations previously determined in Section 8.1.
- 10.2 Condition the mixtures according to R 30, Section 1 through 7.1.4, and compact the specimens to N_{design} gyrations according to T 312, to the number of gyrations noted in Section 8.1. Record the specimen height to the nearest 0.1 mm after each revolution.
- 10.3 Determine the bulk specific gravity of each of the compacted specimens in accordance with T 166 or T 275 as appropriate, according to the ODOT Manual of Field Test Procedures (MFTP).
- 10.4 Determine the theoretical maximum specific gravity (G_{mm}) of the mixture according to the AASHTO T 209 procedures found in the ODOT MFTP, with the following exceptions. Condition samples in the same manner as the compacted specimens (Section 8.2). Test a minimum of one sample at a minimum of two asphalt contents.

If it was determined in Section 9.1 that the “dryback” procedure is required, use the dryback procedure for G_{mm} samples in determining the design binder content and all subsequent calculations.

The effective specific gravity of the mix (G_{se}), calculated from the G_{mm} tests must be within 0.012. Calculate an average G_{se} for all samples with G_{se} values with 0.012.

Using the average G_{se} , recalculate all G_{mm} values and use the recalculated G_{mm} values for all subsequent calculations.

10.5 Determine design binder content that produces a target air void content (V_a) of 4.0 percent of N_{design} gyrations using the following steps:

10.5.1 Calculate V_a , VMA, and VFA at N_{design} using Equations 2, 3, 12.

$$VFA = 100 \times (VMA - V_a) / VMA \quad (12)$$

10.5.2 Calculate the dust-to-binder ratio, using Equation 13.

$$P_{200}/P_{be} = \frac{P_{200}}{P_{be}} \quad (13)$$

where:

P_{be} = effective binder content.

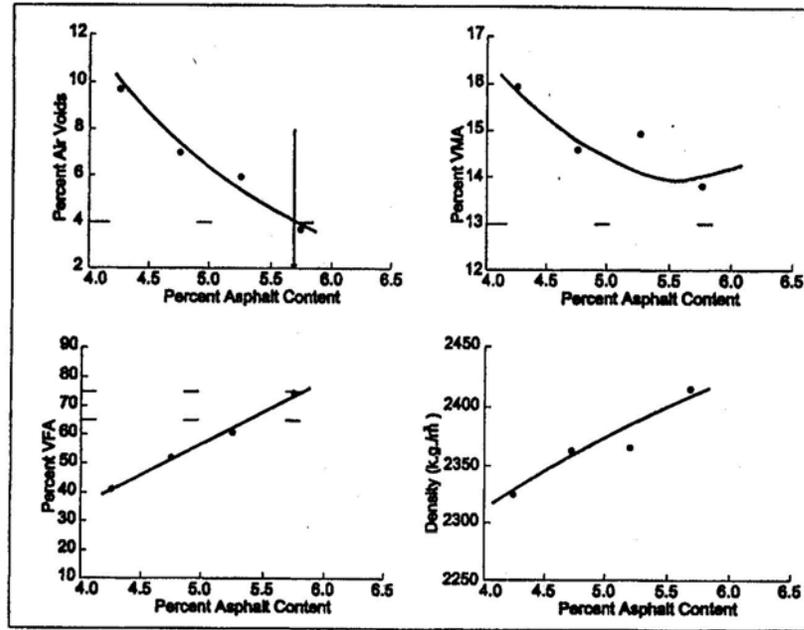
10.5.3 For each of the mixtures, determine the corrected specimen relative densities at $N_{initial}$ ($\%G_{mm-initial}$), using Equation 14.

$$\%G_{mm-initial} = 100 \times \frac{G_{mbh_{des}}}{G_{mmh_i}} \quad (14)$$

10.5.4 OPTIONAL: Plot the average V_a , VMA, VFA, and relative density at N_{design} for replicate specimens versus binder content.

10.5.5 By graphical or mathematical interpolation, determine the binder content to the nearest 0.1 percent at which the target V_a is equal to 4.0 percent or the specified percent. This is the design binder content (P_b) at N_{design} .

10.5.6 By interpolation (Figure 2), verify that the volumetric requirements specified in Section 745.13 of the ODOT Specifications are met at the design binder content.



Average V_a , VMA, VFA, and Relative Density at N_{design}

P_b (%)	V_a (%)	VMA (%)	VFA (%)	Density at N_{design} (kg/m ³)
4.3	9.5	15.9	40.3	2320
4.8	7.0	14.7	52.4	2366
5.3	6.0	14.9	59.5	2372
5.8	3.7	13.9	73.5	2412

- Notes:
1. In this example, the estimated design binder content is 4.8 percent; the minimum VMA requirement for the design aggregate structure (19.0-mm nominal maximum size) is 13.0 percent, and the VFA requirement is 65 to 75 percent.
 2. Entering the plot of percent air voids versus percent binder content at 4.0 percent air voids, the design binder content is determined as 5.7 percent.
 3. Entering the plots of percent VMA versus percent binder content and percent VFA versus percent binder content at 5.7 percent binder content, the mix meets the VMA and VFA requirements.

Figure 2 – Sample Volumetric Design Data at N_{design}

11. EVALUATING MOISTURE SUSPCEPTIBILITY

- 11.1 Test the specimens and calculate the tensile strength ratio in accordance with AASHTO T 283 as described in the ODOT Manual of Field Test Procedures (MFTP).
- 11.2 If the tensile strength ratio is less than 80, as required in Section 00745.13 of the ODOT Specifications, remedial action such as the use of anti-strip agents is required to improve the moisture susceptibility of the mix. When remedial agents are used to modify the binder, retest the mix to assure compliance with the 80 minimum requirement.

12. ADJUSTING THE MIXTURE TO MEET PROPERTIES

- 12.1 *ADJUSTING VMA* – If a change in the design aggregate skeleton is required to meet the specified VMA, there are three likely options: (1) change the gradation (Note 9); (2) reduce the passing No. 200 (0.075-mm) fraction (Note 10); or (3) change the surface texture and/or shape of one or more of the aggregate fractions (Note 11).

NOTE 9 – Changing gradation may not be an option if the trial aggregate blend gradation analysis includes the full spectrum of the gradation control area.

NOTE 10 – Reducing the percent passing the No. 200 (0.075-mm) sieve of the mix will typically increase the VMA. If the percent passing the No. 200 (0.075mm) sieve is already low, this is not a viable option.

NOTE 11 – This option will require further processing of existing materials or a change in aggregate sources.

- 12.2 *Adjusting VFA* – The lower limit of the VFA range should always be met at 4.0 percent air voids if the VMA meets the requirements. If the upper limit of the VFA is exceeded, then the VMA is substantially above the minimum required. If so, redesign the mixture to reduce the VMA. Actions to consider for redesign include: (1) changing to a gradation that is closer to the maximum density line; (2) increasing the passing No. 200 (0.075mm) fraction, if room is available within the specification control points) or (3) changing the surface texture and shape of the aggregates by incorporating material with better packing characteristics, e.g., less thin, elongated aggregate particles.
- 12.3 *Adjusting the Tensile Strength Ratio* – The tensile strength ratio can be increased by: (1) adding chemical anti-strip agents to the binder to promote adhesion in the present of water; or (2) treating aggregate with hydrated lime.