SUPPLEMENTAL TEST PROCEDURES FOR ACP AND EAC

CITED IN:

"Contractor Mix Design Guidelines for Asphalt Concrete"

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Standard Practice for

Compressive Strength and Mix Design of **Emulsified Asphalt Mixtures** (Modified AASHTO Designation T 165 & 167)

ODOT TM 313-11

1. 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.

2. APPARATUS

2.1 Steel compaction mold – 4.000 to 4.005 in (101.6 to 101.7mm.) 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 C of ASTM E 4. 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 plate 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 ± 1°F (25 ± 0.5°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.

3. 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 4.00 in (101.6 mm.) in diameter and 4.0 ± 0.1 in (102 ± 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: Calculation for weight of emulsion at 5.0% of oven dry aggregate when the aggregate weight is 1720 grams:

$$\textit{Mass of Emulsion} = \frac{\textit{(Dry Aggregate) (\%Emulsion)}}{100}$$

$$= \frac{\textit{(1720 grams)(5.0)}}{100}$$

$$= \textit{86.0 grams}$$

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. 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. Record the final weight of water used and report it on the mix design.

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 until the emulsion “breaks” and for a minimum of 24 hours. Additional curing time will be required if any “unbroken” emulsion remains in the pan, but should not exceed 72 hours. 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.

4. 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 37,800 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.

5. 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.

6. BULK SPECIFIC GRAVITY DETERMINATION

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

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

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)

7. 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 it in the air bath at this temperature for 24 hours before testing.

7.3 The “B” specimens will be placed in a container full of water, then into a water bath at 140 ± 1.8°F (60 ± 1°C) for a period of 24 hours.

7.4 After 24 hours of curing, place the “B” specimens in a container full of water, then into water bath at 77 ± 2°F (25 ± 1°C) for 2 hours.

8. 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).

9. THEORETICAL MAXIMUM SPECIFIC GRAVITY

9.1 After compression testing described in 8.1 of ODOT TM 313, perform maximum specific gravity tests (G_{mm}) 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 AASHTO T 209.

10. 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:

$$\textit{Index of Retained Strength} = \frac{S2}{S1} \times 100$$

Where:

S1 = Compressive Strength of dry specimens ("A" specimens) in psi.
S2 = Compressive Strength of immersed specimens ("B" specimens) in psi.

11. 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 (V_a)	15 - 30 %
PERCENT COATING	90 % minimum
IRS	40 recommended minimum

12. 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.

13. REPORT

13.1 The report shall include the following:

13.2 The Bulk Specific Gravity of the specimens.

13.3 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.

13.4 The nominal height and diameter of the test specimens.

13.5 The Index of Retained Strength (IRS) for each emulsion content calculated to the nearest integer as calculated in section 10.1.

13.6 The air void content (V_a) of each dry specimen based on specific gravities determined in Sections 6.1 and 9.1.

13.7 Recommended emulsion content as a percent of the dry weight of aggregate.

13.8 Percentage of oil distillate contained in the emulsion sample.

Standard Practice for

Adding Anti-Strip Additives, Lime, or Latex Polymer to Mix Design Samples

ODOT TM 316-11

1. SCOPE

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

2. 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.

3. ADDING LIME TO THE SAMPLES

3.1 Lime should not be added to the samples until at least the night before the samples will be mixed with asphalt.

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, base the mass of lime 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 and achieve a “Surface Damp Condition”.

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.

4. 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°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% anti-strip x 850 grams of asphalt = 2.1 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.

5. 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. Provide a copy of the latex polymer manufacturer's recommendations/technical paper along with a report of the masses of the dry aggregate, and added latex polymer concentrate and water for the dilution of the latex polymer for each sample. Show the calculations used to determine the quantity of concentrate and water added to the required mass of aggregate for the samples to get the desired mass of dry latex per ton of aggregate.

Example: Using Ultracote UP-5000, the concentration is an emulsion of 65% solids. For the hot mix plant this should be diluted to 15%, but it is recommended that the solution be diluted to 5% for laboratory use. To dilute the solution to 5% it must be mixed with water in a 1.00 part emulsion to 12.00 parts water ratio. For 1 pound of polymer latex solids per ton of Aggregate dosing (0.05% latex polymer solids), the following dosing would be required for a mix design sample with 4600 g of aggregate:

Water addition to make 5.00% from 65.00% solution = 12.00 x Mass 5.00% Solution (g)

Ex. $$50.00\ g\ 65.00\%\ Solution\ x\ \frac{12.00\ parts\ water}{1.00\ part\ 65.00\%\ Solution} = 600.00\ g\ Water$$

Thus the addition of 600 grams to 50 grams of 65.00% solid solution results in a 650 gram solution reduced to 5.00% solids.

$$Virgin\ Agg.\ Sample\ Size\ (g)\ x\ \frac{\#\ latex\ solids\ req'd}{2000\#\ Production\ Aggregate} = Mass\ Latex\ Solids\ (g)$$

Ex. $$4600.\ g\ Virgin\ Aggregate\ x\ \frac{1.00\#\ latex\ solids}{2000.\#\ Aggregate} = 2.30\ g\ latex\ solids$$

With a 5.00% Solution:

$$\frac{Mass\ Latex\ Solids\ (g)}{5.00\%\ Solution} = \frac{Mass\ Latex\ Solids\ (g)}{0.0500} = Mass\ 5.00\%\ Solution\ (g)$$

Ex. $$\frac{2.30\ g\ latex\ solids}{5.00\ \%\ Solution} = 46.0\ g\ of\ 5.00\%\ Solution$$

Standard Practice for

Open Graded ACP & PAC Designs
ODOT TM 318-17

1. 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 ⅜", ½" (12.5 mm.) and ¾" (19 mm.) open graded hot mixes (including PAC) are found on pages 12-18 of the *Supplemental Procedures for ACP and EAC*, protocols and procedures for ¾" (19 mm.) Asphalt Treated Permeable Base (ATPB) are found on page 19, and draindown charts are found on pages 20-24.

2. TERMINOLOGY / VARIABLES

2.1 *Absorbed Binder Volume (V_{ba})* – 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).

2.2 *ACP* – Asphalt Concrete Pavement.

2.3 *Aggregate Apparent Specific Gravity (G_{sa})* – The specific gravity of the solid phase of the aggregate ignoring the volume of the surface pores and voids.

2.4 *Aggregate Bulk Specific Gravity (G_{sb})* – The specific gravity of the solid phase of the aggregate including the volume of the permeable and impermeable voids in the particles.

2.5 *Aggregate Effective Specific Gravity (G_{se})* – The specific gravity of the solid phase of the aggregate including all void spaces except those that absorb asphalt.

2.6 *Air Voids (V_a)* – 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.

2.7 *Binder Content (P_b)* – The percent by mass of binder in the total mixture including binder and aggregate.

2.8 *Binder Bulk Specific Gravity (G_b)* – The specific gravity of the asphalt cement, usually supplied at 60 °F and converted for use in ACP calculations to the specific gravity at 77 °F.

2.9 *Dust-to-Binder Ratio ($P200/P_{be}$)* – by mass, ratio between percent passing the No. 200 (0.075 mm.) sieve (P200) and the effective binder content (P_{be}).

2.10 *Effective Binder Volume (V_{be})* – The volume of binder which is not absorbed into the aggregate.

2.11 *Maximum aggregate size* – one size larger than the nominal maximum aggregate size (See Note 1).

2.12 *Nominal maximum aggregate size* – one size larger than the first sieve that retains more than 10 percent aggregate (See Note 1).

NOTE 1 - The definitions given in Sections 2.11 and 2.12 apply to Superpave mixes only and differ from the definitions published in other AASHTO standards.

2.13 *Percentage of Absorbed Asphalt (P_{ba})* – The percent by mass of asphalt that is absorbed into the surface voids of the aggregate and is unavailable to coat the aggregate or lubricate and bind the asphalt – aggregate mixture.

2.14 *Percentage of Effective Asphalt (P_{be})* – The percent by weight of asphalt that is not absorbed into the surface voids of the aggregate and is available to coat the aggregate or lubricate and bind the asphalt – aggregate mixture.

2.15 *Percent Binder (P_b)* – The percent by mass of binder in the ACP mixture.

2.16 *Percent Stone (P_s)* – The percent by mass of stone in the ACP mixture.

2.17 *Primary Control Sieve (PCS)* – The sieve defining the break point between fine and coarse-graded mixtures for each nominal maximum aggregate size.

2.18 *Reclaimed Asphalt Pavement (RAP)* – removed and/or processed pavement materials containing asphalt binder and aggregate.

2.19 *Voids in the Mineral Aggregate (VMA)* – the volume of the intergranular void space between the aggregate particles of a compacted paving mixture including the air voids in the effective binder content, expressed as a percent of the total volume of the specimen.

2.20 *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).

2.21 *Volume Increase Ratio (VIR)* – the volumetric ratio of the effective volume of binder to the volume of stone in ACP, expressed as a percentage.

3. APPARATUS

3.1 For ½” and ¾” Open Graded ACP - Molds used in the testing described in Section 4 of ODOT TM 318 shall be approximately 5 in (125 mm.) minimum length and 4.000 to 4.005 in (101.6 to 101.7 mm.) in internal diameter. Plungers and other apparatus shall generally conform to equipment described in AASHTO T 167. **Compaction of ½” and ¾” Open Graded ACP specimens with gyratory compactors is not acceptable.**

For 3/8” Open Graded ACP a Superpave Gyratory Compactor (SGC) meeting the requirements of ODOT TM 326 and AASHTO T 312 may be used.

4. PREPARING TEST SPECIMENS

4.1 Prepare two compacted G_{mb} 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 G_{mm} samples at 4.5% and 5.5% asphalt content. If lime, latex or liquid antistrip is required, add them according to ODOT TM 316. Refer to Section 6.1 of this procedure to prepare G_{mm} samples.

4.2 Heating Temperature.

4.2.1 Heat asphalt cement to 0 - 36°F (0 - 20°C) above the mixing temperature described in 4.3.1.

4.2.2 Heat all aggregates, mixing bowls, molds, and plungers to 0 - 72°F (0 - 40°C) above the mixing temperature described in 4.3.1.

4.3 Preparation of Mixtures.

4.3.1 Weigh into one pan for each batch, the size fractions of each aggregate (and RAP, if desired) required to produce three batches for G_{mb} testing (approximately 3200 - 4000 grams each for ½” and ¾” Open Graded ACP, approximately 5000 – 5500 grams for 3/8” Open Graded ACP if utilizing the SGC), three 1000 gram batches for draindown samples and two batches for G_{mm} samples sized per the requirements of AASHTO T 209 (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. If fibers are required in the mix by specification, add the specified mass of fibers prior to dry mixing the aggregate. If fibers are required by specification, prepare and test two sets of draindown samples, one set with fibers and one set without fibers. 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 as determined by the asphalt binder supplier on the asphalt temperature / viscosity curve for

unmodified asphalt binders and per the supplier's recommendations for modified binders 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.

For the Gmm and Gmb samples, cover the mixing bowl and place in a convection oven heated to a temperature 20 - 35°F (12 - 20°C) above the appropriate compaction temperature for a period of 90 ± 10 minutes. An alternative method would be to transfer the mix to a buttered pan, cover the pan and place in a convection oven heated to a temperature 20 – 35°F (12 - 20°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 provided by the asphalt binder supplier corresponding to 1400 ± 200 cSt for unmodified binders, or as determined by the asphalt binder supplier for modified binders. (Do not cure the draindown samples per this sub-section. See Section 7 of this test method for the Draindown procedure.) After the curing period, remix the mixture by hand before making the test specimens.

4.3.2 Heat the compaction molds and plungers (for mixes not utilizing the SGC) 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 ± 0.5" (100 ± 12 mm) (3/8" SGC specimens shall be 75 ± 5 mm) in height. Insert a calibrated metal stem thermometer to check compaction temperature. Do not allow the thermometer to touch the mold. For ½" and ¾" non-SGC specimens 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.

4.4 Compaction of Specimen

4.4.1 **½" & ¾" Open-Graded ACP (non-SGC design)** - 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. **Compaction ½" & ¾" Open-Graded specimens with gyratory compactors is not acceptable.**

3/8" Open-graded ACP Designed with the SGC – Set Superpave Gyratory to N_{Des} = 50 gyrations. Compact replicate specimens for each asphalt content (approximately 2500 grams each). Record the final specimen height (as measured by the SGC) of each specimen to the nearest 0.1 mm. .

4.4.2 **½" & ¾" Open-Graded ACP (non-SGC design)** - 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.

5. DETERMINATION OF BULK SPECIFIC GRAVITY OF COMPACTED ASPHALT SPECIMENS

5.1 Determine specimen bulk specific gravity (G_{mb}) by geometric means. Determine the height of each ½" or ¾" Open-Graded ACP specimen to the nearest 0.05 in (1 mm.) by taking the average of at least four measurements. The height of the 3/8" Open-Graded ACP specimens may be taken from the Superpave Gyratory Compactor measured value. Determine the average diameter by measuring the diameter of each specimen in at least four locations to the nearest 0.05 in (1 mm.). Average all the diameter measurements. Calculate the geometric G_{mb} value to three decimal places. Do <u>NOT</u> divide the calculated density by 0.99707 to determine bulk specific gravity. Assume the factor is 1.0.

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

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)

6. PROCEDURE FOR DETERMINATION OF MAXIMUM SPECIFIC GRAVITY

6.1 Determine the theoretical maximum specific gravity (G_{mm}) of the mixture according to AASHTO T 209 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 an asphalt binder percentage of 4.5% and a minimum of one sample at 5.5%. 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 according to the equation below and use the recalculated G_{mm} values for all subsequent calculations, according to the following:

$$back-calculated\ G_{mm} = \frac{100}{\frac{P_s}{G_{se_{avg}}} + \frac{P_b}{G_b}}$$

Where,

P_b = percent binder content by mass

P_s = percent aggregate content by mass $(100 - P_b)$

G_b = specific gravity of the binder at 77°F

$G_{se_{avg}}$ = average effective specific gravity of the aggregate

Note: 'Dryback' procedure is not required for open-graded mixes due to thick film coating inherent in process.

7. DRAINDOWN EVALUATION

7.1 Place each draindown sample of the mixture evenly in an 8" by 8" (200 mm. by 200 mm.) Pyrex dish. Condition 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 20 - 24 of this document.

8. OPEN GRADED MIX DESIGN CALCULATIONS

8.1 Calculate V_a, VMA, and VFA using the equations in ODOT TM 330, Section 10.3 and 11.6.1.

8.2 Calculate the Volume Increase Ratio (VIR) according to Equation 1:

$$VIR = \left(\frac{100\ x\ G_{sb}}{P_s\ x\ G_{mm}} - 1\right) x\ 100\% \qquad \textbf{(1)}$$

Where:

G_{mm} = theoretical maximum specific gravity of the ACP mixture;

G_{sb} = bulk specific gravity of the combined aggregate (determine *according to AASHTO T 84 & 85).*

P_b = percent of binder in the ACP mixture by mass;

P_s = percent of aggregate in the ACP mixture by mass (100-Pb);

Nom. Max. Agg. Size - Open	Expected VIR Range
3/8”	11.0 – 12.5
1/2”	12.5 – 14.0
3/4”	14.0 – 15.5

9. 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. If a set of draindown samples was tested with fibers, contact the ODOT Pavement Quality & Materials Engineer (PQME) for direction on choosing a design asphalt content.

10. OPEN GRADED MIX DESIGN REPORT

10.1 Submit a mixture design report including the following information:

10.1.1 Gradation: Show to the nearest whole percent except for the No. 200 (0.075 mm.) sieve which shall be recorded to the nearest 0.1 percent.

Aggregate gradation:

Sieve	Percent Passing
1” (25 mm.)	
¾” (19 mm.)	
½” (12.5 mm.)	
3/8” (9.5 mm.)	
¼” (6.25 mm.)	
No. 4 (4.75 mm.)	
No. 8 (2.36 mm.)	
No. 16 (1.18 mm.)	
No. 30 (0.60 mm.)	
No. 50 (0.30 mm.)	
No. 100 (0.150 mm.)	
No. 200 (0.075 mm.)	

10.1.2 Final asphalt content chosen reported to the nearest 0.1 percent.

10.1.3 Brand, grade, specific gravity @ 77°F (25°C) and 60°F (15.6°C), 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 V_a, VMA, VFA, VIR and draindown (report draindown percentages to the nearest 5%).

10.1.5 Worksheets for mixture bulk specific gravity (G_{mb}), mixture maximum gravity (G_{mm}), and aggregate specific gravity (G_{sb}) for each aggregate component.

10.1.6 Report all masses required to calculate RAP asphalt content ($P_{b\text{-}RAP}$) to the nearest 0.1g.

10.1.7 Report all $P_{b\text{-}RAP}$ and the average P_{br} to the second decimal place.

10.1.8 Report all masses required for determining the bulk specific gravity of the residual aggregates.

10.1.9 Report the RAP G_{sb} and G_{sa} to be used for mix design purposes.

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.

11. 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 and 7, 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.

<u>Evaluation</u>

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

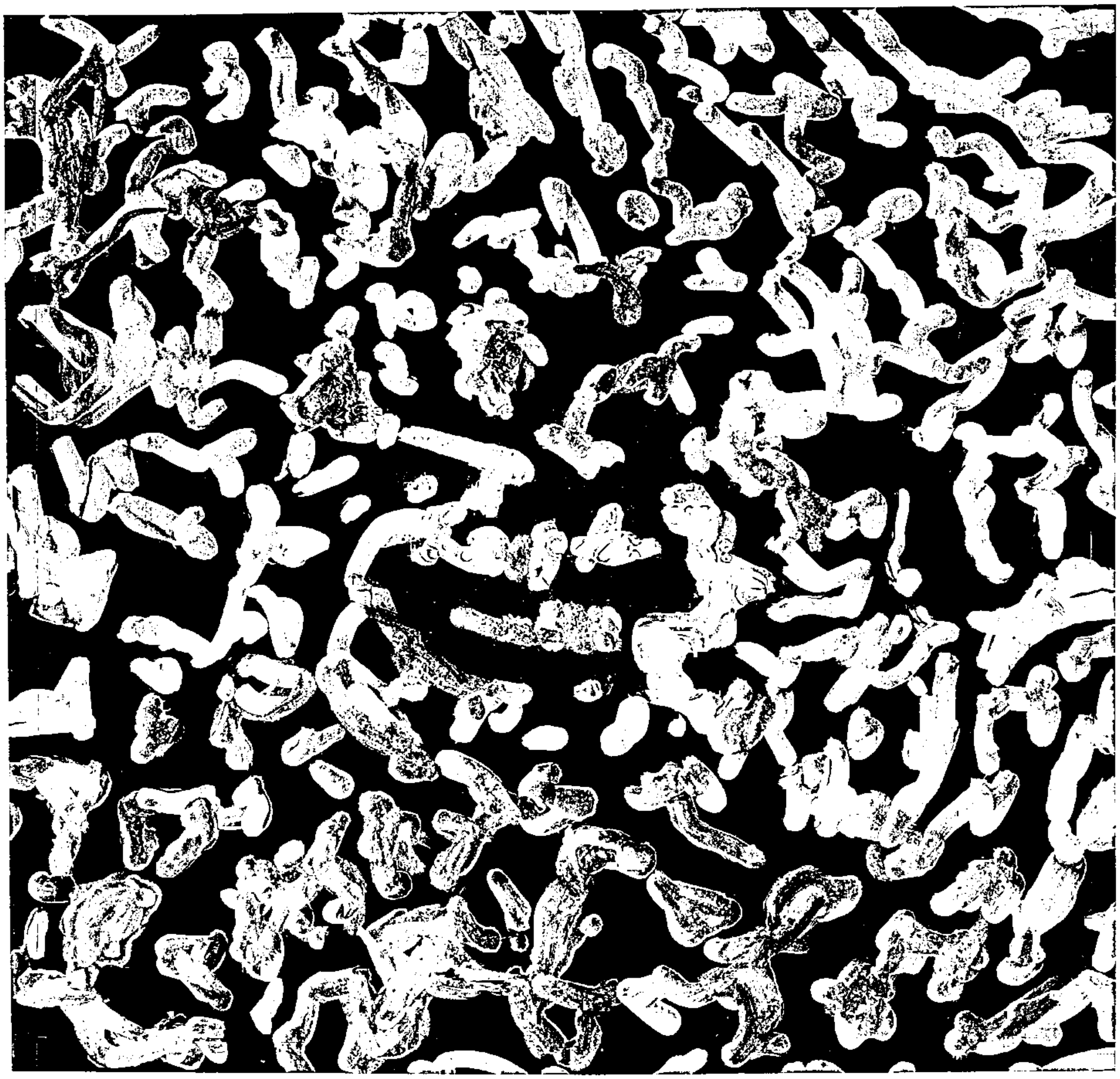
11.3 JMF: Show to the nearest whole percent except for the No. 200 (0.075 mm.) sieve and asphalt cement, which shall be recorded to the nearest 0.1 percent.

Aggregate gradation:

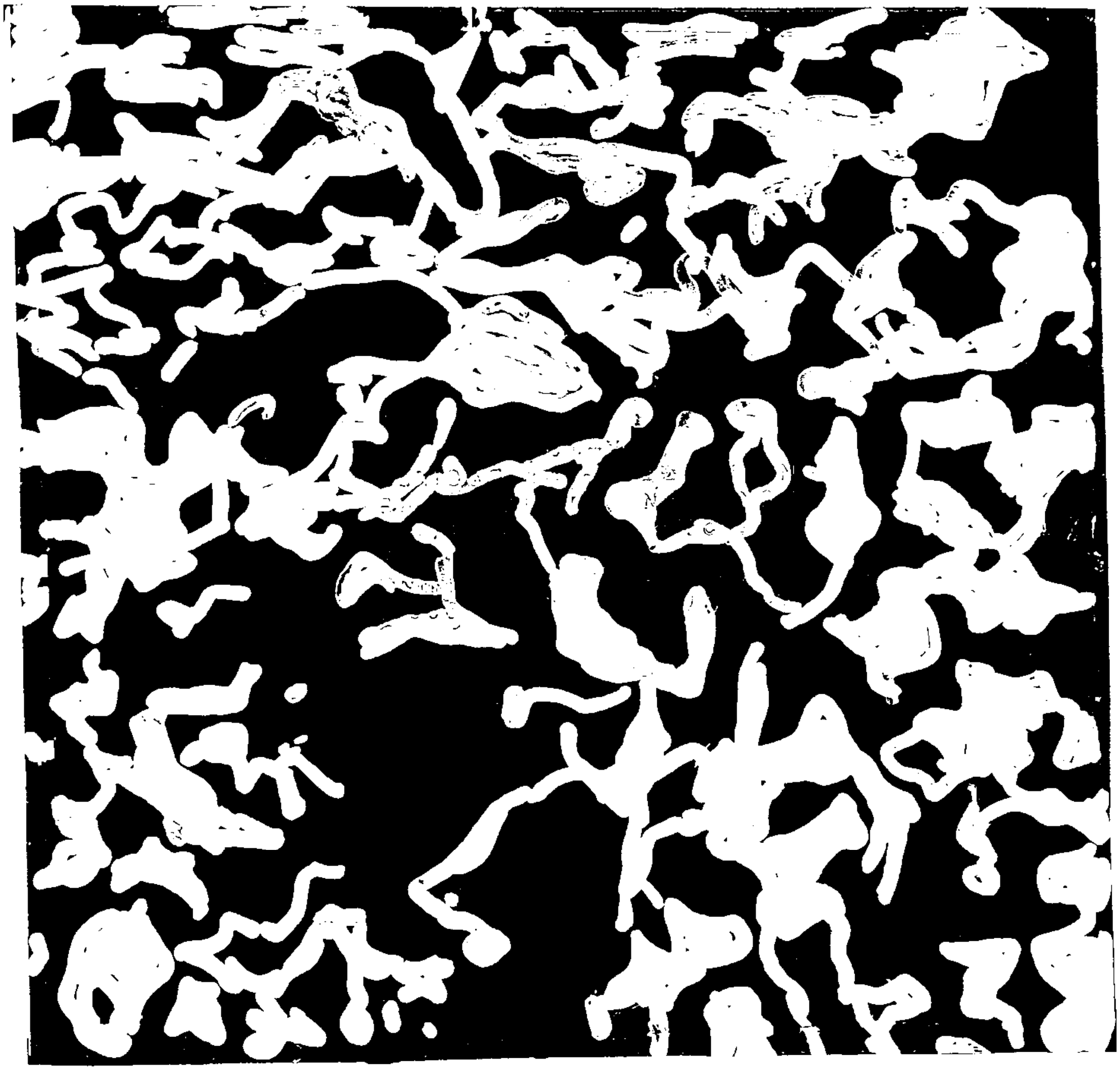
Sieve	Percent Passing
1” (25 mm.)	
¾” (19 mm.)	
½” (12.5 mm.)	
3/8” (9.5 mm.)	
¼” (6.25 mm.)	
No. 4 (4.75 mm.)	
No. 8 (2.36 mm.)	
No. 16 (1.18 mm.)	
No. 30 (0.60 mm.)	
No. 50 (0.30 mm.)	
No. 100 (0.150 mm.)	
No. 200 (0.075 mm.)	

Target asphalt content, percent to the nearest 0.1%.
Percent coating at each asphalt content to the nearest 5%.

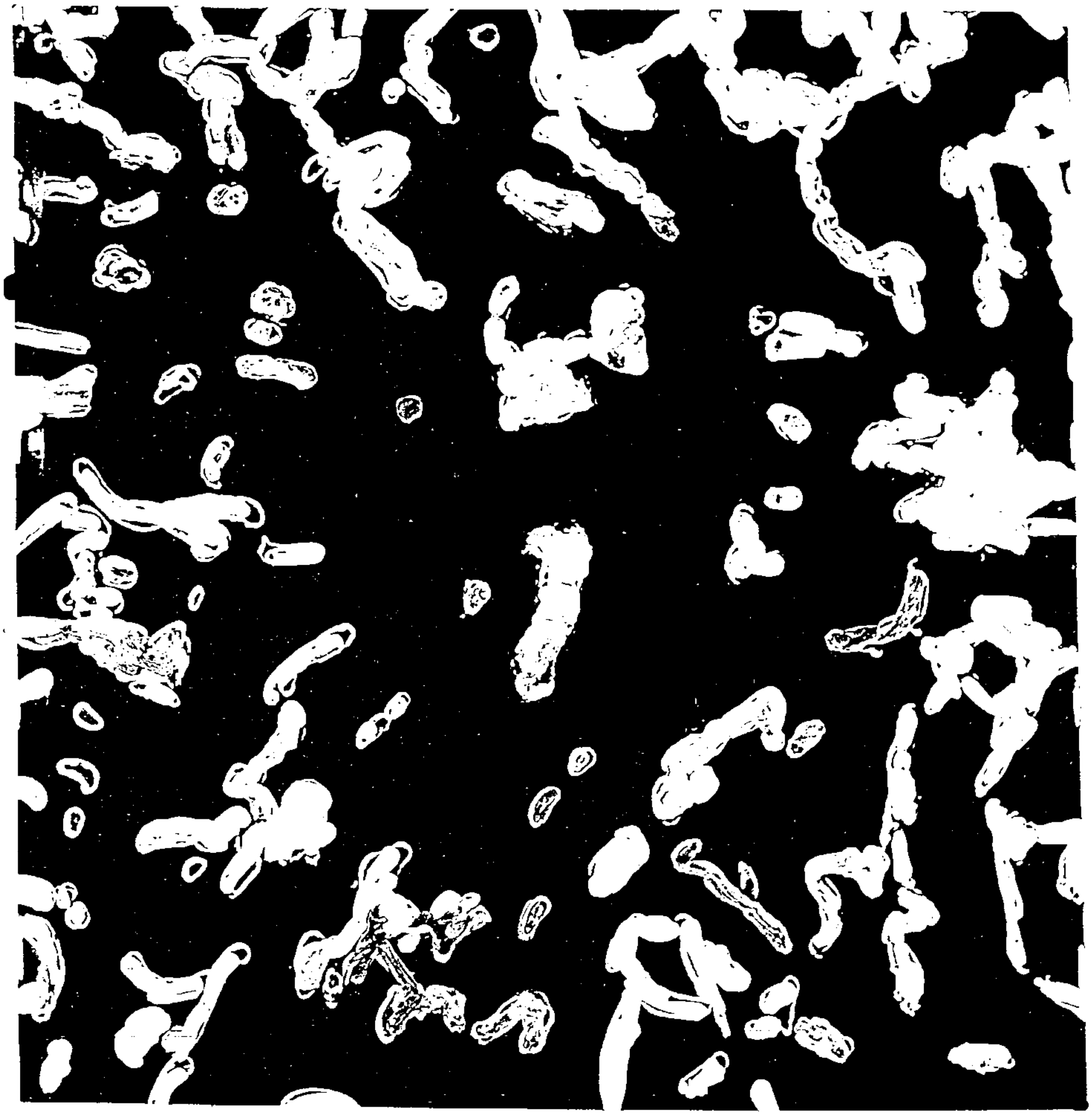
DRAINDOWN CHARTS FOR ODOT TM 318



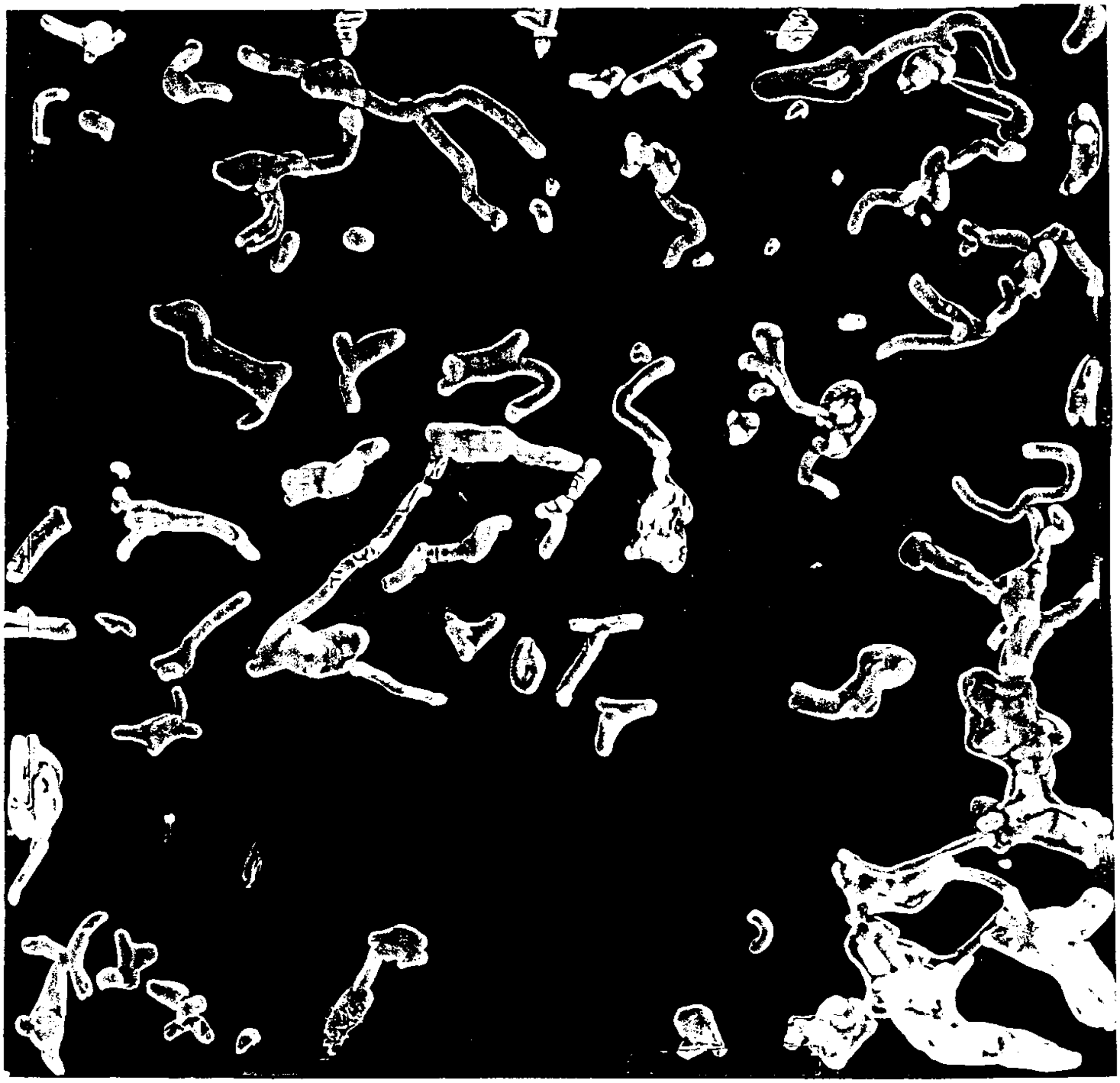
50 %



60 %



70 %



80 %

90 %

Standard Practice for

Superpave Volumetric Mix Design
For Dense Graded ACP
ODOT TM 330-18

1. SCOPE

1.1. This standard for mix design evaluation uses aggregate and mixture properties to produce an Asphalt Concrete Pavement (ACP)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:

- M 320, Performance-Graded Asphalt Binder
- R 30, Mixture Conditioning of Hot-Mix Asphalt (HMA)
- T 2, Sampling of Aggregates
- T 11, Materials Finer Than 75-pm (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 Asphalt Concrete Pavement (ACP) Specimens by Means of the Superpave Gyratory Compactor (See Standard in Appendix A of ODOT TM 326 in the *Manual of Field Test Procedures*)
- TP 63-03, Determining Rutting Susceptibility of Asphalt Paving Mixtures Using the Asphalt Pavement Analyzer (APA)

2.2. Asphalt Institute Standards:

- 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 ACP and EAC
- Oregon Standard Specifications for Construction
- ODOT TM 323 Determining the Asphalt Binder Content of Asphalt Concrete Pavement by the Ignition Method
- ODOT TM 319 Preparation and Characterization of Recycle Asphalt Materials for Mix Design

3. TERMINOLOGY / VARIABLES

3.1 *Absorbed Binder Volume (V_{ba})* – 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).

3.2 *ACP* – Asphalt Concrete Pavement

3.3 *Aggregate Apparent Specific Gravity (G_{sa})* – The specific gravity of the solid phase of the aggregate ignoring the volume of the surface pores and voids.

3.3 *Aggregate Bulk Specific Gravity (G_{sb})* – The specific gravity of the solid phase of the aggregate including the volume of the permeable and impermeable voids in the particles.

3.5 *Aggregate Effective Specific Gravity (G_{se})* – The specific gravity of the solid phase of the aggregate including all void spaces except those that absorb asphalt.

3.6 *Air Voids (V_a)* – 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.

3.7 *Binder Content (P_b)* – The percent by mass of binder in the total mixture including binder and aggregate.

3.8 *Binder Bulk Specific Gravity (G_b)* – The specific gravity of the asphalt cement, usually supplied at 60 °F and converted for use in ACP calculations to the specific gravity at 77 °F.

3.9 *Dust-to-Binder Ratio ($P200/P_{be}$)* – by mass, ratio between percent passing the No. 200 (0.075 mm.) sieve (P200) and the effective binder content (P_{be}).

3.10 *Effective Binder Volume (V_{be})* – The volume of binder which is not absorbed into the aggregate.

3.11 *Immersed to Geometric Ratio (IGR)* – The ratio of the volume of the bulked mix gyratory samples as determined per AASHTO T 166 to that of the geometrically measured and calculated volume.

3.12 *Maximum aggregate size* – one size larger than the nominal maximum aggregate size (See Note 1).

3.13 *Nominal maximum aggregate size* – one size larger than the first sieve that retains more than 10 percent aggregate (See Note 1).

NOTE 1 - The definitions given in Sections 3.12 and 3.13 apply to Superpave mixes only and differ from the definitions published in other AASHTO standards.

3.14 *Percentage of Absorbed Asphalt (P_{ba})* – The percent by weight of asphalt that is absorbed into the surface voids of the aggregate and is unavailable to coat the aggregate or lubricate and bind the asphalt – aggregate mixture.

3.15 *Percentage of Effective Asphalt (P_{be})* – The percent by weight of asphalt that is not absorbed into the surface voids of the aggregate and is available to coat the aggregate or lubricate and bind the asphalt – aggregate mixture.

3.16 *Percent Binder (P_b)* – The percent by mass of binder in the ACP mixture.

3.17 *Percent Binder in RAP (P_{br})* – The percent by mass of binder in the Recycled Asphalt Pavement (RAP) as determined by ODOT TM 319 applying a universal 0.50% correction factor.

3.18 *Percent Stone (P_s)* – The percent by mass of stone in the ACP mixture.

3.19 *Primary Control Sieve (PCS)* – The sieve defining the break point between fine and coarse-graded mixtures for each nominal maximum aggregate size.

3.20 *Reclaimed Asphalt Pavement (RAP)* – removed and/or processed pavement materials containing asphalt binder and aggregate.

3.21 *Recycled Asphalt Material (RAM)* – agency approved recycled asphaltic materials containing asphalt binder and aggregate (Currently limited to RAP and RAS).

3.22 *Recycled Asphalt Shingles (RAS)* – tear-off or manufacturer waste shingle product materials containing asphalt and fine aggregate and fiberglass material.

3.23 *Voids in the Mineral Aggregate (VMA)* – the volume of the intergranular void space between the aggregate particles of a compacted paving mixture including the air voids in the effective binder content, expressed as a percent of the total volume of the specimen.

3.24 *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).

3.25 *Volume Increase Ratio (VIR)* – the volumetric ratio of the effective volume of binder to the volume of stone in ACP, expressed as a percentage.

4. SUMMARY OF THE PRACTICE

4.1 *Materials Selection* – Binder, aggregate and RAM stockpiles, and other additives (e.g. lime) are selected that meet the project specifications related to Sections 00744 or 00745. The bulk specific gravity of all aggregates, additives and RAM 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, a initial trial binder content is determined, and at least two specimens are compacted in accordance with AASHTO T 312. A design aggregate structure and estimated design binder content are selected on the basis of satisfactory conformance of a trial gradation meeting the requirements given in Section 00745.13 of the ODOT Specifications for V_a, VMA, VFA, and dust-to-binder ratio at N_{design}. **Stage 1 is optional for projects under Section 00744.**

4.3 *Design Binder Content Selection* (Stage 2) – Replicate specimens are compacted in accordance with AASHTO 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 Section 00745.13 for V_a, VMA, VFA, and dust-to-binder ratio at N_{design}.

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.

4.5 *Performance Testing* (Stage 3) – If required by specifications, perform the Asphalt Pavement Analyzer (APA) rut test according to AASHTO TP 63-03.

5. SIGNIFICANCE AND USE

5.1 The procedure described in this practice is used to produce ACP that satisfies the mix design requirements of the project specifications.

6. PREPARING AGGREGATE TRIAL BLEND GRADATIONS (STAGE 1)

6.1 Obtain the binder specified in the Contract bid items.

6.2 Determine the specific gravity at 77°F (25°C) and 60°F (15.6°C) of the binder according to AASHTO T 228, or obtain the specific gravity from the manufacturer, along with the mixing (corresponding to 170 +/- 20 cSt for unmodified binders) and compaction (corresponding to 280 +/- 30 cSt for unmodified binders) temperature ranges. Modified binders may require different mixing and compaction viscosities with corresponding temperatures. Consult with the binder supplier for appropriate mixing and compaction temperatures for modified binders. Use the binder specific gravity at 77°F (25°C) for all volumetric calculations where G_b is used.

6.3 Obtain samples of aggregates proposed for use on the project from the aggregate stockpiles in accordance with AASHTO T 2. Obtain crushing records (QL mean gradations) for each stockpile, produced per Section 00745.10(f) of the ODOT Specifications.

6.4 If RAM is to be used, obtain RAM samples and characterize per ODOT TM 319. Use and report results obtained from ODOT TM 319 for mix design purposes.

NOTE 1: If both RAP and RAS are used as separate stockpiles , the CMDT may choose to proportionally blend the two into a homogenous “Super RAP” to be used for all mix design development.

6.5 Batch materials for each sample using a methodology that will result in the correct percent passing each sieve per the tolerances of sub-section 6.13 and 11.1.1. (Also see ODOT PTM 1 “Laboratory Batching of Aggregates for ACP Mix Design, Proficiency, and Calibration Samples” on page 51 of these *Supplemental Test Procedures for ACP and EAC* for two possible batching options.) Report all Sieves to the tenth for batching and blending purposes. Batch samples with ‘dirty’ aggregates. Batching ACP samples with laboratory ‘washed’ aggregate is unacceptable.

6.5.1 If wasting dust is required to meet the target gradation, correct all sieves for the loss of the dust passing each respective sieve according to the following calculation:

$$\%P_f = 100 - \frac{(100 - \%P_i) * 100}{100 - \%D_w} \qquad \textbf{(1)}$$

Where:

$\%P_i$ = Unadjusted Percent Passing the respective sieve

$\%D_w$ = Percent Dust Wasted

$\%P_f$ = Dust Adjusted Percent Passing the respective sieve

6.6 Determine the bulk and apparent specific gravity for each aggregate stockpile according to AASHTO T 85 and/or T 84 (see Note 4). Use a volumetric flask of 500 mL capacity, which is able to meet the volume reproducibility requirements of +/-100mm^3. Rice pycnometers are not acceptable for use when running the T 84 test. **For each stockpile perform duplicate specific gravity tests.** The pair of test results must be reported individually and meet the acceptable range of two results for single operator stated in the respective test method. Also report the average of the two test results. The average result for each stockpile should be used in mix design calculations. If any aggregate stockpile or the RAP has more than 15% of the mass above or below the breaking sieve (See Note 2), split the material on the breaking sieve and perform a T 84 test on the material passing the breaking sieve and a T 85 test on the material retained on the breaking sieve. Determine the combined bulk and apparent specific gravities by weighted average of the separate gravity results. If less than 15% of the mass of a sample is either retained or passing the breaking sieve, that fraction of the sample can be ignored for specific gravity purposes.

For any stockpiles requiring both AASHTO T 84 and T 85, determine the specific gravity of the stockpile using the following equation:

$$G_{sb} = \frac{P_{\#4\ or\ 8+} + P_{\#4\ or\ 8-}}{P_{\#4\ or\ 8+}/G_{sb_{\#4\ or\ 8+}} + P_{\#4\ or\ 8-}/G_{sb_{\#4\ or\ 8-}}} \qquad \textbf{(2)}$$

To determine the combined aggregate specific gravity of an aggregate blend, use the following equation:

$$G_{sb} = \frac{P_1 + P_2 + \ldots + P_n}{P_1/G_{sb_1} + P_2/G_{sb_2} + \ldots + P_n/G_{sb_n}} \qquad \textbf{(3)}$$

Combined G_{sa} can be determined with the same equations by replacing G_{sb} values with G_{sa} values.

NOTE 2 - It is acceptable to break the coarse and fine aggregates on either the #4 or #8 sieves.

NOTE 3 - Determine specific gravity of RAM material per ODOT TM 319.

NOTE 4 – The Standard AASHTO T 84 test is often complicated with crushed material. The material may not readily slump at SSD condition. At SSD condition check for airborne fines per the T 84 procedure to determine if an alternate means of determining the SSD condition will be required. Another indicator that the SSD condition has been passed are T 84 results that are greater than T 85 results, as the T 85 results should usually be higher than T 84 results due to the lesser surface area of the plus aggregate fractions.

6.7 Determine the specific gravity of the mineral filler in accordance with AASHTO T 100. If lime is used, provide the manufacturer's specific gravity data.

6.8 If lime is to be added to the mix, add the lime at the target percentage, which is currently 1.0% by weight of dry aggregate, rather than the upper or lower tolerance limit.

6.9 Blend the aggregate fractions, including all constituents such as lime, and mineral filler using Equation 4:

$$P = Aa + Bb + Cc, \text{ etc.} \qquad \textbf{\textit{(4)}}$$

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.

6.10 Prepare a minimum of three trial aggregate blends. Each of the three trial blends must differ by a minimum of **3 percent** passing the No. 8 (2.36 mm.) sieve so that the coarse and fine blends differ by at least 6 percent on the No. 8 sieve. Dry sufficient amounts of aggregate and RAM to prepare laboratory samples for all stages of the mix design process. Fractionate each stockpile on the required sieves per AASHTO T 27. Store the fractionated material in a manner that minimizes moisture absorption.

6.10.1 COARSE AND FINE AGGREGATE RATIO ANALYSIS OF STAGE 1 BLENDS

Define the following sieves:

Mix Size	1”	3/4"	1/2"	3/8”
Half Sieve	1/2"	3/8”	1/4"	No. 4
PCS*	No. 4	No. 4	No. 8	No. 8

*Primary Control Sieve

1. Calculate the Coarse Aggregate (CA) Ratio on each Stage 1 blend and report to three decimal places:

$$CA\ Ratio = \frac{\%Pass\ Half\ Sieve - \%Pass\ PCS}{100\% - \%Pass\ Half\ Sieve} \qquad \textbf{(5)}$$

The Coarse Aggregate Ratio for each blend should be within 0.650 to 1.000.

2. Calculate the Fine Aggregate (FA) Ratios on the sieves listed in the table below and report to three decimal places:

$$FA\ Ratio = \frac{\%Pass\ Sieve}{\%Pass\ Double\ Sieve} \qquad \textbf{(6)}$$

Where,

Sieve	Double Sieve
No. 8	3/8”
No. 16	No. 4
No. 30	No. 8
No. 50	No. 16
No. 100	No. 30
No. 200	No. 50

3. Calculate the average and standard deviation of the six FA Ratios and report to three decimal places. The FA Ratios should meet the following:

Value	Criteria
Average FA Ratio	0.350 – 0.500
Standard Deviation	≤ 0.050
Individual FA Ratio	Average FA Ratio ± 0.075

6.10.2 If the QL mean percent passing is less than 10% on any sieve for a given stockpile then like material from another stockpile crushed from the same source may be substituted in the batching process.

NOTE 5 - Consideration of particle shape must be evaluated before substitution, as different stockpiles may have significant particle shape difference. Different particle shapes have been shown to impact mixture volumetric properties.

6.11 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 batching trial samples.

6.12 Develop a batch plan that utilizes the aggregate fractioned per AASHTO T 27 to produce a sample that meets the required blend targets when tested per AASHTO T 27/T 11.

6.13 Batch to the size required in AASHTO T 27/T 11 one sample for each trial blend and perform sieve analysis on each sample per AASHTO T 27/T 11. Confirm that the trial batches meet the trial blends with the following tolerances on percent passing (Report percent passing on all sieves to 0.1%):

Sieves	Allowable Difference (%)
Larger than No. 8	±1.5
No. 8 to No. 50	±1.0
Smaller than No. 50	±0.5

If any sample fails to meet the above, adjust the batch plan and reconfirm per AASHTO T 27/T 11 until the criteria is met. If RAM is used, mathematically combine the RAM gradation(s) to obtain the final gradation results.

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.

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

7.1 Designers can either use their experience with the materials or the procedure given in Appendix X1, AASHTO R 35-15 to determine an initial trial binder content for the trial aggregate blend gradations which will achieve approximately 4% air voids. The same binder content shall be used for all trial blends.

NOTE 6 - When using RAM, the initial trial asphalt content should be reduced by an amount equal to the average asphalt content provided by the RAM.

For “virgin” mixes, the mass of asphalt binder is calculated from the mass of “hot” aggregate as follows:

$$Mass_{binder} = \frac{P_b \ x \ Mass_{agg}}{(100 - P_b)} \qquad \textbf{(7)}$$

For RAM mixes, calculating the mass of binder to add is a two step procedure. RAM is a combination of aggregate and asphalt binder, and the mass of each must be calculated from the mass of RAM and the asphalt content of the RAM (P_{br}):

$$Mass_{RAM\ binder} = Mass_{RAM} \ x \ \frac{P_{b\text{-}ram}}{100} \qquad \textbf{(8)}$$

The mass of RAM binder must be subtracted from the total binder to determine the amount of new asphalt binder to be added:

$$Mass_{virgin\ binder} = \frac{P_b\left(Mass_{agg} + Mass_{RAM} - Mass_{RAM\ binder}\right)}{(100 - P_b)} - Mass_{RAM\ binder} \qquad \textbf{(9)}$$

7.1.1 As a check for mixes containing RAS, verify that the percent virgin binder replacement does not exceed the specification limits by calculating the % recycled binder per equation(s) 10 below:

$$\%Binder\ Replaced = \frac{P_{b\text{-}ras} \ x \ \%RAS + P_{b-rap} \ x \ \%RAP}{P_b} \qquad \text{or}$$

$$\%Binder\ Replaced = \frac{P_{b\text{-}ram} \ x \ \%RAM}{P_b} \qquad \textbf{(10)}$$

Where,

P_{b-ram} = percent of asphalt cement in RAM specimen

P_b = Percent Binder in Mix

%RAM = Percent recycled asphalt material (RAP and/or RAS) as a percentage of aggregate blend

%RAS = Percent RAS as a percentage of aggregate blend

%RAP = Percent RAP as a percentage of aggregate blend

7.1.2 To Calculate an estimate of the maximum percentage of RAS allowed in a mix based upon an initial estimate for percent total binder in mix, use the following equation:

$$Max\ \%RAS / RAM = \left(\frac{Est.\ P_b}{P_{b-ras/ram}}\right) x\ Max\ Binder\ \mathrm{Re}\,placement \qquad \textbf{(11)}$$

8. MIXING AGGREGATE AND ASPHALT BINDER

8.1 Follow HMA Mixture Preparation from AASHTO T 312

9. COMPACTING SPECIMENS OF EACH TRIAL GRADATION

9.1 Prepare replicate mixtures (See Note 7) at the initial trial binder content for each of the chosen trial aggregate blend gradations. **Trial blends are optional for mixes specified under Section 00744.** Mixing (corresponding to 170 +/- 20 cSt for unmodified binders) and compaction (corresponding to 280 +/- 30 cSt for unmodified binders) temperature ranges should be determined by the binder supplier. Modified binders may require different mixing and compaction viscosities with corresponding temperatures. Consult with the binder supplier for appropriate mixing and compaction temperatures for both modified and unmodified binders. Refer to ODOT Specification Section 00745.13 for the proper number of gyrations for the specified level of ACP. These gyrations are designated "N_{design}".

NOTE 7 - 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 2.550 to 2.700, respectively.

9.2 Condition the mixtures according to AASHTO R 30, Section 7.1.1 through 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. Adjust the mass of future samples to achieve a sample height of 115 mm.. The sample size may be initially estimated by the following:

The G_{mb} sample size may be estimated using the following approximate relationship with G_{sb}:

$$\textit{Estimated } G_{mb} = 0.9 \times G_{sb} \qquad \textbf{(12)}$$

Where:

G_{sb} = combined aggregate and RAM specific gravity

Use the below table and Equation 13 to calculate a starting point for the G_{mb} sample mass:

Mass Factor (MF)
3/4" Mix = 1755.8
1/2" Mix = 1774.1
3/8" Mix = 1792.4

$$\textit{Initial Sample Size (grams)} = G_{sb} \times MF\ \textit{Factor} \qquad \textbf{(13)}$$

Compact your first sample and record the sample *dry mass* and *height*. Using these measurements, adjust the sample mass for the subsequent samples, to target the 115.0 mm. height using Equation 14:

$$New\ G_{mb}\ Sample\ Mass = \left(\frac{115.0\ mm}{height}\right) x\ dry\ mass \qquad \textbf{(14)}$$

9.3 Determine the bulk specific gravity (G_{mb}) of each of the compacted specimens in accordance with AASHTO T 166 or T 275 as appropriate, according to the *ODOT Manual of Field Test Procedures (MFTP).* If the difference between replicate compacted specimens exceeds ±0.010, then compact two additional specimens, and discard the highest and lowest of the four specimens. However, if the difference between replicate samples after the high and low have been discarded is greater than ±0.020, compact two additional samples until the ±0.020 tolerance is met.

9.4. Determine the theoretical maximum specific gravity (G_{mm}), according to AASHTO T 209 in the ODOT Manual of Field Test Procedures, on separate samples representing each of these combinations that have been mixed and conditioned to the same extent as the compacted specimens. Use the “Supplemental Procedure for Mixtures Containing Porous Aggregate”, hereafter called the “dryback” method, found in Section 11 of AASHTO T 209 for the trial blends.

10. EVALUATING COMPACTED TRIAL MIXTURES

10.1 Determine the volumetric requirements for the trial mixtures in accordance with ODOT Specification Section 00745.13. Use the binder specific gravity at 77°F (25°C) for all volumetric calculations where G_b is used.

Calculate P_{ba} with both the “dryback” and standard procedure. Beginning in 2018, the “dryback” will also be performed for all Stage 2 AASHTO T209 testing.

10.2 To check for sample preparation and testing procedural errors, calculate the Immersed Volume to Geometric Volume Ratio (IGR) and the G_{ma} according to Equations 15 through 18:

$$Immersed\ Volume = B - C \qquad \textbf{(15)}$$

$$Geometric\ Volume = (height,\ mm)\ x\ 5.625\pi \qquad \textbf{(16)}$$

$$Ratio = \frac{Immersed\ Volume}{Geometric\ Volume} \qquad \textbf{(17)}$$

$$G_{ma} = \frac{A}{A - C} \qquad \textbf{(18)}$$

Where:

A = Dry Mass of Compacted Sample

B = SSD Mass of Compacted Sample

C = Immersed Mass of Compacted Sample

Compare the ratios of the replicate specimens and verify that they are within +/- 0.005. Generally the ratio should be between 0.965 & 0.985 for ½" nominal aggregate size.

Compute the difference between G_{ma} and G_{mb}. The difference between G_{ma} and G_{mb} should be between 0.008 and 0.020. Verify that the difference of the replicate samples is within +/- 0.005.

10.3 Calculate V_a and VMA at N_{design} for each trial mixture using Equations 19 and 20:

$$V_a = 100 \times \left(\frac{G_{mm} - G_{mb}}{G_{mm}} \right) \qquad \textbf{\textit{(19)}}$$

$$VMA = 100 - \left(\frac{G_{mb} \times P_s}{G_{sb}} \right) \qquad \textbf{\textit{(20)}}$$

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 8 - 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.

10.4 Estimate the volumetric properties at 4.0 percent air voids for each compacted specimen, as follows:

10.4.1 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 21:

$$\Delta V_a = 4.0 - V_{a\ trial} \qquad \textbf{(21)}$$

Where:

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

10.4.2 Estimate the change in binder content (ΔP_b) needed to change the air void content to 4.0 percent using Equation 22.

$$\Delta P_b = -0.4\left(\Delta V_a\right) \qquad \textbf{(22)}$$

10.4.3 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 23 or 24.

$$\Delta VMA = 0.2\left(\Delta V_a\right) \text{ if } V_a > 4.0 \qquad \textbf{(23)}$$

$$\Delta VMA = 0.1\left(\Delta V_a\right) \text{ if } V_a < 4.0 \qquad \textbf{(24)}$$

NOTE 9 - A change in binder content affects the VMA through a change in the bulk specific gravity of the compacted specimen (G_{mb}).

10.4.4 Calculate the VMA for each aggregate trial blend at N_{design} gyrations and 4.0 percent air voids using Equation 25.

$$VMA_{4.0} = VMA_{trial} + \Delta VMA \qquad \textbf{(25)}$$

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.

10.4.5 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 26 and 27:

$$P_{be_{4.0}} = -\left(P_{s_{4.0}}\ x\ G_b\right)\frac{\left(G_{se} - G_{sb}\right)}{\left(G_{se}\ x\ G_{sb}\right)} + P_{b_{4.0}} \qquad \textbf{(26)}$$

Where:

$P_{be_{4.0}}$ = estimated effective binder content @ $V_{a_{4.0}}$,

$P_{s_{4.0}}$ = aggregate content $\left(100 - P_{b_{4.0}}\right)$,
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.

$$P_{200}/P_{be} = P_{200_{trial}}/P_{be_{4.0}} \qquad \textbf{\textit{(27)}}$$

Where:

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

NOTE 10 - 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.

10.4.6 Graph the 4.0% normalized VMA versus the passing #8 of the trial blends. Also graph the P_{ba} versus the passing #8 of the trial blends. Evaluate both versus the expected trends.

10.4.7 Compare the estimated volumetric properties from each trial aggregate blend gradation at the normalized design binder content with the criteria specified in the ODOT Specification Section 00745.13. Choose the trial aggregate blend gradation that best satisfies the volumetric criteria. An interpolated aggregate blend gradation may be established based upon the three trial blends. If an interpolated blend is selected, determine the Coarse and Fine Aggregate Ratios per 6.10.1 for the interpolated blend and evaluate the results. All blends, including an interpolated blend, must be composed of all of the same stockpiles used in the trial blends (i.e. a blend may not drop a stockpile used in the other blends). Describe in the report the reason for selecting a particular blend.

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. The Coarse and Fine Aggregate Ratios should also be considered. 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.

10.4.8 If the mix includes RAS or RAP/RAS, the percent replacement binder must be calculated for the trial mixes to ensure that the replacement binder specification is not exceeded, per equation(s) 10 above.

If the normalized estimate of design asphalt is within ±0.50% of the initial binder content used for Stage 1 Samples, then the maximum RAS allowed may be computed per Equation 11 above using the normalized design asphalt content and the %RAS may be adjusted with slight changes in the selected blend to closely replicate the blend targets to apply to Stage 2. If the design asphalt normalized estimate is greater than ±0.50% of the initial binder content used for Stage 1 Samples, then new Stage 1 samples must be fabricated with appropriate changes to trial binder content and %RAS.

11. SELECTING THE DESIGN BINDER CONTENT (STAGE 2)

11.1 Prepare replicate mixtures (See Note 6) containing the selected design aggregate structure at each of the following four binder contents: (1) the estimated design binder content, P_b (estimated); (2) 0.5 percent below P_b (estimated); (3) 0.5 percent above P_b (estimated); and (4) 1.0 percent above P_b (estimated). As an alternate procedure, prepare four sets of replicate samples, two sets above and two sets below the estimated design asphalt content, straddling the P_b (estimated), with each successive set 0.5% binder content apart. The 'P_b (estimated)' binder content is the binder content determined by the 4.0% normalization process in Stage 1. **Do not use the data from AGGREGATE TRIAL BLEND GRADATIONS (STAGE 1) with the data collected for SELECTING THE DESIGN BINDER CONTENT (STAGE 2).** Use the binder specific gravity at 77°F (25°C) for all volumetric calculations where G_b is used.

11.1.1 If an interpolated blend is selected, then at the same time the samples in Section 11.1 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 T 11 and T 27. Report the test results with the mix design data.

For RAM mixes, remove the asphalt from the appropriate mass of RAM by incineration according to AASHTO T 308. Gradations for the residual aggregate from the RAM and the virgin aggregate (including mineral filler, lime, fibers or any other additive) may be determined separately according to AASHTO T 30 and combined mathematically (using the average RAM gradations determined according to ODOT TM 319).

11.2 Condition the mixtures according to AASHTO R 30, Section 7.1.1 through 7.1.4, and compact the specimens according to ODOT TM 326, to the number of gyrations required for N_{design}. Record the specimen height to the nearest 0.1 mm. at N_{design}.

11.3 Determine the bulk specific gravity of each of the compacted specimens in accordance with AASHTO T 166 or T 275 as appropriate, according to the ODOT Manual of Field Test Procedures (MFTP). If the difference between replicate compacted specimens exceeds ±0.010, then compact two additional specimens, and discard the highest and lowest of the four specimens. However, if the difference between replicate samples after the high and low have been discarded is greater than ±0.020, compact two additional samples until the ±0.020 tolerance is met.

11.4 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. Test a minimum of one sample at a minimum of two asphalt contents that are 0.5% apart either straddling the estimated binder content or with one of the samples at the estimated binder content.

Use the dryback procedure for Stage 2 G_{mm} samples. Calculate the percent difference between the Mass of Sample (A) to Mass of saturated surface-dry sample in air (A_{ssd}) according to the following formula:

$$\frac{A_{ssd-A}}{A_{ssd}}\ X\ 100\% = \%\ Difference\ (Compute\ to\ the\ nearest\ 0.01\%) \quad \textbf{(28)}$$

Drybacks are required if a JMF has a % Difference that exceeds 0.17%. All JMF's will be analyzed for % Difference under production, regardless of % Difference calculated during mix design. In order to select a design binder content that utilizes the non-dryback G_{mm} value, AASHTO T 209 and corresponding % Difference calculation must have been performed with the selected gradation at an asphalt content equal to or less than the final design asphalt content(P_b). This may require a 3rd AASHTO T 209 in Stage 2, if none of the originally tested asphalt contents are equal to or less than the design binder content (when run, this 3rd AASHTO T 209 does not need to be used for G_{se} determination).

The "non-dryback" 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 "non-dryback" G_{se} values within 0.012, using the "dryback" or "non-dryback" G_{se}'s, as applicable. Using the average G_{se}, recalculate all G_{mm} values according to equation 28 and use the recalculated G_{mm} values for all subsequent calculations.

$$back-calculated\ G_{mm} = \frac{100}{\frac{P_s}{G_{se_{avg}}} + \frac{P_b}{G_b}} \quad \textbf{(29)}$$

Where,

P_b = percent binder content by mass

P_s = percent aggregate content by mass $(100 - P_b)$

G_b = specific gravity of the binder at 77°F

$G_{se_{avg}}$ = average effective specific gravity of the aggregate

11.5 To check for sample preparation and testing procedural errors, calculate the Immersed Volume to Geometric Volume Ratio and the G_{ma} according to Equations 13 through 16.

Compare the ratios of the replicate specimens and verify that they are within +/- 0.005. Generally the ratio should be between 0.950 & 0.970.

Compute the difference between G_{ma} and G_{mb}. The difference between G_{ma} and G_{mb} should be between 0.010 and 0.030. Verify that the difference of the replicate samples is within +/- 0.005.

Also verify that the ratios and differences for the Stage 1 and Stage 2 replicate samples with the same asphalt content are within the above limits.

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

11.6.1 Calculate V_a, VMA, and VFA at N_{design} using Equations 19, 20 and 29.

$$VFA = 100 \text{ x } \frac{(VMA - V_a)}{VMA} \qquad \textbf{(30)}$$

11.6.2 Calculate the dust-to-binder ratio (P_{200}/P_{be}).

Where:

P_{200} = Percent passing the No. 200 Sieve

P_{be} = effective binder content.

11.6.3 Calculate the Volume Increase Ratio (VIR), using equation 30.

$$VIR = \left(\frac{100 \text{ x } G_{sb}}{P_s \text{ x } G_{mm}} - 1 \right) \text{ x } 100\% \qquad \textbf{(30)}$$

Where:

G_{mm} = theoretical maximum specific gravity of the ACP mixture;

G_{sb} = bulk specific gravity of the combined aggregate.

P_s = percent of aggregate in the ACP mixture by mass (100-P_b);

P_b = percent of binder in the ACP mixture by mass (100-P_s);

Nom. Max. Agg. Size - Dense	Expected VIR Range*
3/8”	12.9 – 15.7
1/2”	11.6 – 14.3
3/4”	10.3 – 12.9

11.6.4 Plot the average V_a, VMA, VFA, and G_{mb} at N_{design} for replicate specimens versus binder content.

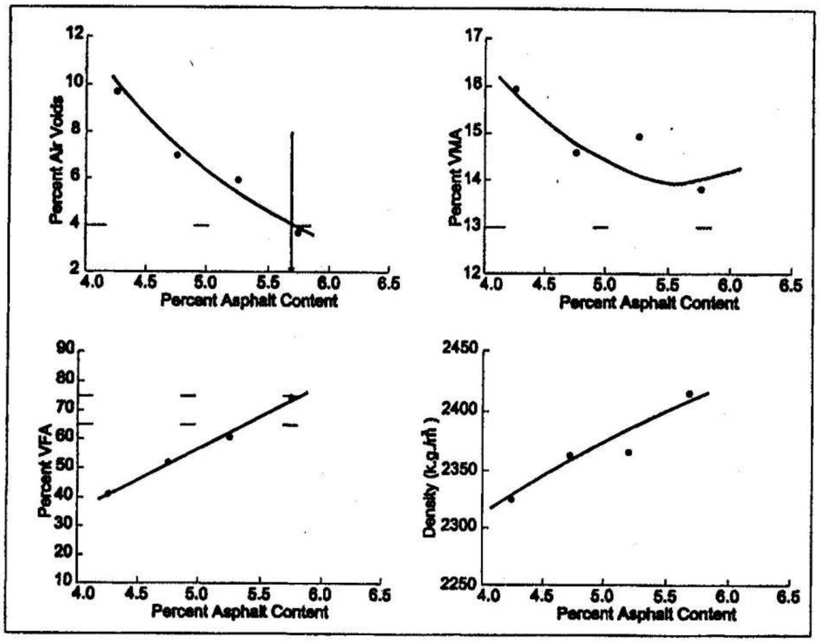
11.6.5 By graphical or mathematical interpolation, determine the binder content to the nearest 0.1 percent at which the target V_a is equal to 4.0 percent or other specified percent. This is the design binder content (P_b) at N_{design}.

11.6.6 By interpolation (using Figure 2), verify that the volumetric requirements specified in Section 00745.13 of the ODOT Specifications are met at the design binder content. In addition to the requirements under 00745.13, the selected design binder content shall not fall on the 'wet' side of the VMA curve. This may require the selection of a different blend for which Stage 2 work will have to be redone.

11.6.7 If the mix design contains RAS or RAP/RAS, the percent binder replacement must be calculated per Equation 10 and reported. The percent binder replacement shall not exceed the specified maximum per the specification. Should the optimum binder content in Stage 2 result in a % virgin binder replacement in excess of the specification then the following applies:

- If an adjustment within 0.20% of the binder content estimated for Stage 2 will be able to decrease the % virgin binder replacement to under the specified maximum, then the maximum RAS allowed may be computed per Equation 11 above using the normalized design asphalt content and the %RAS may be adjusted with slight changes in the selected blend to closely replicate the blend targets to apply to Stage 2.
- If the difference between optimum asphalt content and the estimated binder content is in excess of 0.20%, then the Stage 2 work must be redone with a %RAS contribution that will not exceed the specified limits for binder replacement.

11.6.8 Plot Stage 1 data on the Stage 2 Graphs.



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}

12. EVALUATING MOISTURE SUSCEPTIBILITY (STAGE 3)

12.1 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).*

12.2 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, or aggregate treatments, such as lime or latex is required to improve the moisture susceptibility of the mix. When remedial agents are used to modify the binder or treat the aggregate, retest the mix for TSR to assure compliance with the 80 minimum requirement.

13. ADJUSTING THE MIXTURE TO MEET PROPERTIES

13.1 *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 11); (2) reduce the passing No. 200 (0.075 mm.) fraction (Note 12); or (3) change the surface texture and/or shape of one or more of the aggregate fractions (Note 13).

NOTE 11 - Changing gradation may not be an option if the trial aggregate blend gradation analysis includes the full spectrum of the gradation control area.

NOTE 12 - 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 (0.075 mm.) sieve is already low, this is not a viable option.

NOTE 13 – This option will require further processing of existing materials or a change in aggregate sources.

13.2 *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 (0.075 mm.) 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.

13.3 *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 presence of water; or
(2) treating aggregate with hydrated lime, or
(3) treating the aggregate with a latex polymer emulsion (see ODOT TM 316).

Standard Practice for

Preparation and Characterization of RAM Materials for Mix Design

ODOT TM 319-17

1. SCOPE

This standard for preparation and characterization of RAM materials uses field samples of RAP/RAM to produce laboratory ready materials that may be incorporated into Superpave™ or other ACP mixtures as allowed by specifications.

This Test Method may involve hazardous materials, operations or equipment. It does not claim to address all safety issues that may pertain to its use. It is the responsibility of the user of the Test Method to establish proper safety procedures and PPE use to address these safety issues and all applicable regulatory limitations.

2. REFERENCED DOCUMENTS

AASHTO Standards:

- T 30, Mechanical Analysis of Extracted Aggregate
- T 84, Specific Gravity and Absorption of Fine Aggregate
- T 85, Specific Gravity and Absorption of Coarse Aggregate
- T 209, Theoretical Maximum Specific Gravity of Bituminous Paving Mixtures
- T 308, Asphalt Binder Content of HMA by the Ignition Method

Asphalt Institute Standards:

- SP-2 Superpave Mix Design

3. TERMINOLOGY

ACP – Asphalt Concrete Pavement

RAP – reclaimed asphalt pavement

RAM – recycled asphalt materials (e.g. RAP or RAS or a combination of RAP and RAS)

RAS – recycled asphalt shingles

Binder Content of RAM (P_{br}) – The percent by mass of binder in the RAM as determined by AASHTO T 308 applying a universal 0.50% correction factor

Effective Specific Gravity of Aggregates (G_{se}) – Specific gravity of aggregates including the water permeable voids not filled with asphalt.

4. BACKGROUND

Incorporating RAM into a mix design poses a unique set of problems. In the majority of instances the properties of the original aggregates and binder used to create the RAM are not readily available. The CMDT must take reasonable steps to quantify the asphalt binder content (P_{br}), the aggregate gradation, and the specific gravity of the aggregates contained in the RAM.

The amount of binder in the RAM is accounted for when adding virgin binder to a new mixture. The specific gravity of the RAM binder may lead to a minor change in the overall specific gravity of the blended virgin and RAM binders, however, for mix design purposes, this minor change will be ignored and all calculations will be based on the specific gravity (G_b) of the virgin binder.

RAM received from the field for mix design purposes may be processed or unprocessed. Unprocessed RAM is material that is in a raw state that will actually receive some type of processing before being fed into the asphalt plant during mix production. Processed RAM, on the other hand, has been through whatever crushing and screening has been elected by the contractor and is ready to feed into the asphalt plant.

Unprocessed RAM adds more work for the CMDT. Worst case it may arrive as large pieces of the roadway that is intended to be milled during actual paving operations. In other instances a small grinder is used to obtain some “representative” samples from various locations on the project. The material obtained from these small grinders may differ in gradation from material produced by a full size milling machine. Designs incorporating unprocessed RAM may require adjustments to JMF gradation targets once production begins.

Processed RAP may come from a commercial stockpile and may or may not be crushed and screened into one or more separated sizes. RAS must be processed per Section 00745.04 of the Standard Specifications before it can be characterized in accordance with this standard practice. Systematic sampling and testing of produced materials will provide the necessary QL information for gradation and average P_{br}.

Accurately measuring the aggregate specific gravity of RAM is problematic. There is no simple way to completely separate the binder and the aggregate in a RAM sample without altering the aggregate. Chemical extractions are imperfect at removing the binder and burning RAM samples in ignition ovens generally lowers aggregate bulk specific gravities. A combination of measurements on burned and unburned samples will be made to better estimate the actual RAM aggregate bulk specific gravity.

5. SAMPLING AND SAMPLE PREPARATION

Material Sampling (Unprocessed Material) – Representative samples are taken from a minimum of five locations for each mix type along the project or stockpile. If the mix to be milled was constructed from different mix types, (e.g. – a portion of the mix to be milled is ¾” open-graded and a portion is ½” dense-graded) then sample and evaluate the RAM for each mix type separately.

Material Sampling (Processed Material) – Establish a QC random sampling and testing program comparable to the requirements for producing a virgin ACP aggregate stockpile. A sublot shall be defined as every 2000 tons or a minimum of 5 tests. Sample processed RAM materials per AASHTO T 2. Product compliance testing as required under Section 4A of the Manual of Field Test Procedures is not required for RAM.

Sample Preparation (Unprocessed Material) – RAM material received as slabs, chunks or otherwise large intact pieces shall be warmed in a controlled oven per AASHTO R 47 and broken apart per Section 9.1 of AASHTO T 209. Discard any cut or broken aggregate. If a small grinder was used on the grade, then sieve the material on a 3/4” sieve to remove and discard any isolated oversize material. If significant oversize exists, then process as above per AASHTO R 47 and Section 9.1 of AASHTO T 209.

Sample Preparation (All RAM) – Dry RAM materials overnight at 125 ± 5°F. Cool to room temperature and reduce to a minimum of 3 samples of the test size listed in AASHTO T 209 and a minimum of 5 test samples of the greater test size listed in AASHTO T 308 and/or AASHTO T 30 per AASHTO T 248. Split out additional material for AASHTO T 84 to be run on the - #4 residual aggregate. A splitter may be used if the material is free flowing; if not, use the quartering method. For mix designs that contain both RAP and RAS, combine the RAP and RAS in their respective portions in the mix design for the following tests.

6. COATING OF RAM SAMPLES WITH NEW BINDER

Preheat 1 quart of liquid asphalt to the JMF mixing temperature. Determine the dry mass of each AASHTO T 209 RAM sample to the nearest 0.1 gram. If RAP and RAS material are added as separate stockpiles, combine the two samples proportionally to their contribution to the ACP and thoroughly mix into one homogenous specimen. (Designate as the final mass as “R”). Heat each of these RAM samples to approximately 250° F. Heat a mixing bowl to the approximately 250° F. Place the hot mixing bowl on a protected scale and zero out or tare the scale. EXCEPTION: For RAS only mixes, do not coat the RAS with new binder.

Place the heated RAM in a tared mixing bowl. Record the exact hot mass of RAM to the nearest 0.1 gram (Designate as “R_{hot}”). Re-tare the mixing bowl and hot RAM and add 3.0% by mass new binder based on the hot mass of the RAM (R_{hot} x 0.03) (see Note 1 below). Record the exact hot mass of new hot binder added to the nearest 0.1 gram (designate as $binder_{new}$).

Mix until thoroughly coated. Immediately cool sample by spreading it on a non-stick surface (splitting table). Do not age the sample. As the sample cools break up the agglomerations of fines per AASHTO T 209.

Calculate the actual added asphalt percentage by mass to the nearest 0.01% as follows:

$$P_{b_{new}} = \frac{Binder_{new}}{Binder_{new} + R_{hot}} \; x \; 100$$

Note 1 - The percentage of added new binder may be increased or decreased at the discretion of the technician for RAM materials with more or less existing binder. The purpose of adding the additional binder is to capture the small particles created from the grinding and processing of the RAM, to make the AASHTO T 209 procedure with ‘dryback’ more manageable.

7. DETERMINATION OF RICE GRAVITY

Determine the mass of the empty pycnometer and lid. Place the empty Rice pycnometer on the scale and zero out or tare the scale. For RAP or RAP-RAS samples place the room temperature coated sample in the pycnometer and determine the dry mass of the coated sample to the nearest 0.1 gram (Designate as “C”).

Because material may have been lost in the mixing cooling operations, it is necessary to re-determine the dry mass of the uncoated RAP or RAP-RAS sample. Determine the actual dry mass of uncoated RAM material to the nearest 0.1 gram (Designate as “A”) as follows:

$$A = \frac{C}{\left[1 + \frac{Pb_{new}}{(100 - Pb_{new})}\right]}$$

Compare the actual dry mass “A” with the original dry mass of RAM (“R”) in Step 6. If the difference exceeds 30.0 grams, then discard the sample and start over.

Test each coated sample for theoretical maximum specific gravity per AASHTO T 209 with dryback (**EXCEPTION: for RAS only** see Note 2 below). Calculate the dryback G_{mm} to three decimal places as follows:

$$G_{mm_{ssd}} = \frac{A}{A_{ssd} + D - E - \left[\frac{C-A}{G_b}\right]}$$

Where,

A = actual mass of uncoated dry RAM
A_{ssd} = SSD mass of coated RAM
C = mass of coated dry RAM
D = mass of pycnometer filled with water at 77±0.5° F
E = mass of pycnometer, sample and water at 77±1.0° F
G_b = specific gravity of new liquid asphalt at 77° F

Note 2 - For RAS only, test a 1500 gram non-coated sample using the standard/non-dryback procedure under AASHTO T 209 and calculate the G_{mm} accordingly. A small amount (a single drop may suffice) of liquid dish soap (e.g. Dawn, Joy, Palmolive, etc.) may be used to lower surface tension of the water if RAS pieces are floating in the Rice pot.

8. DETERMINATION OF GRADATION AND ASPHALT CONTENT

Test a minimum 5 samples for asphalt content per AASHTO T 308 according to the following table:

Material Type	Number of RAP samples	Number of RAS samples	Number of RAM samples
RAP	5	0	0
RAS	0	5	0
RAM	0	0	5
Unblended RAM (RAP and RAS to be blended during production)	5	5	0

For RAS Only samples: the sample size shall be between 500 and 750 grams and the incineration time will be determined using AASHTO T 308, including steps 10-14 of Method B. The duration of the test will be determined according to a mass loss of less than 0.03% after 15 minutes of additional burn time. Method A may also be used to determine the incineration time utilizing the internal scale to indicate a mass loss of less than 0.03% according to Step 10.

Calculate the asphalt content using the following formula:

$$P_{b\text{-}rap/ram} = \left[\left(\frac{M_i - M_f}{M_i}\right) x\ 100\right] - 0.50$$

Where,

$P_{b-rap/ram}$ = percent of asphalt cement in RAM specimen

M_i = initial oven "dried" mass of RAM mixture prior to ignition

M_f = final mass of aggregate remaining after ignition

Note: the 0.50 constant is the universal correction factor of 0.50% when determining the asphalt content for RAM.

Perform gradation analysis per AASHTO T 30. Apply a negative 1.0% correction factor to the Passing No. 200 value. (Note: The material No. 4 and above may be set aside for testing per AASHTO T 85 for RAP and RAP-RAS samples. Loss of fines during washing precludes using the material smaller than the No. 4 for gravity testing.) The RAM asphalt content (P_{br}) shall be the average of all tests (5 minimum). The RAM gradation shall be the average of all tests (5 minimum). QL's for processed RAP products may be used for RAM asphalt content and gradation, as long as a minimum of 5 tests have been performed, with the results provided in the submittal package.

9. DETERMINATION OF BULK SPECIFIC GRAVITY OF RAM RESIDUE AGGREGATE

Burn additional RAP or RAP-RAS material per AASHTO T 308 to obtain a minimum of 1500 g of unwashed passing No. 4 material. Combine + No. 4 material with + No. 4 material from step 8 to obtain a sample size meeting the requirements of AASHTO T 85 for duplicate specific gravity tests. Perform duplicate fine aggregate gravity tests per AASHTO T 84* using a 500 mL flask on the - No. 4 residue aggregates and AASHTO T 85 on the +No. 4 residue aggregates. Combine as follows:

$$Burnt\ G_{sb} = \frac{100}{\dfrac{P_1}{G_{sb_1}} + \dfrac{P_2}{G_{sb_2}}}$$

*NOTE - The Standard AASHTO T 84 test is often complicated with crushed material; burning the material further complicates the determination of the SSD point. The material may not readily slump at SSD condition. At SSD condition check for airborne fines per the T 84 procedure to determine if an alternate means of determining the SSD condition will be required. Another indicator that the SSD condition has been passed is T 84 results that are greater than T 85 results, as the T 85 results should usually be higher than T 84 results due to the increased surface area of larger aggregate fractions.

Where G_1 & G_2 are the bulk specific gravities for T 84 & T 85 and P_1 & P_2 are the respective average percentages by mass for the – No. 4 & + No. 4 as determined by AASHTO T 30 above.

Note: the 0.50 constant is the universal correction factor of 0.50% when determining the asphalt content for RAM.

RAS Only - For mix designs that will contain RAS, but no RAP, a T84 is not required for the residual material after the burn. The RAS G_{sb} will equal the RAS G_{se} as determined using the AASHTO T 209 and AASHTO T 308 results for the RAS material.

10. DETERMINATION OF DESIGN BULK SPECIFIC GRAVITY OF RAM AGGREGATES

Calculate G_{se} – Using the corrected average RAM binder content (P_{br}), the average 'dryback' Rice Gravity ($G_{mm\ ssd}$) and a universal specific gravity of RAM asphalt (G_{br}) = 1.030, calculate G_{se} as follows:

$$RAM\ G_{se} = \frac{100 - P_{br}}{\dfrac{100}{G_{mm_{ssd}}} - \dfrac{P_{br}}{1.030}}$$

Compare the Average Burnt G_{sb} and RAM G_{se} :

If RAM G_{se} – Burnt $G_{sb} \leq 0.080$, then

$$RAM\ G_{sb} = \frac{RAM\ G_{se} + 2(Avg\ Burnt\ G_{sb})}{3}$$

If RAM G_{se} – Burnt $G_{sb} > 0.080$, then

$$RAM\ G_{sb} = \frac{RAM\ G_{se} + 3(Avg\ Burnt\ G_{sb})}{4}$$

For RAS only, the RAS G_{se} will be used for the RAS G_{sb} value.

11. DETERMINATION OF DESIGN APPARENT SPECIFIC GRAVITY OF RAM AGGREGATES

Calculate the RAM G_{sa} as follows:

$$RAM\ G_{sa} = Burnt\ G_{sa} + \frac{\left(RAM\ G_{sb} - Burnt\ G_{sb}\right)}{2}$$

Note: There is no requirement for RAS G_{sa} reporting for designs that contain RAS, but no RAP

12. REPORT

12.1 The laboratory report shall include the following:

12.1.1 All masses required to calculate G_{mm} per procedure to the nearest 0.1g.

12.1.2 The specific gravity of the asphalt binder used (G_b) to the third decimal place.

12.1.3 The mass of new binder added to each RAM sample for determining G_{mm} to the nearest 0.1g.

12.1.4 All specific gravities are reported to the third decimal place.

12.1.5 The results of sieve analysis shall be reported as follows: (a) masses retained on each sieve for each sample, (b) calculated percent passing each sieve to the nearest 0.1% for each sample, (c) average calculated percent passing each sieve reported to the nearest 0.1%.

12.1.6 Report all masses required to calculate RAM asphalt content ($P_{b\text{-}RAM}$) to the nearest 0.1g.

12.1.7 Report all $P_{b\text{-}RAM}$ and the average P_{br} to the second decimal place.

12.1.8 Report all masses required for determining the bulk specific gravity of the residual aggregates.

12.1.9 Report the RAM G_{sb} and G_{sa} to be used for mix design purposes.

Provisional Method of Test for

Laboratory Batching of Aggregates for ACP Mix Design, Proficiency, and Calibration

ODOT PTM 1-17 (Optional)

1. SCOPE

1.1 ACP mixing plants generally combine unwashed aggregates from various stockpiles and/or RAM into a final blend for the purpose of producing a specification mixture that is to be tested with a washed process. This test method describes laboratory techniques for hand blending virgin aggregates and RAM to closely model the blend that a full scale plant would produce with like materials. The test method may be used for both open and dense-graded ACP mixtures.

2. REFERENCED DOCUMENTS

2.1 AASHTO Standards

- T 2, Sampling of Aggregates
- T 11, Materials Finer Than 75-pm (No. 200) Sieve in Mineral Aggregates by Washing
- T 27, Sieve Analysis of Fine and Coarse Aggregates
- T 30, Mechanical Analysis of Extracted Aggregate
- T 248, Reducing Samples of Aggregate to Testing Size

3. SUMMARY OF PRACTICE

3.1 Two methods are described in this test procedure; Dry to Washed Adjustment Method and Iterative Method. The Dry to Washed Adjustment Method is generally more useful when preparing multiple blends because the factors developed are independent of any set of coldfeed percentages. The Iterative Method is more useful when preparing a batch for a single blend such as when working off an existing JMF. The CMDT, however, may submit an alternate plan for batching aggregates if it meets the tolerances of Table 1 below.

4. APPARATUS

4.1 *Sampling Equipment* - per AASHTO T 2

4.2 *Splitting Equipment* – per AASHTO T 248

4.3 *Sieves and Shaker* – per AASHTO T 27/T 11 or AASHTO T 30

4.4 *Bins or buckets* – provide bins or buckets of adequate size to accommodate fractionated material for each stockpile

4.5 *Labels* – provide labels for each bin that note the aggregate Source Number, stockpile designation, and sieve size upon which the material was retained.

4.6 *Lids or plastic covering* – provide lids or plastic covering for bins and buckets to minimize moisture pickup in the fractionated material when not in use.

4.7 *Drying/Batch Containers* – provide shallow flat metal pans large enough to accommodate a 4500 gram batched sample.

4.8 *Balance* – capable of measuring a principal mass of 12 kg and accurate to 0.1 gram.

4.9 *Forced Air, Ventilated or Convection Oven* - capable of maintaining the temperature surrounding the sample at 325 ± 9°F.

5. SIGNIFICANCE AND USE

5.1 This method covers batching of ACP aggregates for use in Stage 1, 2, and 3 mix design work as outlined in the ODOT Contractor Mix Design Guidelines. This method may also be used for developing proficiency samples as required under the ODOT QA program and for preparing oven calibration samples as required per ODOT TM 323.

6. AGGREGATE PRODUCTION RECORDS AND JMF BLENDS

6.1 Obtain the Quality Level (QL) mean values for each of the stockpiles to be used in preparing the samples. If batching is for Stage 1 mix design purposes, develop trial blends per the ODOT Contractor Mix Design Guidelines. If batching is for proficiency samples or oven calibration for an existing design, obtain the coldfeed percentages and stockpile gradations from the JMF.

7. SAMPLE PREPARATION OF FRACTIONATED MATERIAL

7.1 Sample materials per AASHTO T 2. Sample size depends on the percentage of the total mix that each stockpile represents and the laboratory work to be performed. A three stage SuperPave™ mix design will usually require 50 to 100 lbs per separated size (stockpile).

7.2 Dry the samples per AASHTO T 255. If samples are dried overnight at 230±9 °F, then a constant mass determination is not required. After drying, cool and cover to minimize moisture pickup.

7.3 Sieve each separated size over the required sieves. Carefully empty the material retained on each sieve into the properly labeled bin or bucket for that material.

Note 1: To reduce the number of sizes of fractionated materials from which the batch is prepared, the ODOT Contractor Mix Design Guidelines allow small amounts of materials to be batched from material sieved from other stockpiles. To do so the following conditions must be met:

- The Adjusted QL %Passing for the sieve to be moved elsewhere is less than 10%.
- Stockpiles to be combined were produced from the same source and same parent material. Materials from different aggregate sources may not be combined.
- The particle shape and texture is essentially the same for the sieve sizes to be combined.
- Stockpiles are produced using similar processes (i.e. – do not mix stockpiles with crushed material with stockpiles of uncrushed material, do not mix unwashed stockpiles with washed stockpiles, etc.).

7.4 Cover all fractionated material to prevent moisture pickup prior to batching.

7.5 Dry processed RAM materials overnight at 125±5 °F and cool. If RAM is unprocessed, see ODOT TM 319 on how to break up materials and then dry overnight at 125±5 °F and cool. Cover to minimize moisture pickup.

8. METHOD 1: DRY SIEVE TO WASHED SIEVE ADJUSTMENT

For each separated size of aggregate:

8.1 Sample representative production materials per AASHTO T 2.

8.2 Reduce the sample per AASHTO T 248 to a test size meeting Table 2 of AASHTO T 27.

8.3 Dry the sample to constant mass per AASHTO T 255. Cool and weigh the sample to the nearest 0.1 gram (Initial Dry Mass).

8.4 Dry sieve over the required sieves without loss of material per AASHTO T 27. Weigh and record the mass retained on each sieve and pan to the nearest 0.1 gram.

8.5 Carefully recombine the sample without loss of material and reweigh. The total must compare with the Initial Dry Mass from Step 8.3 above within 0.10%. If not resample and test again.

8.6 Wash the recombined sample per AASHTO T 11.

8.7 Dry the sample to constant mass per AASHTO T 255. Cool and weigh the sample to the nearest 0.1 gram (After Wash Mass).

8.8 Sieve over the required sieves without loss of material per AASHTO T 27/T 11. Weigh and record the mass retained on each sieve and pan to the nearest 0.1 gram.

9. CALCULATIONS

9.1 Using the initial dry mass from Step 3, calculate the Dry to Washed adjustment for each sieve to the nearest 0.1% as follows:

$$\%Retained\ Adjustment = \frac{Dry\ Sieved\ Mass - Washed\ Sieved\ Mass}{Initial\ Dry\ Mass} x\ 100$$

9.2 Calculate the %Retained for the Production QL Means to the nearest 0.1% by subtracting the %Passing for each sieve from the %Passing from the next larger sieve.

9.3 Calculate the Adjusted QL Retained for each sieve as follows:

$$Adjusted\ QL\ \%\ Retained = QL\ \%\ Retained + \%\ Retained\ Adjustment$$

EXAMPLE: The following masses were measured for a No. 4 to No. 8 stockpile.

Sieve	Dry Sieve Mass	Washed Sieve Mass	% Retained Adjustment	QL % Retained	Adjusted QL % Retained
1”	0.0	0.0	0.0	0.0	0.0
3/4"	0.0	0.0	0.0	0.0	0.0
1/2"	0.0	0.0	0.0	0.0	0.0
3/8”	14.7	11.0	0.4	0.9	1.3
1/4"	251.2	252.0	-0.1	29.6	29.5
No. 4	256.9	255.4	0.2	28.2	28.4
No. 8	348.7	348.9	-0.0	32.4	32.4
No. 16	30.6	31.3	-0.1	4.2	4.1
No. 30	4.2	4.3	-0.0	1.1	1.1
No. 50	1.9	1.9	0.0	0.6	0.6
No. 100	2.9	2.5	0.0	0.3	0.3
No. 200	3.6	3.5	0.0	0.0	0.0
Pan	14.6	18.5	-0.4	2.7	2.3
Total	**929.3**	**929.3**	**0.0**	**100.0**	**100.0**

10. METHOD 1: DEVELOPMENT OF THE TRIAL BATCH PLAN

Batch plans are developed one virgin stockpile at a time starting with the coarsest stockpile and progressing through consecutively finer stockpiles.

10.1 Calculate the required mass for each aggregate constituent (i.e. – virgin stockpile, lime, RAM, etc.) by multiplying the desired sample size by the coldfeed percentage for each constituent and record to the nearest 0.1 gram. As a check the sum of the individual constituent masses should add up to the desired total sample mass.

10.2 Starting with the coarsest virgin stockpile, for each sieve, multiply the individual constituent mass for that stockpile by the dry to washed Adjusted QL %Retained determined above and record to the nearest 0.1 gram.

10.3 Identify those sieve sizes to be carried to other stockpiles as allowed under Note 1 above and clearly document the mass to be carried and the stockpile to which that mass will be assigned.

10.4 To preclude the need to re-zero the balance between masses when batching, it is permissible (and recommended) to calculate a cumulative mass total beginning with the largest sieve on the coarsest stockpile. Do not include those sieves that are "carried" elsewhere. Begin the cumulative total on subsequent finer piles with the ending cumulative total from the previous stockpile.

10.5 Repeat Step 10.2 through 10.4 with each successive stockpile. If cumulative totals are not used, verify mathematically that the batch plan produces the correct mass of virgin materials for each stockpile and the total of all virgin stockpiles.

METHOD 1 EXAMPLE: A CMDT is batching for a gyratory sample of 4750 grams of mix. She estimates the aggregate portion will conservatively be *4500 grams*. The mix is to have 25% RAP with three virgin stockpiles of 18%, 27%, and 30%.

Stockpile	**1/2" to No. 4**	**No. 4 – No. 8**	**No. 8 - 0**	**RAP**
Coldfeed %	18%	27%	30%	25%
Batch Mass	810.0 gr	1215.0 gr	1350.0 gr	1125.0 gr

Note: *The sum of the batch masses must add up to the original aggregate target mass, in this example: 810.0 + 1215.0 + 1350.0 + 1125.0 = 4500.0 grams.*

The CMDT now calculates trial batch plan for the 1/2" to No. 4 stockpile. Using the Batch Mass above for the 1/2” to No. 4 stockpile (810.0 grams) the individual sieve batch weights are as follows:

Separated Size: 1/2" to No. 4 (18% = 810.0 grams)

Sieve	Adjusted QL %Retained	Batch Mass	Mass Carried to Next Pile	Cumulative Batch Mass
1”	0.0	0.0	0.0	**0.0**
3/4"	0.0	0.0	0.0	**0.0**
1/2"	3.3	26.7	0.0	**26.7**
3/8”	49.4	400.1	0.0	**426.8**
1/4"	39.8	322.4	0.0	**749.2**
No. 4	3.5	28.4	-28.4	
No. 8	1.7	13.8	-13.8	
No. 16	0.2	1.6	-1.6	
No. 30	0.0	0.0	0.0	
No. 50	0.1	0.8	-0.8	
No. 100	0.0	0.0	0.0	
No. 200	0.0	0.0	0.0	
Pan	2.0	16.2	-16.2	
Total	**100.0**	**810.0**	**-60.8**	

Note that the Adjusted QL %Retained column summed correctly to 100.0% indicating that the calculations for percent retained were performed correctly. The Batch Mass Column sums correctly to the desired 810.0 grams for this stockpile.

Finally, the Total Batch Mass for this stockpile minus the Total Mass Carried for the sieves smaller than the 1/4" computes correctly: 810.0 – 60.8 = 749.2grams, which is the final Cumulative Batch Mass total on the 1/4" sieve.

The minus sign in front of the masses to be carried shows mass is being removed from this portion of the Batch Plan. On subsequent forms it will be changed to a “+” sign to indicate that it is being added to those portions of the batch plan.

The significance of being able to carry minor amounts of material when batching is in this example it reduces the number of fractionated sizes by eight. This means when batching, there are eight less bins from which the CMDT must take and measure material just on this stockpile alone.

An observer might ask why the 1/2” sieve was not also carried to another pile because it retained only 3.3%. The reason is the exception is based on %Passing and not %Retained. The amount passing the 1/2" sieve is in fact 96.7%, therefore, we must batch it from this stockpile. Only when we get to the No. 4 does the percent passing fall below 10%.

The CMDT continues on with the next stockpile, the No. 4 to No. 8.

Separate Size: No. 4 to No. 8 (27% = 1215.0 grams)

Sieve	Adjusted QL %Retained	Batch Mass	Mass Carried to Next Pile	Cumulative Batch Mass
1"	0.0	0.0	0.0	**749.2**
3/4"	0.0	0.0	0.0	
1/2"	0.0	0.0	0.0	
3/8"	1.3	15.8	0.0	**765.0**
1/4"	29.5	358.4	0.0	**1123.4**
No. 4	28.4	345.1 + 28.4	0.0	**1496.9**
No. 8	32.4	393.7 + 13.8	0.0	**1904.4**
No. 16	4.1	49.8 + 1.6	-51.4	
No. 30	1.1	13.4 + 0.0	-13.4	
No. 50	0.6	7.3 + 0.8	-8.1	
No. 100	0.3	3.6 + 0.0	-3.6	
No. 200	0.0	0.0 + 0.0	0.0	
Pan	2.3	27.9 + 16.2	-44.1	
Total	**100.0**	**1215.0 + 60.8**	**-120.6**	

Note as was checked before, the Adjusted QL %Retained sums to 100.0. The batch mass was checked in two parts; the 1215.0 agrees with the total and the 60.8 matches the mass carried from the 1/2" to No. 4.

To check on the Batch Mass Total we must include the Cumulative Batch Mass from the previous stockpile. Therefore, the previous Cumulative Batch Mass plus the Current Total Batch mass minus the Mass Carried must match the final Cumulative Batch Mass on the No. 8 sieve; 749.2 + 1215.0 + 60.8 – 120.6 = 1904.4.

It should also be noted that the masses carried from the No. 16 sieve down are a combination of material from this stockpile and from the previous one. Again by carrying these masses the CMDT has reduced the number of bins of fractionalized material by another six bins.

The CMDT continues on with the last stockpile, the No. 8 - 0.

Separate Size: No. 8 - 0 (30% = 1350.0 grams)

Sieve	Adjusted QL %Retained	Batch Mass	Cumulative Batch Mass
1"	0.0	0.0	**1904.4**
3/4"	0.0	0.0	
1/2"	0.0	0.0	
3/8"	0.0	0.0	
1/4"	0.0	0.0	
No. 4	0.2	2.7	**1907.1**
No. 8	20.2	272.7	**2179.8**
No. 16	26.5	357.8 + 51.4	**2589.0**
No. 30	17.1	230.8 + 13.4	**2833.2**
No. 50	14.8	199.8 + 8.1	**3041.1**
No. 100	11.9	160.7 + 3.6	**3205.4**
No. 200	2.8	37.8 + 0.0	**3243.2**
Pan	6.5	87.7 + 44.1	**3375.0**
Total	**100.0**	**1350.0 + 120.6**	

The final Cumulative Batch Mass on the Pan matches exactly the sum of the three virgin stockpiles; 810.0 + 1215.0 + 1350.0 = 3375.0.

11. ADJUSTING THE BATCH PLAN TO WASTE DUST

11.1 Determine the amount of dust to be wasted as a percentage of the total aggregate.

11.2 Increase the aggregate portion of the desired batch size by that percentage.

METHOD 1 EXAMPLE: Using the same numbers from the above batch plan for Method 1, a CMDT elects to waste 1.0% dust. She increases the desired batch size as follows:

Adjusted Aggregate Batch Size = 1.01 x 4500 grams = 4545.0 grams

11.3 Develop the batch plan as described in Method 1 above using the Adjusted Aggregate Batch Size.

11.4 Edit the final Cumulative Batch Mass on the Pan for the last virgin stockpile by subtracting increase in grams determined in Step 2 above from the Pan.

METHOD 1 EXAMPLE: The CMDT developed a batch plan using the Adjusted Aggregate Batch Size of 4545.0 grams to account for a 1.0% wasting of dust and 25% RAP. The final unedited Cumulative Batch Mass on the last virgin stockpile for the Pan was 3408.8 grams (0.75 x 4545.0). The CMDT subtracts the 45.0 gram increase from the Pan as follows:

Pan: 3408.8 – 45.0 = 3363.8 grams

The CMDT strikes through the ~~3408.8~~ and edits the final cumulative batch mass to read 3363.8.

12. METHOD 1: VERIFICATION OF VIRGIN PORTION OF TRIAL BATCH PLAN

12.1 Using a tared container, prepare a trial batch sample of the virgin portion of the batch plan by carefully measuring the amount of material to the nearest 0.1 gram from the appropriate bin per the trial batch plan down to the No. 200 material.

12.2 Wash the trial batch per AASHTO T 11.

12.3 Dry the sample to constant mass per AASHTO T 255. Cool and weigh the sample to the nearest 0.1 gram (After Wash Mass).

12.4 Sieve over the required sieves without loss of material per AASHTO T 27. Weigh and record the mass retained on each sieve and pan to the nearest 0.1 gram.

12.5 Calculate the Percent Passing on the Trial Batch to the nearest 0.1%.

12.6 If the JMF or design blend includes RAM, it will be necessary to calculate new combined blend targets for the virgin portion of the aggregate only.

Note: *To calculate virgin only coldfeed percentages, divide the original coldfeed percentages by the percentage of virgin aggregate. (e.g. – for this example with 75% virgin aggregate the new virgin coldfeeds would be 18%/0.75 =* ***24.0%,*** *27%/0.75 =* ***36.0%,*** *and 30%/0.75 =* ***40.0%*** *for the three stockpiles. Re-compute the virgin only blend using these new values.*

12.7 The Trial Batch Percent Passing must compare with the Virgin Blend Percent Passing per Table 1 below. If not adjust the virgin portion of the batch plan and re-verify per this process.

Table 1: Allowable Differences Between Batched and Actual Gradations

Sieves	Allowable Diff. (%Passing)
Larger than No. 8	±1.5%
No. 8 to No. 50	±1.0%
Smaller than No. 50	±0.5%

13. METHOD 1: ADJUSTMENT TO TRIAL BATCH PLAN

13.1 Calculate the Target Retained Mass for each sieve from JMF or design gradation targets using the same mass as the trial batch. If RAM is used calculate the Target Retained Mass based on the "Virgin Only" blend developed above.

13.2 For each sieve, determine the Error in Retained Mass by subtracting the Actual Washed Retained Mass from the Target Retained Mass determined in Step 1 above and record to the nearest 0.1 gram.

13.3 Generate a new Adjusted Batch Plan by modifying the Trial Batch Plan by the Error in Retained Mass. Apply the Error in Retained Mass to the stockpile with the largest contribution of material for a given sieve. If the sieve in question is batched from several stockpiles, it is permissible to use a weighted average to distribute the Error in Retained Mass over the appropriate stockpiles.

13.4 Batch a new adjusted trial sample and repeat the verification process until the sample meets the Batch Verification Requirements listed in Table 1 above.

EXAMPLE: The following masses were measured for a virgin only verification:

Sieve	Target Retained Mass	Actual Retained Mass	Error in Retained Mass
1”	0.0	0.0	0.0
3/4"	0.0	0.0	0.0
1/2"	42.5	42.5	0.0
3/8”	192.5	188.5	4.0
1/4"	405.0	391.7	13.3
No. 4	385.0	390.4	-5.4
No. 8	600.0	588.1	11.9
No. 16	302.5	278.6	23.9
No. 30	147.5	155.2	-7.7
No. 50	85.0	91.0	-6.0
No. 100	70.0	82.5	-12.5
No. 200	75.0	83.0	-8.0
Pan	195.0	208.5	-13.5
Total	**2500.0**	**2500.0**	**0.0**

Note: The total of the Error in Retained Mass must sum to 0.0.

14. METHOD 2: ITERATIVE METHOD – TRIAL BATCH PLAN

14.1 Determine the aggregate mass for each stockpile using the same procedure as Step 10.1 in Method 1 above. The trial batch size must meet the requirements of Table 2 of AASHTO T 27/T 11.

14.2 Calculate the % Retained for each sieve from the ***original*** production QL mean values.

14.3 Multiply the % Retained for each sieve by the aggregate mass for that stockpile determined in Step 14.1.

14.4 Similar to Method 1 above it is permissible to carry minor amounts of material from stockpile to stockpile for those stockpiles that meet the conditions of Step 10.3 in Method 1 above.

14.5 Similar to Method 1 above it is permissible (and recommended) to calculate a cumulative total for purposes of batching following Step 10.4 of Method 1 above.

14.6 Repeat Step 14.2 through 14.5 with each successive stockpile. If cumulative totals are not used, verify mathematically that the trial batch plan produces the correct mass of virgin materials for each stockpile and the total of all virgin stockpiles.

EXAMPLE: A CMDT is batching an 810.0 gram batch for the 1/2" to No. 4 stockpile using the iterative method as follows:

Sieve	QL Mean %Passing	QL Mean %Retained	Retained Mass	Mass Carried	Cumulative Mass
1”	100.0	0.0	0.0	0.0	0.0
3/4"	100.0	0.0	0.0	0.0	0.0
1/2"	93.0	7.0	56.7	0.0	56.7
3/8”	61.0	32.0	259.2	0.0	315.9
1/4"	16.0	45.0	364.5	0.0	680.4
No. 4	7.0	9.0	72.9	-72.9	
No. 8	4.0	3.0	24.3	-24.3	
No. 16	3.0	1.0	8.1	-8.1	
No. 30	3.0	0.0	0.0	0.0	
No. 50	2.0	1.0	8.1	-8.1	
No. 100	2.0	0.0	0.0	0.0	
No. 200	1.8	0.2	1.6	-1.6	
Pan	0.0	1.8	14.6	-14.6	
Total		**100.0**	**810.0**	**-129.6**	

Note the two Retained columns correctly sum to 100.0 indicating the calculations were performed correctly. The Total Retained Mass and the Mass Carried total to match the final Cumulative Mass: 810.0 – 129.6 = 680.4. The CMDT continues the same process for each successive stockpile.

15. METHOD 2: VERIFICATION AND ADJUSTMENT OF TRIAL BATCH PLAN

15.1 Use the same verification and adjustment process as Method 1 above. The final batch plan must meet the requirements of Table 1 above.

16. METHOD 1 AND 2: LABORATORY BATCHING

16.1 Using a verified batch plan, tare an appropriate drying container and weigh into the container the planned mass from each separated size beginning with the coarsest stockpile.

16.2 Reduce the correct mass of dry RAM per AASHTO T 248 to the nearest 0.1 gram and place into a separate drying container. The RAP is kept separate from the virgin aggregates until mixing per ODOT TM 330.

17. REPORT

17.1 Report batch plans to the nearest 0.1 gram on all specification sieves.

17.2 Report the final batch plan verification percent passing results to the nearest 0.1%. Report the “Virgin Only” target percent passing to the nearest 0.1%. Report the Difference between the two results to the nearest 0.1%.