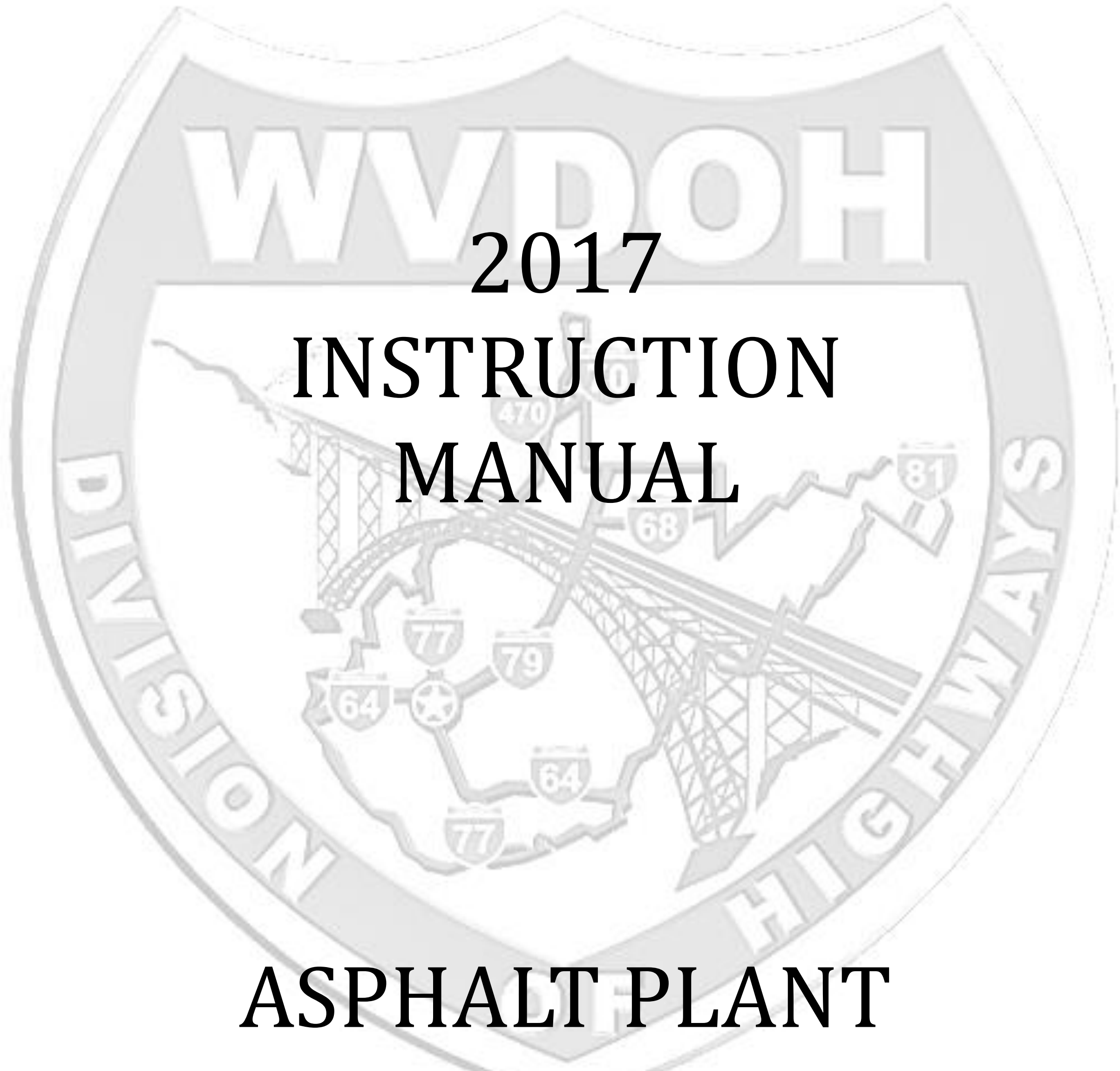
WEST VIRGINIA DIVISION OF HIGHWAYS



2017
INSTRUCTION MANUAL

ASPHALT PLANT TECHNICIAN

WEST VIRGINIA DIVISION OF HIGHWAYS
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Chapter 1 - Background

I HISTORY OF ASPHALT CONCRETE

Even though many advanced technologies are used in order to produce and place asphalt mixtures today, the basic knowledge that asphalt can be used as an engineering material has been around since 6000 B.C. Its earliest uses were in the shipbuilding industry by the Sumerians. The word "asphalt" itself is believed to be derived from the Akkadian term "asphaltic." The earliest forms of asphalt were naturally occurring. Besides the Middle East, major deposits of naturally occurring asphalt have been found in North and South America, with the most famous being Trinidad Lake on the island of Trinidad, shown in Figure 1 and Figure 2.

Figure 1 - Workers mining Trinidad Lake Asphalt

Figure 2 - Workers unloading wooden barrels of Trinidad Lake asphalt

Using asphalt paving blocks, roads were constructed in Europe as early as 1823, but the first compacted asphalt pavement wasn't laid in London, England until 1869. A year later the first asphalt roadway in the United States was placed in Newark, New Jersey. These pavements were not very cost effective because the natural asphalts used were in high demand and had to be imported. In the early 1900's a method for refining asphalt from crude petroleum was discovered which made asphalt plentiful and more cost effective.

Figure 3 - Pennsylvania Ave. in Washington, DC being paved in 1876

The use of asphalt pavements has grown steadily throughout the years, peaking in 1956 when Congress passed the State Highway Act. This Act allotted $51 billion to states for road and bridge construction. In order to maintain quality of its highways, the West Virginia State Road Commission (Created in 1913, now the WVDOH) decided to hold classes in the production and usage of asphalt mixtures as well as other construction materials. The first Asphalt Plant Technician certification class was held in 1966.

Figure 4 - HMA Technician Class of 1967

II ASPHALT PLANT TECHNICIAN

Since the first Asphalt Plant Technician School, many technical advancements have been made to the aspects of producing and testing Asphalt materials, however the role of the Asphalt Technician remains unchanged. An asphalt plant technician, whether a WVDOH employee or a producers employee, is responsible for the quality of asphalt concrete and its essential materials produced at the mixing plant. This includes but is not limited to the handling, storing, stockpiling, mixing, hauling, sampling, and testing of all asphalt concrete materials. Asphalt Plant Technicians are responsible for checking material sources, grades, types, temperatures, moisture contents, truck beds and tarps, verify scale checks, monitor plant operations and mixing time, observe condition of mix in the truck, load tickets for proper information, and review materials documentation and test reports. Along with the plant and yard monitoring, technicians must be able to properly perform the sampling and testing necessary to measure the quality of the materials. Technicians must also be fully capable of reviewing and interpreting mix design data, laboratory test results, and specifications.

Through the remainder of this manual, workshop manual, and additional resources much of the aforementioned responsibilities will be covered. This instruction manual will cover the fundamental properties and characteristics of Asphalt concrete and its components, an introduction to two commonly used mix design methods, asphalt mixing plant control and inspection, and quality control and testing of asphalt concrete.

III DEFINITIONS

A) ASPHALT CONCRETE

A composite material of mineral aggregate and asphalt binder, laid and compacted in layers, Asphalt Concrete is a typical material used in the construction of driveways, roadways, and airport runways. Given the flexible nature of Asphalt binder, Asphalt Concrete roads are considered a flexible pavement. Asphalt Concrete can be divided into three broad categories: Hot Mix, Warm Mix, and Cold Mix Asphalt. These divisions describe the temperatures in which the Asphalt Concrete is mixed. This will be discussed further in the proceeding chapters.

B) BITUMINOUS MATERIAL

Bituminous Materials consist of occurring hydrocarbon byproducts of organic decomposition. These materials are dark brown or black, oily, and viscous materials. They are commonly classified as Tar and Asphalt.

i) Tar

Tars are produced by the destructive distillation of bituminous coal or by the cracking of petroleum vapors. Tars are commonly used as sealers or waterproofing membranes for roofs. Since tars are less susceptible to petroleum fuels then Asphalt Binders, tars are used as surface treatments on parking lots, airport aprons, and driveways where fuels spills are more likely.

ii) Asphalt Binder

Also called Asphalt Cement, this dark brown or black material is found in natural deposits or manufactured by distilling crude oil. Asphalt Binder has no definite chemical composition, but is made of large chains of mostly hydrogen and carbon atoms. Asphalt binder can be used in either a neat or a modified fashion when used in asphalt concrete.

a) Modified Asphalt Binder

Modified Asphalt Binders are those which have been altered with a chemical additive or an elastomer to enhance the properties of the parent “Neat” Asphalt Binder. These additives can make parent asphalt binders harder at high temperatures, less brittle at low temperatures or even more elastic to resist permanent deformation.

b) Asphalt emulsions

Asphalt Emulsions consist of globules of asphalt binder suspended in water. Since asphalt and water do not naturally mix into solution, the asphalt globules are coated with an emulsifying agent (soap), which gives the globules an electrically charged film. When added to water the charge film forces the globules to repel each other which allow them to flow freely. This also allows the asphalt particles to remain suspended in water. Emulsions can be used at lower temperatures than binders. They require little or no heat for use.

c) Cut Back Asphalts

Cut-Back Asphalts are Asphalt Binders that have been diluted with a solvent, such as naphtha, kerosene, or diesel fuel. They can be used with little or no heating. Due to the harmful nature of the solvents used, environmental regulations in recent years have dramatically reduced the use of cut-back asphalts.

d) Asphalt Binder Production

Asphalt Binders are produced at refineries during the distillation of crude oils or other petroleum products. Heating the crude oil in a still allows for it to separate into various fractions, known as distillates. The lightest distillates of the oil become gasoline; the middle is used for such products as diesel fuel, motor oil and kerosene. What remains in the still after everything else has boiled off may be processed into asphalt. See Figure 5, for a visual of the process that crude oil undertakes. Unfortunately for the asphalt industry advancements in petrochemical technology has given rise to alternate products, such as plastics, which can now be produced from the heavy residuum. As a results only about 25% of the petroleum refineries in the US produce asphalt.

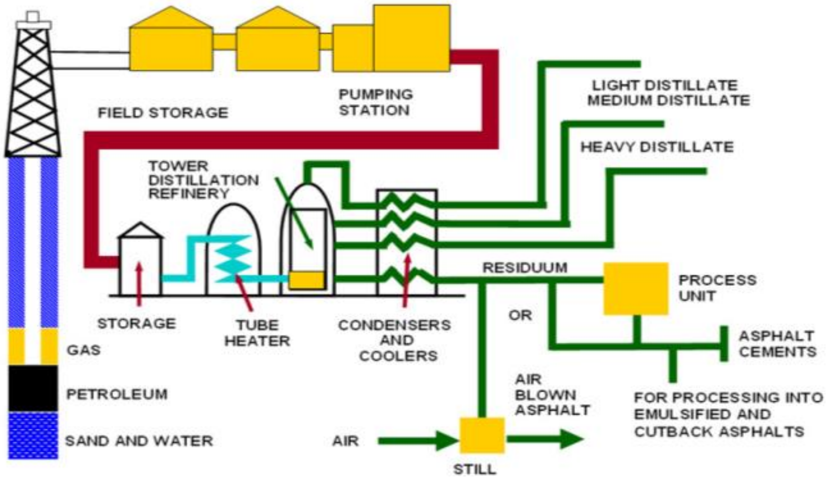


Figure 5 - Refinery Operation

The world's first successful oil well was drilled in southern Ontario in 1858. Shortly after, in 1859 the first American well at Titusville, Pennsylvania was established. In the late

1800's, asphalt that was refined from crude oil became available for paving. However, being a by-product of fuel production, at the time there was no attempt to make Asphalt binder into a quality paving material since the focus was on fuel for automobiles. The growing popularity of the automobile meant that more crude oil was needed to provide gasoline, making the refinery by-product, asphalt, readily available and cheap. More cars increased the demand for paved roads. Refined asphalt quickly became a quality paving material and began to price natural asphalt out of the market.

Even with the technical refinements from the last decade, Asphalt Binder is still not a consistent product across the globe. Asphalt binders may be softer or harder, depending on the source of the crude. Some crudes sources, like Nigerian oil, barely contain any of the heavier fractions used to produce asphalt, while oils from the Middle East contain larger quantities and produce more asphalt binder.

C) MINERAL AGGREGATE

Mineral Aggregate or aggregate is a term that means a mixture of various types and sizes of stone. Typically Aggregates make up approx. 95 percent of Asphalt Concrete. The aggregate within Asphalt Concrete is responsible for carrying the loads of the passing traffic and transferring them to the subgrade under the pavement. Therefore to ensure a quality pavement we must begin with quality aggregates. Below is a list of the commonly used aggregates in West Virginia for highway construction.

i) Limestone

Limestone is formed from the compression of sediment at the bottom of a body of water. As it was covered with other layers of sediment it was compressed into rock. As the land rose, erosion began to cut away the new land surface. The limestone was exposed as thick rock layers in the sides of hills. Limestone is quarried, usually by blasting, and then reduced to a suitable size by crushing. This produces an angular stone that compacts into a strong, durable paving mat. There is an abundance of limestone in West Virginia, providing us with an inexpensive source of high quality paving stone, unlike many other parts of the country, where suitable paving aggregates are scarce.

ii) Gravel

Gravel is a naturally occurring aggregate, dredged from river bottoms or dug from deposits where rivers once flowed. It is made up of various kinds of stone that have been rounded by being rolled along the river bottom by the water current. Gravel is a durable and plentiful resource. However, due to the roundness of the stone particles, gravel poorly interlocks and has little skid resistance. Also, a mixture comprised of only gravel would be extremely hard to compact, due to the rounded nature of gravel, which would allow for the aggregate particles to slip by one another under the load of the roller. Once gravel is crushed, to create angularity, it is more suitable in asphalt concrete. The angularity increases skid resistance and allows the aggregate to interlock, which allows for more stone surface contact to aid in stability of asphalt concrete.

iii) Blast Furnace Slag

Blast Furnace Slag is a co-product of the reduction of ore for metal manufacturing, iron ore being the most common. Slag can also come from the production of other metal ores, like copper, gold, silver, or aluminum. In the blast furnace the ore will melt and the slag, usually being lighter in weight than the metal that is being extracted, will float in the furnace. The slag, being a molten rock, is then removed from the furnace and allowed to cool and harden. The conditions and the rate of cooling will heavily affect the properties of the slag. A rapid cooling will lead to large amounts of voids in the slag. This large amount of pores can entrap water and can be a problem during asphalt production. These also soak up addition asphalt and require higher binder content mixtures. Slag is a good skid resistant aggregate with a high durability.

iv) Sand

Sand is used as the fine aggregate in Asphalt concrete mixes. Sand is classified into two groups; manufactured sand, which is made by crushing stone and screening out the coarser particles, or natural sand, which is sand that occurs in natural deposits and is usually found along with gravel. Manufactured sand is more angular than natural sand.

Sand is classified by the material from which it is made, for example: limestone, slag and sandstone. Sand that is made from crushed sandstone is called silica sand, to distinguish it from other kinds of sand. The name comes from the fact that its main ingredient is silicon dioxide.

v) Mineral Filler

Mineral Filler is a dust sized aggregate (passing the #200 sieve). Paving mixes need a small amount of dust to fill voids and act as a binder extender. An asphalt concrete production plant's dust collection system usually captures the mineral filler that is released as the aggregate is dried. The amount of dust required for the mixture is then metered back to the plant's mixer.

vi) Recycled Asphalt Pavements (RAP)

Recycled Asphalt Pavement (RAP) is asphalt pavement that has been pulverized, usually by milling, and is used like an aggregate in the recycling of asphalt pavements. There are economic and environmental advantages to recycling pavement materials. The use of RAP in Asphalt concrete reduces the need for virgin binder and aggregate which reduces costs and limits the impact on the environment.

Gradation inconsistency and age hardening of the asphalt binder are the main disadvantages of using RAP. For these reasons most specifying agencies put restrictions on the amount of RAP that can be used in asphalt concrete. However, further processing of the RAP into two or more stockpiles of different aggregate sizes and proper stockpile management provides the potential for a substantial increase in the amount of RAP that can be used in asphalt concrete. Chapter 4 - Mix Design and Testing discusses the WVDOH design limits for using RAP in asphalt concrete, and Appendix-C contains a copy of MP 401.02.24 which is a guideline for designing mixtures containing RAP using the Marshall Design method. MP 401.02.28 covers the use of RAP in Superpave mixtures.

IV HIERARCHY OF SPECIFICATIONS

No matter what kind of work that is being performed, there are documents that govern the performance of the work. In the case of asphalt production and paving, the WVDOH has a hierarchy of details that will govern any such work. Beginning from the bottom of the hierarchy is the WVDOH Standard Specifications for Roads and Bridges. The standards are then superseded in the following order, Supplemental Specifications, Contract Document and Notes, Special Provisional Specifications, and finally Memorandums. All of these items will be discussed in the following sections.

A) STANDARD SPECIFICATIONS FOR ROADS AND BRIDGES

Within this book, most of the general specifications for various types of materials and procedural methods will be defined and explained. Within this document however, there will be many references to other documents that may also be required to complete the work. Since this is an Asphalt Manual, the pertinent sections in order to conduct a technicians day to day tasks are as follows: Asphalt concrete production and placement is covered in Sections 401 and 402; the use of tack coat application is covered in Section 408; liquid asphalt materials are covered in Section 705; and aggregates are covered in Sections 702 – 704.

Section 401 references AASHTO and ASTM standard test methods. Copies of the latest versions of these test methods will be required in order to properly conduct these tests. Also within Section 401 are references to various Materials Procedures (MP’s). Some MP’s are for designing Asphalt concrete mixtures, while others are for quality control and quality assurance requirements. Copies of these MP’s will be required in order to perform all of the necessary mix design, QC, and QA procedures and processes that are as much a part of the governing specifications as the specification manual.

B) SUPPLEMENTAL SPECIFICATIONS

A supplemental specification manual contains updates to various sections and subsections of the specification manual, and it is issued after the standard specification manual was issued. There are often more than one supplemental specification manual issued in between the issuance of the WVDOH Standard Specifications for Roads and Bridges manuals. Each new version of the supplemental specification manual contains all of the changes from the previous manuals plus any new additions or changes that are approved after the last edition. Therefore the latest version of the supplemental specification manual should be reviewed to determine if any of the governing specification sections that apply to the project have been updated. Sometimes these changes may be subtle changes that add or delete words or entire sentences, but they can also be major changes that apply to an entire Section or Subsection. The thing to remember is that changes in the supplemental specification manual override the standard manual.

C) PROJECT PLANS/NOTES

Contained in the contract proposal there might be specific items that are changed for a specific project that address a certain aspect of the project. An example of a note would be the use of a polymer-modified PG Binder, PG 76-22, in lieu of the standard PG 70-22 or PG 64-22 at a certain intersection. If the intersection was on a low volume road it would not normally spec a PG 76-22, but if there was a large amount of trucks like at a coal loading facility it may be necessary.

D) SPECIAL PROVISION SPECIFICATIONS

Also contained in the contract proposal, Special Provisions contain the necessary information that applies to a specific project, which may also contain totally new specifications, a revision to the standard or supplemental specification manuals, or even a revision to an MP. These items usually only apply to specific projects, so they must be included in the contract proposal to apply.

E) MEMORANDUMS

Finally in some rare cases, while an MP or specification is in a very important updating process, there could be a memorandum from WVDOH management that is issued to temporarily act as a governing specification until the official update is completed. Check with the local District to see if any such memorandum is in effect.

V QUALITY ASSURANCE SYSTEM

Quality Assurance is the total system of activities designed to assure that the quality of the construction and materials is acceptable with respect to the plans and specifications under which it was produced. The three major components of the Asphalt Concrete Quality Assurance System are (1) Quality Control (QC); (2) Quality Acceptance or Verification Testing (QA); and (3) Independent Assurance Testing (IA).

A) QUALITY CONTROL (QC)

Quality Control (QC) is the activities designed to make a quality product that meets the required specifications through periodic inspection and testing. Quality Control is the producer’s responsibility. It can be performed by certified Asphalt Plant Technicians that either work for the producer or work for a consulting agency. The minimum required Quality Control activities at an asphalt plant are listed in the QC Plans described in MP 401.03.50.

B) QUALITY ACCEPTANCE (QA)

Quality Acceptance or Verification Testing is the random sampling and testing activities conducted by the WVDOH to assure that satisfactory quality control has been exercised and the proper degree of compliance to the specifications has been attained. Producer and WVDOH test results are statistically compared to determine if this is being done.

If a statistical dissimilarity is detected through this comparison process, an immediate investigation is conducted to determine the cause. The intent of this investigation is to define and correct any testing deficiencies that may cause a misrepresentation of the tested material. This investigation should point out any sampling, lab equipment, or test procedures that are not meeting the requirements of the specifications for either the WVDOH or the Producer laboratory.

C) INDEPENDENT ASSURANCE (IA)

Independent Assurance (IA) Testing is testing conducted by a third party that is not responsible for quality control or making acceptance decisions. The Central Materials Division takes a sample and splits it between our Asphalt Lab and the District's Lab. These results are statistically compared to determine similarity between the two labs. IA testing also may include a comparison between the Central Lab and the Producer Lab, or even a three way comparison between the Central, District, and Producer labs.

The WVDOH uses producer's test results as part of the acceptance plan, so both the producer's QC and the District's QA are critical components to a good Quality Assurance System. It is crucial that both entities use the same standard methods and properly calibrated equipment to eliminate statistical outliers. In addition, all technicians involved must be properly trained in the various standard sampling and testing procedures. Training assures the WVDOH of a reliable quality assurance system.

Chapter 2 - Material Fundamentals

I ASPHALT

A) TYPES OF ASPHALT

The types of asphalt used in road construction are asphalt binders, asphalt emulsions, and cut-back asphalt.

- Performance Graded binder is the type of asphalt used in asphalt concrete. They are solid at ambient temperatures and must be heated to make them fluid enough to mix with stone as a paving mix.
- Asphalt emulsions are globules of asphalt suspended in water. Since asphalt and water do not go into solution, the asphalt globules are coated with an emulsifying agent that allows the asphalt particles to be suspended in water. They can be used at lower temperatures than binders. They require little or no heat for use. Asphalt emulsions can be used for numerous applications, but the most prevalent is as a "tack coat" for bonding layers of pavements.
- Cut-back asphalt is diluted with a solvent, such as naphtha or kerosene. They can be used with little or no heating. Environmental regulations in recent years have dramatically reduced the use of cut-back asphalts.

B) PERFORMANCE GRADED BINDERS

The Performance Grade specification is the current method for grading asphalt binders. These have names like PG 64-22. All grades start with the letters PG, which stands for "Performance Graded". The numbers are temperatures in degrees Celsius. For example, PG 64-22 is for use when the road temperature has a seven day average no higher than 64° Celsius and is not expected to a single day minimum lower than -22° Celsius, as shown in Figure 6. Computer programs such as LTPP Bind can be utilized to determine the appropriate binder to be used in a given region.

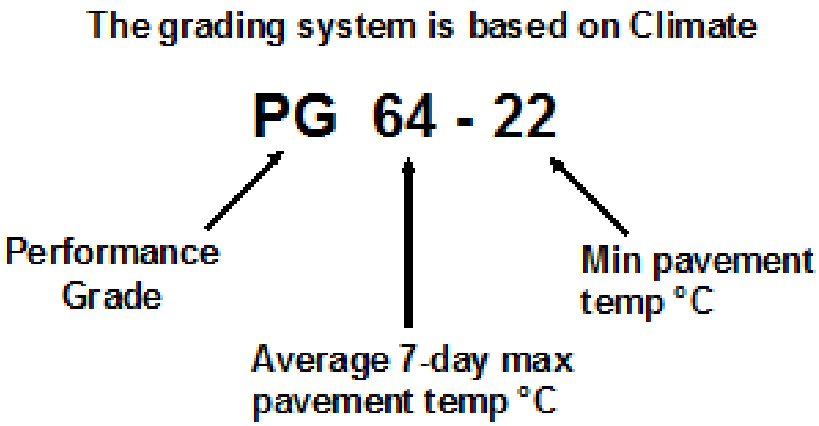
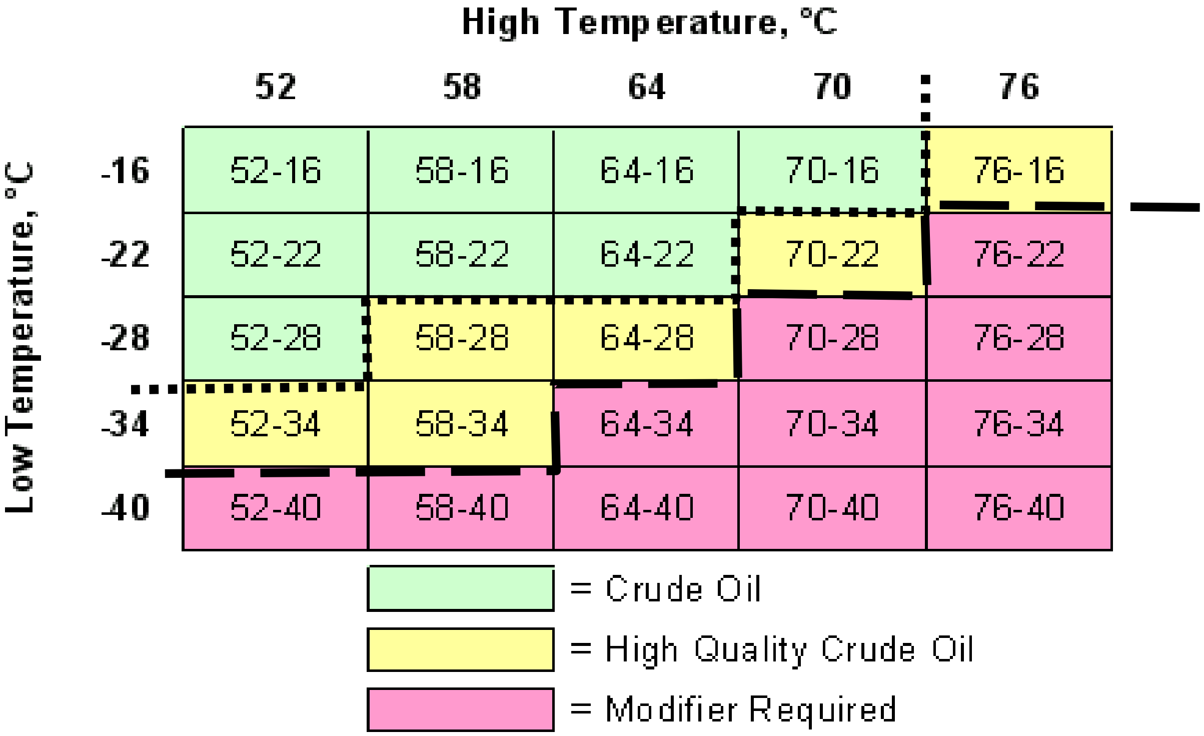


Figure 6 - Performance Graded Binder System

The standard binder grade used in West Virginia is a PG 64-22. PG 58-28 has been used in the higher mountain regions due to the colder temperatures at high elevations. Another grade that is used to for Interstates and other major highways is a PG 70-22. These grades can be made from standard crude without additives or modifiers. See Figure 7 for which grades of asphalt that can be produced from crude oil alone and for those that must be modified.

For some intersections and steep grades where a significant number of large trucks cause severe rutting and shoving of the pavement, a polymer modified PG 76-22 has been shown to mitigate issues. Modified binders are higher priced than neat asphalts binders and can be more difficult to use. Potential problems with polymer modified binders include separation of the modifier and the asphalt, clogging of asphalt lines in the plant, and higher resistance to compaction in the field.

The Performance Grade specification covers several grades for use in a variety of climatic conditions. Some of these grades are very similar to the traditional asphalt cement grades, others require additives. The usual additives are various types of polymers. Since these additives may be present, the Performance Grade specification is called a "Binder Specification" rather than as "Asphalt Specification". One of the main ways that the Performance Grade binder specification differs from our older specifications is that instead of having different specification requirements for each grade, we have the same requirements for all grades but test the different grades at different temperatures.



High Temperature, °C

Low Temperature, °C

	52	58	64	70	76
-16	52-16	58-16	64-16	70-16	76-16
-22	52-22	58-22	64-22	70-22	76-22
-28	52-28	58-28	64-28	70-28	76-28
-34	52-34	58-34	64-34	70-34	76-34
-40	52-40	58-40	64-40	70-40	76-40

🟩 = Crude Oil

🟨 = High Quality Crude Oil

🟥 = Modifier Required

Figure 7 - Binder Grade Chart

The purpose of evaluating asphalt binders is to find out how well they hold up when subjected to the conditions that can make a pavement fail. During the life of a pavement, the asphalt may be subjected to heat, cold, stretching, bending, and repeated heavy loads. Tests for these properties were developed in research laboratories. The equipment used to conduct tests that measure the asphalt's ability to withstand such conditions is complex and expensive. Even understanding how the equipment determines the test results may be difficult, but computer software does all of the hard work and produces the necessary test data. However, since the technology is available, and the cost of replacing failed pavement is enormous. It would be false economy not to take advantage of this technology.

Binders are tested under three different conditions. The initial tests are run on the asphalt as it comes from the refinery. Then the asphalt is conditioned (artificially aged in the laboratory) to duplicate the hardening that takes place as it goes through the mixing plant, and additional tests are conducted. This hardening is caused by the oxidation of the asphalt. Finally the binder is artificially aged again, this time to duplicate the hardening that takes place in the road, and more tests are conducted.

i) Binder Tests Conducted on Tank Binder

a) Safety and Constructability Testing

Flash Point - The flash point of a material is the temperature at which it gives off vapors that will catch fire in the presence of an open flame. The asphalt is heated while passing a flame over it, until the asphalt vapors catch fire. The test is conducted partly for safety reasons and partly as a quality test. A low flash point usually means that the asphalt has been contaminated with a solvent or a petroleum distillate. The flash point must be at least 230°C.

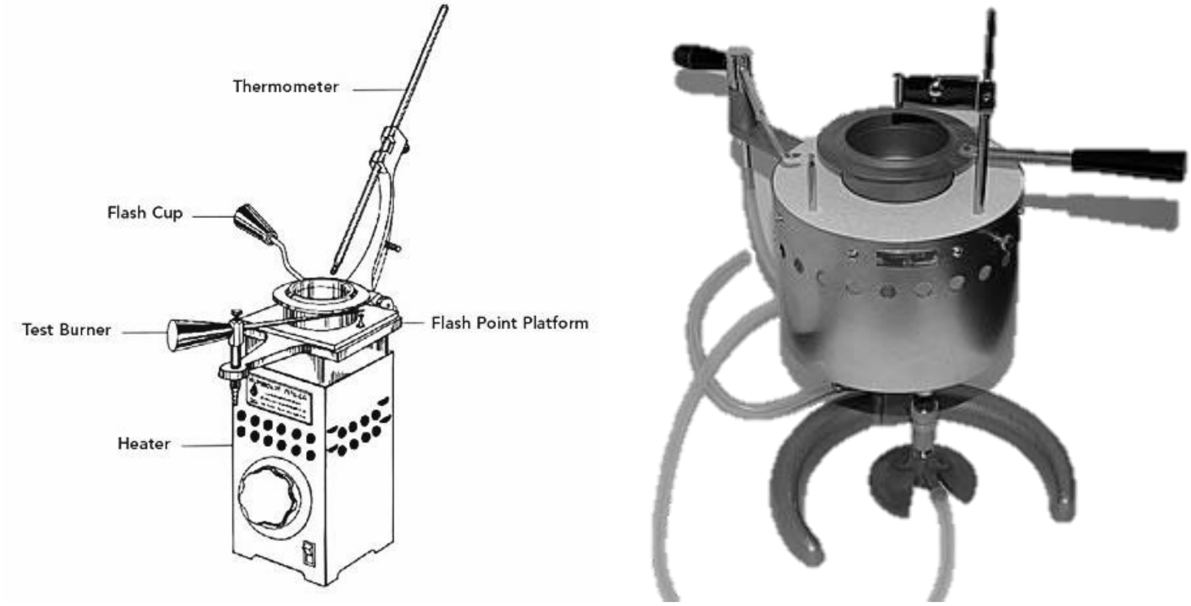


Figure 8 - Cleveland Open Cup Flash Point Tester (AASHTO T48)

Rotational Viscosity - The viscosity test measures the flow characteristics of asphalt at the asphalt concrete mixing temperature. Viscosity is defined as resistance to flow. A material that is thick and flows slowly has a high viscosity, while one that flows rapidly has low viscosity. For example, water is a low viscosity material compared to molasses. Liquids flow more readily as temperature increases, so viscosity goes down as temperature goes up.

Rotational viscosity is determined by measuring the torque needed to rotate a spindle in a container of the asphalt. The test is conducted at 135° Celsius (275°F), which is typically the minimum mixing temperature for asphalt concrete. We want the asphalt to be thin enough to flow over the aggregate and coat it but not so thin that it drains from the aggregate. Rotational viscosity is used to find the best mixing and compaction temperatures and to ensure its pumpability.

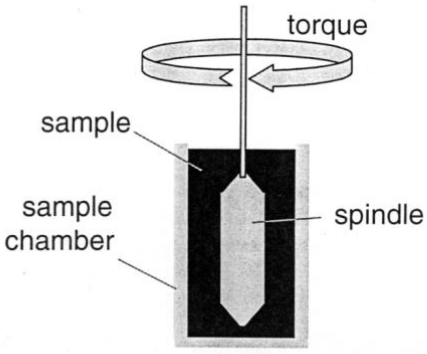


Figure 9 - Rotational Viscometer (AASHTO T316)

Figure 10 - Elastic Recovery Mold

Elastic Recovery (AASHTO T301) – Polymer modified binders also require a simple test that indicates the presence of polymer in the material. A sample of RTFO aged binder or emulsion residue is stretched to 20 cm and then cut in the middle. After an hour the elastic properties of the polymer in the sample will allow the two pieces to recover back toward their original shape. The two pieces are then brought back together until the two ends meet, and a final measurement is made to calculate the percent recovery of the sample. A high percent recovery (> 70% for modified binders and > 50% for emulsion residue) demonstrates the presence of polymer modifiers.

b) Properties to Resist Distress

The performance grade method was designed to evaluate asphalt cement with respect to three pavement distresses: rutting, fatigue cracking and thermal cracking. The Dynamic Shear Rheometer is used to evaluate rutting and fatigue performance. Thermal cracking characteristics of asphalt are evaluated with the Bending Beam Rheometer and the Direct Tension Test.

Dynamic Shear Rheometer (DSR) - Viscosity depends both on asphalt temperature and flow characteristics (how readily the molecules flow over each other). At high temperatures, asphalt is a viscous material and behaves like a sticky liquid. When something forces it to move, it does not return to its original shape. This is why ruts and waves appear in pavement during hot weather.

At low temperatures asphalt is more elastic. When forced to move, it tries to return to its original shape. Cold asphalt can't relieve stresses by flowing, so the stresses built up by traffic loads and temperature changes cause thermal cracking and fatigue failure. This is why asphalt cracks in cold weather.

At intermediate temperatures asphalt and paving mixes tend to exhibit some of both behaviors (elastic and viscous). The dynamic shear rheometer is used to measure these properties.

The dynamic shear rheometer test, the theory behind it, and the calculations are rather complex. The test consists of placing a layer of asphalt between two round discs and twisting one of the discs. This forces the sample to move. The less it moves, the more elastic it is, and the bigger the time lag between when the load is applied and when the sample begins to move, the more viscous it is.

The dynamic shear rheometer test is used to evaluate the load-response characteristics of the binder before it is conditioned as a measure of the consistency of the binder. In the unconditioned state the DSR test is performed at the upper rated temperature of the binder, e.g. for a PG 64-22 binder the test is performed at 64°C.

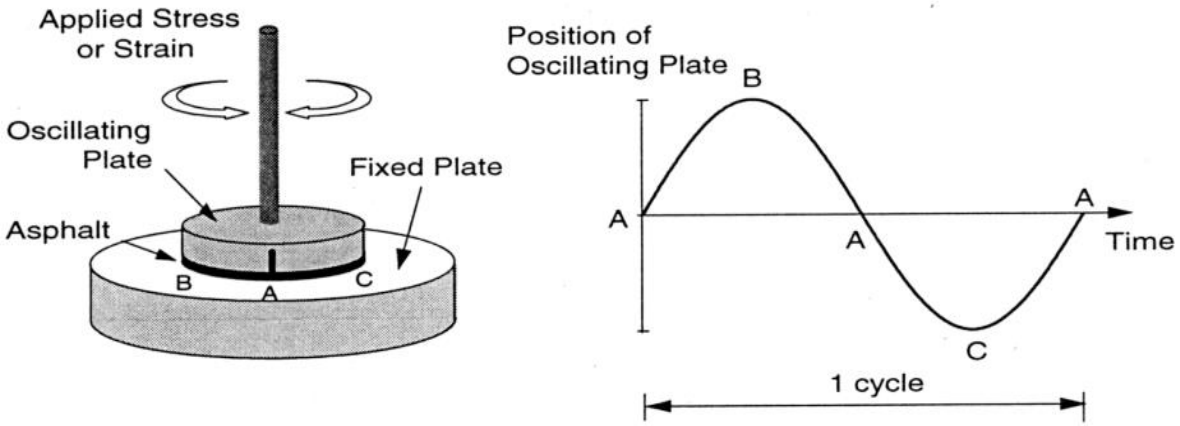


Figure 11 - Dynamic Shear Rheometer Test (AASHTO T315)

ii) Conditioning Methods of Tank Binder

The properties of binders change during the production process and during the life of the pavement. The binder as received from the producer is called Tank binder; it hardens rapidly during production and construction of hot mix, and continues to harden over the life of the pavement.

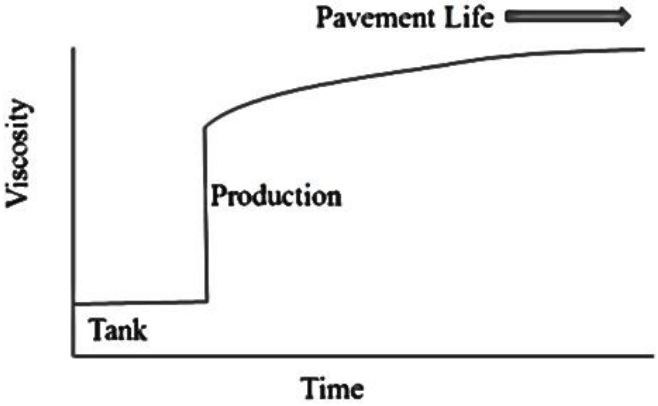


Figure 12 - Aging of binder

The two methods used to condition the asphalt are the Rolling Thin Film Oven Test (AASHTO T240) and the Pressure Aging Vessel (AASHTO R28).

a) Rolling Thin Film Oven Test (RTFO)

This simulates in the laboratory, the hardening that takes place during mixing and transport to the job site. The sample is placed in bottles that rotate around in a hot oven. The rotation spreads the asphalt into a thin film, similar to the asphalt coating on aggregate. During this process, blasts of compressed air are injected into the bottles as they rotate. The rotation also helps to keep any additives in the asphalt in suspension. At the end of the test, the asphalt should have about the same consistency that it would have when delivered to the job site. The main purpose of the procedure is to obtain oxidized asphalt for further testing. There is also a requirement which limits weight loss during the conditioning process.

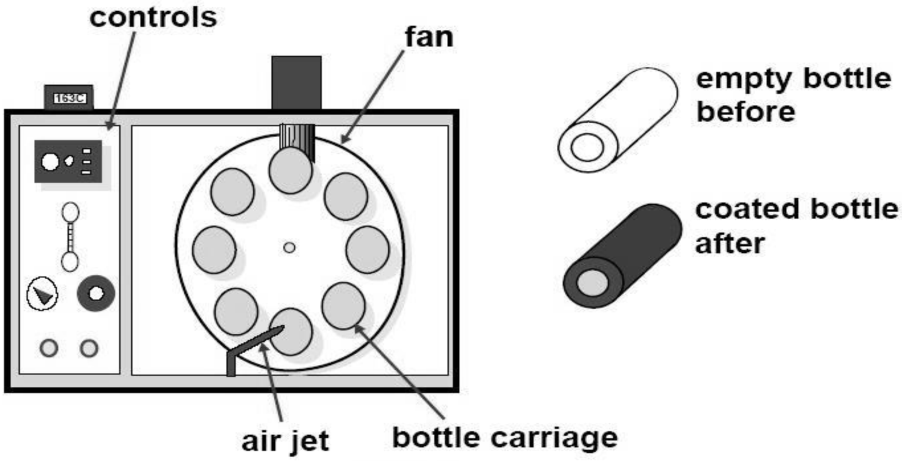


Figure 13 - Rolling Thin Film Oven (RTFO)

b) Pressure Aging Vessel (PAV)

The pressure aging vessel is a conditioning device that simulates what happens to the binder over a long period of time. It artificially ages the asphalt by subjecting it to high temperature and pressure for 20 hours, simulating what happens to the asphalt in the road over a period of months or years. Samples are always conditioned in the RTFO prior to being conditioned in the PAV.

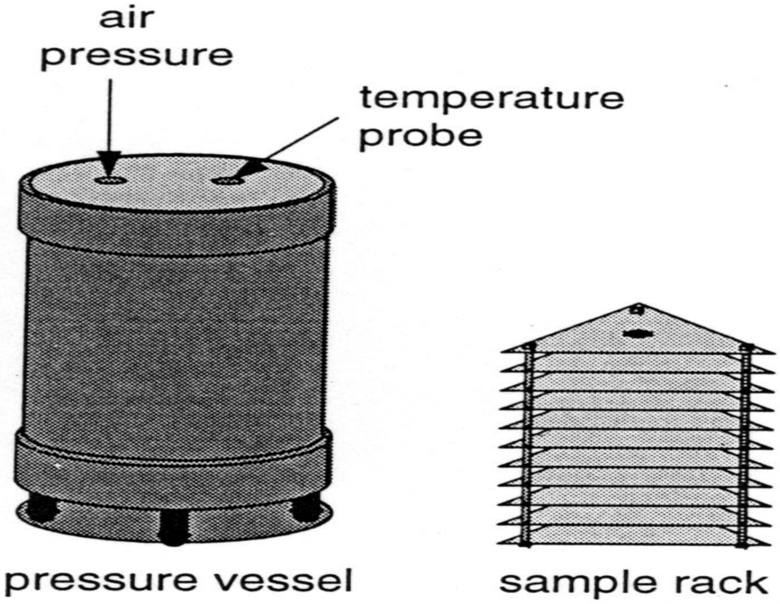


Figure 14 - Pressure Aging Vessel

iii) Binder Testing on Conditioned Samples

Tests are performed on conditioned samples to evaluate the binder properties with respect to specific distress types that develop in pavements. In the performance grade system, three types of distress are considered:

Rutting or Permanent Deformation – these are longitudinal depressions in the wheel path. The binder can contribute to rutting if the viscosity is too low for the loading conditions. Since binder becomes stiffer with age, the critical time in the pavement's life with respect to the binder's contribution to rutting is early in the pavement's life. So the binder is conditioned with the RTFO and then tested with the dynamic shear rheometer. Since high pavement temperatures reduce viscosity and thereby increase the binder's potential contribution for rutting, the test is conducted at the highest rated temperature of the binder; e.g. for a PG 64-22 binder the test is performed at 64°C.

Fatigue Cracking – Repeated applications of traffic loads can produce interconnected cracking in the wheel path. Asphalt that has been hardened due to long term exposure to the environment is more susceptible to fatigue cracking than fresh asphalt. Therefore, samples are conditioned with both the RTFO and PAV before testing with the dynamic shear rheometer. The critical temperature for rutting is between the high and low pavement temperatures.

Thermal Cracking – Materials reduce in volume as the temperature drops. If the material is constrained from changing volume, which is the case for pavements, then stresses develop in the material. With a sufficiently large temperature drop, the stress exceeds the strength of the material and cracks develop. The performance grade system uses two tests to evaluate binders for thermal cracking potential. Both tests are performed on samples that are conditioned with both the RTFO and the PAV. The tests are performed at the lowest rated temperature for the binder plus 10°C, e.g. a PG 64-22 binder is tested at -12°C.

The Bending Beam Rheometer (BBR) is a device in which the asphalt, molded into the shape of a beam, is bent by applying a load to it. In the specifications, the requirements are listed as the Creep Stiffness, M value and S value. The theory behind this test is complicated. Basically, asphalt is supposed to be flexible, but it loses its flexibility in cold weather. If it becomes too brittle it tends to crack in cold weather.

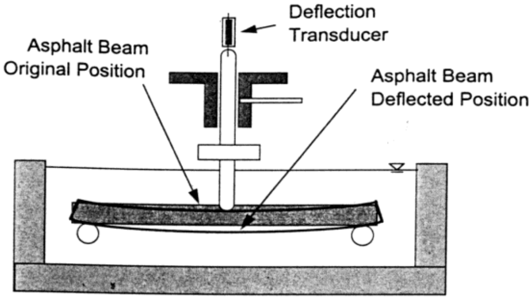


Figure 15 - Bending Beam Rheometer (AASHTO T313)

Table 1 - Summary of conditioning and test methods

Stage	Temperature			Quality
	Low	Inter-mediate	High	
Original Binder	-	-	DSR	Rotational viscosity, Flash point, Solubility, Elastic Recovery
As constructed RTFO	-	-	DSR	-
Long term aging RTFO + PAV	BBR	DSR	-	-

C) EMULSIONS

Asphalt Emulsions are a suspension of asphalt binder and water. Asphalt and water do not mix, so an emulsifying agent is added to keep them in solution. Asphalt emulsions can be used with little or no heating. Asphalt emulsions will not withstand freezing and are very slow to set in cold weather, so they are limited to seasonal use. Emulsions are used primarily for tack coat, chip seals (tar and chip), and surface treatments, which are all described later in this chapter.

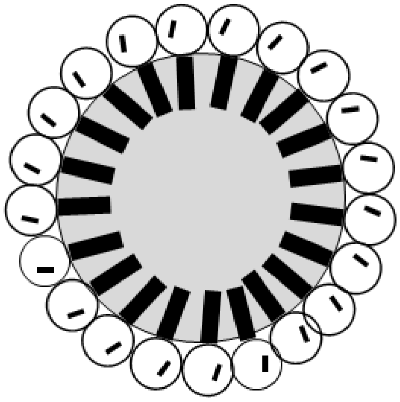


Figure 16 - Anionic Asphalt Emulsion Globule

Although asphalt emulsions readily flow at ambient temperatures, they are heated to 140 to 160F for application to soften the asphalt for better adhesion. Once applied, the emulsion globules coagulate because the water evaporates. The speed at which the asphalt and water separate depends on the weather, the amount of dust in the aggregate and the amount of emulsifier in the asphalt.

Asphalt emulsion terminology uses a standard nomenclature for easily identifying various grades and types. For example, a typical name for an asphalt emulsion is RS-2. The RS stands for rapid setting, which means that the emulsion has only a small amount of emulsifier and tends to coagulate rapidly. There is also a medium setting (MS) grade, which has more emulsifier and water, and a slow setting (SS) grade that has still more emulsifier and water. The number following the grade designation will be a “1” or a “2”. These numbers represent standard and high viscosity (thicker) material respectively. As an example, an RS-1 would flow more readily than a thicker RS-2.

Anionic emulsions are negatively charged, while cationic emulsions are positively charged. They can be easily identified using a particle charge test. Asphalt emulsion grades are either anionic or cationic. Anionic emulsions typically use a type of soap as the emulsifier, while cationic emulsions, designated with the letter “C” in front of the code name, typically use an amino acid for the emulsifier. Emulsion may also be designated with the letter “h” such as an SS-1h. This means that a harder grade of base asphalt is used in producing the material.

In recent years the development of emulsions containing polymers and latex additives has become popular. These emulsions use the letter “P” or “L” after the number designation to indicate the presence of the additive. Example of these emulsion grades would be CRS-2P and CRS-2L. These “L” and “P” grades are popular for chip seals and can typically be used interchangeably.

The letters “HF” may precede an emulsion grade such as HFMS-2. These letters stand for high float. These high float emulsions have a quality that permits a thicker asphalt film on the aggregate particles. “HF” type emulsions are used in Chip seals because they are less temperature susceptible than other emulsions. This allows for higher applications rates while minimizing bleeding potential.

Table 2 shows some of the typical emulsion grades approved for use by the WVDOH.

Table 2 - Typical Asphalt Emulsion Grades used by the WVDOH

	Rapid Setting	Medium Setting	Slow Setting
Anionic Emulsions	RS-1, RS-2 & HFRS-2	MS-1, MS-2 & HFMS-2	SS-1 & SS-1h
Cationic Emulsions	CRS-1, CRS-2 & CRS-2P	CMS-1 & CMS-2	CSS-1 & CSS-1h

Note: Grades on this list may not be on the current WVDOH approved source list simply because no local sources are available. Additional grades may sometimes be added to this list.

i) Emulsion Testing

Asphalt emulsion grades all have standard test methods and test requirements. AASHTO M140 covers anionic emulsions. AASHTO M208 covers cationic emulsions. AASHTO M316 covers polymer emulsions.

Viscosity is an important property of all asphalts and is a key test for asphalt emulsions. There are several methods of measuring viscosity. The method used by the WVDOH to determine viscosity for asphalt emulsions is called the Rotational Paddle Viscometer Test (ASTM D7226).

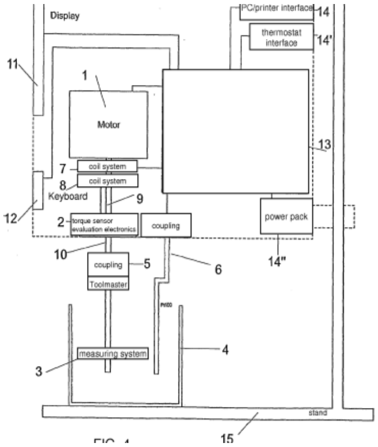


Figure 17 - Rotational Paddle Viscosity Apparatus

Viscosity changes with temperature, so we have to specify both a viscosity and a temperature at which to conduct the test. Asphalt emulsion viscosity is measured at 122° F for RS grades and 77° F for most other grades.

The **demulsibility test**, **classification test**, and **cement mixing test** (AASHTO T59) measures the tendency of an asphalt emulsion to break, or separate in the presence of dust, such as is found on the road or as a coating on the aggregate.

The **Sieve test** (AASHTO T59) detects the presence of coagulation of asphalt globules in the emulsion.

The **Storage Stability test** (AASHTO T59) measures the tendency of the asphalt globules to coagulate and settle to the bottom or rise to the top of the storage tank.

Residue by Distillation (AASHTO T59) – An asphalt emulsion is a mixture of asphalt and water. The amount of water determines the viscosity of the emulsion, and also the cost of the product, since water is cheaper than asphalt. The amount of water is determined by boiling off the water in a still.

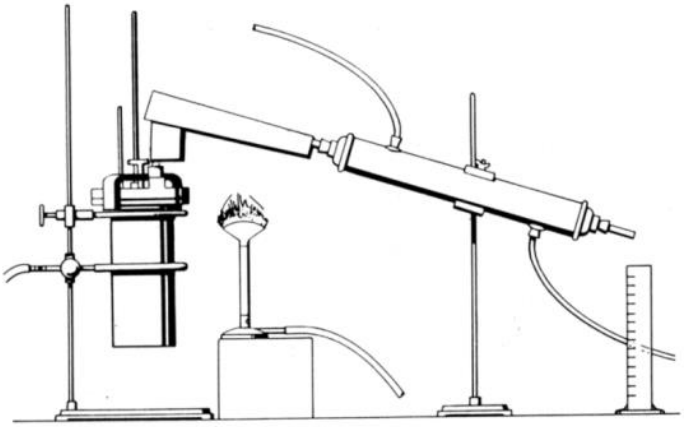


Figure 18 -Emulsion Distillation Still

ii) Emulsion Residue Testing

Some of the required tests for asphalt emulsions are conducted on the residue after distillation or evaporation of the water from the sample. Three such tests as listed below include solubility, penetration, and ductility.

Solubility (AASHTO T44) - Solubility tests for contaminants in the asphalt/emulsion residue. Anything that does not dissolve is considered contamination which could affect the asphalt properties. The test consists of dissolving a sample with trichloroethylene and then filtering which removes the dissolved asphalt leaving behind any contaminates. One purpose of the test is to detect free carbon, which forms when the asphalt is overheated.

Penetration Test (AASHTO T49) - This test measures the consistency of asphalt by seeing how far a weighted needle (100g) will sink into the sample in five seconds at 25°C. The distance that the needle sinks into the asphalt, measured in tenths of a millimeter, is the penetration, shown in Figure 19.

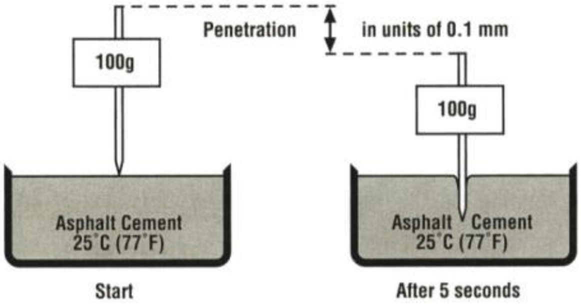


Figure 19 - Penetration Test

Ductility (AASHTO T51) - Ductility measures the ability of the asphalt/emulsion residue to deform without breaking. A sample of the asphalt is molded to a standard size and then slowly stretched at 25°C until it either breaks or is stretched to minimum deformation as required by the material specification. A ductility mold is shown in Figure 20.

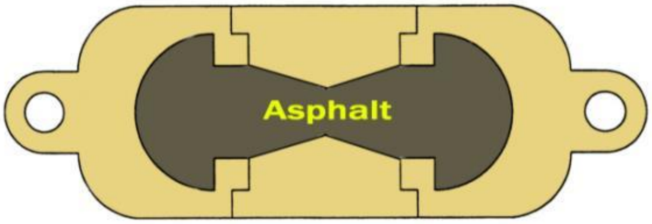


Figure 20 - Ductility Mold Showing Asphalt Specimen

Elastic Recovery (AASHTO T301) – Polymer modified emulsions also require a simple test that indicates the presence of polymer in the material. The elastic recovery test is based on the ductility procedure, except that the side pieces are flat rather than v-shaped. A sample of emulsion residue is stretched out to 20 cm and then cut in the middle. After an hour the elastic properties of the polymer in the sample will allow the two pieces to recover back toward their original shape. The two pieces are then brought back together until the two ends meet, and a final measurement is made to calculate the percent recovery of the sample. The higher the percent recovery, the greater the delay will be in the elastic response of the material. A Recovery mold used for emulsions is identical to those used with binders, refer to Figure 10.

D) CUTBACK ASPHALT

A Cut-Back Asphalt is a mixture of asphalt and a solvent such as naphtha or kerosene. The term cut-back means that the asphalt has been cut, or diluted, by adding back some of the lighter materials that were removed during refining. Cut-backs are more fluid than asphalt binders and will coat aggregates at lower temperatures. Some of the lighter grades can be used without any heating. After mixing, the solvent gradually evaporates and the asphalt becomes about as hard as an asphalt binder. The solvents used to make cut-back asphalt are expensive and are a source of air pollution, so cut-back asphalts have largely been replaced by asphalt emulsions; however they are still heavily used in cold mix asphalt used for patching during the winter.

E) ASPHALTIC PRODUCTS

Hot-Mix Asphalt Concrete is produced at a central mixing plant and transported to the paving site in trucks. Heat is used to dry the aggregate, melt the asphalt so that it will coat the stone, and heat the mix so it can be spread and compacted. Hot-mix is the preferred pavement for any high quality, heavily traveled roads, but warm-mix asphalt may be used interchangeably.

Warm-Mix Asphalt Concrete(WMA) is produced using one of several technologies that allow the mixture to be mixed in a plant, placed, and compacted at temperatures of somewhere between 20 to 55 °C (35 and 100 °F) lower than typical Hot-mix. This lower temperature provides the benefits of paving in cooler ambient temperatures, hauling longer distances, using higher RAP percentages (with proper handling and processing), reducing fuel consumption, and reducing plant emissions. The technologies in use are typically variations of chemical and organic additives or some type of water-induced asphalt foaming process.

Cold Mix Asphalt Concrete is made at a mixing plant, but instead of asphalt binder, a cut-back asphalt or emulsified asphalt is substituted. The advantage of cold mix is that it remains workable until the solvent evaporates or until the water separates from the asphalt. It does not have to be kept hot and can be stockpiled for a period of time before use. Many years ago, when hot-mix plants were few and far between, paving mix often had to be hauled to the job site in railroad cars. As this could take days, cold mix was the only practical mix to use. Cold mix is used primarily for patching material during winter months when the mixing plants are shut down and hot-mix is not available.

Surface Treatments consist of spraying asphalt on an existing pavement or stone base, and then rolling stone chips into the asphalt. This process is often called "tar-chip” since many years ago, tar was used in this type of pavement. Surface treatments are often used for pavement maintenance. They are a good, inexpensive way of waterproofing and prolonging the life of a pavement. Because a surface treatment is very thin, it cannot smooth out bumps in a road, and it does nothing to improve the load bearing capacity. It is seldom used on heavily traveled roads.

Micro-Surfacing consists of a mixture of polymer-modified emulsified asphalt, crushed dense graded skid aggregate, water, and additives, proportioned, mixed and uniformly spread over a properly prepared surface. It provides a thin resurfacing of 10 to 20 mm (3/8 to 3/4 inch) to the pavement. Micro-surfacing can perform in variable thickness cross-sections such as ruts, scratch courses and milled surfaces. It is a quick-traffic system that allows traffic to return shortly after placement. After curing and initial traffic consolidation, the thin mat resists further compaction and maintains a skid-resistant texture throughout its service life.

Tack Coat is a thin layer of asphalt that is sprayed on a road just before it is repaved. Its purpose is to make the new pavement stick to the old pavement. Just about any grade of asphalt can be used for a tack coat. The WVDOH most often uses emulsified asphalt because of its low cost.

Prime Coat is similar to a tack coat, except that it is sprayed on a stone base before placing asphalt concrete over it. The prime coat helps to waterproof the stone and it consolidates the dust on the surface of the base stone so the pavement can adhere to it. The lighter grades of cut-back asphalt and emulsified asphalt are used as prime coats. Emulsified asphalts are often diluted with water so that they will soak into the stone base rather than pooling on the surface of the stone base. The WVDOH has discontinued the use of prime coat, so it is no longer a part of the standard specifications.

II AGGREGATE

A) STORAGE/HANDLING

Since the majority of Asphalt concrete is comprised of aggregates, aggregate management is crucial for consistent production of asphalt concrete. Degradation, segregation, contamination, and excessive moisture are the main concerns that occur at an asphalt plant.

During the production of aggregates, materials are repeatedly crushed, washed, moved, conveyed, loaded, dropped, blended, stockpiled, etc. All this moving contributes to degradation, segregation, and contamination, which is more likely to occur if proper procedures are not followed. These steps should be constantly monitored to minimize these concerns. Degradation, or the breakdown of aggregate into smaller pieces, occurs when the material is dropped from excessive heights, pushed with bulldozers, handled with front-end loaders, or when material is placed in very large stockpiles. Degradation will also lead to an increased production of dust and fines that could contaminate the material and yield failing tests results.

Segregation is the separation of particle sizes leaving a nonhomogeneous and unrepresentative material. Segregation occurs during every step of aggregate production, thus minimizing movement of the material is critical. Segregation in a truck bed or on a convey belt is caused by the vibrations the materials are exposed to, which allows for the finer particles to migrate to the bottom of the material. Segregation is then further compounded when off loaded from the truck or conveyor, where the finer material tends to draw closer to the belt or truck bed, shown in Figure 22. Conversely the coarse material tends to flow away from the belt or truck bed. If stockpiling techniques are ignored the separation on the belt or truck bed can again be furthered. Stockpiles should be constructed in layers or many stacked mini stockpiles shown in Figure 23 or Figure 24 respectively, rather than a single large stockpile. Stockpiles can also be made using a telescoping conveyer as shown in Figure 25.

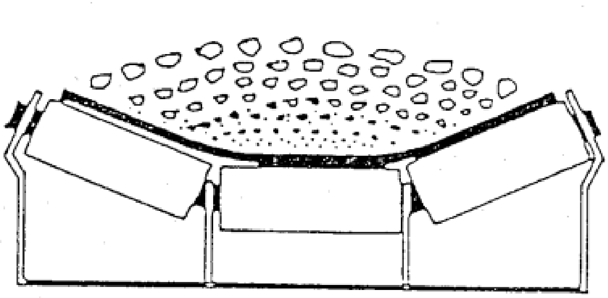


Figure 21 - - Belt Segregation

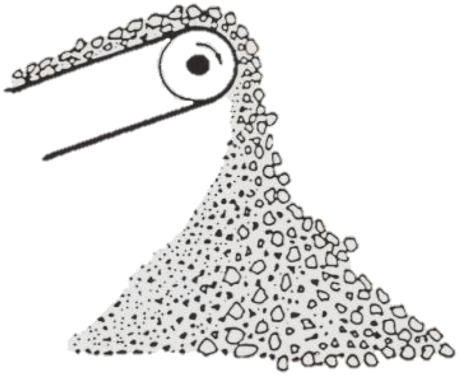


Figure 22 - Stockpile Segregation off a Belt

Figure 23 - Building a Stockpile in Layers

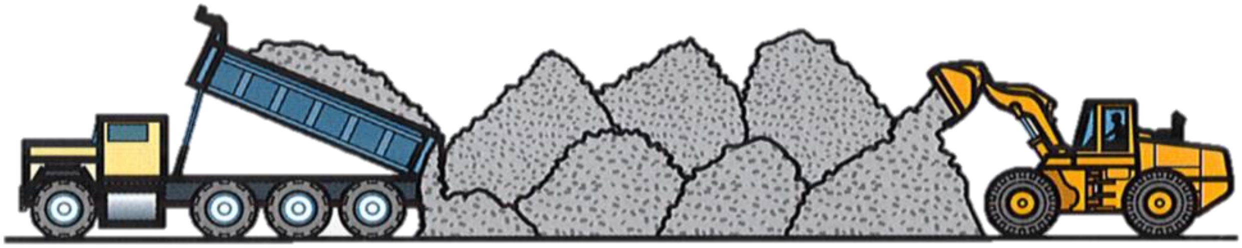


Figure 24 - Building a Stockpile with Smaller Piles

Figure 25 - Building a Stockpile using a Telescoping Conveyer

Contamination generally thought of as foreign objects in the material can also include any unwanted mixing of different aggregates in the same stockpile, for instance if the stockpile overflows the bulkhead wall and flows into an adjacent pile. This can also occur during cold feed bin loading, or from digging into the ground surface when loading material with a front-end loader. While a few leaves would not really be an issue in a mixing plant, a large branch or log might clog the cold feed bins or tear a conveyer belt. Also, if any foreign objects made it into the plant, the plant would then over estimate the amount of asphalt binder for the mix due to the weight of said object. Minimizing degradation, segregation, and contamination will allow for the consistent production of Asphalt concrete.

Excessive Moisture affects the drying times and asphalt adhesion during the production of asphalt concrete. In order to avoid these issues, stockpiles should be well drained. This can be accomplished by building the stockpile on slightly sloped ground to allow the water to flow away from the pile. Another option is to place aggregate under large covers so that rain water can not affect the pile at all. See the Figure 26 below.

Figure 26 - Stockpile Cover

B) GRADATION AND SIZES

i) Aggregate Sizes

- Coarse Aggregate – material that is retained on a No.4 sieve
- Fine Aggregate – material that passes the No.4 sieve
- Mineral Filler (Dust) – material that passes the No.200 sieve

ii) Gradation

Gradation is a measure of the size distribution of the aggregate. The size distribution is determined as the percent passing specific sieves. In the metric system the size of a sieve is given as the measurement between the screen wires on opposing sides. In the US customary system, the sieve sizes 3/8” and larger are also defined by the opening. Sieves smaller than 3/8” are defined as the number of opening per linear inch, i.e. a No30 screen has 30 openings in a linear inch of screen.

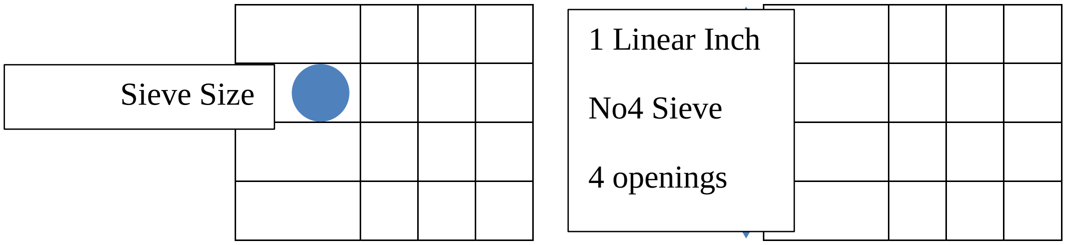


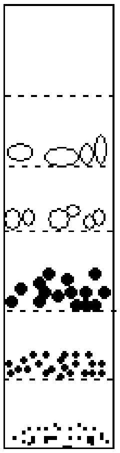
Figure 27 - Sieve Screen Openings

Table 3 – Master Range Control Points

Standard Sieve (mm)	Percent Passing Criteria (Control Points) Nominal Maximum Sieve Size					
	Superpave mixtures					
	4.75 mm	9.5 mm	12.5 mm	19 mm	25 mm	37.5 mm
	Marshall Mixtures					
	Wearing III	Wearing I (Scratch)		Base II Wearing IV		Base I
50						100
37.5					100	90 - 100
25				100	90 - 100	90 Max
19			100	90 - 100	90 Max	
12.5	100	100	90 - 100	90 Max		
9.5	95 - 100	90 - 100	90 Max			47
4.75	90 - 100	90 Max		47	40	
2.36		32 - 67	28 - 58	23 - 49	19-45	15-41
		47	39			
1.18	30 - 60					
0.075	6.0 - 12.0	2.0 -10.0	2.0 - 10.0	2.0 - 8.0	1.0 - 7.0	0.0 - 6.0

The sieve size distribution required for mix design is control points for several sieve sizes. These control points are for a blend of aggregates rather than for individual stockpiles.

Several gradations are specified, each with its own use scenario. For example, the 9.5mm gradation, which requires 100% passing the 12.5mm sieve, is intended as a surface course to be placed about 1.5 inches thick. The 37.5mm gradation is for a base course placed a minimum of four inches thick. Making the different mixes in this table requires blending one or more coarse aggregates with sand and perhaps mineral filler. An example gradation is shown in Figure 28.



	Weight Retained	Percent Retained	Percent Passing
3/8"	0	0	100
# 4	50	5	95
# 16	150	15	80
# 50	300	30	50
# 200	350	35	15
Pan	150	15	
	1000	100	

Figure 28 - Example Gradation

iii) Gradation Charts

In WV all of the standard asphalt concrete mixtures are considered dense graded mixes. Which means, as much aggregate as possible is packed into the available space, giving us a strong and inexpensive paving mix. The best way to examine a gradation is to plot it on a gradation chart. An example is shown below Figure 29. The percent passing is on the left side of the graph and the sieve sizes are on the bottom. The sieve sizes are spaced so that the denser the gradation, the closer the graph comes to being a straight line. In the example, the gradation reference line (the center line) follows the line of a maximum density gradation. Gradation Line “A” shows a fine graded aggregate and Gradation “B” shows a coarse graded aggregate.

A uniform gradation is one in which there are fairly uniform amounts of each aggregate size, while a gap gradation is a gradation where one or more sizes is missing or only present in small quantities. A very steep slope on a portion of the gradation chart indicates a gap gradation.

Although our mixtures are called dense graded they do not follow the maximum density gradation line. A straight line indicates that the gradation is as dense as it is possible to get. Gradations that follow the maximum density line do not have sufficient space between the aggregate particles for the asphalt and air voids needed for good asphalt concrete.

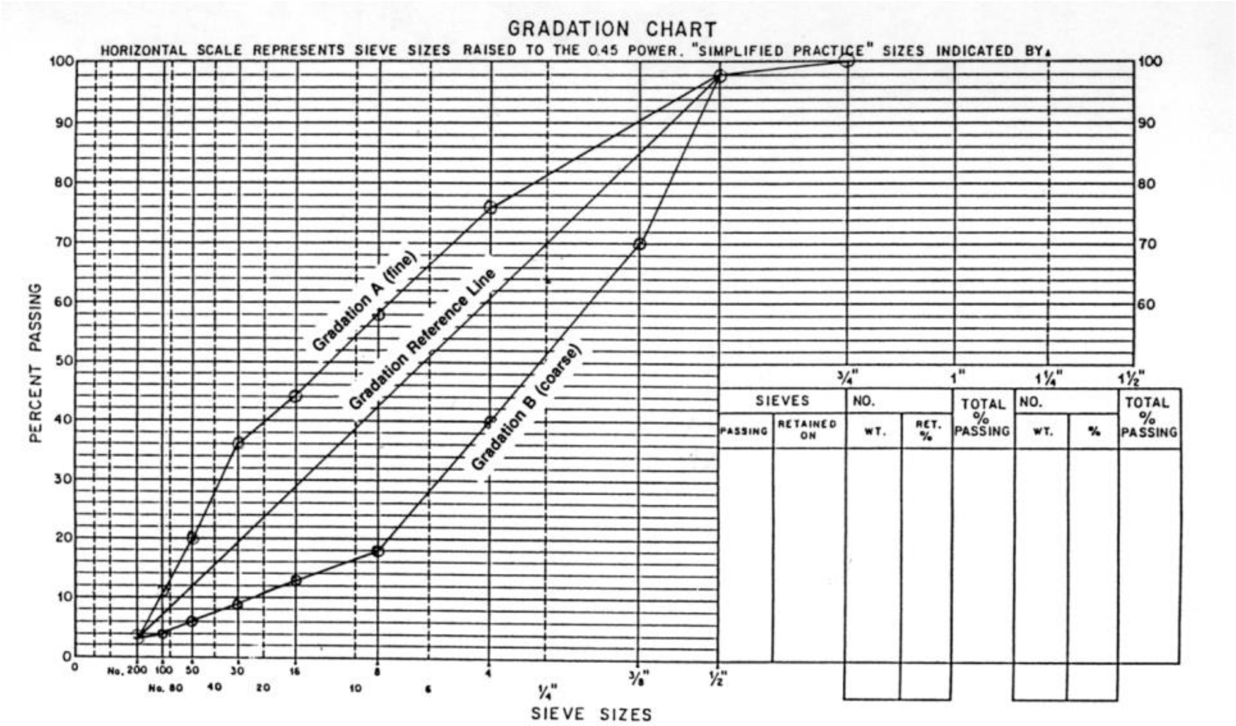


Figure 29 - Example Gradation Chart

C) KEY PROPERTIES

i) Los Angeles Abrasion (AASHTO T-96)

Abrasion is the degradation of the aggregates due to loading. The test that measures abrasion resistance (wear resistance) is the Los Angeles Abrasion test (AASHTO T96). In this test, aggregate that has been graded to a standard size, is placed in a steel drum along with steel balls. As the drum revolves, a flange lifts and drops the steel balls and aggregate. After 500 revolutions, the aggregate is again sieved and the percent loss on the specified sieve is the Los Angeles abrasion.

ii) Soundness (MP 703.00.22)

This test measures the resistance of aggregate to weathering. Aggregate of a specified gradation is soaked in water that contains dissolved sodium sulfate. The aggregate is then dried, and as the water evaporates, sodium sulfate crystals form inside the stone. These crystals act in the same way as ice crystals, causing the stone to break apart. After several cycles of soaking and drying, a gradation test is conducted to see how much the gradation of the aggregate has changed.

iii) Deleterious Materials

Deleterious materials in aggregates are such things as clay, shale, sticks, coal and friable partials. The amount of deleterious material permitted in asphalt concrete mixtures is determined by (1) shale content (MP 703.00.27); (2) coal and other lightweight deleterious material (MP

702.01.20); and (3) friable particles (MP 703.01.20). The WVDOH specifies that the total amount of deleterious materials determined from these three test methods cannot exceed 3% in Asphalt Concrete.

iv) Unit Weight (AASHTO - T19)

The specifications include a minimum weight per cubic foot for slag. This requirement applies only to slag, which is usually much lighter than other aggregates.

v) Specific Gravity

The density or specific gravity of aggregates must be measured for the analysis of asphalt mixtures. Density is the mass of a material divided by its volume. Specific gravity is the density of a material divided by the density of water at a specific temperature. Using the metric system, density and specific gravity are numerically equal, since the specific gravity of water is “1”. The specific gravity must be determined for the individual stockpiles and an equation may be used to calculate the blended specific gravity of the aggregates.

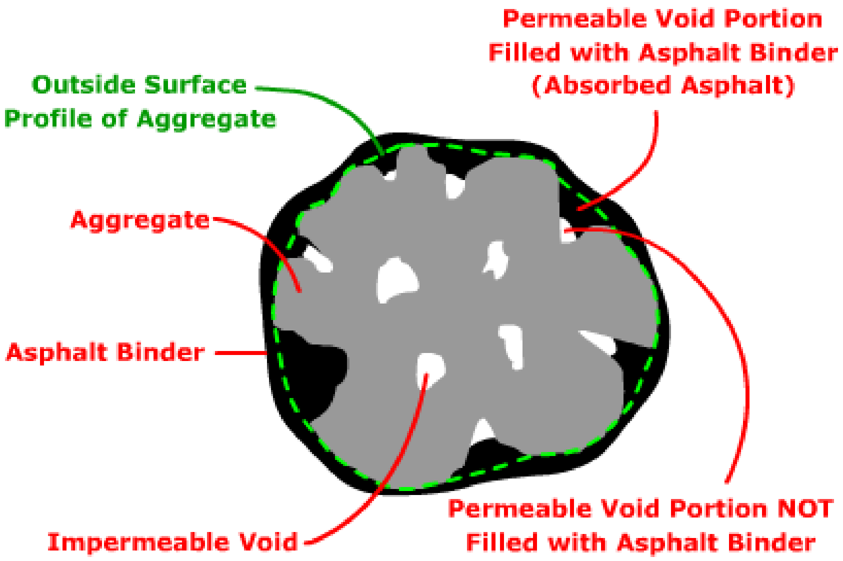


Figure 30 – Definition Rock for Specific Gravity

Depending on the treatment of the volume of the aggregate, there are three types of specific gravity: Apparent, Bulk, and Effective. Above is the definition rock and below are visual representations of volumes (Blue) and masses (Red) that are used to calculate each specific gravity.

- **Apparent Specific Gravity** – the mass of the stone divided by the volume of the solid stone plus the internal voids.

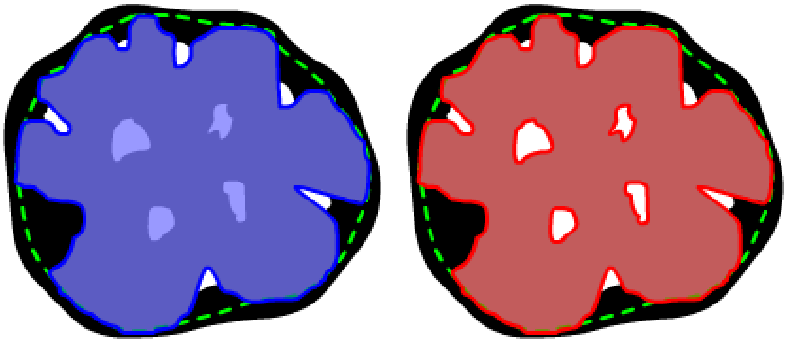


Figure 31 - Apparent Specific Gravity

- **Bulk Specific Gravity** – the mass of the stone divided by the volume of the solid stone plus the internal voids plus the volume of the external voids.

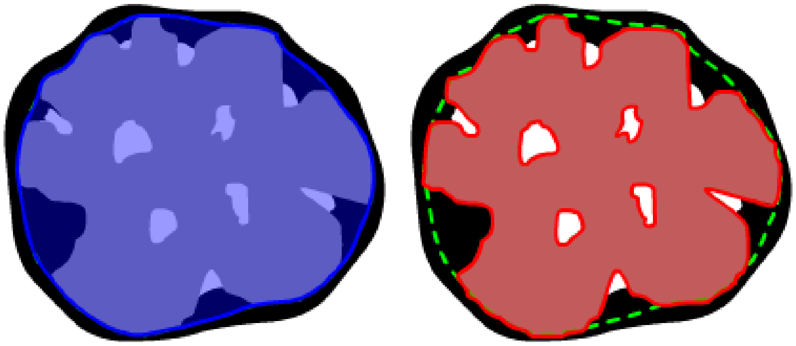


Figure 32 - Apparent Specific Gravity

- **Effective Specific Gravity** – the mass of the stone divided by the volume of the solid stone plus the internal voids plus the volume of the external voids minus the volume of the absorbed asphalt. Determining the effective specific gravity can only be measured after the aggregate has been mixed with the binder.

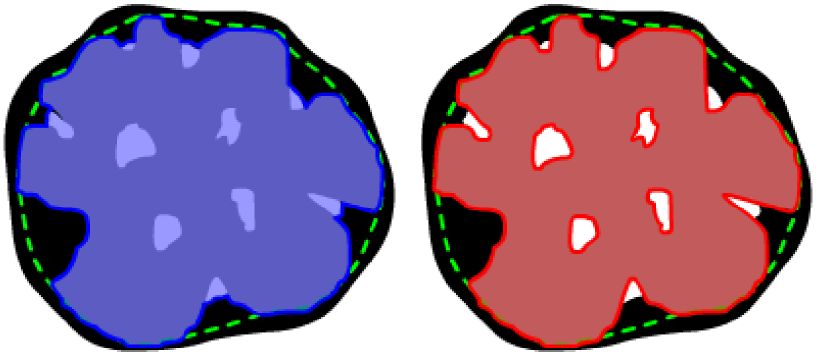


Figure 33 - Apparent Specific Gravity

vi) Face Fracture

Quarried stone is crushed to reduce it to the size needed for road building aggregates. Crushing the stone gives it an angular shape, sharp edges, and high textured faces. Aggregates like gravel that are dredged from rivers, have a round shape. They tend to roll and spread instead of compacting, so gravel must be crushed before it can be used in asphalt concrete. The face fracture test is conducted by counting the crushed particles in a sample of the gravel. For Marshall mix designs, the face fracture is determined in accordance with MP 703.00.21. For Superpave mix designs, the face fracture is determined in accordance with ASTM D5821.

Figure 34 - Difference between river gravel before and after crushing

vii) Skid Resistance

The WVDOH specifications require that the surface course of roads with an average daily traffic (ADT) of 3,000 vehicles or more shall contain skid resistant aggregates. These aggregates are usually gravel, slag, sandstone, quartzite, or a polish resistant limestone. WVDOH maintain a list of suppliers that have approved skid resistant aggregate.

viii) Sand Equivalency (AASHTO - T176)

This test determines the presence of excess clay in a fine aggregate. A flocculating agent is used to separate the clay from the fine aggregate. The sample is then shaken and allowed to settle. The top of the sand and clay levels are measured. The Sand Equivalency value is the ratio between the heights of the sand and the clay. This test procedure is only required for Superpave mixture design method and the set up can be seen in Figure 35.

ix) Fine Aggregate Angularity (AASHTO - T304)

This test measures the uncompacted void content in the fine aggregate. Sands with a high uncompacted void content have a high texture and angularity and contribute to the stability of the asphalt concrete. This test procedure is only required for Superpave mixture design method and the set up can be seen in Figure 36.

Figure 35 – Sand Equivalency

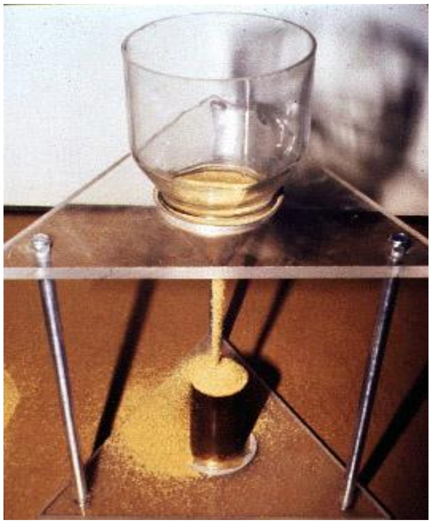


Figure 36 - Fine Aggregate Angularity

III ASPHALT CONCRETE MIXTURES

A) DESIGN TYPES

There are three major mix design methods for producing Asphalt Concrete, namely: Marshall, Superpave, and Hveem. The WVDOH currently only allows the use of the Marshall and Superpave design systems; therefore, Hveem will not be covered in this manual.

i) Marshall

The Marshall mix design method was developed by Bruce Marshall, formerly with the Mississippi State Highway Department around 1939. This design method was then refined by the U.S. Army Corp of Engineers during World War II for the use in airfield pavement design. The goal of the Marshall design method is to select an asphalt binder content at a desired void content that satisfies a minimum stability value and a range of flow values.

In general, asphalt binder and aggregate are combined and mixed at a defined temperature based on the binder (roughly 300°F), conditioned, and then compacted to a standard cylindrical specimen size of 2½ inches in height by 4 inches in diameter. The sample is compacted using a Marshall Compaction Hammer Figure 37, at a certain number of blows, depending on traffic levels. The specimens are then tested in the Marshall Stability and Flow machine Figure 38. A sample's Stability is a measure of maximum load resistance and the Flow is a measure of cumulative deformation until maximum load occurs.

Figure 37 - Marshall Compaction Hammer

Figure 38 - Marshall Stabilometer

ii) Superpave

Superpave is an acronym for ***Sup***erior ***Per***forming Asphalt ***Pave***ments. It is a comprehensive asphalt mixture design and analysis system. It is the product of the Strategic Highway Research Program (SHRP) that was established by Congress in 1987 as a five year, $150 million research program to improve the performance and durability of United States roads. Superpave is based on a performance system for selecting materials, introducing new binder physical property testing requirements, different aggregate testing, as well as a new mixture design procedure and analysis.

Superpave sample creation is still a combination of aggregate and asphalt binder which is mixed at a specific temperature depending on the binder grade. The mix is then conditioned and compacted in a Superpave Gyratory compactor, shown in Figure 39. The sample is exposed to a constant pressure and the sample gyrates at a certain angle and rate around that fixed pressure. The number of gyrations is dependent on the traffic level expected. Volumetric analysis is then conducted on the compacted sample.

Figure 39 - Superpave Gyratory Compactors

B) PRODUCTION

Asphalt concrete in its simplest form is a combination of mineral aggregate and liquid Asphalt. To be used on trafficked roadways asphalt binder should be used. In order to do this, the materials must be heated to allow for blending, this is the function of the asphalt mixing plant. All mixing plants are designed to accomplish the same thing; dry, heat stone, blend aggregates to the required gradation, and add the liquid asphalt needed to produce a paving mix. *Chapter 5 - Asphalt Mixing Plants* discusses the production of Asphalt concrete in greater detail, but the general procedure will be discussed here for reference.

To begin, aggregates from stockpiles must be transported to the Cold feed bins which meter material to the plant. There are individual cold-feed bins for each aggregate size that will be used in the mixture. From the cold-feed bins material flows on conveyer belts to a heating/drying drum that has a large flame burner at the end. Inside the drum are metal protrusions called flights that pick up the aggregate as the drum rotates and cascades it in the path of the burner. This allows the aggregates to dry and get hot. At this point procedures differ depending on the type of plant being used. The two types of plant that will be covered are batch plants and drum plants; the main difference between them is how the aggregates and liquid asphalt are mixed together.

In a batch plant, shown in Figure 40, the heated aggregate leaves the drum and are carried via a conveyer elevator to the batch tower. The material is then separated into sizes to be proportioned out. The material is then dropped into a pugmill mixer, where the asphalt is metered in. The Batch tower, shown in Figure 40, has hot bins that screen the material into sizes. The material then is weighed out in the pugmill where large paddles mix the aggregate with liquid asphalt. From the pugmill the material can be dumped directly into a dump truck or feed into a silo for storage.

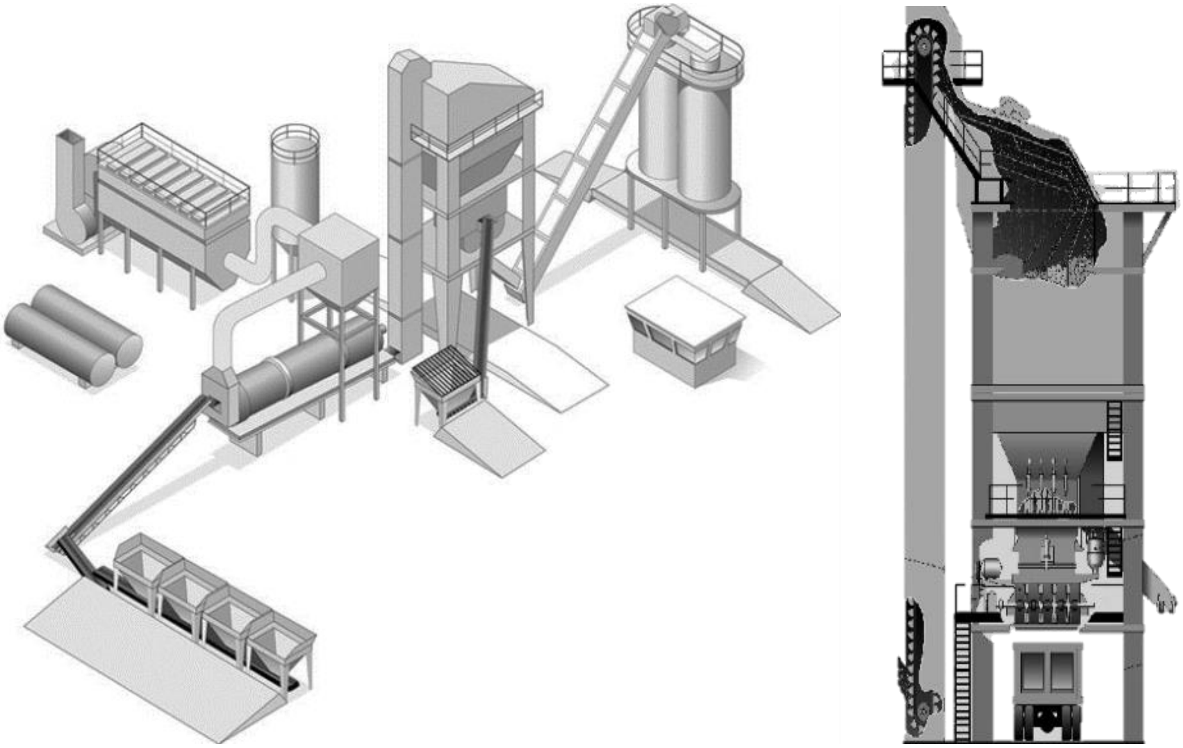


Figure 40 – Batch Mixing Plant and Batch Tower

With a drum mixing plant, shown in Figure 41, once the aggregate has past the burners the asphalt is metered into the mixing drum onto the aggregates. The materials are then mixed with paddles as the drum continues to rotate. Once the materials are thoroughly mixed, they drop from the drum onto a conveyer which takes them to a silo for storage. In a drum plant storage silos are essential since the plant is operated continuously.

From the storage silo or pugmill, material is metered into trucks parked on scales. The Asphalt concrete should be dropped in a way to avoid segregating the mixture. Best practices dictate the three drop method shown in Figure 42. A single drop should be placed at each end of the truck and then a final drop in the center of the truck. This method will significantly decrease the chances of segregation over a single continuous drop, which could cause the larger particles to gather at the outside edges of the truck.

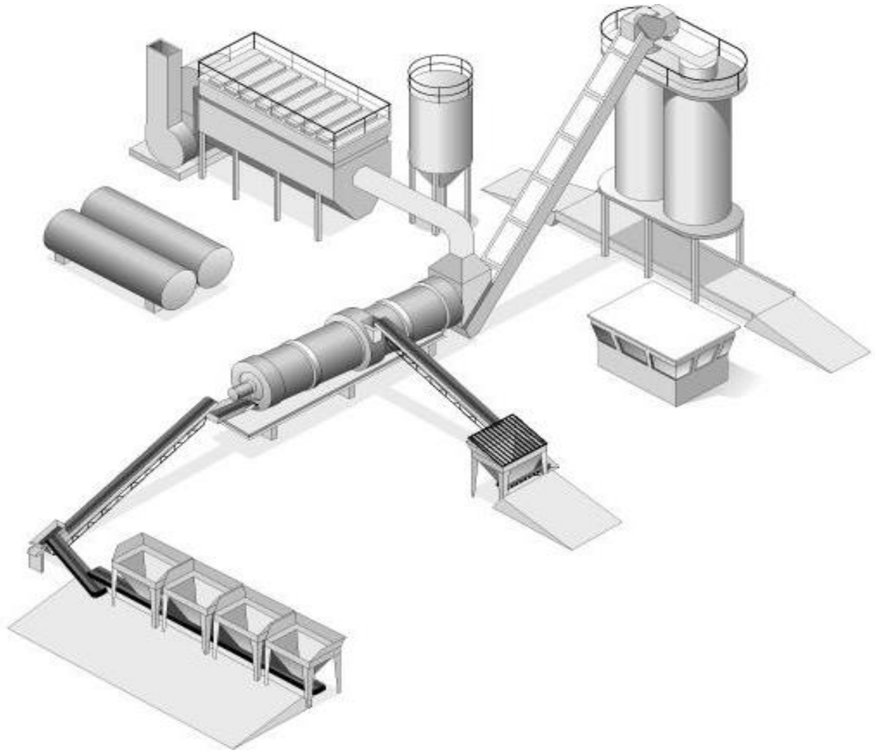


Figure 41 - Drum Mixing Plant

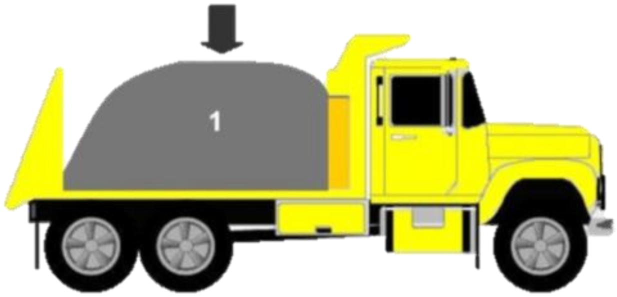


Figure 42 – Incorrect Truck Loading Scenarios

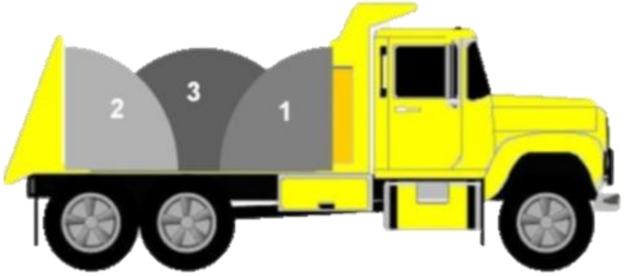


Figure 43 – Correct Truck Loading Scenarios

C) PLACEMENT

Arriving from the asphalt mixing plant in dump trucks the asphalt concrete is spread evenly on the roadway using an asphalt paver, Figure 44. Also shown in Figure 44, a Materials Transfer Device (MTD) which can be beneficial during long hauls or cooler conditions where the asphalt concrete could thermally segregate. The MTD remixes the material prior to loading it into the paver to make a more uniform product. After the material is loaded into the hopper on the paver it travels via slat conveyors to the augers. The auger spread the material transversely across the mat in front of the screed. The screed is a wide flat piece of heated steel that squeezes the asphalt concrete deposited from the augers into a smooth surface. Set properly the screed provides the initial compaction of the asphalt concrete and sets the depth, grade, and cross slope of the pavement.

Figure 44 – Asphalt Paving Train

Once laid by the paver the asphalt concrete is further compacted using compaction rollers, shown in Figure 45. There are three general types of rollers; Static Steel Wheel, Vibratory Steel Wheel, and Pneumatic-Tire roller. The rollers apply a force to the mat, reorienting and consolidating the aggregate particles to reduce the volume occupied by the asphalt concrete. Once compacted, the road surface is allowed to cool before used by the driving public.

Figure 45 - Compaction Rollers

D) SAMPLING

Asphalt concrete can be sampled during multiple stages of production/placement depending on the desired property that needs to be evaluated. Samples for quality assurance (QC/QA) are typically taken from the truck bed while the trucks are still on the plants yard. QC/QA samples can also be taken in the field from behind the paving machine prior to compaction to best represent the “finished product.” After compaction, cores may be obtained and evaluated to determine final in-place density and thickness of the asphalt concrete layer. Sampling will be discussed further in the proceeding chapter.

IV SUMMARY

The standard binder grade used in West Virginia is a PG 64-22.

Emulsion designation SS-1h is a slow setting, low viscosity emulsion containing a hard asphalt base. And a CSS-1h is the same thing with the exception that it is produced as a cationic emulsion using an amino acid emulsifier.

Listed below are some important Asphalt liquid tests.

- The Rolling Thin Film Oven Test (RTFO) is a laboratory procedure that simulates the aging of asphalt than takes place during mixing and transportation to the job site.
- The Pressure Aging Vessel (PAV) is a device that simulates the aging of asphalt over its service life.
- The Dynamic Shear Rheometer (DSR) test is a key test for asphalt binders. It is used to eliminate asphalts that are too soft and tend to move under traffic, or are too brittle in cold weather and tend to crack.
- The Bending Beam Rheometer (BBR) measures how asphalt behaves at low temperatures. It is used to eliminate asphalts that are too stiff at low temperatures and tend to crack.
- Viscosity is a measure of the resistance of a liquid to flow. Water is an example of a low viscosity liquid. High viscosity liquids such as grease, often require heat or pressure to make them flow.
- Penetration is a consistency test. It is conducted on materials that are not fluid enough for a viscosity test.
- Flash Point is the temperature at which asphalt gives off fumes that would catch fire in the presence of an open flame.
- Ductility is a measure of how far asphalt will stretch before it breaks.
- Solubility is a test for impurities in asphalt.

Listed below are some of the tests conducted on aggregates:

- Soundness measures resistance to weathering.
- Los Angeles Abrasion Test measures resistance to abrasion.
- The Deleterious Material test measures impurities in the aggregate.
- Face Fracture is a test to determine if round aggregates (such as gravel) have been sufficiently crushed.
- Gradation is a way to measure the size distribution of aggregate.
- Unit Weight measures how much a certain volume of aggregate weighs.

Listed below are some of the properties of paving mixes.

- Surface Texture is a measure of the roughness of a pavement surface. It is important in skid resistance.
- Resistance to Polishing measures the ability of an aggregate to resist being worn smooth by traffic. It is important in skid resistance.
- Stability is a measure of pavement strength which comes primarily from the aggregate structure. It is one of the factors used in selecting the optimum asphalt content for a paving mix.
- Workability is a measure of how easily a paving mix can be placed and compacted.
- Durability is a measure of how long a pavement will last.

V REVIEW

1. A _____________ gradation is one in which one or more of the aggregate sizes are missing or only present in very small quantities.
    a. uniform
    b. gap
    c. stable
2. The type of asphalt most often used in Asphalt Concrete is:
    a. Cut-back asphalt
    b. Performance Graded Binder
    c. Emulsified asphalt
3. Aggregate surface texture affects which property of the mix?
    a. Air Voids
    b. Asphalt content
    c. Skid resistance
4. Cut-back asphalt is a mixture of asphalt and:
    a. Water
    b. Aggregate
    c. A solvent
5. Too much asphalt in a paving mix can cause:
    a. Raveling
    b. Low ductility
    c. Flushing or bleeding
6. The test that measures the resistance of aggregate to weathering is called:
    a. Unit weight
    b. Los Angeles abrasion
    c. Soundness
7. Loss of aggregate from a pavement surface is called __________________.
    a. Bleeding
    b. Raveling
    c. Rutting
8. Which of the following is a grade of asphalt binder?
    a. MC-250
    b. RS-2
    c. PG 64-22
9. Which of the following might be caused by too much fine aggregate in the paving mix?
    a. Low stability
    b. Failing gradation
    c. Both of the above

10. What would happen if the asphalt viscosity at mixing temperature was too low?
    a. The asphalt would not flow.
    b. The asphalt would not coat the stone.
    c. Asphalt would drain from the aggregate.
11. Which of the materials listed below would flow more readily?
    a. An asphalt with a viscosity of 120 at 135 °C.
    b. An asphalt with a viscosity of 220 at 135 °C.
    c. An asphalt with a viscosity of 320 at 135 °C.
12. If an asphalt viscosity is 1000 at 60 °C, we would expect the viscosity at 135 °C to be:
    a. higher
    b. the same
    c. lower
13. Which of the following is not a consistency test?
    a. Flash point
    b. Viscosity
    c. Penetration
14. Which aggregate is more resistant to abrasion?
    a. An aggregate with a Los Angeles abrasion of 40.
    b. An aggregate with a Los Angeles abrasion of 25.
15. Which of the following states would you expect to have the most trouble with weathering of aggregate?
    a. Florida
    b. Maine
    c. Maryland

VI REVIEW ANSWERS

1. (b) Gap
2. (b) Performance Graded Binder
3. (c) Skid Resistance
4. (c) A Solvent
5. (c) Flushing or bleeding
6. (c) Soundness
7. (b) Raveling
8. (c) PG 64-22
9. (c) Both of the Above
10. (c) Asphalt would drain from the aggregate
11. (a) Viscosity of 120 AT 135°C
12. (c) Lower
13. (a) Flash Point
14. (b) 25
15. (c) Maryland

References

Additional information on the material covered in this chapter may be found in the Asphalt Institute Manuals MS-5, Introduction to Asphalt; Manual MS-22, Principles of Construction of Hot-Mix Asphalt Pavements; Manual SP-1, Superpave Asphalt Binder Specification; Manual MS-25, Asphalt Binder Testing; and Manual MS-26, The Asphalt Binder Handbook.

Chapter 3 - Materials Sampling

I INTRODUCTION

This chapter explores the sampling of asphalt mixtures, liquid asphalt, and aggregate. In any program for sampling and testing, the primary objective is to determine the properties of a large object or group, based on the test results of a small set of samples. Depending on what is being examined, properties that could be determined could range from asphalt content to aggregate gradations to liquid viscosity. Those properties could represent a day of production at an asphalt plant or an entire stockpile of aggregate or a 10,000 gallon tank of asphalt binder. The major problem with sampling is the ability to guarantee that the properties of a tiny sample are the same as those of the large object in question.

There are two methods of handling this sampling problem. The first is to test a large number of samples across the entire object and average the test results. With this method, accuracy and care in sampling are not essential. The differences in individual samples will average out and we will end up with a good idea of the properties for the object that we are studying. The problem with this method is that it becomes expensive and very time consuming when large quantities are involved, such as the large amounts of material that are used daily in a asphalt mixing plant. The second method, and the one that we must use if we are to keep sampling expenses within reason, is to test only a small number of representative samples. A representative sample is one whose properties are as close as possible to being the same as those of the object that we are trying to measure. The samples that we take are very small in proportion to what is being measured, so it is very important that they be representative. A five pound sample may represent a few hundred tons of Asphalt mixtures, or a one gallon sample may represent the contents of a 10,000 gallon liquid asphalt tank. In the following sections, we will explain how to take a sample and how to insure that it is representative.

A) MAKE IT RANDOM – THE IMPORTANCE OF RANDOM SAMPLING

Sampling is the most effective means for estimating the acceptability of a quantity, or Lot, of material. The selection of the sampling locations within the lot must be entirely random. Random does not mean haphazard; it means that the sample is selected without bias. Random Sampling is a sampling procedure where any specimen in the population has an equal chance of being sampled. Biased sampling often results when the technician uses his or her judgment regarding when or where to take the sample. The tendency for some technicians may be to take a sample where the materials may appear to be defective, while others may take a sample where the material looks good. Each method is incorrect and the technician may be unconsciously biasing the sample. Random sampling is a vital part of any statistical based Quality Control/Quality Assurance program.

There is a misconception that a test on a single sample will show the true quality of the material, and that if any test result is not within some limit, there is something wrong with the material, construction, sampling, or testing. Thus, terms such as investigation, check, and referee specimens are in common use to either confirm or document these failures. Nature dislikes uniformity; variation is the rule. Therefore, any acceptance or process control sampling must account for variability of materials and construction. Multiple sampling and a procedure for identifying outliers will help accomplish this objective.

Random Sampling of Construction Materials (ASTM D3665) details the determination of random locations/time at which samples of construction materials should be taken. Included in AASHTO standards are procedures for securing the sample, description of the sampling tool, number of replicates, and sizes of the samples. Asphalt Concrete sampling is described in AASHTO T 168 and AASHTO T-40 discusses liquid asphalt sampling.

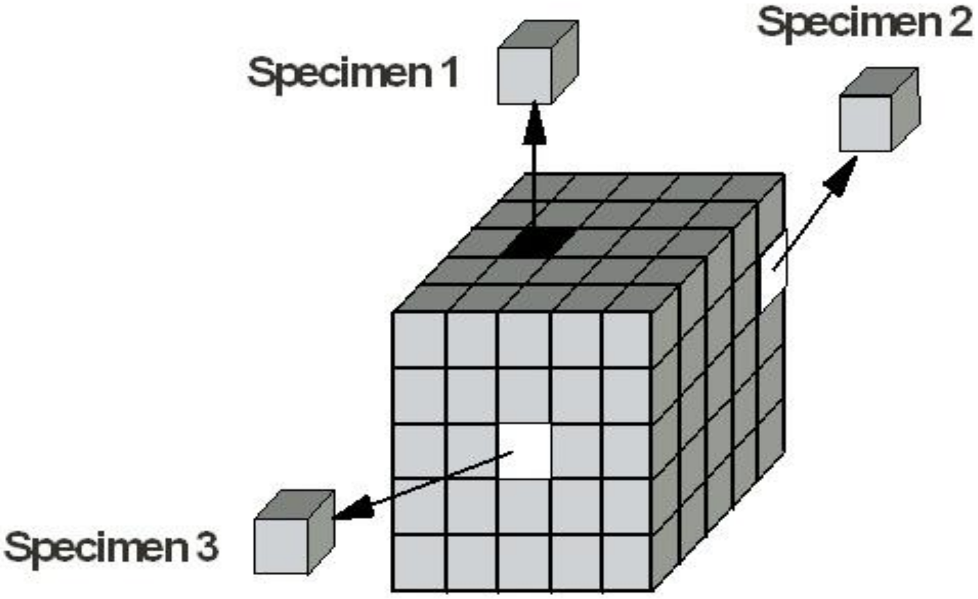


Figure 46 - Sampling Cube

Sampling locations can be determined on the basis of time, tonnage, volume, distance, area, etc. The only other necessary information needed is the size of the lot to be sampled and the number of samples that will be taken to evaluate the lot. The cube above represents a “Lot” of material and the smaller cubes represent individual specimens. The “Lot” may be defined as a physical location, a sampling time, or quantity of material. With random sampling, any of the individual specimens in this “Lot” has an equal chance of being selected. Therefore a random number should be assigned to each sample. Random number tables or random number generators on an electronic device are both common methods for determining random numbers. An example of a random number table is shown in Table 4. This is the same table that is included in the materials procedure for aggregate sampling, MP 700.00.06. When using a random number table, the key is to avoid bias, therefore you should never begin in the same place consecutively and you should never choose a specific spot that would favor something or someone. A simple way to be unbiased is the “pencil flip”, flip a pencil in the air and allow it to fall on the chart and begin where it points. Once a starting place is selected proceed in any direction to collect the quantity of random number needed. The “pencil flip” may also be used to select each individual sample.

Table 4 - Random Number Table

.858	.082	.886	.125	.263	.176	.551	.711	.355	.698
.576	.417	.242	.316	.960	.879	.444	.323	.331	.179
.587	.288	.835	.636	.596	.174	.866	.685	.066	.170
.068	.391	.739	.002	.159	.423	.629	.631	.979	.399
.140	.324	.215	.358	.663	.193	.215	.667	.627	.595
.574	.601	.623	.855	.339	.486	.065	.627	.458	.137
.966	.589	.757	.308	.025	.836	.200	.055	.510	.656
.608	.910	.944	.281	.539	.371	.217	.882	.324	.284
.215	.355	.645	.450	.719	.057	.287	.146	.135	.903
.761	.883	.771	.388	.928	.654	.815	.570	.539	.600
.869	.222	.115	.447	.658	.989	.921	.924	.560	.447
.562	.036	.302	.673	.911	.512	.972	.576	.838	.014
.481	.791	.454	.731	.770	.500	.980	.183	.385	.012
.599	.966	.356	.183	.797	.503	.180	.657	.077	.165
.464	.747	.299	.530	.675	.646	.385	.109	.780	.699
.675	.654	.221	.777	.172	.738	.324	.669	.079	.587
.269	.707	.372	.486	.340	.680	.928	.397	.337	.564
.338	.917	.942	.985	.838	.805	.278	.898	.906	.939
.316	.935	.403	.629	.130	.575	.195	.887	.142	.488
.011	.283	.762	.988	.102	.068	.902	.850	.569	.977
.683	.441	.572	.486	.732	.721	.275	.023	.088	.402
.493	.155	.530	.125	.841	.171	.794	.851	.797	.367
.059	.502	.963	.055	.128	.655	.043	.293	.792	.739
.996	.729	.370	.139	.306	.858	.183	.464	.457	.863
.240	.972	.495	.696	.350	.642	.188	.135	.470	.765

i) Random Sampling Example

During a morning's production at an asphalt mixing plant, a sample is required for the Quality Assurance program. The plant must produce 600 tons of asphalt concrete and they begin production at 7:00am. Assume the plant can operate at a continuous 150 tons per hour. A random number of 0.439 was selected for the sample, what time and after how many tons should the sample be taken?

Givens:	Unknowns:
Start time = 7:00am	Sample Time = ??
Production = 600 tons	Sample Tonnage = ??
Production Rate = 150 Tons/hr	
Random Number = 0.439	

Step 1: To find the time that the sample should be taken, the total production time needs to be calculated.

$$Production\ Time = \frac{Production\ (tons)}{Production\ Rate\ (ton/hr)}$$

$$Production\ Time = \frac{600\ (tons)}{150\ (ton/hr)} = \mathbf{4\ hrs}$$

Step 2: Determine the hours after starting production in which the sample should be taken.

$$Hours\ after\ start = Production\ Time\ \times Random\ Number$$

$$Hours\ after\ start = 4hrs\ \times 0.439 = 1.756\ hrs$$

Step 3: Determine the time the sample should be taken to the nearest minute.

$$Sample\ Time = 7{:}00am + 1.756\ hrs$$

$$Sample\ Time = 7{:}00am + 1hr + (.756hrs * 60\frac{min}{hr})$$

$$Sample\ Time = 7{:}00am + 1hr + 45.36min$$

$$Sample\ Time = \mathbf{8{:}45am}$$

Step 4: Determine the cumulative tonnage where a sample should be taken.

$$Tonnage = Production\ Quantity\ \times Random\ Number$$

$$Tonnage = 600(tons)\ \times 0.439$$

$$Tonnage = \mathbf{263.4(tons)}$$

ii) Stratified Random Sampling

Stratified Random sampling ensures that not only are samples random, they are dispersed throughout the entire sampling area. When using stratified random sampling, the material is divided into sections and random numbers are generated for samples within each division. These divisions ensure that all the samples are not taken within the same small section of the larger area. See the example below for an illustration of the issue and how stratified sampling distributes sampling.

iii) Stratified Random Sampling Example

During a paving project, 2500 tons of asphalt is produced and according to specifications five samples are needed. Using both simple and stratified random sampling, at what tonnage quantity should the five samples be taken? Assume the pencil pointed to Column 2 & Row 18 from Table 4 and you proceeded right with the five random numbers.

Givens:	Unknowns:
Production = 2500 tons	Sample tonnage = ??
Samples = 5	
Random Number = Column 2 & Row 18 from Table 4	

Step 1: Simple Random sample

0.917, 0.942, 0.985, 0.838, and 0.805

Step 2: Using the random number calculate the 5 sample locations

$$Sample1 = 2500tons \times 0.917 = 2292.5tons$$
$$Sample2 = 2500tons \times 0.942 = 2355.0tons$$
$$Sample3 = 2500tons \times 0.985 = 2462.5tons$$
$$Sample4 = 2500tons \times 0.838 = 2095.0tons$$
$$Sample5 = 2500tons \times 0.805 = 2012.5tons$$

Step 3: For the Stratified Random sampling divide the sampling object into equal parts (sublots) according to the number of samples needed.

$$Sample\ Rate = 2500tons \div 5sublots = 500\frac{tons}{sublot}$$

Step 4: Using the random numbers and the sampling rate, calculate the quantity at which the samples should be taken within each sublot.

$$Sample1 = 500tons \times 0.917 = 458.5tons$$
$$Sample2 = 500tons \times 0.942 = 471.0tons$$
$$Sample3 = 500tons \times 0.985 = 492.5tons$$
$$Sample4 = 500tons \times 0.838 = 419.0tons$$
$$Sample5 = 500tons \times 0.805 = 402.5tons$$

Step 5: Using the quantity location of each sample within the sublots, determine the cumulative quantity for each sample.

$$SampleX = Quantity(tons) + \left[(Sublot\ number - 1) \times 500\frac{tons}{sublot}\right]$$
$$Sample1 = 458.5tons + [(1-1) \times 500] = 458.5tons$$
$$Sample2 = 471.0tons + [(2-1) \times 500]$$
$$Sample2 = 471.0tons + (1 \times 500) = 971.0tons$$
$$Sample3 = 402.5tons + [(3-1) \times 500]$$
$$Sample3 = 402.5tons + (2 \times 500) = 1402.5tons$$
$$Sample4 = 419.0tons + [(4-1) \times 500]$$
$$Sample4 = 419.0tons + (3 \times 500) = 1919.0tons$$
$$Sample5 = 402.5tons + [(5-1) \times 500]$$
$$Sample5 = 402.5tons + (4 \times 500) = 2402.5tons$$

Looking at the results from each method, Figure 47 shows that simple random sampling would have every sample located in the last 500 tons of the material. However, using the same random numbers, if the material was stratified and divided into 500 ton sublots then the samples would be distributed throughout all the material.

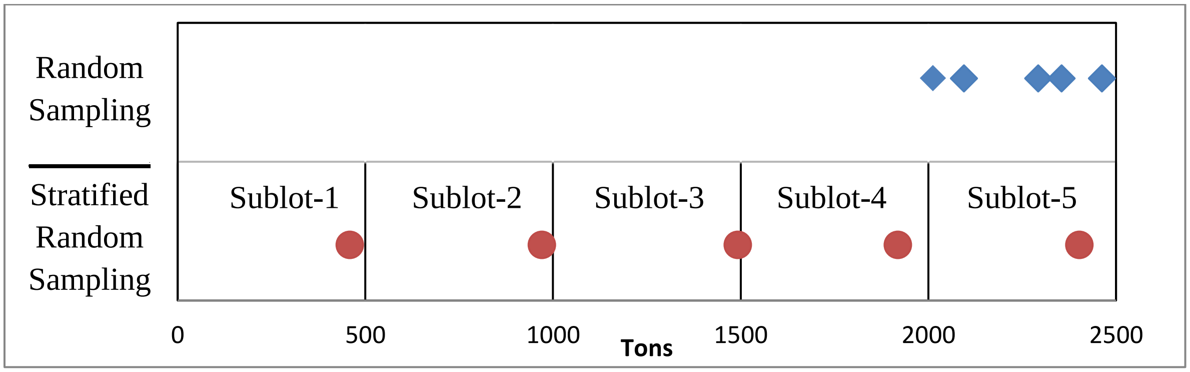


Figure 47 - Stratified Random Sampling Example

II SAMPLING LIQUID ASPHALT

A) Safety Precautions

PG Binders must be stored at a high temperature (300°F and above) to remain fluid enough for pumping. With that said, always wear the proper Personal Protective Equipment when handling hot asphalt binder. PPE includes heavy gloves, protective clothing, safety goggles, etc. If a PG binder has splashed on skin, it will likely cause burns. DO NOT ATTEMPT TO WIPE MOLTEN ASPHALT FROM SKIN. Instead cool the area immediately and seek medical assistance to remove any asphalt that has adhered to the skin.

Some Asphalt Emulsion grades are heated to remain viscous, but in general Asphalt emulsions are not stored at such high temperatures as PG binder, but similar precautions should still be used. Even at room temperature asphalt emulsions that have splashed onto the skin or clothing can be very difficult to remove.

B) GENERAL RULES AND PROCEDURES

When sampling Liquid Asphalt materials, there are two primary rules that should be followed. Avoid contamination and never sample from the extreme edges of the tank. Petroleum distillates cause the most problems, but nearly any liquid can contaminate an asphalt sample. The presence of a petroleum distillate will be evident in the results for the binder testing and if the contamination occurred during sampling, the sample will likely fail resulting in a rejection of material. Contamination can also occur during the transportation of the liquid from the manufacture or distributer to the mixing plant or Emulsion Distributer truck. If the tanker used to carry the liquid asphalt previously carried another product which was not fully emptied, it could easily contaminate the asphalt.

If liquid asphalt becomes contaminated with a heavy grade of oil, it may become worthless as a paving material. These oils make asphalt become much softer and will lack the strength to hold the mix together, and the pavement may tend to rut in the wheel tracks, which can deteriorate rapidly. A small amount of naphtha or gasoline will have the same effect on the penetration test as a large amount of oil. However, if this mixture of asphalt and petroleum distillate was used in a mixing plant, there is a possibility of the plant catching on fire. There is no simple or cheap test to tell which type of petroleum has contaminated a sample. If the WVDOH suspects that a shipment of asphalt is contaminated, the load could be rejected on the assumption that it has been contaminated with fuel oil.

It has been found that even a very small amount of petroleum distillate in a one gallon sample can cause the sample to soften. This could result in a low penetration and low viscosity, possibly causing the sample to fail. It would also make a sample more volatile and, if required, the flash point test may fail to meet the minimum requirement. So, under no circumstances, should a container that has been cleaned with a petroleum distillate, such as naphtha, gasoline or kerosene, be used to sample or ship a liquid asphalt sample. ALWAYS USE A NEW CONTAINER.

Even though most storage tanks are circulated, sampling from the extreme top or bottom of a liquid asphalt tank will likely increase the chance of getting an unrepresentative sample. Impurities in asphalt generally either settle to the bottom or float to the top of the tank. Since liquid asphalt tanks are seldom completely emptied or cleaned, the impurities and contaminants from the past loads may have collected in these two places. Never take a sample from the extreme top or bottom of the tank. The few gallons of material in these two locations will not be representative of the several thousand gallons in the middle of the tank.

Asphalt binder can be sampled at the refinery, distribution center, or the asphalt mixing plant. Due to some Federal safety regulations, asphalt refineries and distribution centers typically prefer their employees, rather than visitors sample from their production line. At the refineries, distribution centers and mixing plant liquid asphalt samples are typically taken from either circulating lines or the storage tanks, via open ended valves on either, shown in Figure 48. In either case, there will likely be material stuck in the valve that should be discarded and not collected for the sample. Place a waste container under the valve, then open the valve, the material may have solidified in the pipe, it might be necessary to heat the pipe to induce flow. Once again, proper PPE is required when performing these sampling operations. If the material had clogged the pipe it might splatter when it breaks free, stand back and use caution to avoid injury. Once the material is flowing freely and the valve has had time to purge, obtain a liquid sample. Always use a new container when sampling.

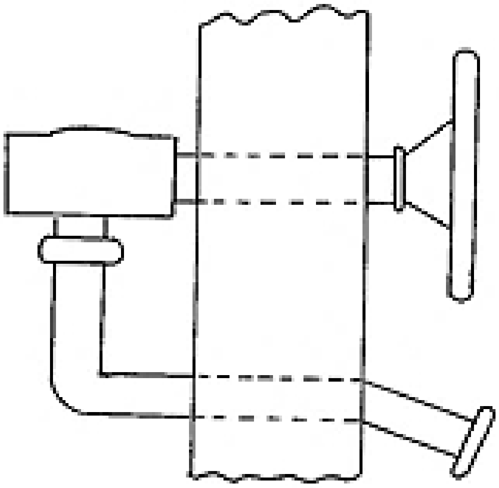


Figure 48 - Asphalt Liquid Sampling Valve

In the absence of a valve, Asphalt tanks and tanker trucks can also be sampled using a “Sampling Thief.” This device is typically a long stick with a container that can be mechanically opened and closed from outside the tank. The sampling thief is lowered through a hatch at the top of the tank, passes through the top layer of liquid and then opened to allow the liquid to fill the container. The container is then closed under the asphalt and removed from the tank. Once the container is removed the sample should be transferred to a clean container for shipping.

The best place to take a sample from a storage tank at an Asphalt Mixing plant is from the line between the storage tank and the asphalt metering device. The plant should be in operation when the sample is taken, so that the hot liquid asphalt will be circulating through the lines. AASHTO T-40 gives the procedures for sampling asphalt. Refer to this specification in case any question should arise concerning the proper method of sampling liquid asphalt. WVDOH sampling requirements for individual materials can be found in Section 703 of the Standard Specification book. Table 5 shows the sampling requirements for liquid asphalts and asphalt concrete.

Table 5 - Asphalt Material Sampling Requirments

Asphalt Material					
Material	Sample Location	Minimum Frequency	Sample Size	Sample Testing	Remarks
Performance Graded Binders	See Note 2	See Note 3	1 qt (1 L)	See Note 1	Refer to AASHTO T40 for sampling procedures.
Cutback Asphalts	See Note 2	See Note 3	1 qt (1 L)	See Note 1	Use a can with a cork-lined screw cap lid or other suitable container. Refer to AASHTO T40.
Asphalt Emulsions	See Note 2	See Note 3	1 gal (4 L)	See Note 1	Use a glass or plastic container. Do not use a metal can. Refer to AASHTO T40.
Hot-Mix Asphalt					
Asphalt Concrete for quality	Plant, truck or roadway	Refer to MP 401.02.27 for Marshall and MP 402.02.29 for Superpave	Sufficient size to comply with nominal aggregate size for each mix.	% Asphalt, % Air Voids, %VMA, Stability, Flow, and gradation (as required per MP)	Refer to AASHTO T168 for sampling procedures.
Pavement Density	Roadway	Refer to MP 401.05.20 and Section 401 Specification	One test per lift per 1,000 ft (300 m). Avg. of 5 additional tests if single test fails.	Determine density 92% to 96% of design maximum density.	Refer to MP 401.05.20 for lot-by-lot density testing.
			Minimum of one test section per lift	Determine number of roller passes	Refer to MP 401.05.20 for rollerpass density testing

Note 1: Refer to the governing section of the contract documents.

Note 2: Unless otherwise specified, take samples at the point of delivery if the material has not been previously sampled and tested by the WVDOH Materials Control, Soils and Testing Division (MCS&T). Certain material sources consistently demonstrate an ability to supply acceptable products. WVDOH periodically samples and test products from selected material sources and, if acceptable, will designate the source as approved and certified. Contact MCS&T for an updated list of approved and certified materials sources (or visit the MCS&T web site). Unless otherwise specified, if the Contractor provides sufficient documentation to substantiate that a material has been supplied by an approved and certified source, accept the material for use upon delivery to the project site (i.e., no further sampling and testing is required). Otherwise, further sampling and testing may be required. The Project Office should maintain an up-to-date list of all approved and certified material sources that are applicable to the project.

Note 3: Unless the shipment is certified or pretested, take one sample per shipment at its point of delivery. An asphalt shipment is considered certified if it is shopped from a WVDOH approved and certified material source. Contact the Project Office or MCS&T (or visit the MCS&T web site) for an updated list of approved and certified material sources. A shipping document will accompany each pretested asphalt shipment. A laboratory number will appear on the shipping document from which the asphalt material's test results can be obtained. As needed, use this laboratory number to confirm the acceptability of the material.

Many of the sampling requirements are in place for obvious reasons. It would not be safe to sample hot liquid asphalt binder in a glass or plastic container. However, asphalt emulsions which are never stored at extremely high temperatures are safe to sample in glass or plastic. Emulsions should never be stored in metal cans (unless plastic lined) because the acid flux used in soldering the seams, reacts with the emulsifying agent and could cause the sample to fail. Emulsions also contain water which can corrode metal containers and could cause the sample to fail. Due to asphalt emulsions tendency to separate, they should be shipped and tested as quickly as possible.

C) QUALITY CONTROL

The WVDOH quality control plan for asphalt is explained in Materials Procedure MP 401.02.25. There are two methods, or levels of quality control, which are explained in the following paragraphs.

i) Level 1 (Approved Source)

The WVDOH inspects the supplier's shipping terminal and the laboratory is inspected by the AASHTO Materials Reference Laboratory. The supplier tests his own samples and sends us the test results. We also test the asphalt and compare test results. If they agree, and if enough of them are passing, the shipping terminal is certified. A list of certified producer’s approved materials is issued quarterly.

ii) Level 2 (Batch Approval)

Some suppliers do not qualify for Level One Quality Control, either because the manufacturer does not sell the WVDOH enough material to be evaluated, or because too many of samples fail specifications. In these cases, the WVDOH samples and tests the products each time the storage tank is refilled and issues test reports. When the products are shipped to the project the shipping documents will contain the word "Meets Specifications" followed by a WVDOH laboratory number. This shows that the material has been tested and meets specifications.

iii) Acceptance of Shipments

To determine if a shipment of asphalt is acceptable, check the shipping invoice, and the current list of certified suppliers. The asphalt liquid may be accepted only if it is on the current list of approved materials, or if the shipping documents contain a DOH laboratory number, showing that the shipment is from a batch, or lot that has been tested and approved.

III AGGREGATE

Being the most abundant material in Asphalt Concrete, Mineral Aggregate needs to be sampled for various reasons; design, production, and quality control. In order to create an Asphalt mixture design, aggregate must be sampled accurately to best represent how the mixing plant will produce the mixture. During the production of Asphalt concrete, one of the first steps is weighing and drying of the aggregate.

A) STOCKPILE SAMPLING

Stockpile sampling for gradation is done only as a last resort. It is very important to take great effort to obtain a random sample from the stockpile. Various methods are used to construct stockpiles including conveyor belts and haul trucks. Segregation in stockpiles will generally cause the larger particles to fall to the bottom and concentrate there while finer particles will not fall as far and remain in higher concentration near the top (Figure 49). Obviously this will cause the intended original grading of the aggregate to be different than that in various levels of the stockpile. Two samples, one taken from the bottom of the stockpile and one from the top, could have very different gradations yet have been produced with the same gradation. In order to obtain a truly representative sample of stockpiled material, all levels of the stockpile should be included in a field sample (Figure 50). Stockpile construction should be such that these effects are limited or some means of mixing should be performed prior to shipment and use or placement.

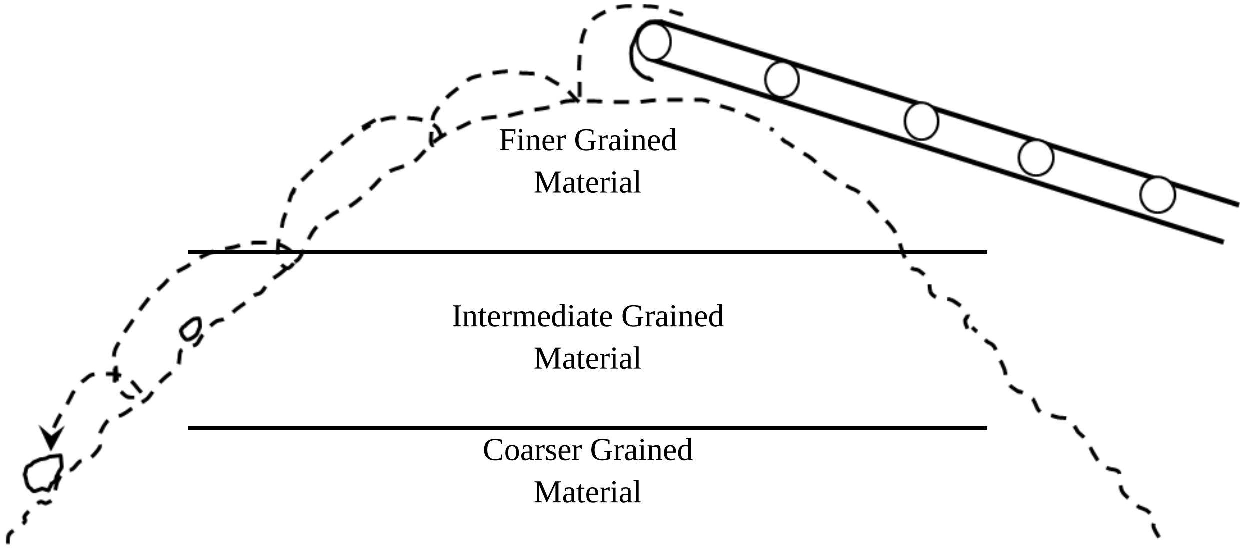


Figure 49 - Stockpile Segregation

Material quality can also be affected by stockpile construction methods. Quality of production material can often vary on a daily basis depending on the type of material. Different methods of stockpile construction will result in material being placed in the various parts of the stockpile from different times of production. Segregation can also result in areas of differing quality within the same stockpile if particles of various sizes exhibit different quality characteristics. Due to the particle size differences and variations in quality in different areas of the stockpile, a representative sample must have portions or increments taken randomly throughout the stockpile. Samples should not be taken from one location or at different locations around only the base of the stockpile. When sampling from a stockpile, it is advisable to get a piece of power equipment to create a mini-stockpile composed of material from different locations and levels of the stockpile mixed together. Another acceptable method is to sample diagonally around the stockpile from top to bottom (Figure 50).

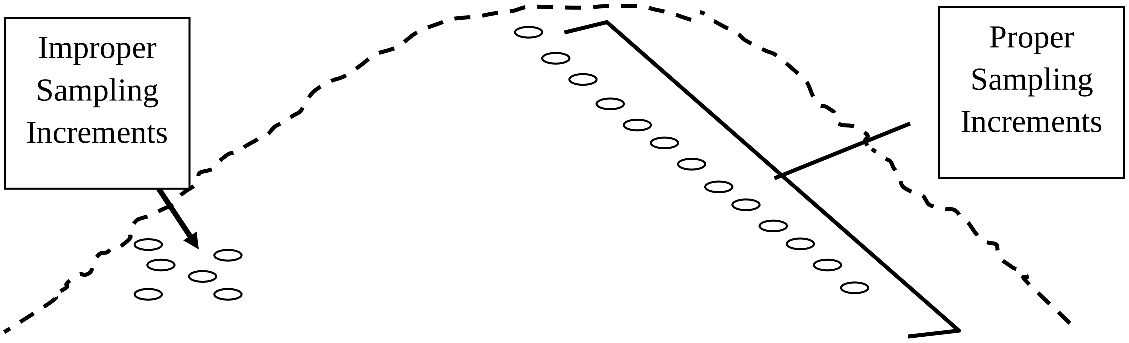


Figure 50 - Stockpile Sampling

When obtaining gradation samples, sampling should be done diagonally from top to bottom around the stockpile. Portions of the field sample should be taken around the stockpile in a pattern similar to that shown above. Samples taken for testing in the field may be placed in any suitable clean container of appropriate size. The container should be large and secure enough to prevent loss of material in transferring the sample to the testing location. Since it is possible that a moisture content of the aggregate may be required, the sampling container shall be made of a material that will not wick away surface moisture.

B) MIXING PLANT SAMPLING

i) Conveyer Belt Sampling

To obtain the sample from a conveyer, stop the belt and insert a template at the desired location along the belt, remove all material between the templates. In belt sampling, the width of the templates should be spaced just far enough apart to yield an increment of the correct weight, or approximately one fifth the weight of the field sample. If solid templates are used, this means a set is needed for each aggregate size sampled. However, it is easy to construct the templates with sliding cross members which allows a single set to be adjusted for any size material.

ii) Batch Plant Hot Bins

In a batch plant, hot bin samples are taken as the aggregate falls from the hot bin to the weigh hopper. On the following page are two drawings of a hot bin sampling device. The first drawing is a view from above, looking through the screens. The four sides are labeled a, b, c and d. Access doors for sampling may be located on any of the four sides, depending on the make of the plant. The second drawing is a view of the sampling device from the side with a flowing steam of aggregate from the hot bin. In this drawing the finest aggregate is shown on the left side which would be closest to the hot elevator where the aggregate is dropped onto the screens. The reason is that the finest aggregate falls through the screens first, while the coarser aggregate bounces further along the screen before falling through, so that there is segregation of the aggregate in the hot bin. This is illustrated on the cut-away view of the hot bin area of a batch plant on the following page.

Figure 51 - Aggregate Sampling Device

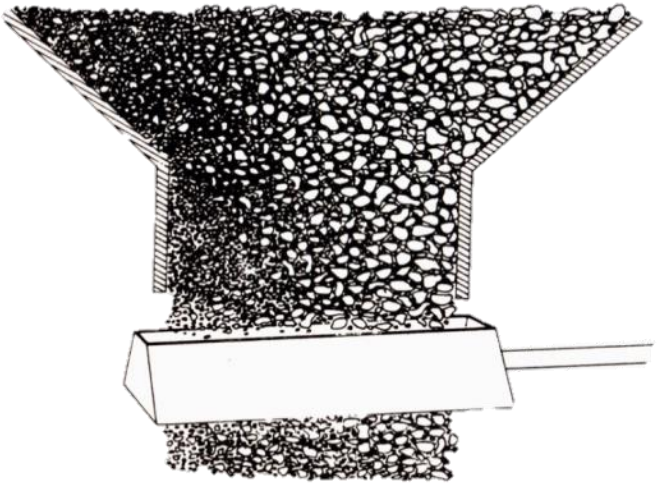


Figure 52 - Aggregate Sampling Device (Side View)

IV ASPHALT MIXTURES

Asphalt mixtures usually contain two or more sizes of aggregate, liquid asphalt and sometimes mineral filler, mixed in a pugmill or drum mixer. If the mixing device is in good condition, then these materials should be uniformly combined at the end of the mixing period. So, a sample taken from any part of the mixer box should have the same proportions as the entire batch. However, samples are not typically taken during the mixing process; they are taken from the asphalt trucks or from the roadway. As discussed, when the mix is dumped into the truck, there is a tendency for mix to segregate, the tendency for coarse and fine aggregate particles to separate. In order to obtain a representative sample, from the truck or roadway, care should be taken to properly load trucks.

As discussed in Chapter 2, Section III, the best practice for filling an asphalt concrete truck is to use three drops. In this case you decrease the likelihood for severe segregation. If the mix is dropped in a single coned pile in the truck, the pile would act like a stockpile and the momentum from the larger particles would carry them to the outside of the pile, leaving the fine particles to collect in the middle.

This practice is not only detrimental for sampling accuracy it will also have ill effects during paving operations. When the segregated material enters the paver it is not recombined well enough to remove the segregation so it will be placed on the road that way. Figure 53 shows how truck segregation affects the pavement surface. The segregated areas in the pavement will likely have low density and high air voids, which leads to high permeability. This will increase the chance for water intrusion into the pavement, which will cause premature deterioration of the pavement.

Figure 53 – Truck Segregation Effects

Various methods for sampling Asphalt mixtures are discussed in AASHTO T-168. We will discuss two popular methods used for Quality Assurance system for the WVDOH: Truck sampling and Roadway Sampling.

A) TRUCK SAMPLING

As with any material, random sampling is important with asphalt concrete. When sampling from an asphalt truck, sampling times are usually based on production time or tonnage. The examples in Section I of this chapter demonstrate how to calculate sampling times. To take a truck sample you will need a sample container and a shovel or scoop having high sides, so that the coarse aggregate will not roll off the sides. The sample must be taken from at least three random locations and the samples are then combined.

When sampling from a truck that is loaded with a single drop, a sample collected is likely segregated. Testing such a sample would give misleading results, lead to improper plant adjustments, and could cause rejection of material that may have been satisfactory. However, we do not wish to give the false impression that whenever the gradation of a mix is erratic, that it is caused by segregation in the truck. The material may never have been properly mixed in the first place. One of the most common causes of erratic gradation is changes in the stockpile gradations.

B) ROADWAY SAMPLING

In lieu of sampling from an asphalt truck, samples can be taken from behind the paver prior to compaction. These samples will better represent the final product than would a truck sample. Roadway Sampling is required on all Percent Within Limits project (Section 410 of the 2017 Standard Specifications). Samples can be collected from the roadway using a flat-bottomed, high-sided scoop or a flat plate. Once the paver has moved over the sampling area, acquire the sample making sure to sample from the entire depth of the lift. When sampling, the best practice is to scoop once from either side, once in the middle and then clean up in between those. See Figure 54 for reference.

Figure 54 - Roadway Scoop Sampling

Another method of taking a roadway sample is to use a plate of adequate size with attached wires. You lay the plate down on the existing surface and arrange the wires in a way that they won’t be snagged by paver. Once the paver has past, pull the wires which lead to the plate and extract the plate. The materials on the edge of the plate should be removed to avoid any segregation, and then the sample should be quartered with opposite corners being retained. See Figure 55 for reference.

Figure 55 - Roadway Plate Sampling

C) SAMPLING SIZE

Samples taken are generally used for multiple tests, for instance Superpave requires two pills be made for QC/QA testing. Each sample weights roughly 4750g, so be sure what is being tested when sampling. Table 6 gives estimated minimum sampling quantities by mixture type.

Table 6 - Minimum Asphalt Concrete Sample Sizes (AASHTO T168)

Mix Type	Nominal Maximum Sieve Size	Minimum Sample Mass
4.75 mm or Wearing-III	4.75 mm (#4)	10 kg
9.5 mm or Wearing-I	9.5 mm (3/8 inch)	16 kg
12.5 mm	12.5 mm (1/2 inch)	20 kg
19 mm or Base-II/Wearing-IV	19 mm (3/4 inch)	20 kg
25 mm	25 mm (1 inch)	24 kg
37.5 mm or Base-I	37.5 mm (1 ½ inch)	30 kg

V SAMPLE IDENTIFICATION

Regardless of whether the technician is sampling liquid asphalt, aggregate, RAP, or hot-mix asphalt, a critical part of the sampling process is proper sample identification and documentation. Without this documentation a laboratory technician cannot identify what material was delivered to them, and the sample must be discarded and new samples taken. Some typical material identifiers are listed below. Other documentation may also be necessary for samples, refer to the proper Material Procedures and specifications.

- Material Description & Material Code
- Material Source & Source Code
- Sample Date & Time
- Name of Sampler
- Field Sample Identification Number
- Test Required
- Lot & Sublot Numbers
- Station & Offsets Locations
- Tank or Batch Numbers, etc.

VI REVIEW

Answer the following practice questions, and then check your answers against those given on the page following the last question.

1. A test sample which has the same properties as the batch, group or lot from which it was sampled is called a ___________________ sample.
2. The tendency for something to separate into coarse and fine particles is called ________________.
3. In a drum mix plant, aggregate samples must be taken from the hot-bins. True or False _________________.
4. What is the minimum sample size for a Hot Mix Asphalt for which the specification requirements are: 100% passing the 9.5 mm (3/8 inch) sieve and 90 - 100% passing the 4.75 mm (#4) sieve? ________
5. The two primary rules for sampling liquid asphalt are: avoid ____________ and do not sample from the ________ or _________ of the tank.
6. A ________ or ________ container may be used to ship asphalt emulsion samples.
7. A plant will be producing Asphalt Concrete for 8 hours and you want to take one sample for each four-hour sublot. Using a random number table, the numbers .385 and .109 are picked for the two sublots. Assuming that the plant starts up at 6:00 AM, determine the time that each sublot sample will be taken.
8. A liquid asphalt sample taken from the extreme top of the tank is likely to be contaminated. True or False ____________.
9. In the hot bins of a batch plant the aggregate is not uniformly distributed across the bin because (CHOOSE ONE)
   (a) The screens have holes in them.
   (b) Aggregate leaks from the discharge gate.
   (c) The finer aggregate tends to fall through the screen first.
10. In a hot bin, the coarsest aggregate will usually be found
    (a) In the upper 1/3 of the bin.
    (b) On the side nearest the hot elevator.
    (c) On the side away from the hot elevator.

VII REVIEW ANSWER

1. Representative
2. Segregation
3. False (drum plants do not have hot bins)
4. 10 kg or 10,000 Grams
5. Contamination; Top; Bottom
6. Glass or plastic
7. Sublot Number 1: 6:00 AM + (0.385 x 4 hours) = 7:32 AM
   Sublot Number 2: 10:00 AM + (0.109 x 4 hours) =10:26 AM
8. True (contaminants typically float on top or settle to bottom of the tank)
9. (c)
10. (c)

Chapter 4 - Mix Design and Testing

I INTRO / BACKGROUND

The WVDOH uses two mix design methods; Superpave and Marshall. Mix design of asphalt mixture is a process of performing laboratory test procedures on precisely blended combinations of asphalt and aggregate and coming up with an economical mix that will meet the requirements of the specified mix criteria for a given pavement. This process includes (1) laboratory compaction of trial mix specimens, (2) stability, flow, and volumetric testing, and (3) analysis of the results.

Mix design, along with proper construction techniques, is a crucial part of assuring that an asphalt pavement will perform well. It is beyond the scope of this manual to thoroughly cover every phase of designing a mix. The main purpose here is to summarize the test procedures and the calculations that are used in the mix design process and discuss the method for determining the optimum asphalt content. Three excellent sources of information on asphalt mix design are the Asphalt Institute's MS-2 Mix Design Manual; the National Center For Asphalt Technology's textbook - Hot-Mix Asphalt Materials, Mixture Design and Construction; and NCHRP Report 673, A Manual for Design of Hot Mix Asphalt with Commentary.

In order to design a proper Marshall or Superpave mixture, knowledge of the design methods, calculations, and laboratory procedures are required. To ensure that mix designs are properly performed, the mix designs must be prepared by a certified technician for both the Marshall and Superpave methods. Certification requires successfully completing an approved mix design course that includes hands-on testing. The Asphalt Institute and several bordering states offer courses. In addition, courses for both the Marshall and Superpave methods are offered through the West Virginia Asphalt Technology Program in cooperation with the WVDOH.

II PROPERTIES OF ASPHALT CONCRETE

A mix that is properly designed should contain a sufficient amount of asphalt for durability and impermeability. It should have sufficient stability (resistance to shoving and rutting under load) for the projected traffic level. It should have sufficient air voids to allow for densification under traffic but not so few as to cause instability. It should also have sufficient workability to permit ease of construction. Once it has been constructed, it must be flexible to resist cracking during subgrade settlement. It must resist the fatigue of repeated bending under traffic loads. And finally, it must have skid resistance. Meeting all of these properties is the major goal of the mix design process. No single asphalt content will maximize all of these properties. Instead, the asphalt content must be selected on the basis of optimizing these properties.

A) STABILITY

The ability of an asphalt pavement to resist rutting and shoving under traffic loads is called stability. It is very important that a pavement is stable so that it will maintain its shape under repeated loads. Stability specifications must be high enough to handle traffic loads, but not so high that it makes the mix too stiff and less durable.

Stability of the mix depends on the internal friction and particle interlocking of the aggregate along with cohesion resulting from the bonding of the asphalt. Angular shaped aggregates with rough surface texture provide a higher stability in a mix. Rounded aggregates with little or no crushed surfaces result in low stability and often rutting of the pavement under heavy loads.

Excessive amounts of medium size sand in a mix can cause low stabilities. It can also result in a mix that is tender when rolling and very difficult to compact.

Too much asphalt in a mix can cause a low stability because the extra asphalt allows particles to move around in the mix. Rutting can occur and the excessive asphalt can be squeezed to the surface under traffic loads.

B) DURABILITY

The durability of an asphalt pavement is its ability to resist oxidation of the asphalt, disintegration of the aggregate, and stripping of the asphalt from the aggregate. Durability can be enhanced by using the maximum asphalt content for the specific design to increase the film thickness of the asphalt. This slows down the oxidation process on the asphalt and seals off any interconnected air voids that would allow air and water to infiltrate. The key here is to not add too much asphalt because a certain amount of air voids is necessary to allow for expansion of the asphalt in hot weather.

A dense gradation of the aggregate will contribute to the durability of the pavement by providing a closer contact of the aggregate particles. This along with the proper asphalt content effectively seals out air and water.

C) IMPERMEABILITY

Impermeability is the resistance of an asphalt pavement to air and water infiltration. This characteristic is directly related to the air void content of the compacted mix. Decreasing the air void content of the pavement will decrease the permeability. All pavements have some degree of permeability but designing the mix with the proper asphalt content and a dense gradation will keep it to a minimum, assuming that adequate compaction is achieved during construction.

D) WORKABILITY

Workability is the ease with which asphalt mixture can be placed and compacted. Workability can be improved by changing aggregate types and/or gradation. A mix with large maximum size aggregates can result in a rough surface and difficult placement. A mix that is harsh to work with will tend to segregate and make compaction difficult. A mix that is too easily worked is referred to as a tender mix and remains unstable for long periods of time and is difficult to compact. As mentioned earlier, a tender mix is usually caused by excessive amounts of medium-sized sand. The asphalt binder can also effect the workability. Thicker grades of asphalt and low mix temperatures that stiffen the asphalt can adversely affect workability.

E) FLEXIBILITY

Asphalt pavements are supposed to be flexible to some degree. Flexibility is the ability of the pavement to adjust to gradual settlements and movements in the subgrade without cracking. Open-graded mixes with high asphalt contents are usually more flexible than dense-graded mixes with low asphalt contents. Some trade-offs are usually necessary when flexibility conflicts with stability of the pavement.

F) FATIGUE RESISTANCE

Fatigue resistance is a pavement's resistance to repeated bending under traffic loads. High air voids in the pavement resulting from lack of adequate compaction will shorten the pavement fatigue life. Fatigue resistance is also lowered if the pavement is not thick enough or the supporting subgrade is inadequate. Low asphalt contents or asphalts that have become hardened can result in fatigue cracks in the pavement.

G) SKID RESISTANCE

Skid resistance is the ability of an asphalt surface to minimize skidding of vehicle tires, especially when wet. A rough pavement surface with many little peaks and valleys provides the greatest skid resistance. The best aggregates to use in a skid surface are those with a rough surface that can resist polishing under traffic. Mixes with excessive asphalt that bleeds to the surface under traffic can cause serious skid problems.

III DESIGNING ASPHALT CONCRETE

Both the Marshall and Superpave mix design methods can be described in five steps:

- Select Aggregates
- Select Binder
- Prepare samples
- Test samples
- Select optimum asphalt content

A) AGGREGATES

Good asphalt requires using high quality aggregates. Aggregates are stored in stockpiles to control gradations. The stockpiles are blended to achieve the desired gradation for asphalt concrete. The aggregate requirements are on the individual stockpiles or on the blend. Many of the requirements are common to both Marshall and Superpave but there are some differences:

- Some tests performed for both Marshall and Superpave but the test methods and limits may differ.
- Superpave requires additional tests that are not used with the Marshall method.

i) Stockpile Requirements

The materials used in a design must conform to the requirements set forth in the Agency Standard Specifications. Hot-Mix Asphalt is covered in Section 401 and 402 of the WVDOH Standard Specifications Manual. Fine aggregate specifications are covered under Section 702 and simply states that fine aggregate for asphalt mixture must meet the requirements of ASTM D1073 with the exception that the ASTM gradation requirement is waived. Coarse aggregate specifications are covered under Section 703. Coarse Aggregate Source Properties required for all asphalt mixture designs under the 401 Specification are:

- Toughness is the percent loss of material from an aggregate sample as determined during the Los Angeles Abrasion test discussed in Chapter Two
- Soundness estimates the resistance of aggregate to weathering while in-service and is determined by the Sodium Sulfate Soundness test
- Deleterious materials are defined as the mass percentage of contaminants such as shale, wood, mica, and coal in the aggregate sample.

The WVDOH has requirements for shale content, coal and other lightweight deleterious material, and friable particles, soundness, percent wear, and thin or elongated pieces as indicated in the following tables for Marshall and Superpave mixes.

WVDOH Coarse Aggregate Source Properties Section 703	Maximum Percent By Mass
Shale content (MP 703.00.27)	The total shale, coal and other lightweight deleterious material, and friable particles shall not exceed 3%.
Coal and other lightweight deleterious material (MP 702.01.20)	
Friable particles (MP 703.01.20)	
Soundness (% Loss) (MP 703.00.22)	12
Percent Wear (AASHTO T96)	40
Thin or elongated pieces (MP 703.00.25) Based on 4:1 ratio for Marshall	5

Superpave Mix Design MP 401.02.28 - TABLE 5
Aggregate Consensus Property Requirements

20 Year Projected Design ESALs (millions)	Coarse Agg. Angularity (% Minimum) ASTM D5821 (Note 7)		Fine Agg. Angularity (% Minimum) AASHTO T304, Method A (Note 9)		Fine Agg. Sand Equivalent AASHTO T176	Coarse Agg. Flat and Elongated ASTM D4791
	Top Two Pavement Lifts (Note 8)	Below Top Two Pavement Lifts	Top Two Pavement Lifts	Below Top Two Pavement Lifts	% Minimum	% Maximum (Note 12)
< 0.3 (Note 10)	55 / -	- / -	-	-	40	-
0.3 to < 3 (Note 10)	75 / -	50 / -	40	40	40	10
3 to < 10	85 / 80	60 / -	45	40	45	10
10 to < 20 (Note 11)	90 / 85	80 / 75	45	40	45	10
20 to < 30	95 / 90	80 / 75	45	40	45	10
≥ 30	100/100	100/100	45	45	50	10

Note 7: "85/80" denotes that a minimum of 85 percent of the coarse aggregate has one fractured face and a minimum of 80 percent has two fractured faces.
Note 8: The referenced "top two pavement lifts" does not include a scratch course or patching-and-leveling course that may be placed between these lifts. When a scratch or patching-and-leveling course is placed between the top two lifts, the aggregate requirements for the mix shall fall under the "top two pavement lifts" criteria.
Note 9: For design traffic levels of 3 million ESALs or greater, any mix composed of a 100 percent crushed aggregate blend that will be used in the top two lifts of the pavement structure will be acceptable with an FAA value of 43 or greater. This 43 FAA criteria shall also apply to the 30 million or grater traffic level for mixtures below the top two lifts. It shall also apply to 100 percent crushed aggregate blends that contain no more than 15 percent RAP.
Note 10: The minimum requirement for coarse aggregate angularity for any Section 402 skid resistant mix design with a projected ESAL value of 0.3 to less than 3 million shall be 85/80. For skid resistant mix design with a projected ESAL value of less than 0.3 million it shall be 75/-.
Note 11: The 10 to less than 20 million design ESAL aggregate criteria only applies to Section 402 skid resistant mix designs.
Note 12: Flat and elongated particles in coarse aggregates shall be tested in accordance with D 4791 with the exception that the material passing the 9.5 mm (⅜ in.) sieve and retained on the 4.75 mm (No. 4)sieve shall be included. The aggregate shall be measured using the ratio of 5:1, comparing the length (longest dimension) to the thickness (smallest dimension) of the aggregate particles.

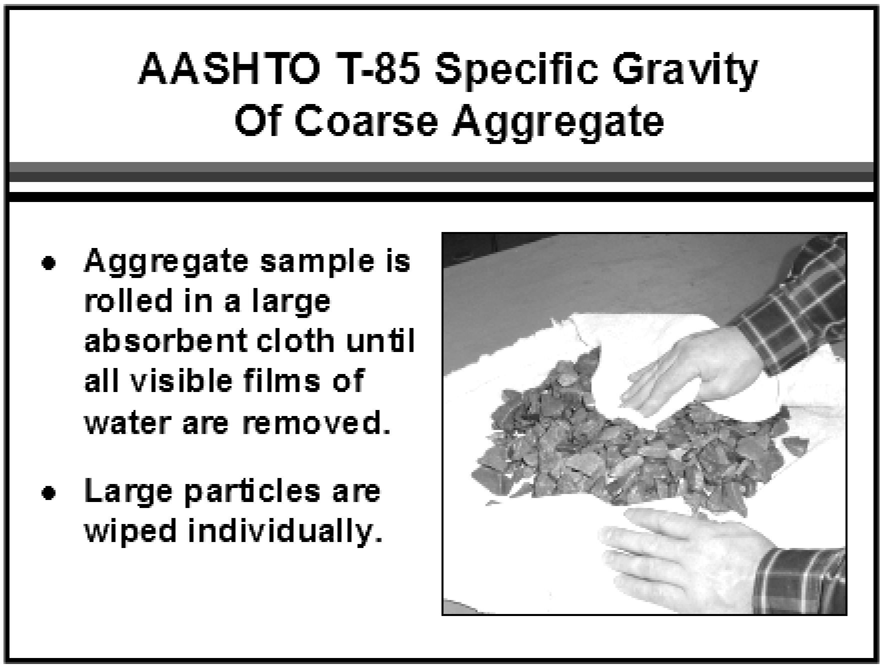
There is also a crushed particle requirement for rounded aggregate such as river gravel when used in Marshall mix designs. For Base-1 (1.5 inch or 37.5 mm nominal maximum size) mix designs it is required that the aggregate have a minimum of 80% one-face fracture. For all other Marshall mix designs the requirement is a minimum of 80% two-face fracture. The percent face fracture is determined in accordance with MP 703.00.21. The requirements for the number of face fractures (1 or > 1) in Superpave designs vary depending on the design traffic for the mix design and the lift of the asphalt in the pavement structure. The Superpave limit for crushed particles is tested on the blend of stockpiles used in the mix design.

In addition, Section 402, asphalt mixture Skid Resistant Pavement, requires the use of approved polish resistant coarse aggregate for surface mix designs used on all roads with an average daily traffic (ADT) of 3000 or greater. The WVDOH's Aggregate Section at MCS&T performs all of the necessary testing required to determine the acceptability of polish resistant aggregates for use in skid resistant asphalt mixture.

Specific gravity is the ratio of the mass of a given volume of a substance to the mass of an equal volume of water, at a given temperature. Since the specific gravity of water is "1", the specific gravity of other materials can be defined as the number of times heavier (or lighter) the material is than water. It is an essential property of the aggregate for the volumetric analysis of a mix. The specific gravity test for coarse aggregate is covered under AASHTO T85 and the specific gravity test for fine aggregate is covered under AASHTO T84.

Specific Gravity of Coarse Aggregate (AASHTO T85) - A representative sample of each coarse aggregate used in the design must be taken from the stockpiles. The aggregate must be screened over a 4.75 mm (No. 4) sieve because this test is only performed on material that is retained on the 4.75 mm (No. 4) sieve. It must also be washed in order to remove all dust from the aggregate surface. The proper test sample mass must be selected by splitting or quartering per nominal maximum size of aggregate as specified below:

Nominal Maximum Size	Minimum Mass (kg)
12.5 mm (1/2 inch)	2
19.0 mm (3/4 inch)	3
25.0 mm (1 inch)	4
37.5 mm (1 ½ inch)	5
50.0 mm (2 inch)	8



AASHTO T-85 Specific Gravity Of Coarse Aggregate

- Aggregate sample is rolled in a large absorbent cloth until all visible films of water are removed.
- Large particles are wiped individually.

The aggregate test sample must be dried to a constant mass and allowed to cool for 1 to 3 hours to a comfortable handling temperature. The aggregate is then immersed in water at room temperature for 15 to 19 hours.

The aggregate sample is next removed from the water and rolled in a large absorbent cloth until all visible films of water are removed. Large particles are wiped individually. Care must be taken to avoid evaporation of water from the aggregate pores during the surface-drying procedure. The mass of the aggregate in the surface-dry condition is then determined.

The sample is then immediately placed in the sample container (wire basket) and placed in the water bath which is maintained at 23 + 1.7 °C (73 + 3 °F). Entrapped air is removed by shaking the sample container. The water depth must be sufficient to completely immerse the container and test sample while determining the mass.

After the sample mass in water is determined it is removed from the container and oven dried to a constant mass. Calculations are as follows:

Apparent Sp. Gravity (Gsb) = A / (A - C)
Bulk Sp. Gravity (Gsb) = A / (B - C)
Absorption, % = [(B - A) / A] x 100
Where: A = Mass of oven-dry sample in air
B = Mass of saturated surface-dry sample
C = Mass of saturated sample in water

Example Problem: A test sample of plus 4.75 mm (No. 4) material taken from a stockpile sample of No. 67 limestone had an oven dry mass of 3950 grams. In the saturated surface-dry condition the mass was 3978 grams. The mass of the saturated sample in water was 2544 grams. What is the bulk specific gravity of the aggregate? What is the percent water absorption?

Solution:

$$\text{Bulk Sp. Gravity } (G_{sb}) = \frac{3950}{3978 - 2544} = 2.755$$

$$\text{Absorption} = \frac{3978 - 3950}{3950} \text{ x} 100 = 0.7\%$$

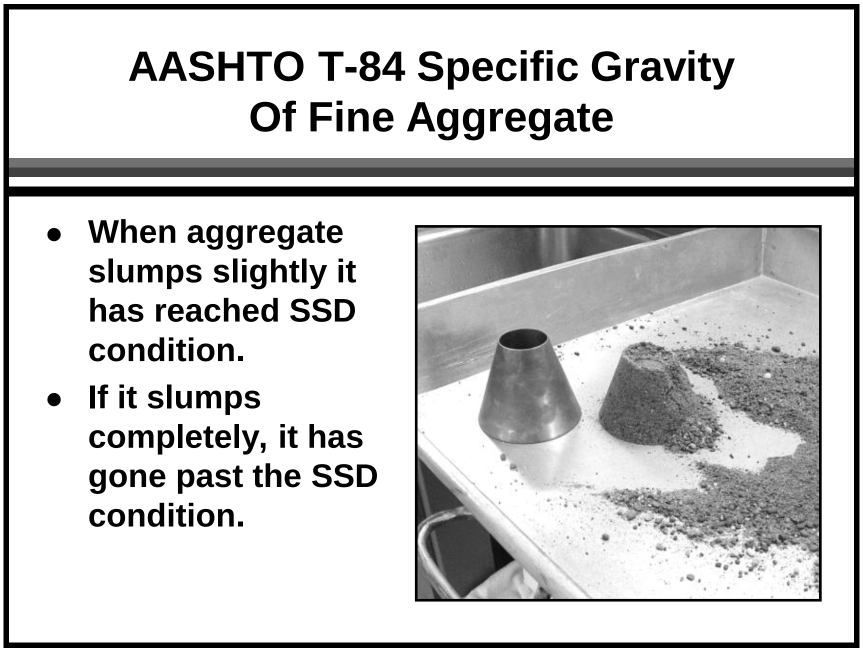
Specific Gravity of Fine Aggregate (AASHTO T840) - Fine aggregate is defined as minus 4.75 mm (No. 4) material. The particles in fine aggregate are too small to be tested in the same manner as coarse aggregate. For determining the specific gravity of fine aggregate, approximately 1000 grams of material is split from the field sample and dried to a constant mass.

The sample is covered with water, either by immersion or by the addition of at least 6% moisture and allowed to stand for 15 to 19 hours. Excess water is decanted with care to avoid loss of fines.

The sample is then spread on a flat nonabsorbent surface and exposed to a gently moving current of warm air (typically a hair dryer is used), and frequently stirred to secure homogeneous drying. The drying is continued until the test specimen approaches a free-flowing condition.

Saturated surface-dry condition is checked by filling a cone-shaped mold to overflowing with hand cupped around the mold. The fine aggregate is lightly tamped into the mold with 25 free falling light drops of a tamper weight from about 5 mm (0.2 in.) above the top surface of the aggregate. The starting height is adjusted to the new surface elevation after each drop. The drops are distributed over the surface.

Loose sand is then removed from around the base and the mold is lifted vertically. Surface moisture is still present if the fine aggregate retains the molded shape. If the aggregate slumped slightly it has reached a surface-dry condition. One trial must always be made before the first slump occurs. If the first trial does slump, however, then the material must be mixed with a few milliliters of water and left to stand in a covered container for 30 minutes.



AASHTO T-84 Specific Gravity Of Fine Aggregate

- **When aggregate slumps slightly it has reached SSD condition.**
- **If it slumps completely, it has gone past the SSD condition.**

Once the slump occurs, a calibrated container (pycnometer or flask) is partially filled with water. 500 ± 10 grams of saturated surface-dry aggregate is immediately introduced into the container. It is then filled with additional water to approximately 90% of capacity. The container is rolled, inverted, and agitated to eliminate all air bubbles.

The water temperature is adjusted to 23 ± 1.7 °C (73 ± 3 °F) and the container is filled to its calibrated capacity. Total mass of container, test sample, and water are determined to the nearest 0.1 gram. The aggregate is then removed from the container for drying to a constant mass. Calculations are as follows:

Apparent Sp. Gravity (G_{sb}) $= A / (A + D - C)$
Bulk Sp. Gravity (G_{sb}) $= A / (B + D - C)$
Absorption, % $= [(D - A) / A] \times 100$
Where: A = Mass of oven-dry sample in air
B = Mass of pycnometer filled with water
C = Mass of pycnometer, sample, and water
D = Mass of saturated surface-dry sample

Example Problem: A test sample of natural sand had an oven dry mass of 503.5 grams. In the saturated surface-dry condition the mass was 511.4 grams. The mass of the pycnometer, sample, and water was 987.9 grams. The mass of the pycnometer filled to the calibration mark with distilled water was 670.3 grams. What is the bulk specific gravity of the aggregate? What is the percent water absorption?

Solution: Bulk Sp. Gravity (G_{sb}) = $\frac{503.5}{670.3 + 511.4 - 987.9} = 2.598$

$$\text{Absorption} = \frac{511.4 - 503.5}{503.5} * 100 = 1.6\%$$

B) AGGREGATE BLENDING

Each mix design must have a job mix formula (JMF) which specifies the gradation of all required sieves and the designed asphalt content. The same JMF can be used on any job that calls for the specific type of design that it represents. For now, only the gradation portion of the JMF will be discussed. A mix is designed with a specific gradation that must be within the tolerance limits of a Master Range which specifies the allowable design range for gradation of each sieve size. Usually, the design should be close to the center of the range. A typical asphalt mixture mix design will usually consist of one or more standard aggregate sizes meeting the gradation requirements of AASHTO M43, as specified in Table 703.4, blended together with fine aggregates to meet the tolerances of the Master Range, see Table 7 and Table 8 for the master ranges for Marshall and Superpave respectively.

Gradations are plotted 0.45 power gradation chart to define a permissible gradation. An important feature of this chart is the maximum density gradation. This gradation plots as a straight line from the maximum aggregate size through the origin. Superpave used a standard set of ASTM sieves and the following definitions with respect to aggregate size:

- Maximum Size: One sieve size larger than the nominal maximum size.
- Nominal Maximum Size: One sieve size larger than the first sieve to retain more than 10 percent.

The method used to come up with the mix design gradation is called trial-and-error proportioning. The first thing that must be done is to determine the gradation (AASHTO T27) of the aggregate stockpiles that will be used in the mix design and plot the specification limits on a gradation chart.

Estimate the plant mix formula near the center of the specification range. Next estimate the percentage of each aggregate needed to meet the plant mix formula. Using the worksheet T-415 found on page 84,calculate the first trial gradation by multiplying the percent passing each sieve by the percentage of that aggregate in the blend. Add the values across the page for each sieve. These totals represent the percent passing each sieve for the blended aggregate. Computer software has been developed to simplify aggregate blending. Even a good spreadsheet program can help by allowing you to quickly change the blend percentages and immediately see the results.

You should continue to adjust the percentages of the aggregates until the adjustments will no longer improve agreement with the estimated plant mix formula. If it is impossible to come up with a good plant mix formula with the selected aggregates then it may be necessary to try other aggregates and repeat the process. The plant mix formula may be any gradation that permits the full use of the tolerance range.

One more thing to remember is that not every aggregate blend that falls within the master range of the specifications will result in a mix design that meets all of the required volumetric properties. When all design criteria can't be met with a particular aggregate blend, the only option for the design technician is to change the blended aggregate proportions or even incorporate other available aggregates into the design.

Table 7 - Design Aggregate Gradation Requirements for Marshall Design

TYPE OF MIX	Base-I	Base-II (Patch & Level)	Wearing-IV	Wearing-I (Scratch-I)	Wearing-III (Scratch-III)
SIEVE SIZE	Nominal Maximum Size				
	1 ½ in (37.5 mm)	¾ in (19 mm)	¾ in (19 mm)	3/8 in (9.5 mm)	No. 4 (4.75 mm)
2 in (50 mm)	100				
1 ½ in (37.5) mm)	90 - 100				
1 in (25 mm)	90 max	100	100		
¾ in (19 mm)		90 – 100	90 – 100		
½ in (12.5 mm)		90 max	90 max	100	
3/8 in (9.5 mm)				85 - 100	100
No. 4 (4.75 mm)			47 min	80 max	90 - 100
No. 8 (2.36 mm)	15 – 36	20 – 50	20 – 50	30 – 55	90 max
No. 16 (1.18 mm)	-	-	-	-	40 - 65
No. 30 (600 µm)	-	-	-	-	-
No. 50 (300 µm)	-	-	-	-	-
No. 200 (75 µm)	1.0 – 6.0	2.0 – 8.0	2.0 – 8.0	2.0 – 9.0	3.0 – 11.0

Table 8 - Design Aggregate Gradation Requirements for Superpave Design

Nominal Max. Size	37.5 mm (1 ½ inch)	25 mm (1 inch)	19 mm (3/4 inch)	12.5 mm (1/2 inch)	9.5 mm (3/8 inch)	4.75 mm (No. 4)
Standard Sieve Size	Type of Mix					
	37.5	25	19 Note	12.5	9.5	4.75
50 mm (2”)	100					-
37.5 mm (1½”)	90 – 100	100				-
25 mm (1”)	90 max	90 – 100	100			-
19 mm (3/4”)		90 max	90 – 100	100		-
12.5 mm (1/2”)			90 max	90 - 100	100	100
9.5 mm (3/8”)				90 max	90 - 100	95 - 100
4.75 mm (No.4)					90 max	90 - 100
2.36 mm (No.8)	15 – 41	19 – 45	23 – 49	28 - 58	32 - 67	
1.18mm (No.16)						30 - 60
600 µm (No.30)						-
300µm (No. 50)						-
75 µm (No.200)	0.0 – 6.0	1.0 - 7.0	2.0 - 8.0	2.0 - 10.0	2.0 - 10.0	6.0 – 12.0

Note-6: When a 19 mm mix is specified for use as a heavy duty surface mix, it shall be designed as a fine graded mix with the additional requirement of a minimum of 47% passing the 4.75 mm (No.4) screen.

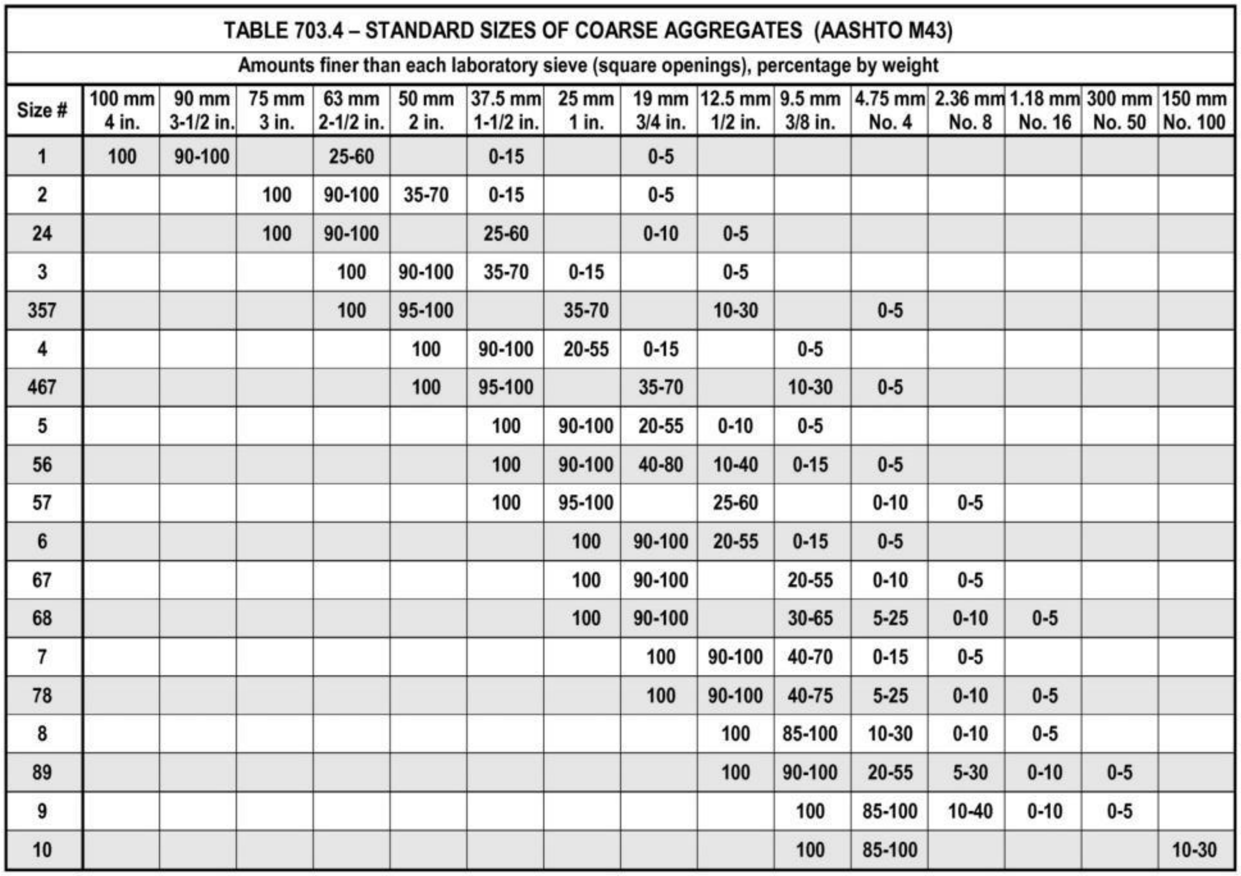


TABLE 703.4 – STANDARD SIZES OF COARSE AGGREGATES (AASHTO M43)

Amounts finer than each laboratory sieve (square openings), percentage by weight

Size #	100 mm 4 in.	90 mm 3-1/2 in.	75 mm 3 in.	63 mm 2-1/2 in.	50 mm 2 in.	37.5 mm 1-1/2 in.	25 mm 1 in.	19 mm 3/4 in.	12.5 mm 1/2 in.	9.5 mm 3/8 in.	4.75 mm No. 4	2.36 mm No. 8	1.18 mm No. 16	300 mm No. 50	150 mm No. 100
1	100	90-100		25-60		0-15		0-5							
2			100	90-100	35-70	0-15		0-5							
24			100	90-100		25-60		0-10	0-5						
3				100	90-100	35-70	0-15		0-5						
357				100	95-100		35-70		10-30		0-5				
4					100	90-100	20-55	0-15		0-5					
467					100	95-100		35-70		10-30	0-5				
5						100	90-100	20-55	0-10	0-5					
56						100	90-100	40-80	10-40	0-15	0-5				
57						100	95-100		25-60		0-10	0-5			
6							100	90-100	20-55	0-15	0-5				
67							100	90-100		20-55	0-10	0-5			
68							100	90-100		30-65	5-25	0-10	0-5		
7								100	90-100	40-70	0-15	0-5			
78								100	90-100	40-75	5-25	0-10	0-5		
8									100	85-100	10-30	0-10	0-5		
89									100	90-100	20-55	5-30	0-10	0-5	
9										100	85-100	10-40	0-10	0-5	
10										100	85-100				10-30

Figure 56 - ASTM Standard Sizes of Coarse Aggregates

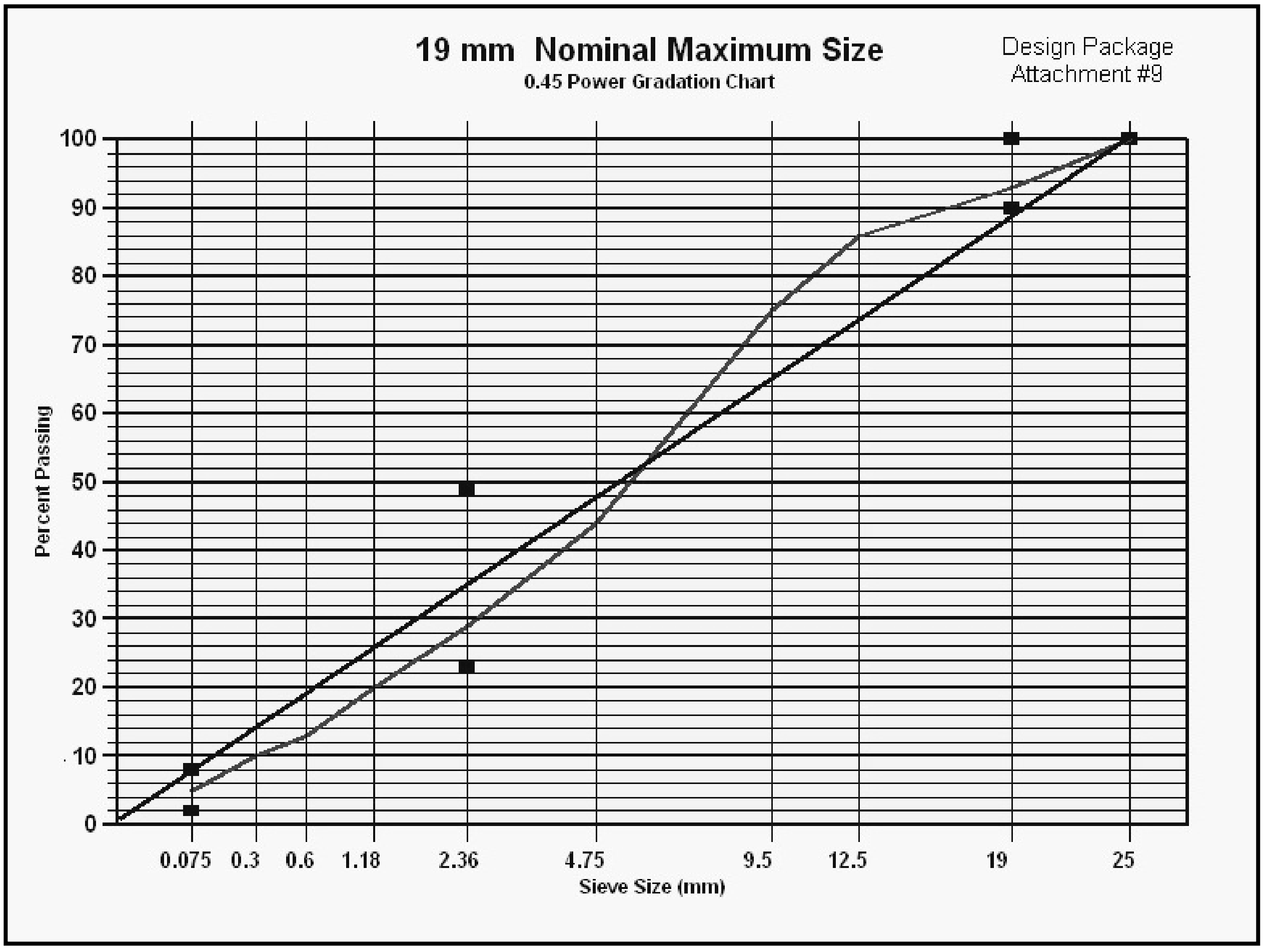
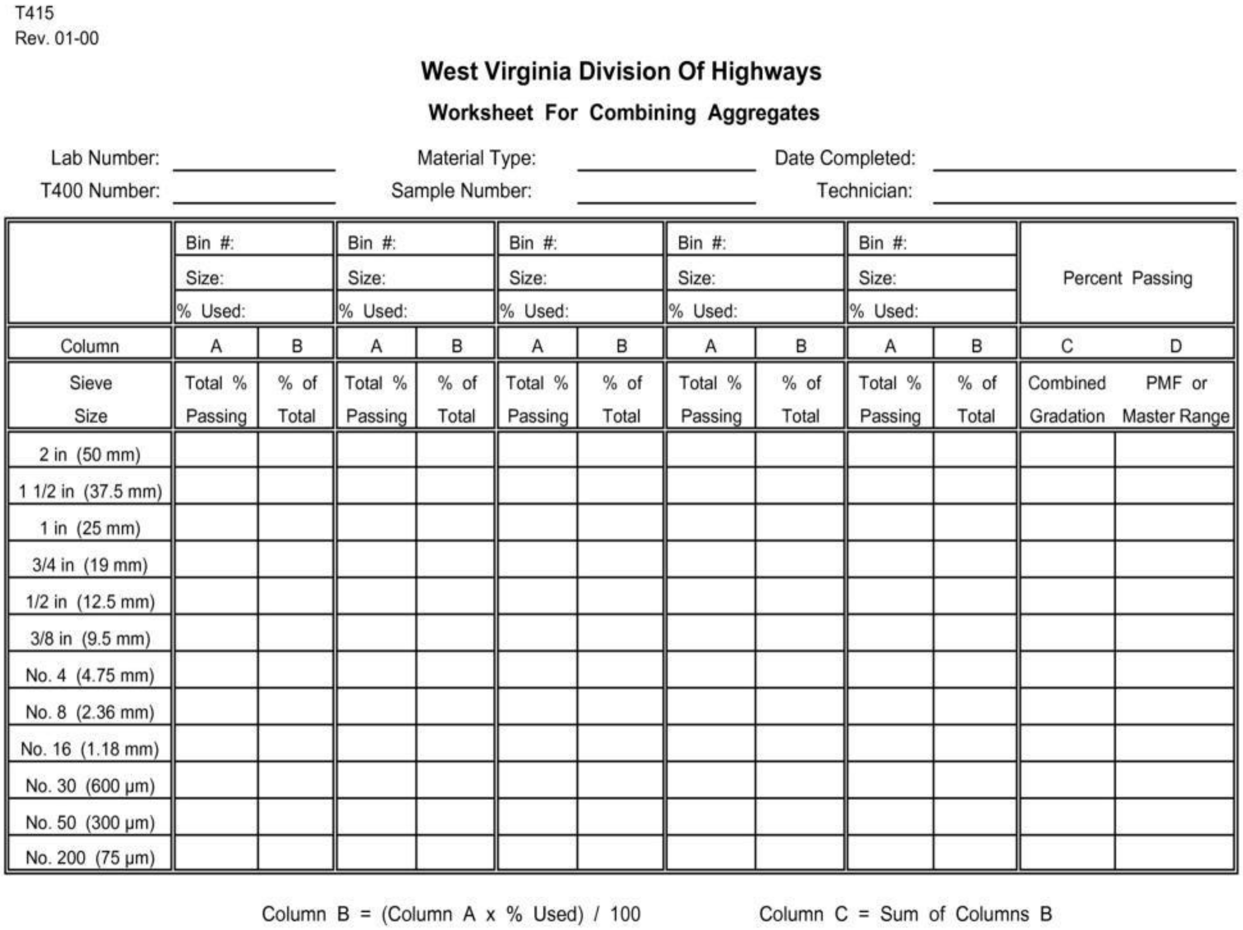


Figure 57 - Power 45 Chart for a 19mm NMAS

Table 9 - Aggregate Combination Worksheet Form T-415



T415
Rev. 01-00

West Virginia Division Of Highways

Worksheet For Combining Aggregates

Lab Number: __________ Material Type: __________ Date Completed: __________

T400 Number: __________ Sample Number: __________ Technician: __________

	Bin #: Size: % Used:		Bin #: Size: % Used:		Bin #: Size: % Used:		Bin #: Size: % Used:		Bin #: Size: % Used:		Percent Passing	
Column	A	B	A	B	A	B	A	B	A	B	C	D
Sieve Size	Total % Passing	% of Total	Total % Passing	% of Total	Total % Passing	% of Total	Total % Passing	% of Total	Total % Passing	% of Total	Combined Gradation	PMF or Master Range
2 in (50 mm)												
1 1/2 in (37.5 mm)												
1 in (25 mm)												
3/4 in (19 mm)												
1/2 in (12.5 mm)												
3/8 in (9.5 mm)												
No. 4 (4.75 mm)												
No. 8 (2.36 mm)												
No. 16 (1.18 mm)												
No. 30 (600 µm)												
No. 50 (300 µm)												
No. 200 (75 µm)												

Column B = (Column A x % Used) / 100

Column C = Sum of Columns B

Table 10 – EXAMPLE 1 Aggregate Combination Worksheet Form T-415

	Bin #:		Bin #:		Bin #:		Percent Passing	
	Size:	#67	Size:	#8	Size:	Sand		
	% Used:	55	% Used:	25	% Used:	20		
Column	A	B	A	B	A	B	C	D
Sieve Size	Total % Passing	% of Total	Total % Passing	% of Total	Total % Passing	% of Total	Combined Gradation	PMF or Master Range
2 in (50 mm)								
1 1/2 in (37.5 mm)								
1 in (25 mm)	100	55.0	100	25.0	100	20.0	100	100
3/4 in (19 mm)	89	49.0	100	25.0	100	20.0	94	90-100
1/2 in (12.5 mm)	74	40.7	100	25.0	100	20.0	86	90 max
3/8 in (9.5 mm)	45	24.8	87	21.8	100	20.0	67	
No. 4 (4.75 mm)	9	5.0	25	6.3	100	20.0	31	
No. 8 (2.36 mm)	3	1.7	4	1.0	93	18.6	***21***	20 – 50
No. 16 (1.18 mm)	2	1.1	3	0.8	65	13.0	15	
No. 30 (600 µm)	2	1.1	1	0.3	40	8.0	9	
No. 50 (300 µm)	0	0.0	0	0.0	29	5.8	6	
No. 200 (75 µm)	0	0.0	0	0.0	12	2.4	***2.4***	2.0 - 8.0

"% of Total" = "% Used" x "Total % Passing" x 100 (when using decimal percentages)
Example: #8 Agg. on the 3/8" (9.5 mm) sieve = (.25 x .87) x 100 = 21.75 or 21.8%
Or
"% of Total" = "% Used" x "Total % Passing" ÷ 100
Example: #8 Agg. on the 3/8" (9.5 mm) sieve = (25 x 87) ÷ 100 = 21.75 or 21.8%

In the example above the first trial blend resulted in a combined percentage near the bottom of the master range on the Number 8 screen and the Number 200 screen. Since almost all of the Number 8 material and the entire amount of minus Number 200 material will be supplied by the sand, it is obvious that the percentage of sand must be increased substantially. Doubling the amount of sand from 20% up to 40% will result in nearly 40 percent passing the Number 8 screen and 4.8 percent passing the Number 200 screen. Since we added 20% of sand we can try splitting the decreased amount of Number 67's and Number 8's by subtracting 10% from each. This results in 45% and 15% respectively. After recalculating the material on all of the screens, we see that all of the design criteria of the master range have been met. See the recalculated worksheet below. We could still tinker with these percentages and attempt to get closer to the middle of the tolerance bands, but for this example, the values are well within the specification limits. Fine tuning may be required later to obtain all of the required volumetric properties for this design.

Table 11 – EXAMPLE 2 Aggregate Combination Worksheet Form T-415

	Bin #:		Bin #:		Bin #:		Percent Passing	
	Size:	#67	Size:	#8	Size:	Sand		
	% Used:	45	% Used:	15	% Used:	40		
Column	A	B	A	B	A	B	C	D
Sieve Size	Total % Passing	% of Total	Total % Passing	% of Total	Total % Passing	% of Total	Combined Gradation	PMF or Master Range
2 in (50 mm)								
1 1/2 in (37.5 mm)								
1 in (25 mm)	100	45.0	100	15.0	100	40.0	100	100
3/4 in (19 mm)	89	40.1	100	15.0	100	40.0	95	90-100
1/2 in (12.5 mm)	74	33.3	100	15.0	100	40.0	88	90 max
3/8 in (9.5 mm)	45	20.3	87	13.1	100	40.0	73	
No. 4 (4.75 mm)	9	4.1	25	3.8	100	40.0	48	
No. 8 (2.36 mm)	3	1.4	4	0.6	93	37.2	39	20 – 50
No. 16 (1.18 mm)	2	0.9	3	0.5	65	26.0	27	
No. 30 (600 µm)	2	0.9	1	0.2	40	16.0	17	
No. 50 (300 µm)	0	0.0	0	0.0	29	11.6	12	
No. 200 (75 µm)	0	0.0	0	0.0	12	4.8	4.8	2.0 - 8.0

The control points for Marshall and Superpave mixes are similar as shown below for a Wearing 1 Marshall mix and a Superpave 9.5 mm mix.

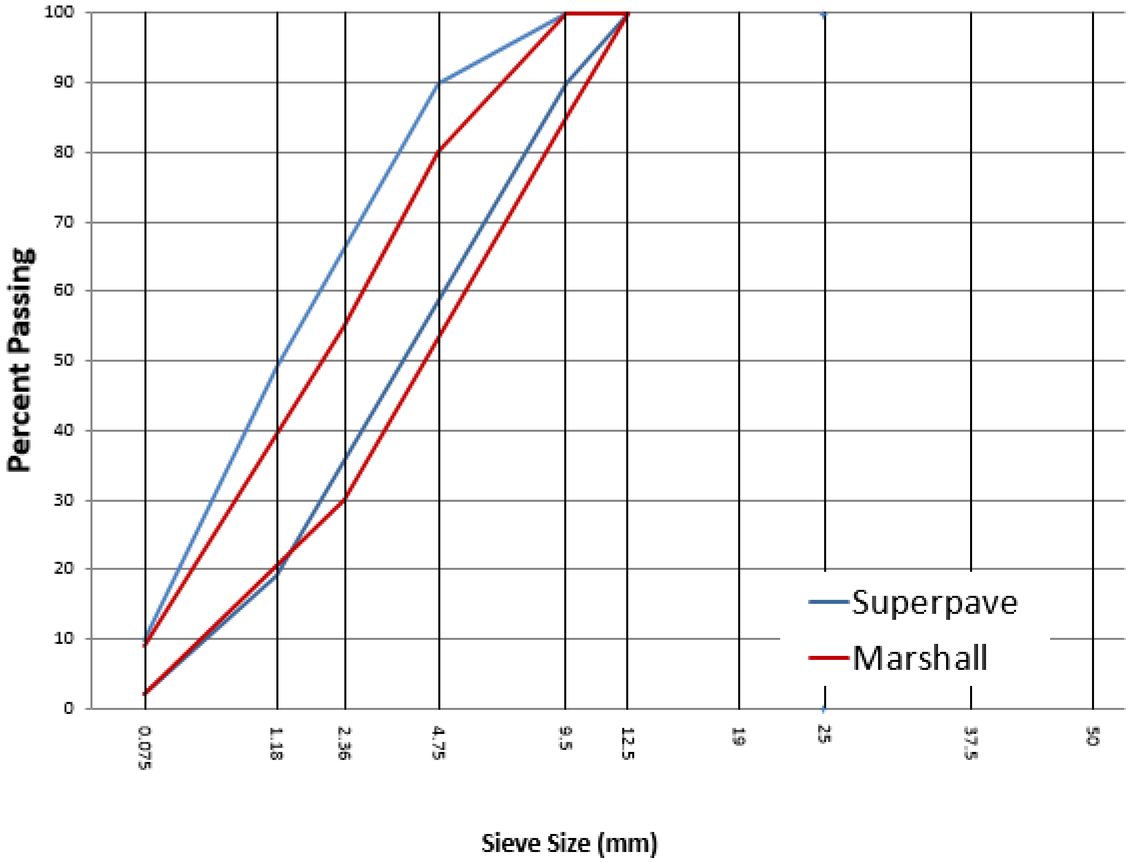


Figure 58 - Control Points for Asphalt Mix designs with 9.5mm NMAS

i) Blended Aggregate Specific Gravity

After determining the specific gravity of each of the coarse and fine aggregates used in the design, the bulk specific gravity for the total aggregate blend can be calculated using the percentages of each aggregate used in the blend. This is done by using the following formula:

$$G_{sb} = \frac{100}{\frac{P_1}{G_1} + \frac{P_2}{G_2} + \ldots + \frac{P_n}{G_n}}$$

Where Gsb = bulk specific gravity for total aggregate

P1, P2, Pn = % of each agg. in blend (must total 100%)

G1, G2, Gn = bulk specific gravity of each aggregate

Example Problem: Two aggregates, #8's and natural sand, are used to design a Wearing-1 mix. The aggregate blend consists of 52% of the #8's and 48% of the sand. The specific gravity of the #8's is 2.684 and the specific gravity of the sand is 2.627. What is the bulk specific gravity of the total aggregate blend?

Solution:

$$G_{sb} = \frac{100}{\frac{52}{2.684}+\frac{48}{2.627}} = \frac{100}{19.374+18.272} = 2.656$$

ii) Blended Aggregate Requirements

The Superpave consensus properties are tested for the blend of stockpiles used in the mix design. The consensus properties are:

- Flat and Elongated (5:1 ratio)
- Fractured Faces
- Sand Equivalency
- Fine Aggregate Angularity

The Flat and Elongated and Fractured Faces requirements are similar to the requirements for the Marshall method. The Sand Equivalency and Fine Aggregate Angularity are unique to Superpave.

Fine aggregate angularity ensures a high degree of fine aggregate internal friction and rutting resistance. It is defined as the percent air voids present in a loosely compacted aggregate sample smaller than 2.36 mm (No. 8). Higher void contents mean more fractured faces. Rounded fine aggregates tend to have lower void contents. The standard test procedure for fine aggregate angularity under the Superpave System is AASHTO T304, using Method A.

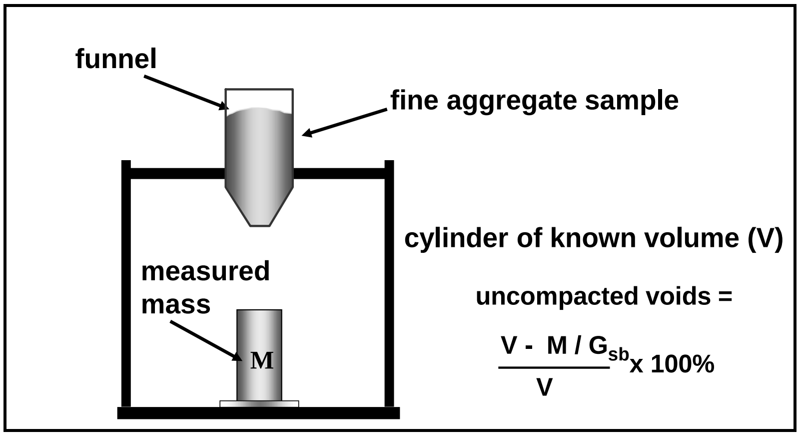


Figure 59 - Fine Aggregate Angularity

Sand Equivalency or Clay content is the percentage of fine dust or claylike material contained in the aggregate fraction that is finer than a 4.75 mm (No. 4) sieve. The test procedure used is AASHTO T176, Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test. The clay content values for fine aggregate are expressed as a minimum sand equivalent and are a function of traffic level.

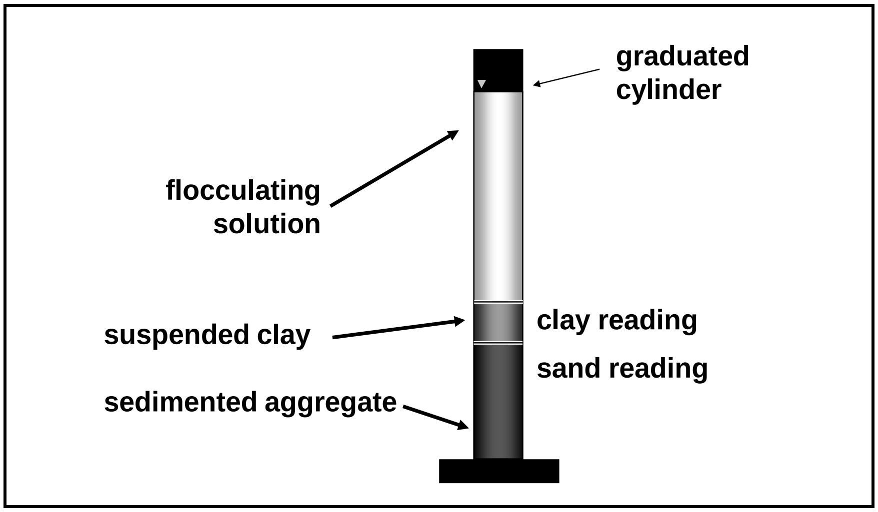


Figure 60 - Clay Content

C) ASPHALT BINDER SELECTION

The binders used for Marshall and Superpave mixes are the same and are based on the Performance Grade method. Performance Grade binders are designated by the letters PG followed by the upper and lower temperature designations of the binder. The first number in the designation represents the average 7-day maximum pavement design temperature (°C). The higher the first number in the grade designation, the stiffer the binder and the more rut resistant it will be. The second number represents the minimum pavement design temperature (°C). The dash line between the numbers is actually a negative sign applied to the second, low temperature designation. For example, "–22" represents the temperature –22 °C. The lower the second number in the grade designation, the more resistant the binder will be to thermal cracking.

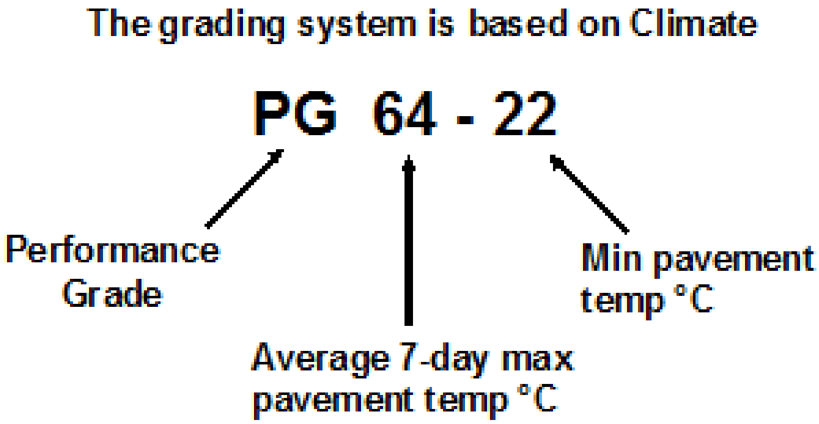


Figure 61 - Performance Graded Binder System

PG 64-22 is the standard grade binder for West Virginia. The other common grades are PG 70-22 and PG 76-22. Selection of these grades requires a design analysis. PG 70-22 is typically used for the top two lifts of high traffic volume roads (over 20 million ESALs). PG 76-22 must be polymer modified; it is used for the highest traffic volume roads, particularly when there has been a performance problem with the existing pavement, possibly due to heavy and/or slow moving traffic. Some projects in the colder mountain regions have been constructed with a PG 58-28.

The first step in the selection of the desired PG binder grade would be to determine the grade that would satisfy both the maximum and minimum pavement design temperatures for the project location. LTPP Bind software provides a database of temperature information for over 6000 weather stations in the United States and Canada to help the users to select the proper binder grades for the climate at the project location. The West Virginia weather stations are indicated on the map below.

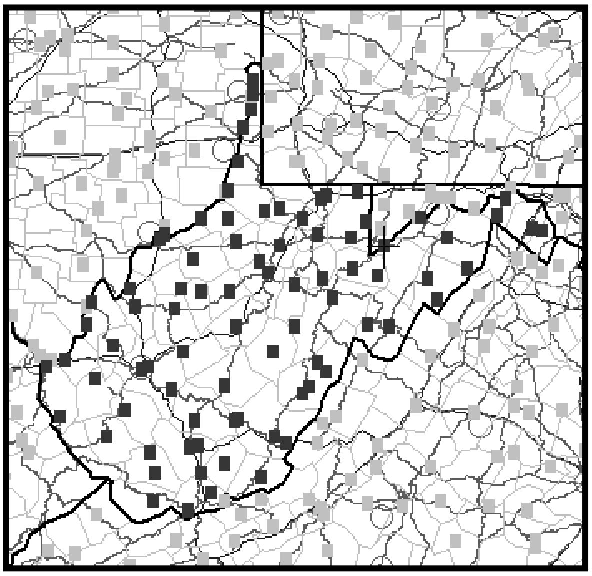


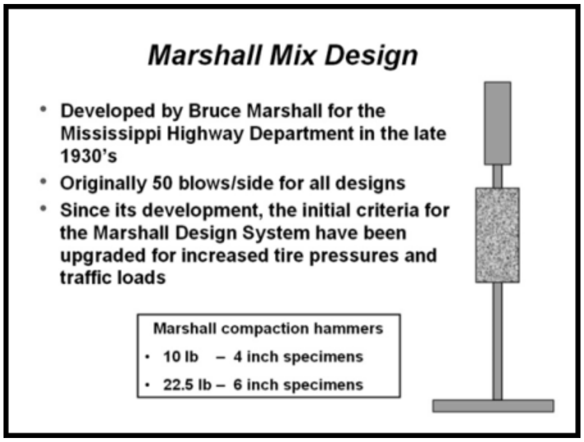
Figure 62 - West Virginia Weather Stations

D) SAMPLE PREP/COMPACTING

For determining the optimum asphalt content for a particular blend of aggregates, a series of test specimens are prepared for a range of different asphalt contents. The gradation of the test specimens must be the same as that proposed in the plant mix formula.

i) Marshall Mix Bulk Specific Gravity Samples

Samples must be fabricated to include a range of asphalt contents of at least 2.0%, at intervals not to exceed 0.5%. Three test specimens are prepared for each of the asphalt contents that are used in the design. Also, at least one specimen is prepared at one of the asphalt contents to be used as a loose mix specimen for determining the maximum specific gravity.

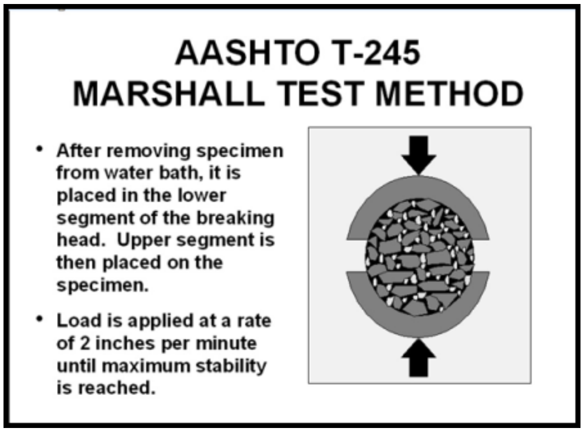


Marshall Mix Design

- **Developed by Bruce Marshall for the Mississippi Highway Department in the late 1930's**
- **Originally 50 blows/side for all designs**
- **Since its development, the initial criteria for the Marshall Design System have been upgraded for increased tire pressures and traffic loads**

Marshall compaction hammers

- **10 lb – 4 inch specimens**
- **22.5 lb – 6 inch specimens**



AASHTO T-245
MARSHALL TEST METHOD

- **After removing specimen from water bath, it is placed in the lower segment of the breaking head. Upper segment is then placed on the specimen.**
- **Load is applied at a rate of 2 inches per minute until maximum stability is reached.**

AASHTO T245 is the test procedure used for preparing and testing standard 102 mm (4 in.) Marshall specimens. The WVDOH is currently using ASTM D5581 for 152 mm (6 in.) specimens when designing a Base-l mix. Mixing and compaction temperature ranges are established from a temperature-viscosity chart Figure 63, which is usually provided by the asphalt supplier. Samples of each aggregate used in the design are oven dried and sieved into the required different sized fractions. The aggregate is then blended, based on design percentages. The batches must be of sufficient size so that when asphalt is added, the compacted specimens will be 63.5 mm (2.5 in.) in height, or 95.2 mm (3.75 in.) for 152 mm (6 in.) specimens. The asphalt is heated to the predetermined mixing temperature.

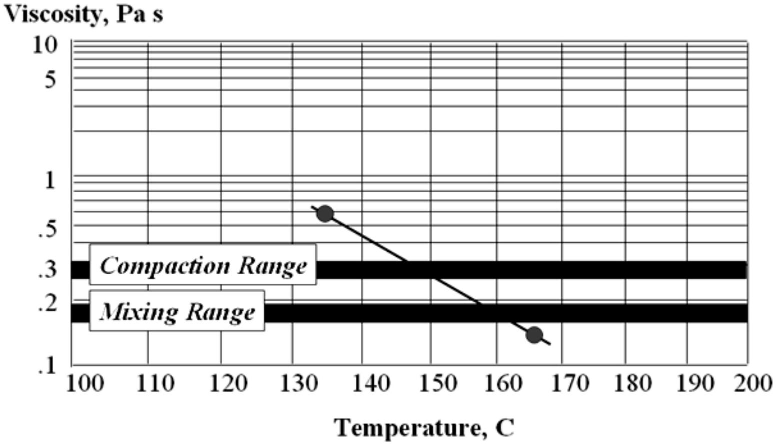


Figure 63 - Binder Temperature - Viscosity Chart

The aggregate heated to the mixing temperature is poured into a mixing bowl and stirred. A crater is formed in the aggregate before adding the specific amount of asphalt required to fabricate a specimen at the desired asphalt content. The aggregate and asphalt are thoroughly mixed together by a mechanical mixer or by hand. If mixing by hand, place the bowl in a hot sand bath so that the temperature will not drop below the compaction temperature.

The standard method for compacting the test specimens is to immediately compact them after the mixing process is completed. However, the WVDOH requires that the specimens are oven aged in a shallow pan for two hours in accordance with AASHTO R30. The addition of the oven aging is to simulate field conditions of the mix from mixing through placement. The process allows for any asphalt absorption to take place which can be detrimental to the mix by lowering the effective asphalt content. The oven aging process will often result in higher asphalt content for the design if additional absorption does take place.

After the two-hour oven aging process, remove the specimen and check the temperature to assure that it is within the compaction temperature range. Specimen molds and the compaction hammer are preheated to 93 - 149 °C (200 - 300 °F). Place a paper protection disk in the bottom of a heated mold and pour in the entire sample. Spade the mix 15 times around the perimeter with a heated spatula or trowel followed by 10 times over the interior. [For 152 mm (6 in.) specimens place half of the batch into the mold and spade it 15 times around the perimeter followed by 10 times over the interior. Then add the remaining half and repeat the process]. The temperature of the mix at this point must be within the limits of the established compaction temperature range. Place a paper protection disk on top of the test specimen.

The mold is placed on the compaction stand and the specified number of blows is applied with the compaction hammer. The mold is then inverted and the same number of blows is applied to the other side of the specimen. The number of blows applied to each side is 50 for medium traffic mixes and 75 for heavy traffic mixes. After a few minutes remove the paper protection disks before the specimen cools. The mold is allowed to cool and the specimen is removed with a mechanical extractor. The test specimen is allowed to cool to room temperature and is measured for thickness. These steps are repeated for the remaining two specimens.

ii) Superpave Mix Bulk Specific Gravity Samples

The gyratory compactor was developed by the SHRP researchers after evaluating the operating characteristics of several other compaction devices. It is based on the Texas gyratory compactor with modifications that make it capable of using compaction principles of a French gyratory compactor. The researchers modified the Texas device by lowering its angle and speed of gyration and adding real time specimen height recordation.

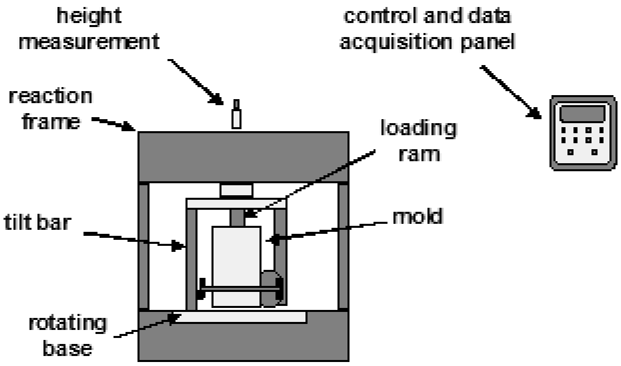


Figure 64 - Key Components of a Gyratory Compactor

Using the AASHTO T312 test procedure, the gyratory compactor produces specimens that are 150 mm in diameter and 115 ± 5 mm in height at the desired number of gyrations. This specimen size accommodates large stone mixes. It operates at 600 ± 18 kPa vertical pressure, at 30 ± 0.5 gyrations per minute, and at an average <u>internal angle</u> of 20.2 ± 0.35 mrad (1.16 ± 0.02 degrees). The only factor that varies in the test procedure is the number of gyrations applied to the test specimen. The entire process, including recording the change in specimen height with each gyration, is automatically controlled by the device based on the input values entered by the operator. The following table contains the WVDOH specifications for the number of design gyrations required for different traffic levels (MP 401.02.28).

Table 12 - Gyratory Compaction Criteria (Note 4)

20-Year Projected design ESALs (millions)	Compaction Parameters	
	Gyration Level-1	Gyration Level-2
	N_{design} for Binder < PG 76-XX	N_{design} for Binders ≥ PG 76-XX or Mixes Placed Below Top Two Lifts $^{\text{(Note-5)}}$
< 0.3	50	50
0.3 to < 3	65	65
3 to < 30	80	65
≥ 30	100	80

Note 4: Unless otherwise specified in the contract documents, a PG 64-22 binder shall be used in mixtures located below the top two pavement lifts. The use of a different binder grade must be approved by the Engineer.

Note 5: The Gyration Level-2 criteria for mixes placed below the top two lifts applies only to mainline paving. Multi-lift base failure and other pavement repairs shall fall under the criteria of Gyration Level-1 unless otherwise specified in the contract documents.

Like the samples for a Marshall design, samples for Superpave must be conditioned in an oven for two hours at the compaction temperature in a shallow pan. After the two hour oven aging process, remove the specimen and check the temperature to assure that it is within the compaction temperature range. Unlike Marshall, specimen molds for Superpave are required to be at the compaction temperature of the mixture. Place a paper protection disk in the bottom of a heated mold and charge the mold with the entire sample at once. The temperature of the mix at this point must be within the limits of the established compaction temperature range. Place a paper protection disk on top of the test specimen. Place the mold top plate if required by the gyratory compactor manufacture. Place the mold into the Gyratory compactor with the appropriate setting and initiate the compaction mode. See Table 12 for the correct number of gyrations.

For the Superpave mixture design two samples are required to be compacted at four asphalt contents as listed below:

- Target asphalt content – 0.5%
- Target asphalt content
- Target asphalt content + 0.5%
- Target asphalt content + 1.0%

IV SPECIFIC GRAVITY

A) BULK SPECIFIC GRAVITY TESTS

Both the Marshall and Superpave methods use volumetric analysis and the bulk specific gravity is needed for accurate density/air voids analysis. Two methods are used to measure bulk specific gravity, the Saturated Surface Dry method (AASHTO T166) and the vacuum seal method (AASHTO T 331). The vacuum seal method is required if the absorption of the sample is greater than 2%, which typically occurs with Base 1 Marshall and 37.5 mm Superpave mixes.

For the Saturated Surface Dry Method, determine the mass of the specimen after it has been cooled to room temperature. Next, weigh the specimen in 25 ± 1 °C (77 ± 1.8 °F) water by suspending it from the balance by a thin wire for 3 to 5 minutes. Remove it from the water bath and surface dry it by blotting it with a damp towel and then quickly determining its mass. Repeat the procedure for the other two specimens. The bulk specific gravity of the mix is the average of the test specimens. The specific gravity is determined by the following formula:

Bulk Specific Gravity $Gmb = F / (G - H)$

Where F = Mass of dry specimen
G = Mass of surface dried specimen
H = Mass of the specimen in water

The test procedure also requires that the percentage of water absorbed (by volume) shall be calculated after the testing is completed. Absorption can be determined using the following formula and the same data from the bulk specific gravity calculation:

$$Percent\ of\ water\ absorbed\ by\ volume = (G - F) / (G - H)\ x\ 100$$

Example problem: The mass of a compacted Marshall test specimen is 1207.9 grams in air. The specimen mass in water is 707.2 grams. After blotting dry with a towel the specimen mass is 1208.6 grams. Calculate the bulk specific gravity, density, and percent water absorption.

Solution:

$$\text{Bulk Specific Gravity (Gmb)} = \frac{1207.9}{1208.6 - 707.2} = 2.409$$

Density = 2.409 x 1000 kg/m3 = 2409 kg/m3

$$\text{\% Water Absorption} = \frac{1208.6 - 1207.9}{1208.6 - 707.2} \text{ x } 100 = 0.1$$

If the percent of water absorbed by the specimen exceeds 2.0 percent, the procedure specifies that AASHTO T331 (Bulk Specific Gravity and Density of asphalt mixture Using Automatic Vacuum Sealing Method) shall be used to determine the bulk specific gravity.

Figure 65 - Vacuuming Sealer for AASHTO T-331

The bulk specific gravity can be used to determine the density (or unit weight) of the compacted specimen. Simply multiply the specific gravity by 1000 (density of water in kilograms per cubic meter) to determine the density.

B) MAXIMUM THEORETICAL SPECIFIC GRAVITY

The maximum theoretical specific gravity, Gmm, is the specific gravity of a void-less asphalt mixture. It is used with the bulk specific gravity to determine the air void content of the compacted sample.

The maximum specific gravity procedure is specified in AASHTO T209. The bowl method is use by the WVDOH labs but the other methods referenced in T209 are also acceptable. The same procedure is used for Marshall and Superpave mixtures. The Marshall method only requires one Gmm test at the target asphalt content. The Superpave method requires a Gmm test for each of the asphalt contents of the compacted samples.

The WVDOH requires that the same oven aging procedure that was used on the compacted specimens also be used on the maximum specific gravity specimen. After the specimen is prepared, place it in a shallow pan and put it in an oven for two hours in accordance with the requirements of AASHTO R30. After two hours remove it from the oven and dump it on a smooth work surface. Spread the heated sample on the work surface and allow it to cool to touch. Break apart the particles and make sure that the fine aggregate portion of the mix contains no pieces larger than 6.4 mm in size (1/4 in.).

Allow the sample to cool to room temperature and place it in the tarred bowl and determine the mass. Cover the sample with 25 ± 0.5 °C (77 ± 0.9 °F) water and place the cover on the bowl. Gradually apply a vacuum until the residual pressure manometer reads 27.5 ± 2.5 mm of Hg. Maintain this pressure for 15 ± 2 minutes. Agitate the bowl either continuously by a mechanical device or manually by vigorous shaking at intervals of about two minutes to dislodge air bubbles from within the mix. Disconnect the vacuum and suspend the bowl and contents in a 25 °C (77°F) water bath and weigh after 10 ± 1 minutes of immersion.

If a mixture contains coarse aggregate that has been determined to absorb 1.5% or more water, there is a supplemental procedure in AASHTO T209 that will help the technician determine if the optional dry-back procedure is necessary. After the vacuum procedure is completed, decant the water from the bowl. Break several large pieces of aggregate and examine the broken surfaces for wetness. If the aggregate has absorbed water, then the dry-back procedure will be necessary. When designing asphalt mixture with absorptive aggregates and when conducting quality control or quality assurance testing on such a mix, it should always be determined whether or not the supplemental dry-back procedure will be necessary.

The maximum specific gravity is calculated as follows:

$$\text{Max. Specific Gravity (Gmm)} = \frac{A}{A-(B-C)}$$

Where A = Mass of dry sample
B = Mass of bowl and sample in water
C = Mass of empty bowl in water

When the dry-back procedure is used the maximum specific gravity is calculated as follows:

$$\text{Max. Specific Gravity (Gmm)} = \frac{A}{D-(B-C)}$$

Where A = Mass of dry sample
B = Mass of bowl and sample in water
C = Mass of empty bowl in water
D = Mass of surface dry sample

The maximum density (or target density used for determining the relative density of the pavement) is calculated by multiplying the maximum specific gravity by 1000 kilograms per cubic meter. For example a maximum specific gravity of 2.432 would result in a maximum density of 2432 kg/m3.

For the Marshall method the maximum specific gravities at different asphalt contents are calculated from the single test at the target asphalt content. First the effective specific gravity of aggregate is computed. This value is the ratio of the mass in air of a unit volume of a permeable material (excluding voids permeable to asphalt) at a stated temperature to the mass in air of equal density of an equal volume of gas-free distilled water at a stated temperature. The effective volume, then is the solid aggregate volume and the volume of pores that are not permeable to asphalt cement. The effective specific gravity actually recognizes the difference between water and asphalt permeable porosity.

For all practical purposes, the effective specific gravity of the aggregate is constant because the amount of asphalt absorbed into the aggregate does not vary appreciably with variations in asphalt content. The effective specific gravity of aggregate is calculated by:

$$\text{Effective Specific Gravity - } G_{se} = \frac{P_{mm} - P_b}{\frac{P_{mm}}{G_{mm}} - \frac{P_b}{G_b}}$$

Where Gse = effective specific gravity of aggregate

Pmm = % by mass of total loose mixture = 100%

Pb = asphalt, % by total mass of mix

Gmm = maximum specific gravity of mix

Gb = specific gravity of asphalt (usually provided by the asphalt cement producer)

After determining the effective specific gravity of the aggregate the maximum specific gravity of the mix at any other asphalt content can be calculated by the following formula:

$$\text{Max. Specific Gravity } (G_{mm}) = \frac{P_{mm}}{\frac{P_s}{G_{se}} + \frac{P_b}{G_b}}$$

Where Gmm = maximum specific gravity of mix

Pmm = % by mass of total loose mixture = 100%

Ps = aggregate, % by total mass of mix

Pb = asphalt, % by total mass of mix

Gse = effective specific gravity of aggregate

Gb = specific gravity of asphalt

Example Problem: The maximum specific gravity of a paving mix containing 5.0% asphalt was determined to be 2.488. The specific gravity of the asphalt was 1.025. What would the calculated maximum specific gravity of this mix be at 6.0% asphalt?

Solution: First determine the effective specific gravity of the aggregate.

$$\text{Gse} = \frac{100 - 5.0}{\frac{100}{2.488} - \frac{5.0}{1.025}} = \frac{95}{40.193 - 4.878} = 2.690$$

Now calculate the maximum specific gravity at 6.0% asphalt. At 6.0% asphalt the percent aggregate would be: 100% - 6.0% = 94.0%.

$$\text{Gmm} = \frac{100}{\frac{94.0}{2.690} + \frac{6.0}{1.025}} = \frac{100}{34.944 + 5.854} = 2.451$$

V VOLUMETRIC ANALYSIS

The bulk and maximum specific gravity of the mix and the bulk specific gravity of the aggregate blend are used to determine the volumetric properties of percent air voids percent voids in the mineral aggregate and the percent voids filled with asphalt. In addition, the dust to binder ratio is determined. The volumetric analysis is similar for the Marshall and Superpave procedures, with the only difference being in the way the dust to binder ratio is computed.

A) PERCENT AIR VOIDS

Air voids are small air spaces that occur between the coated aggregate particles in the final compacted mix. A certain percentage of air voids is necessary in all dense-graded mixes to allow for some additional pavement compaction under traffic and to provide spaces into which small amounts of asphalt can flow during this subsequent compaction.

The durability of an asphalt pavement is a function of the air-void content. The reason for this is the fact that the lower the air voids, the less permeable the mixture becomes. An air-void content that is too high provides passageways through the mix for the entrance of damaging air and water. An air-void content that is too low, on the other hand, can lead to flushing, a condition in which excess asphalt squeezes out of the mix to the surface.

The percent of air voids (Va), also referred to as voids in total mix (VTM), in a compacted mixture can be determined by either of the following formulas:

$$V_a = \frac{G_{mm} - G_{mb}}{G_{mm}} \times 100 \quad \text{or} \quad V_a = \left(1 - \frac{G_{mb}}{G_{mm}}\right) \times 100$$

Where Va = % air void in the compacted mix

Gmm = maximum specific gravity of the paving mix

Gmb = bulk specific gravity of the compacted mix

Example Problem: The average bulk specific gravity of three compacted test specimens is 2.405. The maximum specific gravity of a loose specimen of the same material is 2.492. What is the percentage of air voids in this mix?

Solution: % Air voids (Va) = $\frac{2.492 - 2.405}{2.492} \times 100 = 3.5\%$

B) VOIDS IN THE MINERAL AGGREGATE (VMA)

Voids in the mineral aggregate (VMA) are the air-void spaces that exist between the aggregate particles in a compacted paving mix, including spaces filled with asphalt. VMA represents the space that is available to accommodate the effective volume of asphalt (all of the asphalt except the portion lost by absorption into the aggregate) and the volume of air voids necessary in the mixture. The more VMA in the dry aggregate, the more space is available for the asphalt film. In general, the thicker the asphalt film coating the aggregate particles the more durable the mix, up to the point where the air voids become overfilled with excessive asphalt. The Asphalt Institute's MS-2 manual specifies minimum requirements for VMA based on the aggregate size. This minimum value controls minimum asphalt content that can be used in a mix design. The WVDOH uses these recommended values as the minimum requirements for mix designs.

The percent VMA of a paving mix can be determined by the following formula when mix composition is determined as a percent by mass of total mix:

$$\% \text{ VMA} = 100 - \frac{G_{mb} \text{ x } P_s}{G_{sb}}$$

where Gsb = bulk specific gravity of aggregate
Gmb = bulk specific gravity of compacted mix
Ps = aggregate, % by total mass of mix

Example Problem: The bulk specific gravity of the combined aggregate in a Wearing-1 mix is 2.678. The average bulk specific gravity of three compacted test specimens is 2.428. The percent of asphalt in the mix is 5.7% based on percent by total mass of mix. What is the VMA for this mix?

Solution: First determine the amount of aggregate in the mix. 100% - 5.7% = 94.3%

$$\% \text{ VMA} = 100 - \frac{2.428 \times 94.3}{2.678} = 100 - \frac{228.96}{2.678} = 14.5\%$$

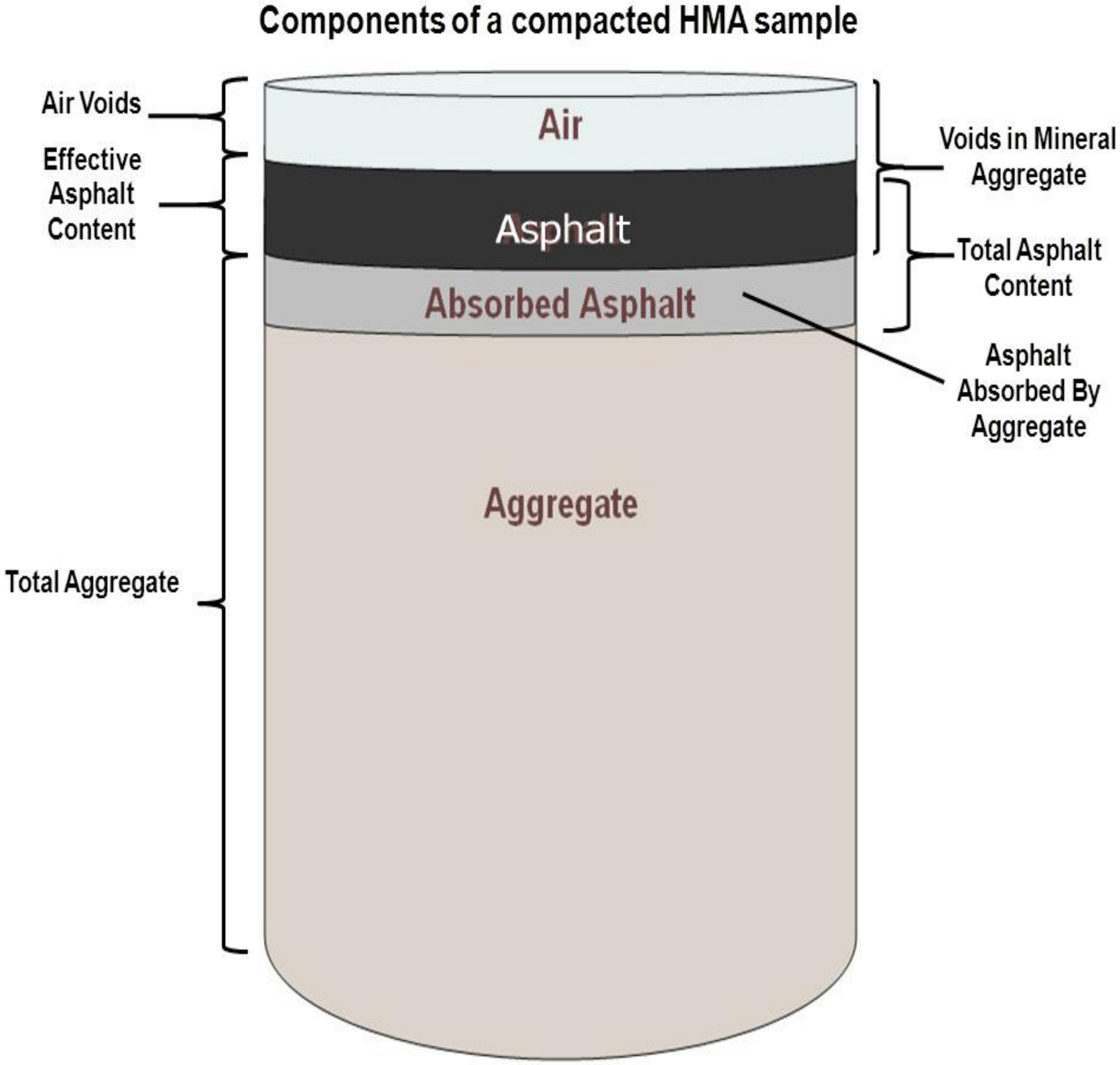
C) PERCENT VOIDS FILLED WITH ASPHALT (VFA)

VFA is defined as the portion of the volume of intergranular void space between the aggregate particles (VMA) that is occupied by the effective asphalt. The required specification value is usually somewhere between 65 and 80%. The Asphalt Institute includes the VFA criteria in the Marshall mix design criteria table of the latest MS-2 Manual.

A VFA requirement can help prevent the design of mixes with marginally acceptable VMA. It limits the maximum levels of VMA and maximum levels of asphalt content. Mixes designed for heavy traffic will not pass the VFA criteria with relatively low percent air voids even though the air voids are within the acceptable range.

The percent voids filled with asphalt can be determined by the following formula:

$$\%\text{VFA} = \frac{(\%\,\text{VMA} - \%\,\text{Air Voids}) \times 100}{\%\,\text{VMA}}$$



D) DUST TO BINDER RATIO

The prior volumetric analysis is identical from Marshall to Superpave, however the Dust to Binder Ratio is different between the two mix design methods. Dust to binder is the ratio between the percent aggregate passing the #200 sieve divided by the asphalt content. For Marshall the total asphalt content is used in the denominator, however in Superpave the Effective Asphalt content is used in the denominator. See below for the two calculations.

Marshall D/B

$$\frac{D}{B} = \frac{\%\, Passing\ \#200}{Total\ Binder\ Content}$$

Superpave D/B

$$\frac{D}{B} = \frac{\%\, Passing\ \#200}{Effective\ Binder\ Content\ (P_{be})}$$

To calculate the Effective binder content, the percent binder absorbed must be calculated, as shown below:

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

Where: P_{ba} = absorbed asphalt, percent by mass of aggregate
G_{se} = effective specific gravity of aggregate
G_{sb} = bulk specific gravity of aggregate
G_b = specific gravity of asphalt

Now that P_{ba} is calculated apply it to the equation below to calculate the effective binder content.

$$P_{be} = P_b - \left(\frac{P_{ba}}{100} \text{ x } P_s\right)$$

Where: P_{be} = effective asphalt content
P_b = asphalt content, percent by total mass of mix
P_{ba} = absorbed asphalt, percent by mass of aggregate
P_s = aggregate content, percent by total mass of mix

VI MIXTURE SPECIFIC REQUIREMENTS

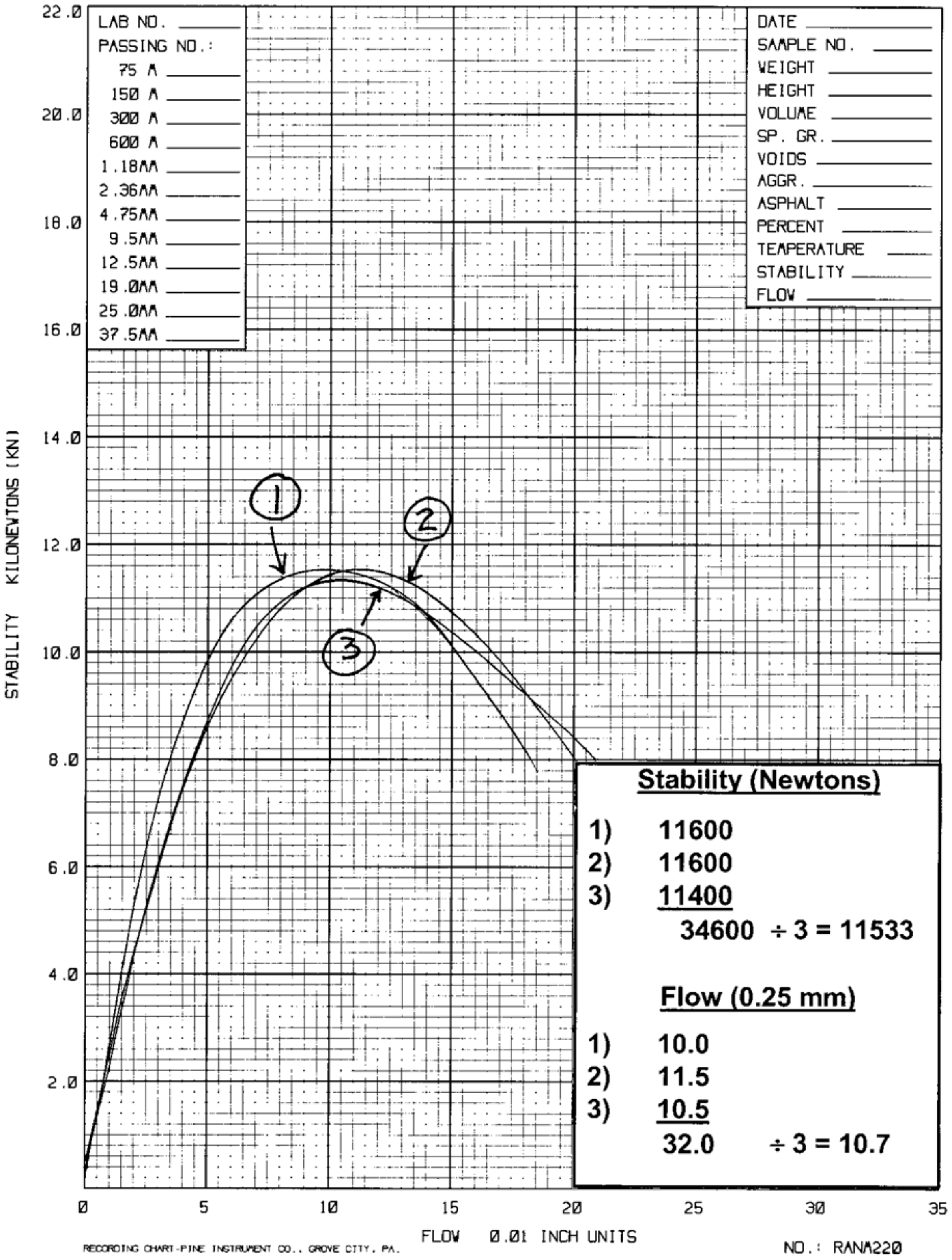
A) MARSHALL STABILITY AND FLOW

The Marshall Method requires measurement of the stability and flow of each of the bulk specific gravity samples. No such test exists for the Superpave method.

The final steps of the Marshall test procedure (AASHTO T245 or ASTM D5581) is measuring the stability and flow. The stability value from this procedure is the measurement of the load (in Newtons) under which the specimen totally yields. The flow value is the measurement of the deformation that occurs during this load and is measured in increments of 0.25 mm (0.01 in.).

AASHTO T245 indicates that the stability reading for a test specimen is only accurate if the test specimen measures 63.5 mm (2.5 in.) in height or 92.2 mm (3.75 in.) for 152 mm (6 in.) test specimens. For test specimens that vary slightly from this value there is a table of correlation ratios that may be used to apply a correction factor for converting the stability value to that of a specimen of standard height. Simply multiply the stability reading by the correlation ratio that is listed in the table (see Page 3-26) for the actual height of the specimen. In addition to the height, the correlation ratio table also can be used with the volume (cm3) of the test specimen. Since the bulk specific gravity test (AASHTO T166) must be ran before breaking the test specimen, the data needed to calculate the volume is already available. Simply subtract the mass of the specimen in water from the mass of the surface-dry specimen in air to determine the volume. The volume-thickness relationship in these correlation tables is based on the specimen diameter. To avoid any confusion, pick either height or volume as a standard method and use it consistently.

The three compacted test specimens are placed in a 60 ± 1 °C (140 ± 2°F) water bath for 30 to 40 minutes [45 to 60 minutes for 152 mm (6 in.) specimens]. One at a time they are removed and quickly placed in a breaking head assembly. The breaking head is placed on the test press which has been set up for the anticipated load and with the proper graph paper. When the test press is started, it applies a load to the specimen at a constant rate of 50.8 mm (2 inches) per minute, and the recorder starts plotting the stability and flow curve. The elapsed time for the test from removal of the test specimen from the water bath to the maximum load determination must not exceed 30 seconds. The stability and flow are read from the graph. The peak of the curve is the stability value in Newtons. The point where the stability peaked and just before it began to drop is the flow value which is read across the bottom of the graph. Remember that the stability value must be adjusted if the test specimen does not meet specified height. Repeat the procedure for the remaining two specimens. The stability and flow values for the mix are the averages of the three test specimens. See Figure 66 for an example on the next page.



Stability (Newtons)

1) 11600
2) 11600
3) 11400
34600 ÷ 3 = 11533

Flow (0.25 mm)

1) 10.0
2) 11.5
3) 10.5
32.0 ÷ 3 = 10.7

Figure 66 - Marshall Stability and Flow Chart

STABILITY CORRELATION RATIO TABLES (AASHTO T245)

102 MM (4 IN.) DIAMETER SPECIMENS

VOLUME	HEIGHT IN MM	HEIGHT IN INCHES	CORRELATION RATIO
406 TO 420	50.8	2	1.47
421 TO 431	52.4	2 1/16	1.39
432 TO 443	54.0	2 1/8	1.32
444 TO 456	55.6	2 3/16	1.25
457 TO 470	57.2	2 1/4	1.19
471 TO 482	58.7	2 5/16	1.14
483 TO 495	60.3	2 3/8	1.09
496 TO 508	61.9	2 7/16	1.04
509 TO 522	63.5	2 1/2	1.00
523 TO 535	65.1	2 9/16	0.96
536 TO 546	66.7	2 5/8	0.93
547 TO 559	68.3	2 11/16	0.89
560 TO 573	69.9	2 3/4	0.86
574 TO 585	71.4	2 13/16	0.83
586 TO 598	73.0	2 7/8	0.81
599 TO 610	74.6	2 15/16	0.78
611 TO 625	76.2	3	0.76

ASTM D5581

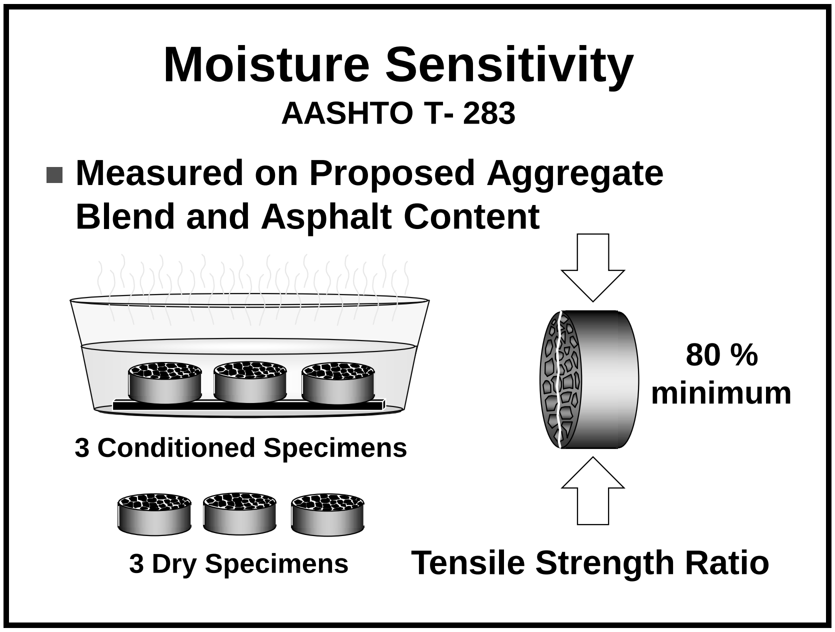
6 IN. DIAMETER SPECIMENS

VOLUME	**HEIGHT IN MM**	**HEIGHT IN INCHES**	**CORRELATION RATIO**
1608 TO 1626	88.9	3 1/2	1.12
1637 TO 1665	90.5	3 9/16	1.09
1666 TO 1694	92.1	3 5/8	1.06
1695 TO 1723	93.7	3 11/16	1.03
1724 TO 1752	95.2	3 3/4	1.00
1753 TO 1781	96.8	3 13/16	0.97
1782 TO 1810	98.4	3 7/8	0.95
1811 TO 1839	100.0	3 15/16	0.92
1840 TO 1868	101.6	4	0.90

B) SUPERPAVE MOISTURE SENSITIVITY TESTING

The Superpave method requires moisture susceptibility test to evaluate the mix for stripping using AASHTO T283, Resistance of Compacted Bituminous Mixtures to Moisture Induced Damage. This test procedure identifies whether a combination of asphalt binder and aggregate is moisture susceptible and it can also measures the effectiveness of anti-stripping additives.

Two subsets of test specimens are produced using this procedure. Specimens are compacted to achieve an air void content in the range 7.0 ± 0.5 %. One subset is tested dry for indirect-tensile strength. The other subset is subjected to a vacuum saturation and a 16 hour freeze cycle, followed by a 24 hour water soaking cycle at a temperature of 60 ± 1 °C (140 ± 2 °F), before being tested for indirect-tensile strength. The test result reported is the ratio of tensile strength of the conditioned subset to that of the unconditioned subset. The ratio is called the tensile strength ratio (TSR). The minimum requirement is a TSR of 80 percent.



Moisture Sensitivity

AASHTO T- 283

- **Measured on Proposed Aggregate Blend and Asphalt Content**

VII PLOTTING TEST RESULTS

In order to understand the characteristics of each specimen in a test series, the volumetric test properties are plotted on graphs. For the Marshall method the stability and flow are also plotted. By studying the charts, it can be determined which specimen in the series best meets all the criteria for the finished pavement. The proportions of asphalt and aggregate in that specimen become the proportions used in the final mix.

There are five test properties that must be plotted before the evaluation process can begin. These properties are stability, flow, air voids, VMA, and VFA (unit weight is also sometime plotted). All five properties are plotted versus the asphalt contents that were used in preparing the series of bulk specific gravity specimens. An example of the five charts is shown in Figure

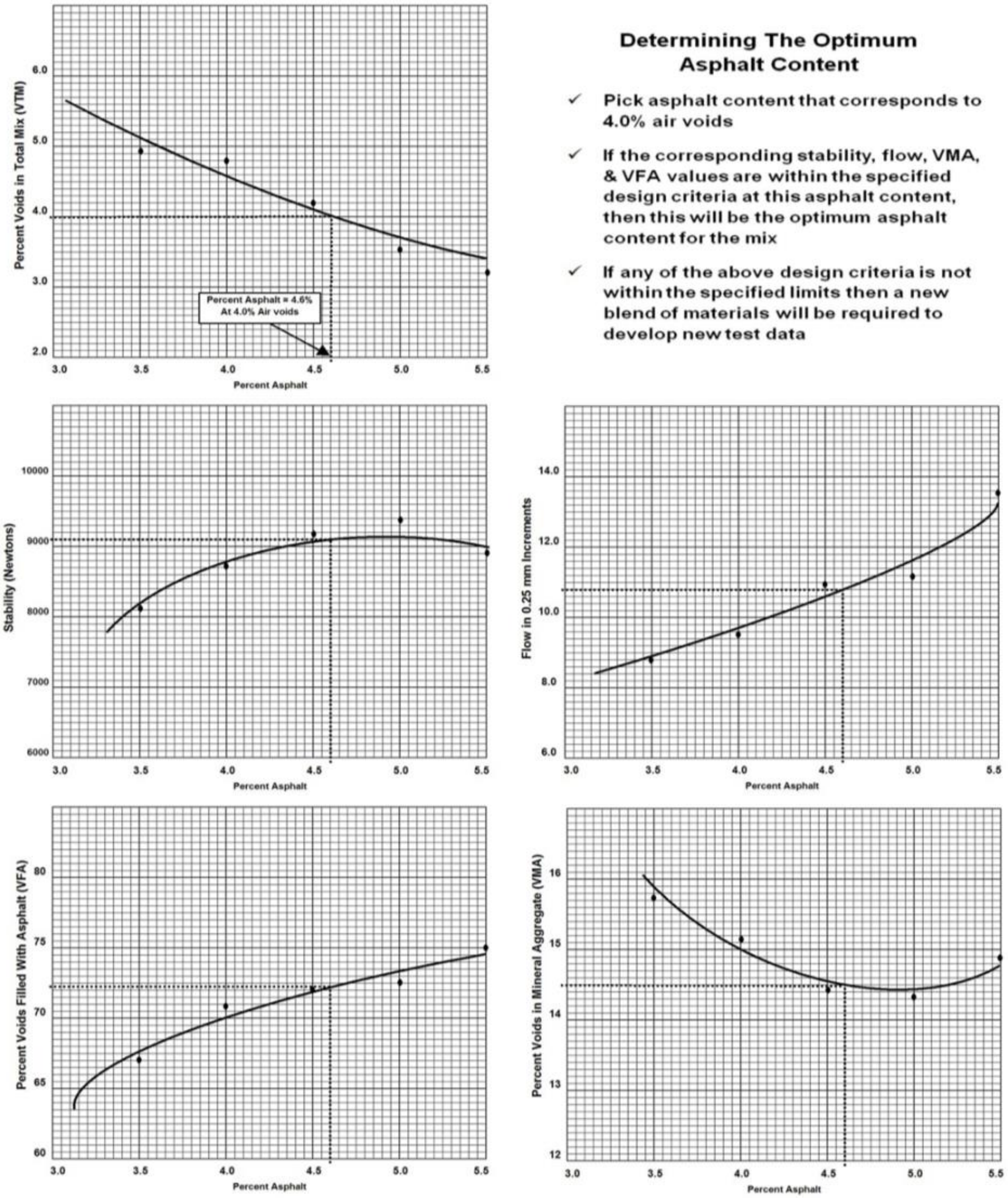
67. Similar plots are prepared for Superpave with the exception that there are no stability and flow values to plot.

The test property curves have been found to follow a reasonably consistent pattern for dense-graded asphalt paving mixes. These trends, as outlined in the Asphalt Institute MS-2 Manual, are as follows:

- The stability value increases with increasing asphalt content up to a maximum after which it decreases.
- The flow value increases with increasing asphalt content.
- The curve for unit weight of total mix is similar to the stability curve, except that the maximum unit weight normally occurs at a slightly higher asphalt content than the maximum stability.
- The percent of air voids decreases with increasing asphalt content, ultimately approaching a minimum void content.
- The percent voids in mineral aggregate, VMA, generally decrease to a minimum value then increase with increasing asphalt content.
- The percent voids filled with asphalt, VFA, steadily increases with increasing asphalt content, because the VMA is being filled with asphalt.

The VMA curve can provide some very important information about the mix. Remember that the goal of achieving adequate VMA is to furnish enough space within the aggregate structure for adequate asphalt adhesion to bind the aggregate particles without bleeding under high temperatures and asphalt expansion. The VMA curve is typically a flattened U-shape which decreases to a minimum value and then increases with increased asphalt content. After the curve bottoms out, the VMA begins to increase due to more dense aggregate material being displaced as the less dense asphalt material pushes the particles apart.

It is usually not desirable to use an asphalt content on the “wet” or increasing side of the VMA curve even if the minimum air void and VMA requirements are met. Mixes designed with asphalt contents in this range have more tendencies to bleed and/or rut when placed in the field because the VMA is only increasing because the additional asphalt is filling the void space as it pushes the aggregate particles further apart. It is more desirable to pick the design asphalt content slightly to the left of the low point of the VMA curve, as long as all of the other mix properties meet the design criteria.



Determining The Optimum Asphalt Content

- ✓ Pick asphalt content that corresponds to 4.0% air voids
- ✓ If the corresponding stability, flow, VMA, & VFA values are within the specified design criteria at this asphalt content, then this will be the optimum asphalt content for the mix
- ✓ If any of the above design criteria is not within the specified limits then a new blend of materials will be required to develop new test data

Figure 67 - Marshall Mix Design Property Charts

If the bottom of the VMA curve falls below the minimum criteria for the nominal maximum aggregate size, this indicates that changes in the aggregate grading are necessary to provide additional VMA. When this happens, it is not desirable to pick an asphalt content on the extremes of the acceptable range even when the minimum VMA criteria is met. On the left hand or dry side of the VMA curve, the mix is usually too dry and will be prone to segregation and probably high air voids. On the right hand or wet side of the VMA curve, the mix could be prone to bleeding and/or rutting. In summary, if the bottom of the VMA curve falls below the minimum requirement, it is best to redesign the mix with a new aggregate structure.

A) DETERMINING ASPHALT CONTENT

By convention the asphalt content determined with the Marshall method is called the optimum asphalt content and for the Superpave method it is called the design binder content. From the data curve for percent air voids, the asphalt content is determined at 4 percent air voids. The corresponding properties for the other design parameters are determined for the asphalt content that corresponds to 4 percent air voids. If all other parameters are within the design limits (Table 13 or Table 14 depending on the method), then this shall be considered the optimum or design binder content.

Table 13 - Marshall Method Mix Design Criteria

Design Criteria	Medium Traffic Design (Note 2)	Heavy Traffic Design	Base-I Design (Note 4)
Compaction, number of blows each end of specimen (Note 3)	50	75	112
Stability (Newtons) minimum	5,300	8,000	13,300
Flow (0.25 mm) (Note 5)	8 – 16	8 – 14	12 – 21
Air Voids (%)	4.0	4.0	4.0
Voids Filled With Asphalt (%) (Note 6)	65 – 80	65 – 78	64 – 73
Fines-to-Asphalt Ratio	0.6 to 1.2		

Note 2: If the traffic type is not provided in the contract documents, contact the District to obtain this information before developing the mix designs.

Note 3: All Wearing-III mixes shall be designed as a 50 blow mix regardless of traffic type.

Note 4: All Base-I mixes will be designed and tested using 112 blows with six inch diameter specimens in accordance with ASTM D 5581.

Note 5: When using a recording chart to determine the flow value, the flow is normally read at the point of maximum stability just before it begins to decrease. This approach works fine when the stability plot is a reasonably smooth rounded curve. Some mixes comprised of very angular aggregates may exhibit aggregate interlocking which causes the plot to produce a flat line at the peak stability before it begins to drop. This type of plot is often difficult to interpret, and sometimes the stability will even start increasing again after the initial flat line peak. When such a stability plot occurs, the stability and flow value shall be read at the initial point of peak stability.

Note 6: A Wearing-I heavy traffic design shall have a VFA range of 73–78 percent. A Wearing-III mix shall have a VFA range of 75–81 percent.

Table 14 - Superpave Method Volumetric Mix Design Criteria

Design air void content, percent	4.0					
Fines-to-effective asphalt (FA) ratio (Note-1)	0.6 – 1.2					
Tensile strength ratio, percent (T 283) (Note -2)	80 (minimum)					
	Nominal Maximum Size, mm (in.)					
	37.5 (1½)	25 (1)	19 (¾)	12.5 (½)	9.5 (⅜)	4.75 (No.4)
Percent Voids in Mineral Aggregate (VMA) (Note-3)	11.5	12.5	13.5	14.5	15.5	16.5
Percent Voids Filled with Asphalt (VFA)	65 – 75	68 – 76	70 – 78	72 – 79	74 – 80	75 – 81

Note 1: When the design aggregate gradation falls within the coarse graded requirement of Table 4, the FA ratio criteria shall be 0.8 – 1.6. For all 4.75 mm (No. 4) mixes, the FA ratio shall be 0.9 - 2.0.

Note 2: Test specimens shall be compacted using a gyratory compactor in accordance with T 312. If the 80 percent minimum tensile strength ratio is not met, a new design will be required. A Division approved antistripping additive, such as hydrated lime conforming to the requirements of M 303 or a liquid antistripping additive, may be added to the mixture if needed. The additive must be identified on the T400SP Form. T 283 shall be waived when a new mix design is developed using all of the aggregate sizes and sources of a previously approved mix design that has met the required tensile strength ratio of at least 85 percent. This waiver information should be noted on the submitted design package along with the previously approved design T400SP number to inform the MCS&T why T 283 test data has not been included. If the approved design contained an antistripping additive, then the new design must also contain this additive. MCS&T may request the tensile strength ratio be checked at any time on any design that is shown to exhibit signs of stripping.

Note 3: Mixtures designed with the VMA exceeding the minimum value by more than two percent may be susceptible to flushing and rutting, especially when used on pavements subjected to slow moving traffic conditions. They may also be difficult to compact as they often have a tendency to shove under the roller.

When the asphalt content has been determined from the Marshall test data, it must be checked to be certain that it satisfies all of the Marshall design criteria set forth in Section 401 of the Standard Specifications. To do this, verify that all of the properties plotted on the charts meet the design criteria at the optimum asphalt content. If they all meet the design requirements then the mix design is acceptable. If not, then the mix must be redesigned so that it does meet the design criteria.

Redesigning a mix is typically done by either one or both of the following methods: 1) change the aggregate gradation by adjusting the component percentages 2) change the composition of the mix by using different aggregates. An experienced design technician can usually look at the properties of the original design and make a fairly accurate judgment about the amount of adjustment in the component percentages that may be necessary to bring the properties within compliance. If the adjustment results in only marginal conformance with design criteria then it may be necessary to actually change one or more of the materials. As noted previously this text is not intended to teach a detailed mix design course. Please reference the publications listed in the intro of this chapter on Page 71.

VIII QUALITY CONTROL TESTING

This section describes the various quality control tests used for evaluating asphalt mixtures. These include the test methods used for determining the asphalt content and gradation of asphalt mixture and the test methods used in field verification of the asphalt mixture design properties.

There is a reason for every step in a test procedure and each step should be followed carefully. These test procedures were designed so that two or more technicians testing the same material will be able to get similar test results. But this only works if everyone carefully follows each step of the procedure to assure that the test method is performed properly. When tests are made at a plant laboratory, speed is important because of the need to get the test results fast enough to take corrective action when the mix does not meet specifications. But it is just as important not to take any shortcuts that would make the test results inaccurate. Incorrect testing could result in the acceptance of bad material, the rejection of good material, or cause unnecessary plant adjustments that might adversely affect the mix rather than improve it.

This discussion begins with the WVDOH accepted methods of determining asphalt content. These methods include; AASHTO T164 which covers the reflux, centrifuge, and vacuum extraction procedures, and AASHTO T308 which uses the asphalt content ignition oven for burning off the asphalt in the test sample.

The AASHTO T164 test procedure covers several methods for determining asphalt content. This method was once the standard procedure used by the WVDOH and most contractors. In West Virginia, Method A, the centrifuge extraction, and Method B, the reflux extraction were used on a regular basis. When this extraction method is used, the remaining aggregate sample can be tested using AASHTO T30, Gradation Analysis of Extracted Aggregate.

The biggest problem with this procedure is that the standard method specifies the use of a chlorinated solvent such as Trichloroethane. Over the last several years many state agencies and contractors have moved away from using chlorinated solvents because they can be hazardous to both humans and the environment. The use of nonchlorinated solvents has become one alternative to this problem. Wherever this test method is specified within the WVDOH specification, the Division will allow a non-chlorinated biodegradable solvent if it can be shown that asphalt content test results are routinely within ± 0.3 % of the value determined by one of the other approved test methods. The District Materials Section will monitor the test comparisons and determine if this requirement can be met. Test results from this evaluation shall be forwarded to MCS&T Asphalt Section along with the name of the solvent and the manufacturer. It should be noted that some of these solvents may require modifications to the T164 test procedure, but these modifications shall only be in accordance with the solvent manufacturer's recommendations.

The centrifuge method was the one most often used at plant laboratories. In this method, the sample and one of the designated solvents that will dissolve asphalt are placed in the bowl of a centrifuge. As the centrifuge revolves, this mixture is forced up the sides of the bowl and the solvent and dissolved asphalt pass through a filter paper and out through holes in the top of the lid. The aggregate is left in the bowl. The main advantage of the centrifuge method is that it is fast. The main disadvantage is that only a small sample can be tested at one time.

A second method, the reflux method was often used in District and Central Laboratories before nuclear gauges and ignition ovens were purchased. With this method, the sample is placed in wire baskets that are lined with filter paper and these are placed in a glass jar with solvent in the bottom. The jar is placed on a hot plate and cold water is circulated through a condenser lid on top of the jar. The solvent is evaporated by the hot plate and it rises to the top of the jar, where it condenses to a liquid and drips over the sample. The main advantage of the reflux method is that one technician can operate several refluxes, so that a large sample can be tested, or several samples can be tested at once. The main disadvantage is that the reflux method is slow.

The current method used to determine the percent asphalt in asphalt mixture was developed by The National Center for Asphalt Technology (NCAT). This method involves igniting and burning the asphalt from the asphalt mixture sample in an ignition oven. This method allows for sampling of the final plant product and the sample size is reasonably small. Once the asphalt is burned off of the sample, the remaining aggregate can be washed and graded using the AASHTO T30 test method. A Round Robin Study showed very impressive results with this method. AASHTO has adopted a standard test method for using the ignition oven. This standard procedure is covered in AASHTO T308. The actual burning process usually takes less than one hour to complete.

A) ASPHALT CONTENT BY THE IGNITION METHOD

The ignition oven method of determining the asphalt content of hot-mix asphalt is covered in AASHTO T308. Test Method A is the simplest and most efficient test method of this procedure because it incorporates an oven with a built in scale and printing capabilities. This is the method that will be discussed in this section. There is some initial calibration work that has to be performed for each mix design before a sample can be tested. Each mix will have a calibration factor which will be used in determining the actual asphalt content. This calibration factor is simply a percentage of aggregate mass that is lost from the test sample when it is exposed to the extreme heat of the ignition oven. The calibration factor is subtracted from the calculated asphalt content determined from the test procedure. Using Test Method A of the procedure, the calibration factor is simply keyed into the oven before the test begins and the oven automatically calculates the asphalt content by incorporating this value.

Figure 68 - Determining Asphalt Content using NCAT Ignition Oven

The asphalt ignition oven works by burning the asphalt from an asphalt mixture sample at a temperature of 538 °C (1000 °F) and leaves an asphalt free aggregate sample for gradation analysis. And since the final asphalt mixture product is being tested, samples are reasonably small.

i) Mix Design Calibration

Asphalt binder content results can be affected by the type of aggregate in the mixture and the ignition furnace. Therefore, asphalt binder and aggregate correction factors must be established by testing a set of correction specimens for each mix design. Correction factors must be determined before any quality control or acceptance testing is completed and repeated each time a change in the mix ingredients or design occurs. Any changes greater than five percent in stockpiled aggregate proportions should also require a new correction factor. By calibrating each specific mix design, the accuracy of the test procedure is optimized. To begin the calibration procedure, prepare two calibration samples at the design asphalt content. Prior to mixing, prepare a butter mix at the design asphalt content in order to condition the mixing bowl with a thin coating of asphalt and fine aggregate. Discard the butter mix before mixing the calibration samples. In addition to the two calibration specimens at the design asphalt content, prepare a blank aggregate specimen. After conducting a gradation analysis on the blank specimen, it will be used for a comparison of the gradations from the oven tested specimens to evaluate the amount of aggregate breakdown due to the extreme temperature of the oven.

For the asphalt calibration procedure, the two prepared specimens are tested as described below, with the exception that they are laboratory prepared samples and a calibration factor is not entered through the oven keypad. If the difference between the measured asphalt contents of the two samples is not more than 0.15 percent then calculate the difference between the actual and measured asphalt content for each sample. The calibration is the average of the differences expressed in percent by mass of asphalt mixture. If the difference between the measured asphalt contents of the two samples exceeds 0.15 percent then prepare and test two additional samples, discard the high and low results of the four samples and use the average difference of the two remaining results as the calibration factor.

If the calibration factor exceeds 1.0 percent, the oven test temperature should be lowered to 482 ± 5 °C (900 ± 8 °F) and repeat the calibration procedure. Use the calibration factor obtained at the lower temperature even if it exceeds 1.0 percent.

Conduct a gradation analysis (AASHTO T30) on the aggregate from two of the calibration samples and compare them to the gradation of the blank aggregate sample to evaluate the amount of aggregate breakdown. Determine the difference in gradation on each sieve size of both specimens. Next, determine the average difference of the two values on each sieve. Using the following table, determine whether or not the average difference of each sieve exceeds the allowable difference of that sieve. For the 75 µm (No. 200) sieve, if the average difference is greater than 0.5 %, then this average difference shall be used as the correction factor for this sieve. For all other sieves, if the difference exceeds the allowable difference in Table 15, then gradation correction factors (equal to the resultant average differences) for all sieves shall be applied to all test results for this mix design. Record all test data on Form T416.

Table 15 - AASHTO T308 Permitted Sieving Difference

Sieve Sizes	Allowable Difference
2.36 mm (No. 8) or larger	± 5.0 %
300 µm (No. 50) to 1.18 mm (No. 16)	± 3.0 %
75 µm (No. 200)	± 0.5 %

ii) Ignition Oven Test Procedure

Obtain a field sample of the asphalt mixture approximately four times larger than the test specimen size. Heat the test sample in an oven at 125 ± 5 °C (257 ± 9 °F). Quarter the field sample down to test specimen size as indicated in the following table.

Table 16 - Minimum Test Sample Size Requirements For Ignition Oven Test Procedure

Nominal Maximum Aggregate Size	Minimum Test Specimen Mass (g)
4.75 mm (No. 4)	1200
9.5 mm (3/8”)	1200
12.5 mm (1/2”)	1500
19.0 mm (3/4”)	2000
25.0 mm (1”)	3000
37.5 mm (1 ½”)	4000

Preheat the ignition oven to 538 °C (1000 °F) unless the calibration factor was obtained at a different temperature (test the sample at the same temperature used to obtain the calibration factor). Place the sample in the preweighed sample basket with catch pan, evenly distributing it with a spatula or trowel. Determine the total mass of the sample, basket, and catch pan. Determine the mass of the sample by subtracting the mass of the basket and catch pan. Input the initial mass of the specimen (in whole grams) through the oven keypad. Place the sample and basket assembly in the ignition oven. Verify that the sample mass (including basket assembly) displayed on the furnace scale equals the total mass as initially weighed within ± 5 grams. Begin the test by pressing the start button on the oven. At the end of the test the oven will indicate that the test is complete by an audible sound and a light indicator. Press the stop button on the oven and a printed ticket will be generated with the asphalt content reported.

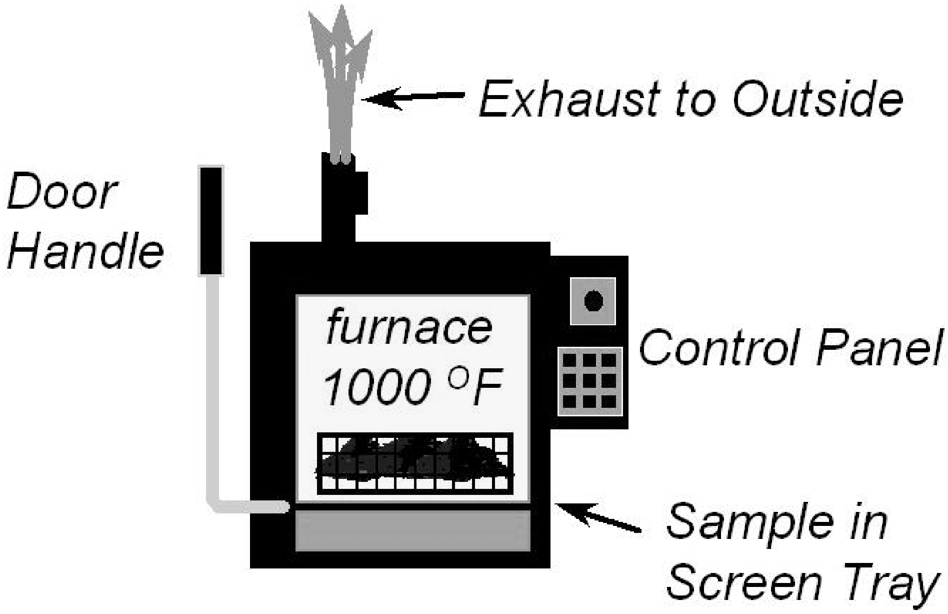


Figure 69 - Asphalt Ignition System Schematic

T416
Rev. 8-2013

West Virginia Division of Highways
Asphalt Content By The Ignition Method (AASHTO T308, Test Method A)
Mix Design Calibration And Gradation Comparison Worksheet

Project ***Source*** ***Material Type*** ***Technician***		***T-400 #*** ***Source Code*** ***Matr'l code*** ***Date Completed***	

Data Before Ignition	Temp: °C	1	2	3	4
	Actual Percent Asphalt Of Prepared Samples	4.8	4.8		
(A)	Weight of Basket + Sample	5534.0	5518.0		
(B)	Weight of Basket	3368.5	3369.0		
(C)	Sample Weight (A - B)	2165.5	2149.0		
	Data After Ignition				
(D)	Weight of Basket + Aggregate	5428.0	5414.2		
(E)	Weight of Basket	3368.5	3369.0		
(F)	Aggregate Weight (D - E)	2059.5	2045.2		
(G)	Asphalt Content From Oven Printout	4.89	4.83		
	or [(C - F) / C] X 100 (only when printer malfunctions)	4.89	4.83		

If the difference between the measured asphalt contents of the first two samples exceeds 0.15 percent repeat the two tests and, from the four tests, discard the high and low result. Determine calibration factor below from the remaining results.

Calibration Factor of Two Tests Determined In Accordance With Above Requirement

(H)	Difference Between Actual Sample Asphalt Content and Measured Asphalt Content (G)	0.09	0.03		
		1	2		
(J)	**Average Calibration Factor of Mix Design**	Average=			0.06

To enter a negative correction factor into an NCAT oven you must hit the "Calibration Factor" button twice, for a positive correction factor the button only needs to be pressed once.

If the calibration factor exceeds 1.0 percent, lower the test temperature from 538 °C to 482 ± 5 °C and repeat test. Use the calibration factor obtained at 482 °C even if it exceed 1.0 percent.

Aggregate Gradation Calibration Results

Sieve Size	Blank Agg. Sample Gradation	Ignition Oven Burn Off Aggregate Calibration Samples					
		Sample 1		Sample 2		Average Difference	Correction Factor (±)
		% Passing	Difference	% Passing	Difference		
2 in (50 mm)							0
1 1/2 in (37.5 mm)							0
1 in (25 mm)	100	100	0	100	0	0	0
3/4 in (19 mm)	98	97	1	97	1	1	0
1/2 in (12.5 mm)	81	82	-1	81	0	-0.5	0
3/8 in (9.5 mm)	72	73	-1	74	-2	-1.5	0
No. 4 (4.75 mm)	43	42	1	42	1	1	0
No. 8 (2.36 mm)	24	24	0	23	1	0.5	0
No. 16 (1.18 mm)	16	16	0	16	0	0	0
No. 30 (600 µm)	11	12	-1	11	0	-0.5	0
No. 50 (300 µm)	8	9	-1	8	0	-0.5	0
No. 200 (75 µm)	4.7	5.3	-0.6	5.7	-1	-0.8	-0.8

For each calibration sample, subtract the % passing each sieve from the actual blank value. Indicate when the subtracted value is more than the blank sample using a negative "-" sign. Calculate the average difference of the two samples. If the average difference for any sieve is greater than the value permitted in Table-2 of AASHTO T-308, then apply the guidelines of Section 6.11 of this procedure in assigning correction factors to individual sieves.

Attach all asphalt content oven printouts and T417 calibration sample gradation results to this report.

T417
Rev. 01-01

West Virginia Division of Highways

Asphalt Content By Ignition Method (AASHTO T308, Test Method A) An
Mechanical Analysis Of Extracted Aggregate - AASHTO T30

Lab Number: ______ Material: Base-2 Field Sample #: ______
Technician: ______ T400 #: ______ Cal. Factor: 0.18 Date: ______

Data Before Ignition Test Temp: 538 °C		**Data After Ignition**	
(A) Weight of Basket + Sample	6097.5	(D) Weight of Basket + Aggregate	5970.1
(B) Weight of Basket	3376.2	(E) Weight of Basket	3376.2
(C) Sample Weight (A - B)	2721.3	(F) Aggregate Weight (D - E)	2593.9
(K) Percent Asphalt Check: { [(C - F) / C] X 100 - (Calibration Factor) }			4.5
Asphalt Content From Ignition Oven Printout Shall Be Used As Actual % Asphalt			4.5
Minus 75 µm Material		**Washed Grading**	
(L) Weight In Pan After Gradation	22.3	(N) Weight Before Wash	2593.9
Loss On Wash (Q)	140.9	(O) Weight After Wash	2453.0
(M) Total - 200 (75 µm) Material (L + Q)	163.2	(Q) Loss (N - O)	140.9
(S) Total Aggregate In Sample For Gradation Calculations : (Line (F) Above)			2593.9

Gradation Analysis

Sieve Size	Weight Retained	Percent Retained	Percent Passing	Reported Percent Passing	Tolerance Limits
2 in (50 mm)					
1 1/2 in (37.5 mm)					
1 in (25 mm)	0.0	0.00	100.02	100	100
3/4 in (19 mm)	59.4	2.29	97.73	98	90 - 100
1/2 in (12.5 mm)	367.2	14.16	83.57	84	90 max
3/8 in (9.5 mm)	171.6	6.62	76.95	77	
No. 4 (4.75 mm)	677.0	26.10	50.85	51	
No. 8 (2.36 mm)	413.9	15.96	34.89	35	30 - 42
No. 16 (1.18)mm	249.9	9.63	25.26	25	
No. 30 (600 µm)	184.2	7.10	18.16	18	
No. 50 (300 µm)	151.5	5.84	12.32	12	
No. 200 (75 µm)	156.5	6.03	6.29	6.3	2.0 - 8.0
- 200 (75 µm) (M)	163.1	6.29			
Total Wt. (W)	2594.3				
0.2% Check: = Total Weight	W - Q (X) 2453.4	100 (O - X) / O -0.02 %			

The Summation Of The Retained Weights Of All Of The Sieves Plus The Pan Weight Must Check The Dry Weight After Wash (O) Within 0.2% Of The Total Weight (X).

Attach all asphalt content oven printouts to this report.

iii) Sieve Analysis of Aggregates

The sieve analysis of aggregates used in hot-mix asphalt is usually determined by one of two separate but similar procedures based on how the sample was taken. Aggregate samples from a solvent extraction test or ignition oven test are tested according to AASHTO T30, while belt samples or hot bin samples from a plant are tested according to AASHTO T27. AASHTO T30 includes a procedure for washing the aggregate before the sieving operation is performed. A separate wash test method, AASHTO T11, is used along with the T27 sieve analysis. The only major differences in the T27 procedure from T30 are in the sample sizes and the method for splitting down the minus 4.75 mm (No. 4) material before sieving. AASHTO T27 and T11 are thoroughly covered in the Aggregate Inspector Manual.

Gradation limits are often placed on aggregates in hot-mix asphalt because when mixes are designed in a lab the percentages of aggregate and asphalt components are controlled very tightly in order to establish the required design criteria. The mix that comes out of the plant must be controlled as close as possible to these percentages so that it still meets the accepted design criteria.

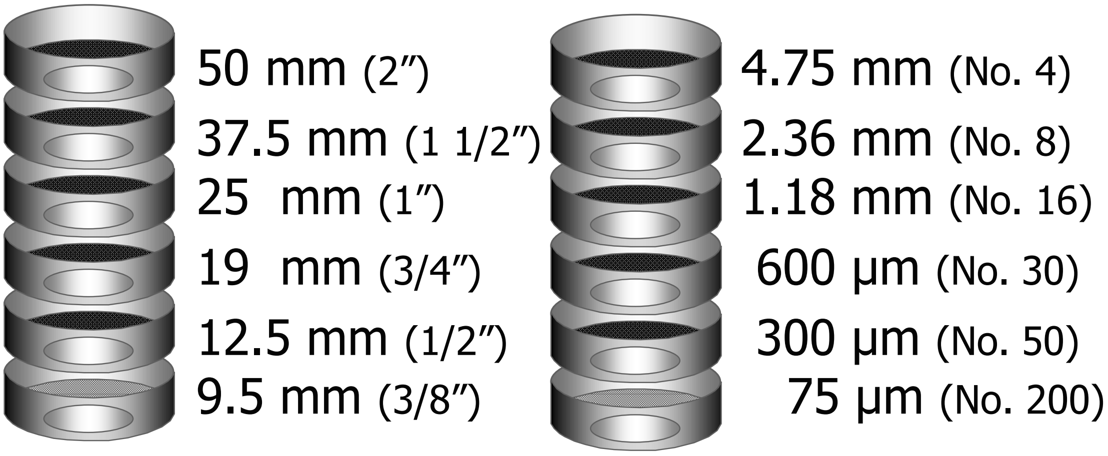
Plants operate on the principle of either mass or volume for controlling the component parts of a mix. Therefore, in the case of aggregate, the mass or volume can be consistent while the actual gradation can vary and change the properties of the mix. For example, in some mixes, the amount of coarse aggregate may affect the strength of the pavement. If there is not enough coarse aggregate in the mix then the strength of the pavement may be adversely affected.

The asphalt content of the designed mix is based on the assumption that the aggregate will have a reasonably consistent gradation. If there is too much fine aggregate in the mix then there will not be enough asphalt to coat all of the aggregate and the pavement durability will be poor. If there is not enough fine aggregate, there will be more asphalt than is needed to coat the aggregate. This excess asphalt could come to the pavement surface and form a layer of solid asphalt that will be dangerously slippery when wet.

MP 700.00.06, in the appendix of the workshop manual for this course, describes the proper sampling procedures to be used when sampling from a conveyor belt (belt samples) and from a flowing stream of aggregate (hot bins). This MP also provides information for determining the proper aggregate sample and test portion sizes based on the nominal maximum size of the aggregate being sampled. The nominal maximum size is the largest standard sieve size listed in the applicable specifications upon which any material is permitted to be retained. For example, if we have a sample which the specifications require 100% to pass the 25 mm (1 inch) sieve, then the first standard sieve size upon which material may be retained is the 19 mm (3/4 inch) sieve. So, the nominal maximum size would be 19 mm (3/4 inch), the sample size would be 25 kg, and the test portion size would be 5 kg.

Before starting the gradation test, the sieves should be checked to be sure there are no punctures, broken or spread wires, or other obvious defects. If the sieve cloth is loose in its frame or if the wires are bent, loose or broken, or the frame itself is split, then the sieve should be replaced.

Section 401 Standard Sieve Sizes



50 mm (2″)
37.5 mm (1 1/2″)
25 mm (1″)
19 mm (3/4″)
12.5 mm (1/2″)
9.5 mm (3/8″)

4.75 mm (No. 4)
2.36 mm (No. 8)
1.18 mm (No. 16)
600 µm (No. 30)
300 µm (No. 50)
75 µm (No. 200)

See Table 401.4.2 for actual gradation requirements.

After taking an appropriate sized sample in accordance with MP 700.00.06, the sample is reduced to the approximate test portion size in accordance with AASHTO T248 by using an aggregate sample splitter. For composite belt samples from base course mixes which contain significant amounts of both plus and minus 4.75 mm (No. 4) material, it will be necessary to separate the sample into a coarse aggregate fraction and a fine aggregate fraction and test each fraction separately. If the fine aggregate portion is significantly larger than the required test portion mass based on nominal maximum size, it may be further reduced by splitting it down to the approximately test sample mass. Course aggregate is normally classified as plus 4.75 mm (No. 4) material and fine aggregate is classified as minus 4.75 mm (No. 4) material. Since hot bins are already separated into different sizes, it is usually not necessary to further separate the material into plus and minus 4.75 mm (No. 4) sizes. The procedure for separating the course and fine aggregates from a composite sample is described in AASHTO T27 and explained in detail in the Aggregate Inspector Manual.

Since the specification calls for a tolerance range on minus 75 µm (No. 200) material, it is necessary to determine the amount of material lost by wash (AASHTO T11). The test sample must first be oven dried to a constant mass at 110 ± 5 °C (230 ± 9 °F). The sample is then placed in a bucket or suitable container. It is covered with water and a wetting agent is added to help disperse the dust. The sample is stirred vigorously with a large spoon or spatula in order to separate the dust from the coarser aggregate and to suspend the dust in the water. The wash water is then poured from the bucket over a nest of two sieves, a 1.18 mm (No. 16) over top of a 75 µm (No. 200). The 1.18 mm (No. 16) sieve is used to protect the 75 µm (No. 200) sieve from any large particles. Pour the water as soon as possible after stirring, before the minus 75 µm (No. 200) material settles. Try to keep the coarser aggregate in the bucket. Do not spill any of the wash water because this would make the test results inaccurate.

Cover the aggregate with more water and repeat the process until the wash water is clear. The coarse aggregate in the bucket and the fine aggregate on the sieves is then washed back into the sample pan in which it was originally weighed. Excess water in the sample pan may be poured over the sieves, after which any aggregate retained on the sieves is washed back into the sample pan.

The aggregate is dried to a constant mass in an oven at a temperature of 110 + 5 °C (230 + 9 °F). After drying, the mass of the sample is again determined. The mass after washing is subtracted from the mass before washing to determine the mass of minus 75 µm (No. 200) material that was washed from the sample.

After the sample has been washed and dried it is ready for the gradation test. The sieves are stacked in order of the size of the openings in the wire with the coarsest or largest opening at the top and the smallest at the bottom. The type of asphalt mix, as defined in the specifications, determines the sieve sizes required for this procedure. The sample is poured through the nest of sieves which is then placed on a mechanical shaker. The test procedure does not specify any definite time for the sample to be shaken. It states that the sieving shall be continued for a sufficient period and in such a manner that, after completion, not more than 0.5% by mass of total sample passes any sieve during one minute of hand sieving. Usually 8 to 10 minutes of mechanical sieving is sufficient to achieve this requirement.

Specifications also require that for fine aggregate [which is defined as 2.36 mm (No. 8) or smaller material] no more than 6 kilograms per square meter of sieving surface should be retained. This amounts to 200 grams on a standard 203 mm (8 inch) diameter sieve. If more than 200 grams is retained, the sample should be divided and resieved. For sieves with openings 4.75 mm (No. 4) and larger, the mass in kg/m2 of sieving surface shall not exceed the product of 2.5 times the sieve opening in millimeters, see Maximum Allowable Retained Weights Table 17. In no case shall the mass be so great as to cause permanent deformation of the sieve cloth.

The next step is to determine the mass of the aggregate retained on each sieve. Since most labs now have digital balances, the easiest method for doing this is to place a sample pan on the balance and tare it. Transfer the aggregate from the first sieve into the pan and record the mass. Tare the pan again and add the aggregate from the next sieve and record the mass. Repeat this process for the remaining sieves.

Pieces of aggregate that stick in the openings of coarse sieves [2.36 mm (No. 8) and above] may be removed with a blunt instrument such as a putty knife edge or spatula as long as excess force is not applied. Too much force can enlarge the sieve openings. A wire brush can be used on sieves down to the 600 µm (No. 30) sieve. A soft brass brush may be used on the 300 µm (No. 50) sieve. Use a soft paint brush on the 150 µm (No. 100) sieve and below.

Table 17 – Maximum Allowable Retained Weights For Standard Sieve Sizes

Sieve Size	Gilson Sieves 372 x 580 mm (15” x 23”)	304.8 mm (12 inch) Diameter	203.2 mm (8 inch) Diameter
50 mm (2”)	27,000 g	8,400 g	3,600 g
37.5 mm (1 ½”)	20,200 g	6,300 g	2,700 g
25 mm (1”)	13,500 g	4,200 g	1,800 g
19 mm (3/4”)	10,200 g	3,200 g	1,400 g
12.5 mm (1/2”)	6,700 g	2,100 g	890 g
9.5 mm (3/8”)	5,100 g	1,600 g	670 g
4.75 mm (No. 4)	2,600 g	800 g	330 g
2.36 mm (No. 8)	1,290 g	500 g	200 g
1.18 mm (No. 16)	630 g	500 g	200 g
All smaller 304.8 (12”) diameter sieves shall not exceed 500 grams. All smaller 203.2 (8”) diameter sieves shall not exceed 200 grams.			

iv) Gradation Calculations

On the following pages are example gradation calculations with the test results filled in for typical gradation tests. The procedure for obtaining this data is as follows:

Step 1: Dry the sample and determine the mass. This original dry sample mass shall be used to calculate the percent material retained on each sieve.

Step 2: Conduct the AASHTO T11 wash test.

Step 3: Sieve the aggregate and determine the mass retained on each sieve.

Step 4: Calculate the total minus 75 µm (No. 200) material. This includes the aggregate that passed through the 75 µm (No. 200) sieve into the pan and the material that was lost through the wash test.

Step 5: Add together the mass of aggregate retained on each sieve plus the total minus 75 µm (No. 200) material to determine the total mass of aggregate. This total should agree closely with the original dry sample mass. The summation of the retained mass of all of the sieves plus the pan mass must be within 0.2% of the dry mass after wash (AASHTO T30) or 0.3% (AASHTO T27) of the total mass. If this value is larger than this specified amount then check your calculations. If necessary, repeat the procedure. If the value is still too high then discard the sample and test another sample.

Step 6: Calculate the percent passing each sieve. An example calculation is shown on the next page. The formula is:

$$\%\,Retained = \frac{Mass\ Retained}{Original\ Dry\ Sample\ Mass}\ X\ 100$$

Always use the original dry sample mass to calculate the percent retained on each sieve! Do not use the sum of the masses retained on each sieve plus the minus 75 µm (No. 200) material. This summation value is only used in Step 5 to verify that it is within the allowable limits of the original dry sample mass.

Step 7: Calculate the percent passing each sieve. The formula that we will use to calculate the percent passing is:

% Passing Any Sieve = The Sum of % Retained on All Finer Sieves and Pan

When using this formula, start at the bottom sieve and work up.

In the example problem below the percent passing each sieve was calculated to the nearest 0.01%. The final calculated percent passing is rounded and reported to the nearest 0.1% for the 75 µm (No. 200) sieve. A percent passing result for all other sieves are rounded and reported to the nearest whole percentage.

WEST VIRGINIA DIVISION OF HIGHWAYS

WASHED SIEVE ANALYSIS

(AASHTO T-11 AND T-27)

Producer		Aggregate Source	
Type of Mix	**Wearing-1**	Aggregate Type	
Technician		Date	

Sieve Size	Weight Retained	Percent Retained	Percent Passing		
63 mm					
50 mm					
37.5 mm					
25 mm					
19 mm					
12.5 mm			**99.99**	=	**100**
9.5 mm	**74.3**	**6.90**	**93.09**	=	**93**
4.75 mm	**374.4**	**34.77**	**58.32**	=	**58**
2.36 mm	**301.7**	**28.02**	**30.31**	=	**30**
1.18 mm	**184.3**	**17.11**	**13.20**	=	**13**
600 µm	**53.8**	**5.00**	**8.20**	=	**8**
300 µm	**18.5**	**1.72**	**6.48**	=	**6**
75 µm	**17.8**	**1.65**	**4.83**	=	**4.8**
- 75 µm (T)	**52.0**	**4.83**			
Total	**1076.8**				

(A) Weight of original sample **1076.9** g

(B) Weight after washing **1029.2** g

(C) Loss of - 75 µm after wash (A - B) **47.7** g

(D) - 75 µm from sieving (Pan Weight) **4.3** g

(T) Total passing 75 µm (C + D) **52.0** g

IX FIELD VERIFICATION OF ASPHALT CONCRETE

Quality control activities are designed to assure that the asphalt mixture being produced at the plant is meeting the designated criteria of the WVDOH specifications. The process control testing that is performed by the contractor at the plant is quality control.

For many years asphalt mixture was designed in the laboratory, produced in a plant, constructed in the field, and then tested for percentages of component materials with asphalt content and gradation analysis. If the asphalt content and gradation were within tolerance limits set forth in the specifications then the mix was considered acceptable. These tests alone, however, do not indicate whether or not the design properties of the mix are being met in the field. It only confirms that the percentages of the component parts of the mix are conforming to the original tolerance limits of the mix design.

When a plant starts producing asphalt mixture there will likely be some differences between the plant produced mix and the original mix design. Field verification of the mix involves testing and analyzing the plant produced material to ensure that the established design criteria are being met. If the design properties of the plant produced material are significantly different, then corrective measures may be needed to adjust the mix. The quality control MP's discussed in Chapter-6 have provisions for adjusting the mix. If these adjustments don't work then a new design may be required.

Field verification of hot-mix asphalt may be used as part of a quality control system designed to assure the quality of the plant produced mix. The testing required on plant produced asphalt mixture is basically the same as what is required in a mix design. For Marshall mix designs the tests include stability and flow (AASHTO T245), bulk specific gravity (AASHTO T166), maximum specific gravity (AASHTO T209), percent air voids (AASHTO T269), and VMA calculations (Asphalt Institute MS-2 Manual). The only major difference between field verification testing and mix design testing is that with field verification the testing is performed on a randomly selected representative sample of the plant produced mix instead of laboratory manufactured samples.

When preparing Marshall test specimens using field samples, a slight variation to the Marshall procedure must be used. If the sample is to be tested in a field lab and the mix is hot enough to maintain the required compaction temperature then a representative sample can be split down to test portion size. The material can then be placed directly into the hot mold. After spading the sample and verifying the compaction temperature it is ready for compaction. Sometimes the sample may cool to slightly below the compaction temperature while preparing the test specimens. If this happens then place the entire mold assembly in an oven set at approximately 10 °C (20 °F) above the maximum temperature of the compaction temperature range to allow the sample to reach the proper temperature. To minimize any hardening of the asphalt during the reheating process the sample should not be left in the oven any longer than it takes to reach the required compaction temperature. Also, if the specimens were left in a hot oven for too long of a period, the asphalt would begin to drain to the bottom of the mold.

If the mix cools to below 110 °C (230 °F) during sample preparation then special precaution should be taken to reheat the sample. In order to minimize the hardening of the asphalt during the long reheating process the sample should be split into three test portions and placed in individual closed containers [1200 gram tins work well for 102 mm (6 inch) test specimens]. Place the containers in an oven set to the maximum temperature of the compaction temperature range to allow the sample to reach the proper temperature. With some older type ovens the mix may not heat to the required temperature in a reasonable time period. In such cases the temperature may be set to no more than 10 °C (20 °F) above the maximum temperature. Periodically check the temperature to assure that the sample is not overheated.

If the sample was allowed to cool below a workable temperature before testing was started then heat the entire sample to a suitable temperature [approximately 110 °C (230 °F)], split it into test portion sizes, place test portions in close containers and heat to compaction temperature as mentioned above.

Daily mix verification testing can provide an early warning by indicating if the mix properties deviate from the specifications. Daily verification is part of plant process control that can identify potential problems before tons of mix have been placed in the field. Following proper sampling and testing procedures exactly is extremely important. It is not desirable to adjust the production process on the basis of inaccurate test results.

All test procedures involve some amount of testing error. The more difficult the test procedure, the greater the possibility for an error to occur. Much of the testing error currently experienced is the result of variations in the testing procedures by the technicians in an attempt to make the test easier or quicker. To reduce this type of error, all procedures must be conducted using the exact steps as indicated in the standard test method. A technician should never make modifications to any test procedures without the written approval of the specifying agency. A technician should be able to repeat a test procedure on the same material and get test results that are within the standards for repeatability (As noted in applicable AASHTO or ASTM Test Method). With proper training and supervision, testing error in a laboratory can be minimized. In addition to the potential for within-laboratory (repeatability) error, another concern is the variability between two laboratories (reproducibility) when testing the same mixture as part of a verification process. In this case, the error associated with different equipment and different technicians often causes further variation in the test results, thus making each step of a test method even more important.

X ADDITIONAL TESTING REQUIRED BY PLANT TECHNICIANS

Plant technicians may have a few extra testing responsibilities beyond testing asphalt mixture for specification requirements. A plant technician may be responsible for the additional duties that are referenced in MP 401.03.50, Guide to Quality Control Plans for asphalt mixture. These additional responsibilities will vary, but may include duties such as: stockpile, cold bin, or hot bin gradations; calibrating cold bins or hot bins; scale checks; calibrating an asphalt pump; face fracture testing on gravel; aggregate moisture content; and asphalt mixture moisture content. All of these tests are crucial to the quality control process for producing asphalt mixture, but aside from the standard gradation test, many of these duties are plant specific and will not be discussed in detail at this time. However, the moisture content of aggregate and moisture content of asphalt mixture are two very important test procedures that a plant technician may be required to perform on a regular basis.

Before asphalt is added to the aggregate in asphalt mixture, it is usually desirable to dry the aggregate until it has no surface moisture and not more than 0.5% absorbed moisture. AASHTO T255, Moisture Content of Aggregate by Drying, is a simple procedure that requires an aggregate sample to be weighed and then dried to a constant mass in an oven at a temperature of 110 ± 5ºC (230 ± 9ºF). The moisture content of the aggregate can be determined as follows:

$$\%\ \text{Moisture} = \frac{\text{Wet Agg. Wt.} - \text{Dry Agg. Wt.}}{\text{Dry Agg. Wt.}} \times 100$$

Example: A wet aggregate sample from a stockpile weighed 5,360 grams. After oven drying, the aggregate weighed 5,105 grams. What was the percent moisture of the aggregate from the stockpile?

$$\%\ \text{Moisture} = \frac{5360 - 5105}{5105} \times 100 = 5.0\%$$

A stockpiled aggregate containing excessive moisture can be used in the production of a WVDOH mix design in a drum plant, along with a couple of other stockpiled aggregates with varying moisture contents. Why would the amount of moisture in the aggregate be a concern to the plant technician and the plant operator? In a drum plant, the drum is used for both drying the aggregate and mixing it with asphalt; so the obvious answer is because the aggregate needs to be reasonably dry before asphalt is added. But it is also important because the mass of all aggregate used for designing the mix were based on dry aggregates. If we used the mass of the wet aggregate entering the plant in place of the dry aggregate mass we may have problems reproducing the mix. Of course most of the moisture will be removed from the wet aggregate as it goes through the dryer, but after this moisture is removed, the aggregate mass will also be lower and the blended aggregates that make up the mix may be out of proportion enough to cause the mix to fall outside of the standard specification requirements. The easy fix for this is to account for the moisture in the aggregates before it enters the dryer.

Let's look at a simple example of how this information would be used. A drum mix plant is producing an asphalt mix containing 5.3% asphalt at a rate of 150 tons/hour. The stockpile of aggregate that contains 5.0% moisture will account for 50% of the total aggregate being used in the mix. The cold feed for this aggregate is set to deliver a constant flow of material during production. Since 5.0% of this aggregate mass is moisture, how many tons/hour of wet aggregate should the cold feed be set to deliver?

The first thing that should be done is to determine how much of the 150 tons/hour of asphalt mixture is actually aggregate. Since 5.3% of the asphalt mixture is asphalt we can multiply 150 tons/hour times 5.3% and determine that 8.0 tons of this hourly production is asphalt. That leaves us with 142.0 tons of aggregate. And in this example the aggregate stockpile with the 5.0% moisture content accounts for 50% of the mix. A quick calculation indicates that 142.0 x 50%, or 71.0 tons/hour, of the aggregate that contains 5.0% moisture is being delivered to the drum. Since this 71.0 tons/hour of aggregate represent the dry mass, then the actual mass of the aggregate entering the plant must include the moisture. We can add the 5.0% moisture to the dry aggregate mass simply by multiplying the mass by 1.05 (105%) or as shown below.

$$\text{Wet Agg. Wt.} = 71.0\ \text{tons/hr}\ \text{x}\ \frac{100\% + 5\%}{100\%} = 74.6\ \text{tons/hr}$$

or

$$\text{Wet Agg. Wt.} = 71.0\ \text{tons/hr}\ \text{x}\ 1.05 = 74.6\ \text{tons/hr}$$

In this example, in order to supply the plant with 71.0 tons/hr of dry aggregate, the cold feed must be set to deliver 74.6 tons/hr of the wet aggregate containing 5.0% moisture. This same procedure would be used to determine the cold feed settings to deliver the other aggregates used to produce this mix.

Another test that a plant technician may be required to run is AASHTO T329 – asphalt mixture Moisture Content by Drying. Plant produced asphalt mixture should always contain less than 1.0% moisture, preferably less than 0.5%, and ideally less than 0.2%. If it contains more, then the plant is not sufficiently drying the aggregate before mixing it with asphalt. This problem starts with excessive moisture in stockpiled aggregates that are not covered or not placed on a sloped surface that would allow water to drain from the pile. Lowering the slope of the dryer will increase the dwell time of the aggregate and help remove additional moisture if needed.

Excessive moisture in asphalt mixture acts to increase the liquid content of the mix and decreases the internal strength of the mix during the rolling process. The moisture in the asphalt mixture at these high production temperatures will be converted to steam which increases the volume of the moisture. The steam exerts internal pressure on the mix that tends to push the aggregates apart as the mix is being rolled. This is usually referred to as a tender mix which will tend to displace laterally and shove rather than compact under roller loads. Excessive moisture in asphalt mixture may also force asphalt to the surface during the rolling process. This results in unsightly "fat" spots of asphalt on the pavement surface. Excessive surface asphalt may have to be removed to avoid slippery conditions.

Using AASHTO T329, the moisture content of asphalt mixture is determined in a similar manner as was described for aggregate. A brief summary of the test method would be to take a sample of newly produced asphalt mixture, reduce it to test sample size (AASHTO R-47), weigh it, and then dry it to a constant mass in an oven at a temperature of 163 ± 14°C (325 ± 25°F). The moisture content of the asphalt mixture can be determined as follows:

$$\text{\% Moisture in asphalt mixture} = \frac{\text{Moist Wt.} - \text{Dry Wt.}}{\text{Dry Wt.}} \times 100$$

Example: A fresh sample of asphalt mixture weighed 2500 grams. After oven drying it weighed 2488 grams. What was the percent moisture of the sample?

$$\text{\% Moisture in asphalt mixture} = \frac{2500 - 2488}{2488} \times 100 = 0.5\%$$

XI REVIEW

Answer the following practice questions and problems. The answers are given on the pages following the last question.

1) Name three test methods for determining the asphalt content.

2) Which AASHTO test procedure describes the proper method of splitting an aggregate sample down to test portion size?
   a. T27
   b. T30
   c. T248

3) $\% \text{Asphalt} = \dfrac{\text{Mass of Asphalt}}{\text{Mass of Aggregate}} x\,100$:True or False_________

4) Impermeability of an asphalt pavement increases as the air void content increases. True or False __________

5) In a washed gradation test, the purpose of the 1.18 mm (No. 16) sieve is to protect the 75 µm (No. 200) sieve from damage. True or False __________

6) Round the following numbers to the nearest whole percent.
   a. 95.5% ___________
   b. 96.5% ___________
   c. 96.49% ___________
   d. 70.5% ___________
   e. 71.5% ___________

7) Specific gravity is the ratio of the mass of a given volume of a substance to the mass of an equal volume of __________.

8) The mass of a sample of hot-mix asphalt is 2500 grams. The aggregate mass of the sample is 2350 grams. What is the percentage of asphalt in the mix?

9) The mass of a stockpile sample of #8 aggregate was determined to be 3575 grams. After oven drying the mass was 3395 grams. What is the moisture content of this stockpile sample?

10) Calculate the percent passing each sieve. Total sample mass = 950 grams.

Sieve Size	Mass Retained	Percent Retained	Percent Passing
9.5 mm (3/8 in.)	0	________	_______
4.75 mm (No. 4)	0	________	_______
2.36 mm (No. 8)	262	________	_______
1.18 mm (No. 16)	180	________	_______
300 µm (No. 50)	428	________	_______
75 µm (No. 200)	58	________	_______
Pan	22	________	

11) Listed below are two aggregate gradations. They are to be combined in these proportions: Aggregate A = 70% and Aggregate B = 30%. Calculate the combined gradation.

Sieve Size	% Passing Agg. A	% Passing Agg. B	Combined Gradation
9.5 mm (3/8 in.)	100	100	_______
4.75 mm (No. 4)	100	50	_______
2.36 mm (No. 8)	74	15	_______
1.18 mm (No. 16)	50	5	_______
300 µm (No. 50)	20	1	_______
75 µm (No. 200)	5	0	_______

12) A Base-1 paving mix is composed of three standard sized aggregates. 36% of the aggregate blend was #4 aggregate with a specific gravity of 2.675. 26% of the blend was #6 aggregate with a specific gravity of 2.637. 38% of the blend was #10 sand with a specific gravity of 2.586. Calculate the bulk specific gravity of the combined aggregate.

13) The bulk specific gravity of a compacted mix specimen was 2.405. The bulk specific gravity of the aggregate was 2.588. The mix contains 5.5% asphalt as a percent by total mass of mix. Calculate the VMA.

14) The data from a Wearing-1 mix design indicates that the asphalt content at the median air voids (4.0%) is 4.7%. The maximum stability was obtained at an asphalt content of 5.3%, but the minimum design criteria will be met at an asphalt content as low as 4.9%. All other design properties are within specification requirements at an asphalt content of 4.7%. Is this design acceptable in accordance to the criteria of MP 401.02.22?

15) Under the Performance Graded Binder System, the second number in the grade designation represents the minimum pavement design temperature (°C). (True or False)

16) In the fine aggregate angularity test, a higher void content would mean more fractured faces. (True or False)

17) The aggregate consensus properties of the Superpave System are applied separately to each aggregate component of a mix design. (True or False)

18) The maximum density gradation represents a gradation in which the aggregate particles fit together in their densest possible arrangement. (True or False)

19) The tensile strength ratio determined by AASHTO T-283 must be at least _______% to meet the design criteria of the Superpave System.

20) MP 401.02.22 is the guideline used by the WVDOH for designing Superpave HMA. (True or False)

On the following two pages are copies of Worksheets used for calculating aggregate gradation and Marshall properties. Enough data has been provided for the completion of all calculations. Answers are given at the end of the "Answers To Practice Questions" section.

WEST VIRGINIA DIVISION OF HIGHWAYS

WASHED SIEVE ANALYSIS
(AASHTO T-11 AND T-27)

Producer __________ Aggregate Source __________

Type of Mix **Base-II** Aggregate Type __________

Technician __________ Date __________

Sieve Size	Weight Retained	Percent Retained	Percent Passing
63 mm			
50 mm			
37.5 mm			
25 mm	**0.0**		
19 mm	**36.2**		
12.5 mm	**305.7**		
9.5 mm	**146.9**		
4.75 mm	**363.1**		
2.36 mm	**420.1**		
1.18 mm	**306.9**		
600 μm	**159.0**		
300 μm	**102.2**		
75 μm	**111.4**		
- 75 μm (T)			
Total			

(A) Weight of original sample	**2080.6**	g
(B) Weight after washing	**1960.3**	g
(C) Loss of - 75 μm after wash (A - B)		g
(D) - 75 μm from sieving (Pan Weight)	**7.9**	g
(T) Total passing 75 μm (C + D)		g

T406
Rev. 01-00

West Virginia Division Of Highways

Hot-Mix Asphalt Design Property Worksheet

Lab Number:		Material Type:	Wearing-1
Source:		Project:	
T400 Design Number:	1234567	Field Sample Number:	
Compaction Temperature:	141 °C	Number of Blows:	75
Percent Asphalt:	5.7	Date Sampled:	
Percent Aggregate (Y):	94.3	Date Completed:	
Bulk Aggregate Sp. Gr. (Z):	2.554	Technician:	

Maximum Specific Gravity - Bowl Method (AASHTO T-209)

A	Sample Weight	1205.0
B	Bowl + Sample in Water Weight	2030.1
C	Bowl in Water (Calibration Weight)	1321.5
D	Surface Dry Sample Weight (For Dry-Back Procedure Only)	*******
E	Max. Sp. Gr. = A / [A - (B - C)] or Dry-Back Max. Sp. Gr. = A / [D - (B - C)]	

Bulk Specific Gravity - (AASHTO T-166)

	Compacted Specimens	1	2	3	Average
F	Weight in Air	1216.2	1203.7	1210.6	▨
G	Saturated Surface Dry Weight	1216.9	1204.4	1211.0	▨
H	Weight in Water	696.8	688.0	692.7	▨
J	Bulk Specific Gravity = F / (G - H)				
	Unit Weight (kg/m^3) = J x 1000				

Marshall Stability And Flow (AASHTO T-245)

	Specimen Thickness (mm)	63.5	63.5	63.5	
K	Correlation Ratio	1.00	1.00	1.00	▨
L	Measured Stability (N)	8550	8650	8500	
	Adjusted Stability (N) = (K x L)				
	Flow (0.25 mm)	11.5	10.5	11.0	

Void Analysis (AASHTO T-269 And The Asphalt Institute MS-2 Manual)

Percent Air Voids = [(E - J) / E] x 100	
Percent Voids in Mineral Aggregate (VMA) = 100 - [(J x Y) / Z]	

XII REVIEW ANSWER

1) Reflux, centrifuge, vacuum extractor, asphalt ignition oven, printout at automatic plant
2) C
3) False
4) False
5) True
6)
   a. 96
   b. 97
   c. 96
   d. 71
   e. 72
7) Water at the same temperature
8) % Asphalt = $\frac{(2500 - 2350)}{2500} \times 100 = 6.0\%$
9) 5.3%
10)

Sieve Size	Percent Passing
9.5 mm (3/8 in.)	100
4.75 mm (No. 4)	100
2.36 mm (No. 8)	72
1.18 mm (No. 16)	53
300 µm (No. 30)	8
75 µm (No. 200)	2.3

11)

Sieve Size	Combined Gradation
9.5 mm (3/8 in.)	100
4.75 mm (No. 4)	85
2.36 mm (No. 8)	56
1.18 mm (No. 16)	36
300 µm (No. 30)	14
75 µm (No. 200)	3.5

12) Bulk S. G. = $\dfrac{100}{\dfrac{36}{2.675} + \dfrac{26}{2.637} + \dfrac{38}{2.586}} = 2.631$

13) VMA $= 100 - \frac{2.405 \times 94.5}{2.588} = 12.2$

14) No, because the design stability requirement is not met at the asphalt content corresponding to the specified 4.0% air voids.

15) True

16) True

17) False, they are applied to the blended coarse and fine aggregates in the mix.

18) True

19) 80%

20) False. It is MP 401.02.28

WEST VIRGINIA DIVISION OF HIGHWAYS

WASHED SIEVE ANALYSIS
(AASHTO T-11 AND T-27)

Producer		Aggregate Source	
Type of Mix	**Base-II**	Aggregate Type	
Technician		Date	

Sieve Size	Weight Retained	Percent Retained	Percent Passing		
63 mm					
50 mm					
37.5 mm					
25 mm	**0.0**	**0.00**	**99.94**	=	**100**
19 mm	**36.2**	**1.74**	**98.20**	=	**98**
12.5 mm	**305.7**	**14.69**	**83.51**	=	**84**
9.5 mm	**146.9**	**7.06**	**76.45**	=	**76**
4.75 mm	**363.1**	**17.45**	**59.00**	=	**59**
2.36 mm	**420.1**	**20.19**	**38.81**	=	**39**
1.18 mm	**306.9**	**14.75**	**24.06**	=	**24**
600 µm	**159.0**	**7.64**	**16.42**	=	**16**
300 µm	**102.2**	**4.91**	**11.51**	=	**12**
75 µm	**111.4**	**5.35**	**6.16**	=	**6.2**
- 75 µm (T)	**128.2**	**6.16**			
Total	**2079.7**				

(A) Weight of original sample **2080.6** g

(B) Weight after washing **1960.3** g

(C) Loss of - 75 µm after wash (A - B) **120.3** g

(D) - 75 µm from sieving (Pan Weight) **7.9** g

(T) Total passing 75 µm (C + D) **128.2** g

T406
Rev. 01-00

West Virginia Division Of Highways

Hot-Mix Asphalt Design Property Worksheet

Lab Number:		Material Type:	Wearing-1
Source:		Project:	
T400 Design Number:	1234567	Field Sample Number:	
Compaction Temperature:	141 °C	Number of Blows:	75
Percent Asphalt:	5.7	Date Sampled:	
Percent Aggregate (Y):	94.3	Date Completed:	
Bulk Aggregate Sp. Gr. (Z):	2.554	Technician:	

Maximum Specific Gravity - Bowl Method (AASHTO T-209)

A	Sample Weight	1205.0
B	Bowl + Sample in Water Weight	2030.1
C	Bowl in Water (Calibration Weight)	1321.5
D	Surface Dry Sample Weight (For Dry-Back Procedure Only)	*******
E	Max. Sp. Gr. = A / [A - (B - C)] or Dry-Back Max. Sp. Gr. = A / [D - (B - C)]	2.427

Bulk Specific Gravity - (AASHTO T-166)

	Compacted Specimens	1	2	3	Average
F	Weight in Air	1216.2	1203.7	1210.6	
G	Saturated Surface Dry Weight	1216.9	1204.4	1211.0	
H	Weight in Water	696.8	688.0	692.7	
J	Bulk Specific Gravity = F / (G - H)	2.338	2.331	2.336	2.335
	Unit Weight (kg/m^3) = J x 1000	2338	2331	2336	2335

Marshall Stability And Flow (AASHTO T-245)

	Specimen Thickness (mm)	63.5	63.5	63.5	63.5
K	Correlation Ratio	1.00	1.00	1.00	
L	Measured Stability (N)	8550	8650	8500	8567
	Adjusted Stability (N) = (K x L)				
	Flow (0.25 mm)	11.5	10.5	11.0	11.0

Void Analysis (AASHTO T-269 And The Asphalt Institute MS-2 Manual)

Percent Air Voids = [(E - J) / E] x 100	3.8
Percent Voids in Mineral Aggregate (VMA) = 100 - [(J x Y) / Z]	13.8

Chapter 5 - Asphalt Mixing Plants

I INTRODUCTION

In this chapter we will explain how an asphalt mixing plant works, how to inspect one and calibrate some of the plant equipment. Additional information can be found in the “Hot-Mix Asphalt Paving Handbook 2000" (HMA Paving Handbook). Section 401 of the Standard Specification Manual contains the WVDOH requirements for asphalt mixing plants.

An asphalt plant technician certification is required for anyone involved in sampling and testing of asphalt mixtures. Technicians may work for the WVDOH or a contractor. The technician may be responsible for obtaining the quality control or acceptance samples that are tested in the laboratory and they may be responsible for actually testing the samples.

The contractor is also required to have at least one certified asphalt plant technician who is in charge of all plant quality control activities such as mix proportioning and adjustment an all sampling and testing activities. With additional Division approved mix design training the technician is also allowed to design asphalt mixtures for the plant.

As mentioned in Chapter 2 - -III there are two main types of asphalt mixing plants: Batch and Drum. There is a third type, continuous mixing plants; however this type of plant is rarely used and will not be discussed in this handbook. Batch and Drum plants differ in the equipment that each uses for mixing and how the materials are proportioned. Each use various combinations of gates, scales, pumps, weight sensors and computer controls to provide the correct combination of aggregate sizes and asphalt content for the mixture being produced. Each plant will be describe below, but for additional information on either refer to Part-II of the HMA Paving Handbook.

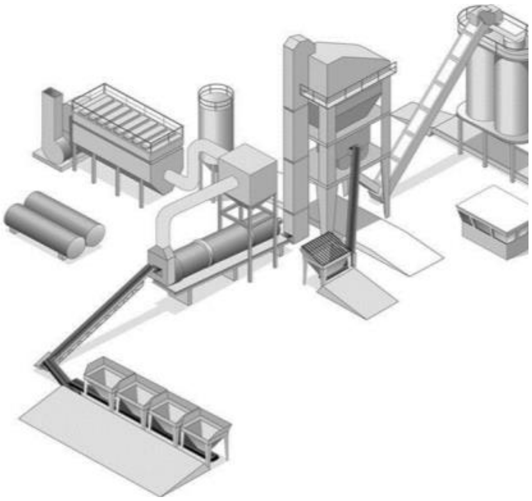


Figure 70 - Asphalt Batch Mixing Plant

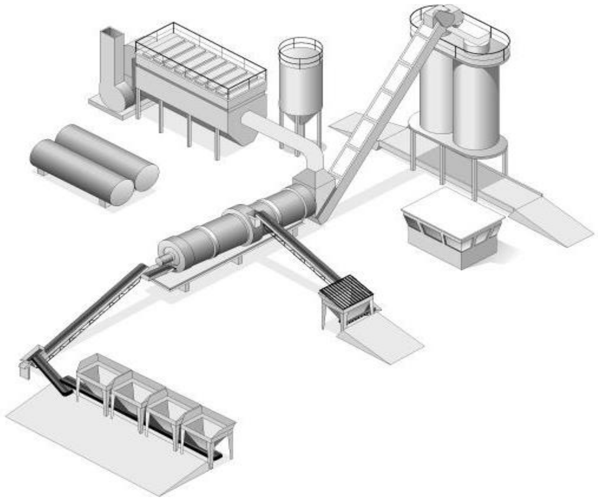


Figure 71 - Asphalt Drum Mixing Plant

II ASPHALT MATERIALS

A) AGGREGATE STOCKPILES

Aggregate should be stored on a clean surface and the various sizes should be separated. The main things to avoid are contamination, degradation, and segregation. Contamination occurs when things get mixed in with the stone. If the stockpile is placed on mud or dirt, the dirt will work its way up into the stockpile. Trucks and loaders working on the stockpile will also deposit mud and dirt. Dust from the plant can also be a problem. We tend not to worry about intermingling of the stockpiles, since all of the aggregates will be blended together in the plant. But this can cause variations in gradation, and is also form of contamination. Placing the stockpile on a stone base prevents contamination from dirt and helps to drain the stockpile. It is important to keep stockpiles well drained because drying aggregate is expensive.

Degradation means that the stone becomes smaller through wear or by being broken. This usually does not change the gradation enough to cause problems, but if it does, the way in which the stone is handled should be changed. For example, try to avoid using tracked vehicles on the stockpile.

Segregation means that the aggregate has become separated by size. Segregation must be kept to a minimum because it can cause large variations in the gradation of the paving mix. A primary cause of aggregate segregation is cone shaped stockpiles. Any time that aggregate is dropped, such as off the end of a conveyor belt, it forms a cone shaped pile. The coarse aggregate rolls down the sides of the pile, while the fine aggregate remains where it was deposited. To reduce aggregate segregation, use more stockpiles with a smaller range of sizes in each pile.

Listed below are some methods for reducing segregation.

- Avoid cone shaped stockpiles.
- When trucks are used, deposit each truckload in a single pile, and keep the piles close together.
- Layer the stockpiles and keep the thickness uniform.
- Avoid any practice that would cause the aggregate to be pushed over the side of the pile.
- Avoid long drops through the air, such as off the end of a conveyor belt.
- When using a crane to stockpile, dump, don't cast.
- Bulkheads can be placed between stockpiles to prevent intermingling of the aggregate.

B) ASPHALT

The asphalt supply system consists of storage tanks, a pump, circulating lines to carry the asphalt between the tank and the plant, a heating system to keep the asphalt hot enough to flow and a means of metering the asphalt into the mix. The asphalt is usually delivered to the plant in trucks and stored in storage tanks. The plant may need more than one storage tank to be able to use more than one grade of asphalt, or to have enough asphalt storage capacity to keep operating between deliveries.

The usual method of heating an asphalt storage tank is to pump hot oil through tubes in the storage tank. In some heating systems, hot gases from the burner pass directly through the tubes. This is called a direct-fired system. When using a direct-fired system, be careful to avoid localized overheating of the asphalt.

A system of circulating lines carries the asphalt between the storage tank and the mixer. The lines must be heated to keep the asphalt viscosity low enough that it will flow through the lines. Low temperature anywhere in the system can clog the lines and stop the asphalt flow.

The combination of heat and air hardens asphalt. The asphalt line should discharge near the bottom of the tank, in order to minimize contact with the air. The pipe that carries unused asphalt back from the plant to the tank will normally have a few slots, located above the level of the asphalt, to break the vacuum when the pump is reversed.

In a batch plant, the asphalt flows continuously from the storage tank, through a pump, and back to the tank. When a batch of paving mix is being made, the asphalt is diverted to a weigh bucket, which is filled until it has enough asphalt for one batch of paving mix. In drum mix plants, asphalt is pumped into the mixer continuously as long as the plant is operating. The amount is controlled by varying the pump speed, or by using a variable volume pump, or with an adjustable valve.

C) MINERAL FILLER

Some rock dust is needed in a paving mix. It fills the spaces between the coarse aggregate particles, reducing the need for asphalt and adding stability. Too much dust causes problems. The dust coats the coarse aggregate so that the asphalt cannot stick to it, or it may combine with the asphalt making it brittle. The amount of dust generated depends on the type of aggregate used and plant's dust collecting system.

Nearly all of the dust can be captured and returned to the mix. If this is more dust than is needed, part of it is can be removed from the system and disposed of. If there is not enough dust in the mix, mineral filler must be added. It should be metered into the mix in controlled quantities. This can be done by packaging the mineral filler in standard sized bags that are added by hand to the mixer, or the filler can be added in bulk from a conveyor belt. Rock dust, cement and fly ash are all used as mineral fillers.

III GENERAL MIXING PLANT COMPONENTS

A) COLD FEED BINS

Aggregate from the stockpiles enters the plant through the cold feed. The cold feed is a set of bins like to that shown in Figure 72. A crane or end loader moves the aggregate from the stockpiles to the cold feed. Each size of aggregate has a separate bin. The purpose of the cold feed is to provide a uniform supply of aggregate to the plant. The bin capacity must be large enough that one bin does not run dry while the other bins are being loaded.

The bin outlet gates are adjustable. The amount of each size of aggregate in the mix can be controlled by changing the gate settings, or adjusting the speed of the conveyor belt that carries the aggregate from the bin.

In a drum mix plant, cold feed adjustment is the only way that to adjust the gradation of the mix. In a batch plant additional adjustments can be made at the hot bins.

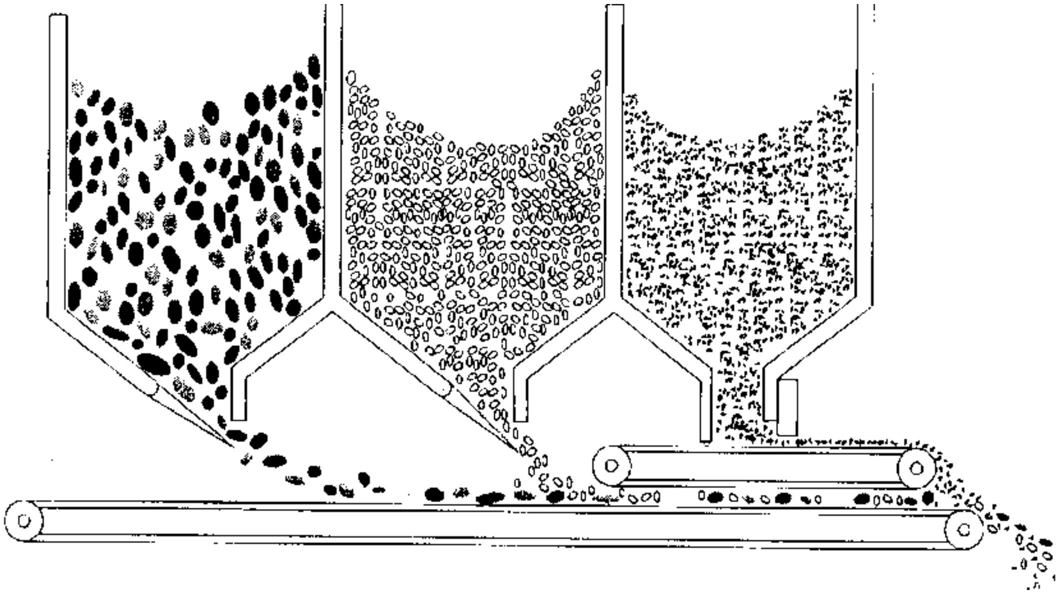


Figure 72 - Typical Asphalt Plant Cold Feed Bins

To keep the aggregate flowing smoothly and to prevent it from hanging up in the bin, one of the following mechanical feeders may be used to help pull the aggregate from the bins:

- Continuous belt - a conveyor belt is used to pull aggregate from the bin. This is the best type of feeder for fine aggregate.
- Vibratory feeder - This shakes the aggregate from the bin.
- Apron flow feeder - A conveyor belt that looks like a tank tread.

Additional information on various feeders types can be found in the HMA Paving Handbook.

B) THE DRYER

The dryer heats and dries the aggregate. It is an essential part of the plant since asphalt will not coat wet or cold stone. The dryer is a steel drum, heated by a gas or oil flame. Steel flanges, called flights are attached to the inside walls of the drum. As the dryer revolves, the flights raise the aggregate and cascade it through the hot air and flame, heating the aggregate and removing moisture. The dryer is tilted, with the aggregate entering at the high end and leaving at the low end. As the stone is raised and dropped by the lifting flights, it moves along to the low end of the drum, where it leaves through a chute.

There are two types of dryers, Counter Flow and Parallel Flow, the difference is the direction of which the aggregate flows to or from the burner. In a Counter Flow dryer the aggregate enters the dryer from the opposite end of the drum from the burner. The parallel flow drum has the aggregate enter on the same end as the burner. Each of the dryers has a section in the Hot-mix Asphalt Paving Handbook.

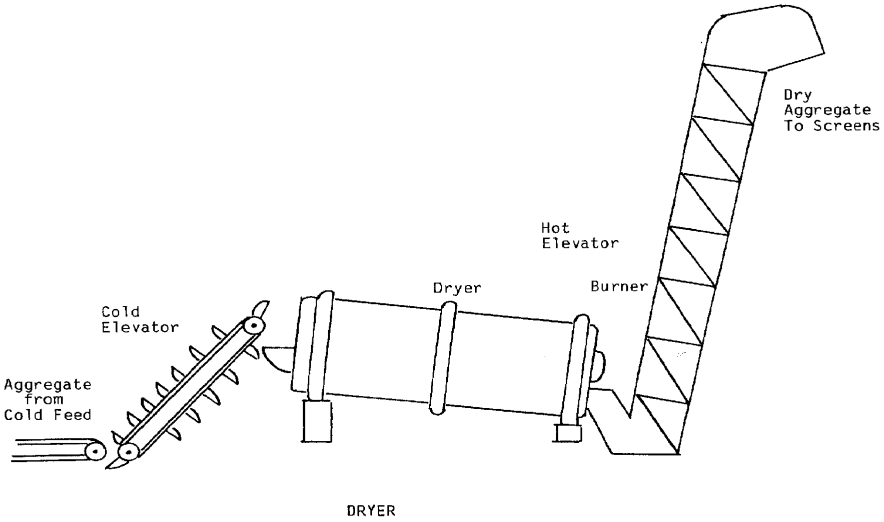


Figure 73 - Typical Asphalt Plant Dryer

Bucket elevators carry the aggregate into and out of the dryer. The elevator that carries the cold aggregate to the dryer is called the cold elevator and the one that carries the hot aggregate out of the dryer is called the hot elevator.

A dryer is expensive to operate. Fuel cost makes it the most expensive part of the plant operation. The amount of aggregate that a dryer can handle depends on its operating efficiency and the amount of moisture in the aggregate. Often the amount of aggregate that the dryer can handle limits the plant production rate. It is important to verify moisture contents of the aggregates being fed into the dryer to monitor the efficiency of the dryer. It is possible that the dryer must be slowed down in order to thoroughly dry the aggregates. One thing to remember is that all aggregates don’t have the same absorption and therefore will likely have differing moisture contents. Fine aggregates typically hold more moisture than coarse.

C) DUST COLLECTORS

One of the by-products of making hot mix asphalt is dust. Dust gets into the plant as a coating on the coarse aggregate and stays there as long as the stone is wet. When the stone dries, the dust blows off into the air. It can be a nuisance and a major source of air pollution.

Asphalt mixing plants located in West Virginia must have a permit from the West Virginia Air Pollution Control Commission. Plants located outside West Virginia must be approved by the air pollution control agency in the state where they are located.

Most dust comes from the dryer. Dust collectors remove the dust from the dryer exhaust gas, either by mechanical means, or by a water spray, or with a fabric filter. Many plants use a combination of these methods.

Mechanical collectors remove the larger dust particles. They are located in the pipes that carry the exhaust gases out of the dryer. They usually consist of baffles in the pipe or an expansion chamber. An expansion chamber is a wide place in the pipe that slows down the gases and allows the dust to fall out.

Another type of mechanical collector is a cone shaped device called a centrifugal collector. As the exhaust gas flows around the cone, the dust hits against the outer wall and falls to the bottom of the collector.

Wet Scrubbers force the exhaust gas through a spray of water. The water and dust are collected in a settling pond. This is an efficient way to collect the dust, but the dust must be discarded in the settling pond and cannot be recovered for further use.

Fabric Filter dust collectors are usually called bag house systems. It works like a vacuum cleaner. The exhaust gases pass through the fabric, leaving the dust on one side and clean air on the other side. Fabric filters are widely used and very effective. Overheating of the dryer must be avoided since the fabric bags will not withstand high temperatures and could melt or catch fire.

D) SURGE AND STORAGE BINS

Surge and storage bins are used for temporary storage of the paving mix. They are intended to make plant operation more efficient. The bin eliminates the need for the plant to stop producing while waiting for trucks, or for the trucks have to wait for the plant to produce more mix. A typical surge or storage bin is a circular silo, which is loaded through the top by a conveyor. It has a gate at the bottom through which the mix can be dumped into a truck.

A surge bin is used to hold paving mix for a short time, usually until a truck is available for loading and not for more than two or three hours. Surge bins are usually not insulated.

Storage bins are used for longer storage. They are bigger than surge bins, are always insulated and usually heated.

Care must be taken to avoid mix segregation in the bin. The mix should enter the bin in such a way that it does not bounce off the side of the bin. The mix must remain hot, but not be overheated. The mix must be protected from air currents, since oxygen hardens the asphalt. The bin gate should be sealed. Sometimes the mix is protected from hardening by filling the bin with an oxygen free atmosphere, such as the exhaust gas from the dryer.

E) TRUCK SCALES

Hot-mix asphalt is usually sold by the ton. The scales are either beam type scales, in which the mass is determined by sliding weights along a calibrated beam, or dial type scales, which is read directly from a dial, or an electronic weighing system, which is often part of a computerized plant operating system.

Computer operated batch plants often use the computer printout of the batch weights, instead of truck scales, to determine the mass of the mix. However this system will only work if the mix is loaded directly from the mixer to the truck without passing through a surge or storage bin.

IV BATCH MIXING PLANT

A) HOT BINS AND SCREENS

A set of vibrating screens, located on the top of the mixing tower, separate the aggregate by size and deposit it in the hot bins. The aggregate is then recombined to meet the specified gradation. Screen openings can be square, rectangular or slotted. Square is most common. The screens can be mounted either on the same level or on top of each other, with the coarsest screen on top.

As the aggregate falls from the hot elevator it lands on a screen that has openings large enough to let sand sized aggregate through into the Number One hot bin. Aggregate that is too large to pass through this screen moves across, or down to the coarser screens, until it either falls through or falls off the end of the last screen. The aggregate that is too coarse to pass through any screen is carried out of the plant through an overflow pipe called a scalping chute.

The screens separate the aggregate by size. Each size is stored in its own bin. Usually two bins are used for a wearing course mix, and up to four bins for a base course. The aggregate falls into the bins, more or less continuously. When the plant operator is ready to make a batch of paving mix, he draws aggregate from each bin in the amount needed to make the mix.

Hot bins smooth out small variations in the cold feed gradation. If the gradation is too variable, or if we try to produce a gradation that cannot be made from the aggregates in the stockpiles, some of the hot bins will either overfill or run dry.

The bin closest to the hot elevator is called the Number One Bin. Since this bin has the screen with the smallest openings over it, it will contain the finest aggregate, and the highest numbered bin will contain the coarsest aggregate.

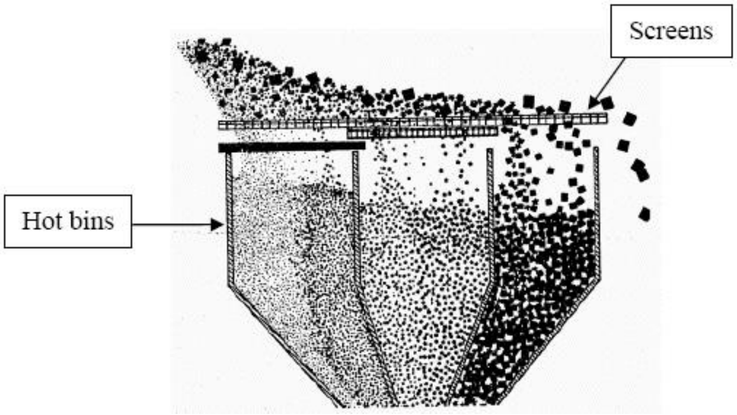


Figure 74 - Batch Plant Hot Bins and Screens

B) WEIGH HOPPER

The weigh hopper is a large steel box attached to a set of scales. It is used to weigh the aggregate and hold it until the mixer is ready for a new batch. The plant operator weighs out the required amount of aggregate from each hot bin, starting with the coarsest aggregate and finishing with the finest (or from the highest numbered bin to the smallest). This insures that when the aggregate is dropped into the mixer, there will be some coarse aggregate at the bottom of the mixer to help blend the other aggregates.

Batch plants have separate scales for the aggregate and asphalt. Older batch plants have either beam type scales, in which the mass is measured by sliding weights along a calibrated beam, or dial type scales, which are read directly from a dial. Nearly all of the newer plants use an electronic weighing system, which is often part of a computerized plant operating system. The most common scale problems are wearing of the knife-edge balances, caused by dust and dirt, and aggregate binding in the scale mechanism.

C) ASPHALT DELIVERY

The asphalt needed to make a batch of mix is weighed into the asphalt weigh bucket. The aggregate is then dropped into the mixer, where after a few seconds of dry mixing, the asphalt is added. On some mixing plants, a fluidometer takes the place of the asphalt weigh bucket. A fluidometer is a pump that can be adjusted to deliver a fixed volume of asphalt to each batch of paving mix.

D) PUG MILL MIXER

A batch plant mixer consists of a mixing chamber, which is lined to reduce wear and two shafts with paddles. The paddle tips are adjustable and fairly easy to replace. Asphalt is pumped into the mixer and sprayed over the aggregate through a spray bar. When the mixing is completed, a gate at the bottom of the mixer is opened and the completed mix drops into a truck.

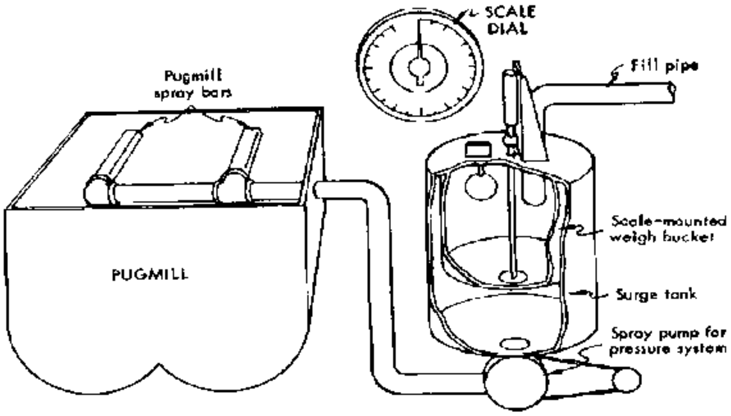


Figure 75 - Batch Plants Pugmill and Asphalt Delivery System

Dry mixing time is the time from when the aggregate enters the mixer until the asphalt is first added. Dry mix time should be as short as possible, usually one or two seconds. Wet mix time begins when the asphalt is added and is normally about 30 seconds.

The hot asphalt spreads in a thin film over the aggregate, which is moving rapidly through the air. All of this promotes very rapid oxidation. More hardening of asphalt takes place in the mixer than in any other part of the paving operation, so the mixing time should be the shortest time that will permit complete coating of the aggregate. When it is necessary to slow down production, either hold the aggregate in the weigh hopper, or periodically stop the plant, but do not increase the mixing time for this purpose.

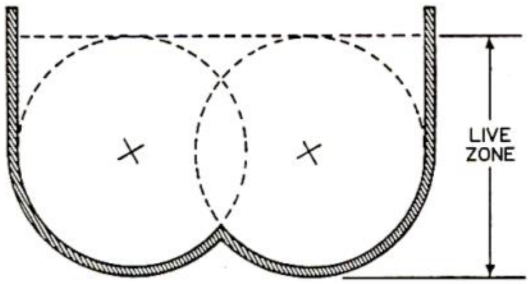


Figure 76 - Live Zone of a Pugmill

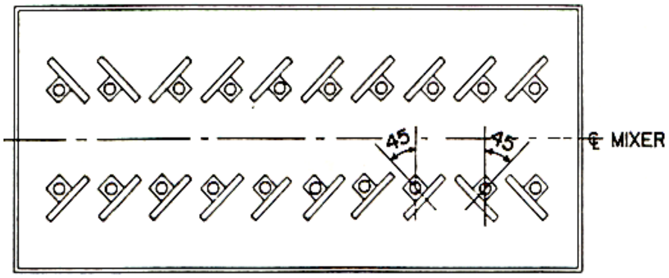


Figure 77 - Pug Mill Typical Paddle Arrangement

The West Virginia specifications specify a mixing time of 45 seconds, unless test data shows that a uniform mix can be obtained in a shorter time.

Any area in the mixer where the material is not thoroughly mixed because the paddles do not reach it is called a dead zone. Some causes of dead zones are as follows:

- The mixer is so overloaded that the paddle tips are completely covered and the aggregate above the paddle tips is not mixed.
- Paddle tips are badly worn, or two adjacent paddle tips are broken or twisted.
- The mixer liner is worn, causing too much clearance between paddle tips and liner.
- The fine aggregate or the asphalt is not evenly distributed through the mixer.
- The mixer is underfilled and the materials are just tossed around rather than mixed.

E) RECLAIMED ASPHALT PAVEMENT (RAP) IN A BATCH PLANT

Reclaimed asphalt pavement (RAP) is not put in the dryer with the other aggregate because the heat would damage the asphalt and produce lots of smoke. The usual method of handling reclaimed pavement is to heat the new aggregate to above the target mix temperature, add the RAP at some point beyond the dryer (usually the weigh hopper) and let heat transfer bring the mix to the desired temperature.

In practice the maximum temperature to which the new aggregate can be heated is about 475° F (250°C) since higher temperatures would damage the dryer. The amount of RAP material in a paving mix can be as high as 50 percent, but often it has to be lower if the moisture content of the RAP is high. RAP content may also be limited by nonuniform gradation if the RAP is not further processed into two or more separate stockpiles of different aggregate sizes.

The RAP can be added at the hot elevator, although this is best done at a plant that does not use screens, since the RAP would tend to clog them. The RAP also can be added at the hot bins; either with the fine aggregate in the Number One bin, or into a separate bin that is not used for any other aggregate. The advantage of using the Number One bin is that the hot aggregate helps to heat the RAP. The disadvantage of using any of the hot bins for RAP is that the asphalt sticks to the bin walls and can cause major aggregate build-up problems.

The weigh hopper is generally the best place to add RAP. It is fed into the hopper from a separate conveyor. It can be added in any order, except it should not be the first aggregate added, since this would cause asphalt build-up on the weigh hopper walls.

V DRUM MIXING PLANT

A drum mix plant is basically a type of continuous mix plant. It is simpler in design or operation than a batch plant, but it is much more automated and requires computer controls to operate. The components of a drum mix plant are:

- Cold Feed
- Asphalt supply system
- Drum mixer (which serves as both a dryer and a mixer)
- Surge or storage bin
- Dust control system

A drum mix plant has no screening unit or hot bins. All mix adjustments must be made at the cold feed. A surge or storage bin is essential, since it produces paving mix continuously, and cannot easily be stopped to wait for a truck to arrive. A drum mix plant requires more stockpiles and more narrowly graded stockpiles to control the gradation. Drum mixer plants are much more portable than batch plants.

Additionally drum mix plant have no screens or hot bins to smooth out variations in the stockpile aggregates, so care must be taken to see that the stockpiles are properly placed and handled, and that they are uniform and have the correct gradation. The aggregate should be stored on a clean surface, and should be split into several stockpiles, each having a small range of stone sizes.

A) COLD FEED BINS

The cold feed bins have adjustable discharge gates and a conveyor belt to carry the aggregate to the dryer. The gate settings and often the belt speed are adjustable. The conveyor belt has a weight sensing device, and a belt speed sensor. The accuracy of the weighing device shall be within 1.0 % of the actual weight being measured when that weight has been determined using another measuring device and shall be within 0.5 % when that weight has been determined using test weights (AASHTO M156). The computer uses this information to calculate how much aggregate is being fed into the plant, corrects for moisture in the aggregate, calculates how much asphalt is needed, and adjusts the asphalt pump accordingly.

Some plants have weight sensors on each cold feed belt, but most have only one, located on the conveyor that carries the aggregate to the dryer. The information supplied by the weight sensor and the belt speed sensor are used to find the rate at which the cold feed is delivering aggregate to the dryer.

The conveyor belt should fit tightly around the pulley to which the belt speed sensor is attached. Otherwise slipping of the belt will cause the belt speed reading to be wrong.

The conveyor belt of a drum mix plant should be equipped with a scraper or brush to clean wet fine aggregate from the belt. Otherwise this wet material will go around and around the belt, being weighed each time, and causing the computer to overestimate the amount of aggregate going into the plant.

The moisture content of the aggregate should be determined, so that the computer can correct for moisture when setting the aggregate feed rate.

B) DRYER - MIXER

The dryer-mixer looks very much like the dryer on a batch or continuous plant, but it has a dual purpose. It both dries the aggregate and mixes the asphalt with the aggregate. As the aggregate first enters the dryer, the lifting flights alternately raise and drop the aggregate through the heated air from the burner. Then the asphalt is added at a point far enough down the dryer that the aggregate is no longer in direct contact with the flame, usually around the middle of the dryer. As the aggregate is lifted and dropped by the lifting flights, it becomes coated with asphalt. The moisture remaining in the aggregate causes the asphalt to foam. This aids in coating the aggregate and also traps dust. What comes out of the far end of the dryer is a completed paving mix, ready to load into trucks and send to the project.

The most frequently used type of drum called a parallel flow mixer. The aggregate enters the drum at the burner end. The asphalt (and recycle material, if used) is added at about the middle of the drum. There are other kinds of drums. In some only the aggregate passes through the dryer, with the asphalt being added in a separate chamber at the end of the drum. There is also a double drum mixer, in which the aggregate is dried in the inner drum and then passes into an outer drum, where the asphalt and reclaimed material are added.

C) RECLAIMED ASPHALT PAVEMENT (RAP) IN A DRUM PLANT

Reclaimed material may contain large chunks of pavement, so there is usually a scalping screen, or sometimes a crusher somewhere in the system. Reclaimed material could be fed into the plant with the new aggregate, but to avoid problems such as smoke, fire, and asphalt sticking to the bin walls, it is added elsewhere, usually at either the midpoint or the far end of the dryer. This allows the reclaimed material to be heated without coming into direct contact with the dryer flame.

D) ASPHALT DELIVERY SYSTEM

The asphalt metering system controls the rate at which the asphalt is added. The control system monitors the mass of the aggregate on the belt and the speed of the belt. It uses this information, and the aggregate moisture, to set and adjust the asphalt feed rate to give the required asphalt content.

If the asphalt enters the dryer too close to the burner end of the drum, it will be overheated. It may be absorbed into the aggregate, and what asphalt is left on the aggregate surface may become so hard and brittle that it loses its adhesive properties. The plant will give off blue smoke from the burning of volatile components of the asphalt. The moisture content may be high because the aggregate was coated with asphalt before the moisture had time to evaporate.

On the other hand, if the asphalt is introduced too close to the outlet end of the drum, the asphalt will not do a good job of trapping dust and the aggregate may be too dry to be completely coated by the asphalt.

VI PLANT INSPECTION

The requirements for asphalt mixing plants can be found in Section 401 of the Standard Specifications with any revisions available in The Supplemental Specifications.

A) BATCH PLANTS SPECIFIC INSPECTION ITEMS

A weigh hopper is used to proportion the aggregate. It consists of a large bin attached to a set of scales. Only batch plants have weigh hoppers to weigh the aggregate and weigh buckets to proportion the asphalt. Some of the things to look for when inspecting a batch plant are as follows:

- The hot bin gates must close tightly. Otherwise aggregate will leak into the weigh hopper and cause the gradation of the next batch to be in error.
- The aggregate scales must be accurate to within 0.5% and easily read. A set of ten 50-pound weights and one 5-pound weight (for sensitivity checks) are used to calibrate the scales.
- A means must be provided for taking hot bin samples. They are usually taken as the aggregate passes from the hot bins to the weigh hopper. The sampling device must be long enough to sample the whole stream of aggregate. This is because the finer stone tends to pass through the screen first, so the gradation is not uniform across the bin. The finer material is found on the side nearest the hot elevator.
- Hot bin samples are needed to determine the batch weights. If the gradation of the combined hot bin samples does not meet the plant mix formula, then the batch weights must be adjusted, or if this does not work, a new plant mix formula must be established.
- The weigh hopper must not bind against any part of the plant. Any aggregate lodged between the weigh hopper and its supports must be removed.
- The asphalt weigh bucket must be insulated, and the asphalt scales must return to zero after the bucket is emptied. The asphalt valve should close tightly and not drip. The tare weight of the weigh bucket should be checked frequently because asphalt tends to build up inside the bucket.
- Some batch plants use a fluidometer instead of asphalt scales and a weigh bucket. This is an adjustable pump that can be set to deliver a fixed amount of asphalt per batch. To calibrate a fluidometer either use the fluidometer to fill a container of known volume and compare the volume to the fluidometer reading, or pump the asphalt into a tared container and weigh it. Some fluidometers are temperature compensated. If not, a temperature correction factor must be applied.
- The spray bar must be heated and must be long enough (at least 3/4 the length of the mixer), so that no aggregate is left uncoated.
- All parts of the asphalt system (tanks, circulating lines, valves, weigh bucket, spray bar) must be heated and insulated.
- It is important to check the condition of the mixer paddles since broken or worn paddles can result in aggregate segregation and uncoated mix. The Asphalt Institute recommends that if the broken or worn paddles are widely spaced, they should be

replaced at the end of the working day, but if two adjacent paddles are broken, they should be replaced immediately.
- The specifications require that hot-mix asphalt produced in a batch plant be mixed for at least 45 seconds, unless tests show that a shorter mixing time gives a satisfactory asphalt coating. A time lock is required to insure that the mix is not dumped from the mixer before the specified mixing time has elapsed.

B) DRUM MIX PLANTS SPECIFIC INSPECTION ITEMS

These plants do not have screens or hot bins and the dryer is also the mixer. The plant consists of three main units: the cold feed, the dryer/mixer, and a surge or storage bin. The plant also has an asphalt storage tank and a dust collector.

A drum mix plant often has more cold bins than other types of plants, because the cold bins are the only means controlling the gradation. Weight sensing devices located on the conveyor belts measure the amount of aggregate entering the dryer.

A computer controls the asphalt content of the mix by adjusting the output of the asphalt pump to compensate for changes in the aggregate feed rate. The asphalt is added through a spray bar at about the midpoint of the dryer. The completed mix then goes from the dryer to a surge or storage bin. Some of the items to look for when inspecting a drum mix plant are as follows:

- The cold feed must be constructed so that aggregate samples can be obtained from it.
- There should be a weight sensing device and a belt speed sensor on the conveyor belt.
- The dryer/mixer must be able to heat and mix the materials without stripping the asphalt from the aggregate or causing excessive hardening of the asphalt.
- There must be positive interlock of asphalt and aggregate feed, so that if one changes there is a proportional change in the other. In practice, this usually means that a computer controls the asphalt and aggregate feed rates.

VII AVOIDING MATERIAL AND EQUIPMENT PROBLEMS

Asphalt Concrete requires quality materials and a mixing plant in good working order. The following paragraphs list some of the problems that can occur at the mixing plant.

A) STOCKPILES

The storage yard should be kept neat and orderly. Stockpiles containing different aggregate sizes should be separated. If there is not enough space, bulkheads may be used to keep them apart.

Materials such as sand and single sized aggregates can be stockpiled by almost any method with little segregation. Aggregates with a range of sizes tend to segregate, especially if the stockpile is formed by dropping the aggregate, such as off the end of a conveyor belt. The segregation occurs because the coarse aggregate tends to roll down the sides of the pile, while the fine aggregate stays where it lands, so the coarser aggregate ends up at the outside edge of the pile. Although cone shaped stockpiles are common, they do not have a uniform gradation and it is difficult to get a representative sample from them.

Trucks or cranes can be used to make layered stockpiles. These are less likely to segregate than cone shaped stockpiles, but the trucks may track mud onto the stockpile, and tracked vehicles may crush the aggregate.

With proper care, segregation can usually be kept within acceptable limits. If not, the segregated aggregate can sometimes be reblended when transferring it to the cold feed. This is usually done by alternately scooping from coarse and fine sections of the pile.

Stockpiles of reclaimed material are handled in about the same way as new aggregate. It may be necessary to limit the height of the stockpile to keep the material from packing together under its own weight.

Dust, in small quantities acts as an extender and reduces the amount of asphalt needed. In large quantities, it increases the amount of asphalt needed and makes the mix brittle. When baghouse dust is added to the paving mix as a mineral filler, it should be added in uniform quantities. If the dryer has not adequately dried the aggregate, or if the mineral filler has not been protected from the weather, moisture can cause dust balls to form in the paving mix.

To get a representative stockpile sample, take the sample at several locations and levels. A metal plate or a piece of plywood can be stuck into the pile above the sample site to keep aggregate from rolling down the pile into the sampling area. A scoop or shovel with raised sides should be used to keep the aggregate from spilling off the sides. Larger aggregates require larger samples. The sample must be big enough so that one large rock does not make a large difference in test results. Once the sample has been obtained, it can be reduced to test size by quartering or with a sample splitter.

B) ASPHALT STORAGE

Asphalt must be kept hot both in the storage tank and in the lines between the tank and the mixer. Asphalt becomes solid when it cools and can completely clog the lines, stopping production, or partially clog the lines and result in a mix that does not have enough asphalt. It is essential that both tank and lines be heated and insulated.

A paving mix contains much more aggregate than asphalt, so the temperature of the aggregate determines the temperature of the mix. If the aggregate is overheated, it also overheats the asphalt, causing it to oxidize, become brittle and have a dull black appearance.

Asphalt in the storage tank can be heated well above the normal mixing temperature without damage. But if the asphalt is too hot when it is added to the mix, the asphalt coating on the stone will be thin, tend to drain from the stone, and the mix will not stick together very well. The mix will have a brown color, and the stone may show through the asphalt.

A return line from the mixer to the storage tank is needed, so that unused asphalt can be returned to the storage tank. Otherwise, the asphalt might solidify in the lines. A thermometer is required in the circulating line and most plants also have one on each storage tank.

C) COLD FEED

The cold feed consists of several bins filled with aggregate. Each size of aggregate should have its own bin. Anything that causes the output of the cold feed to vary must be avoided, since variations in the cold feed can cause problems elsewhere in the plant, such as changes in the gradation or temperature of the mix, or hot bins that overflow or run dry.

The following are examples of problems that may originate in the cold feed:

- Moisture can change the rate at which the aggregate comes out of the cold feed, causing erratic gradation. It can also act as a lubricant and speed up the aggregate, or make it stick together and slow it down.
- Variable moisture content of the aggregate causes the mix temperature to be erratic.
- Wet sand tends to arch or otherwise hang up in the bin. This causes the mix to be too coarse and then when the sand breaks loose, the mix becomes too fine. Using a vibratory feeder can prevent this problem.
- Large rocks sometimes get into the bin and clog the outlet gate. This can be cured by placing a steel grid on top of the bin.
- Incorrect bin proportions cause overloaded hot bin screens. This results in carry-over, hot bins running dry or overflowing, loss of aggregate through the scalping chute, and variable mix gradation.

While some adjustments in gradation can be made in the plant, in the long run, what goes in the cold feed comes out the pugmill, so the cold feed determines the gradation of the mix. The following are some of the things that can be done to reduce cold feed problems and insure that the gradation meets specifications:

- Use the right size of aggregate
- Try to prevent aggregate segregation
- Avoid intermingling of stockpiles
- Once the gates are calibrated secure them so if they are changed, the plant technician will know about it.
- Check for obstructions such as tree branches or rocks blocking the gates.
- Keep cold feed bins full.
- Use bulkheads to prevent intermingling from the bins overflowing.

D) THE DRYER

A dryer is designed to provide a certain amount of air and heat. If the aggregate is too wet, or the feed rate is too high, the dryer can't do its job. Asphalt will not coat aggregate that is cold or wet. If aggregate is dry on the surface, but wet inside, the moisture may come out of the mix as steam and strip the aggregate from the stone. This type of problem is best solved by slowing down the aggregate feed rate into the dryer.

A low mix temperature or high moisture content is an indication of dryer problems. Other indications that the aggregate is not being dried are: an unusually large amount of steam coming from the hot bins or from the mix, flattening of the mix in the truck bed, or water dripping from the truck bed. Too much moisture often causes the mix to look as though it contains too much asphalt. Increasing the heat, slowing down the dryer, or reducing the aggregate feed rate can usually correct dryer problems.

The specifications require that the aggregate temperature be measured as it leaves the dryer. This is usually done with an electric pyrometer. The pyrometer is located in a metal shield at the discharge end of the dryer. The temperature indicator may either show the temperature on a dial or record it on a graph. The temperature indicator must be in a location where the plant operator can see it.

A pyrometer measures small changes in electrical resistance caused by changes in temperature. Moisture, loose connections and splices in the wire also cause resistance changes, so the pyrometer may get out of adjustment and have to be recalibrated.

If a drum mix plant is operating efficiently, the temperature of the exhaust gas should be no more than about 10° C higher than the mix temperature, except that higher temperature differences may be unavoidable if a high percent of reclaimed material is used. High exhaust temperature indicates that the veil of aggregate in the dryer is not being properly maintained, or there may be an air leak in the dust control system.

Fuels used the dryer include gases (natural gas or liquefied petroleum gas), liquids (fuel oil), or solids (pulverized coal). With any of these fuels, the burner adjustment can cause problems. If the balance of the air and fuel is not right, the dryer will produce lots of smoke and not much heat. Dryer problems are commonly caused by soot on the burner, leaks in the air system, or the blower not working properly.

Incomplete combustion occurs when the fuel to air ratio is too high. This wastes fuel and often results in underheated aggregate. The unburned fuel can coat the aggregate with an oily film or dilute the asphalt. Signs of incomplete combustion are black smoke coming from the plant exhaust; dark sooty stains on the aggregate leaving the dryer, or a sputtering sound from the burner. Other signs of incomplete combustion are an oily film on the surface of the settling pond, or dark stains on the filter bags in the bag house, or an increase in the pressure across the bag house.

The material coming from the dryer should have a uniform color and the fine aggregate should be evenly distributed through the mix. A dark stain on the coarser stone indicates incomplete combustion of the fuel.

If a plant uses a highly absorptive or very wet aggregate, modifications to the dryer may be needed. For example, reducing the slope of the dryer, or rearranging the lifting flights to slow down the aggregate, or a second dryer may be needed.

E) SCREENS

Screens can develop rips or tears, or become so worn that they allow oversized aggregate to pass through. The screens must be able to handle the aggregate that is fed to them and have some excess capacity since some of the openings will eventually become blocked by aggregate sticking in them. Even screens that are in good condition can become clogged, or be fed aggregate faster than they can handle it. When this happens, the aggregate that should fall through a screen, passes over it and is deposited in the bin that should contain the next larger size. This is called carry-over. There is always some carry-over and there is no way to eliminate it completely. Up to 10 percent carry-over is considered acceptable. It becomes a problem when it becomes so large or variable that the gradation cannot be controlled.

Screen problems are often discovered by testing samples from the hot bins. Carry-over should be suspected when undersized aggregate is found in a bin. The opposite problem of oversized aggregate in a hot bin, is usually caused by a hole in a screen.

F) HOT BINS

Hot bins provide temporary storage for the aggregate as it comes from the screening unit and remix it to meet the required gradation. Drum mixer plants do not have hot bins. The aggregates are mixed entirely at the cold feed.

Hot bins often overflow or run dry. An overflowing hot bin wastes aggregate. A hot bin that runs dry slows production because the plant operator must wait for more material to fall into the bin before he can continue weighing out the batch. The operator may also be tempted to pull heavily from the bin that has plenty of aggregate, causing the gradation to be considerably off. Although the problem shows up at the hot bins, it usually originates somewhere else. The cold feed may have been set wrong, or the stockpile gradation may have changed, so that the hot bins are getting too much or too little of one of the aggregate sizes. Hot bin problems can usually be corrected by adjusting the cold feed.

Clogged screens, or holes in the bin walls, also cause problems. These should be checked periodically.

Moisture in the aggregate may condense on the bin walls and cause fine aggregate to build up in the corners of the hot bins. This tends to break loose all at once, causing a surge of fines in the mix. It can be corrected by installing fillet plates in the corners of the number one bin, or by installing a steel plate at the top of the bin to deflect the fines toward the center of the bin.

If the overflow pipes are too small or they are stopped up, oversized aggregate may overfill the whole hot bin system. As the bins fill up, aggregate overrides the bin partitions and ends up in the wrong bins. The screens may be damaged by riding on top of aggregate, and the gradation will not be anything close to what was expected.

Loss of aggregate through the overflow pipe should be rare, since it means that the money that was paid to buy and heat the aggregate is being wasted.

Aggregate is sometimes deposited in the hot bins in alternating coarse and fine layers. This is called stratification, and it is usually caused by variations in the stockpiles or erratic operation of the cold feed. Stratification makes it impossible to obtain a representative hot bin gradation, and may show up in the road as variations in the appearance of the mix.

G) SURGE AND STORAGE BINS

Surge bins are used to hold paving mix for a short time. Their purpose is to permit the plant to keep running when there are no trucks available for loading. Storage bins are used for longer-term storage.

Dropping the mix through the bin can cause aggregate segregation, especially when it is dropped a long distance. For this reason, operating at a low bin level is not good practice, and dropping the mix straight through the bin into a truck is prohibited by the specifications.

Aggregate segregation across the bin can happen when the mix is dumped into the bin from a conveyor belt, since the larger pieces of aggregate tend to fall to the far side of the bin. This sometimes shows up as a visible change in gradation across the road. This side-to-side segregation can be corrected by using baffles or a rotating chute to spread the mix around the bin.

When the mix drops to the bottom of the bin, it forms a cone shaped pile. This may cause aggregate segregation, especially if the mix is coarse or gap graded. A small surge hopper at the top of the bin can be used to drop the mix in large enough batches that it flattens out when it hits the bottom of the bin, instead of forming a cone.

Paving mix that is stored in a heated, sealed bin can usually be stored for several hours, or under ideal conditions, for days. Densely graded mixes can be stored longer than coarse or open graded mixes, since air currents do not pass through them as readily. When bins are used for long-term storage, they may have an inert gas system to prevent oxidation of the asphalt. The inert gas is often the exhaust gas from the dryer. The exhaust gas has had most of the oxygen burned out of it, and so it doesn't react with the asphalt as fresh air would.

Prolonged storage may cause the asphalt to strip from the aggregate. The stripping is usually caused by moisture from incompletely dried aggregate. A silicone additive can prevent this.

H) TRUCKS

The paving mix must arrive at the project while it is still hot enough to be compacted. Long haul distances and unexpected delays can cause major problems. The following are some of the items to check when inspecting trucks:

- The truck bed must be insulated.
- A canvas cover is required. This protects the mix from rain and from air currents. Oxygen in the air reacts with asphalt, making it brittle and difficult to compact, so it is important that the canvas cover be used even on hot days and that it extends over the sides of the truck.
- The truck bed must be lubricated to keep paving mix from sticking to it. This is to prevent the formation of lumps of cold paving mix that stick to the truck bed and later work loose and end up in the pavement.
- Soapy or oily liquids can be used to lubricate the truck bed. Several silicone-based materials are also made for this purpose. Petroleum products, such as diesel fuel, should not be used because they dilute the asphalt.
- Check for holes in truck bed, deep indentations, or anything harmful to the mix.

I) OBSERVATION OF THE PAVING MIX

Here are some of the things to look for when checking the paving mix.

- Temperature - a leading cause of trouble. Check frequently.
- Blue Smoke - indicates overheating
- Peaked pile - indicates under heating
- Mixer gate opens slowly or incompletely - causes segregation

Some easy to spot indications of problems with mix:

- Appearance not uniform
- Lean or dry looking mix, usually brown in color
- Fat or over-asphalted mix
- Brown stripped asphalt on top of pile caused by escaping moisture.
- Sluggish appearance as mix settles in the truck (underheating)
- Mix slumps in the truck (moisture or too much asphalt)

Cold Feed	Controls gradation and production rate.	Adjust gates & belt speed to control gradation & production rate.	Adjust gates & belt speed to control gradation and production rate.
Dryer	Heats and dries the aggregate.	Adjust burner & feed rate to control mix temperature & moisture content.	Adjust burner & feed rate to control mix temperature & moisture content. Asphalt added here.
Screening Unit	Smooth out variations in gradation. Separates aggregate by size.	Change mix type by changing screen sizes. Replace worn out screens when needed.	Doesn't have a screening unit. Gradation is controlled at cold feed.
Hot Bins	Aggregate proportioning and temporary storage.	Adjust bin proportions to control gradation Check scales for accuracy.	No hot bins. Aggregates proportioned at cold feed and mixed in dryer.
Mixer	Mixes the aggregates & asphalt.	Check for worn paddles or liner. Time lock regulates mixing time.	No mixer. Mixing is done in dryer. Computer controls mixing time.
Surge & Storage Bins	For temporary mix storage.	Optional equipment. Check periodically. Mix may cool, harden, or strip during storage.	Needed to store mix between trucks. Mix may cool, harden, or strip during prolonged storage.

VIII CALIBRATIONS

A) TEMPERATURE CALIBRATIONS

Temperature is very important to the quality of the pavement and should be checked both at the plant and at the project. Mix temperature may be checked with a dial type thermometer, placed in a hole in the side of the truck. An infrared thermometer may also be used, and is generally preferred because it's greater speed and ease of use.

B) SCALE CALIBRATION

The procedure for scale calibration and accuracy checks is given in Section 708 of the Construction Manual. MP 700.00.30 provides information pertaining to the calibration of the 50-pound weights. The scales must be approved by the Division of Weights and Measures. A summary of this procedure is as follows.

- A zero balance check is required twice a day. Zero balance means that the scale reading must return to zero when the weigh hopper is emptied. If it does not, the cause should be found and corrected immediately.
- A sensitivity check is required twice a day. When a 50-pound weight is placed on the loaded weigh hopper, the scale reading must increase by at least 30 pounds for

aggregate scales and 49 pounds for asphalt scales. If this requirement is not met, the scales must be inspected as soon as possible.

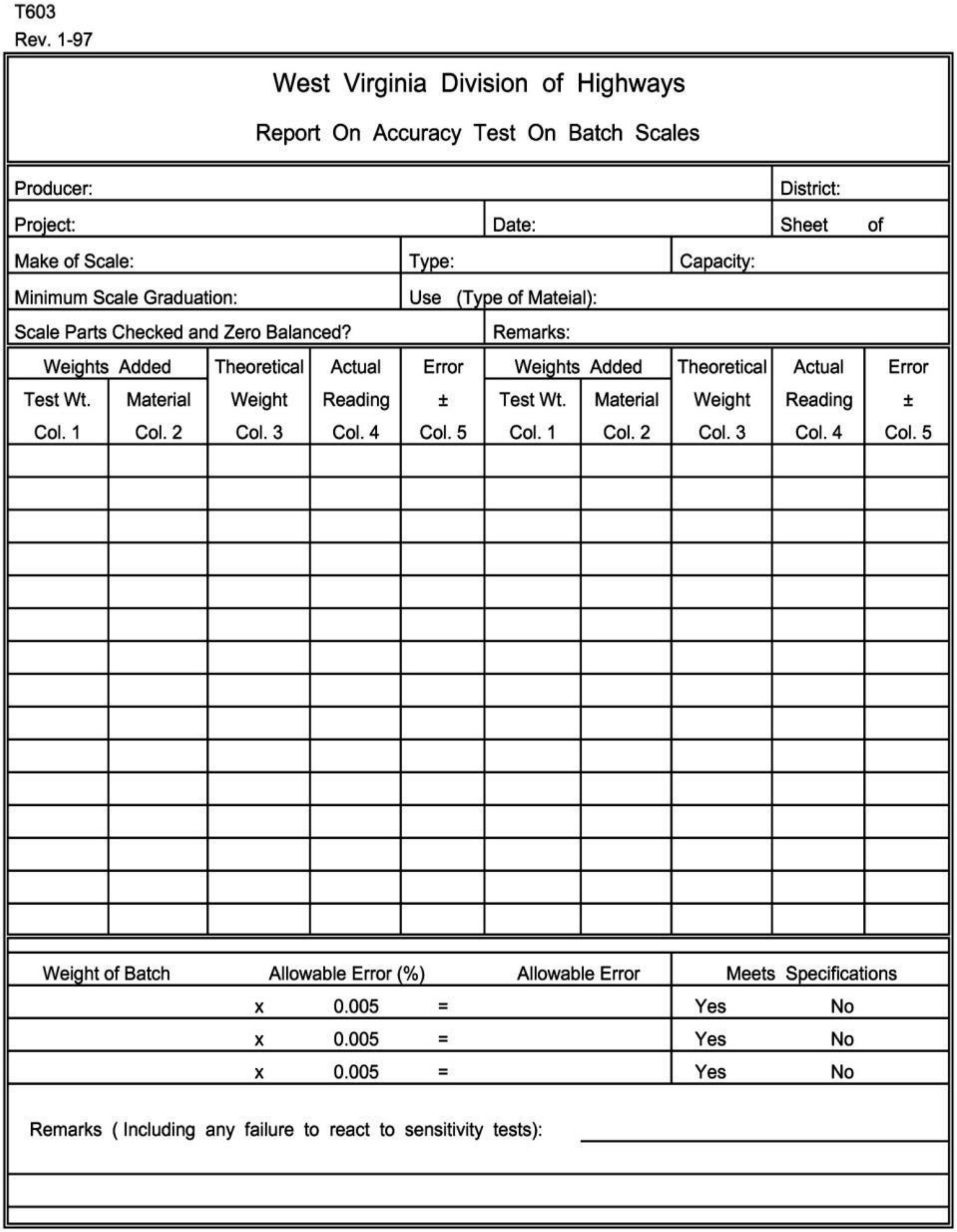
- A simplified calibration of the aggregate scales is conducted weekly and a complete calibration approximately twice a year. The scales must meet the requirements of the Division of Weights and Measures.
- An asphalt scale calibration consists of alternately placing weights and aggregates on the scales at 500 pound intervals, until the total mass is slightly above the expected batch weight. This is usually done twice a year.

C) AGGREGATE SCALE CALIBRATION

On the following page is an example of Form T603. This is the form used for calibrating aggregate scales. The procedure for checking the accuracy of aggregate scales is as follows:

- Place the weights on the weigh hopper. The scale dial should now read 500 pounds. The difference between 500 pounds and what the dial does read is the error.
- Remove the weights.
- Add aggregate to the weigh hopper until the dial reads the same as it did in Step 1.
- Put the weights back on the hopper. The theoretical mass is now 1000 pounds (500 pounds of aggregate and 500 pounds of weights). The difference between 1000 and what the dial reads is the error.
- Repeat, adding 500 pounds more of aggregate each time, until the mass is equal to or greater than the largest weight that you intend to weigh when batching the mix.
- The allowable error is 0.5 percent (1/2 pound in 100 pounds). If any of the observed errors exceed this, the scales must be repaired.

Table 18 - Calibration of Scales Form T603



T603
Rev. 1-97

West Virginia Division of Highways

Report On Accuracy Test On Batch Scales

Producer:
District:
Project:
Date:
Sheet of
Make of Scale:
Type:
Capacity:
Minimum Scale Graduation:
Use (Type of Mateial):
Scale Parts Checked and Zero Balanced?
Remarks:

Weights Added		Theoretical	Actual	Error	Weights Added		Theoretical	Actual	Error
Test Wt.	Material	Weight	Reading	±	Test Wt.	Material	Weight	Reading	±
Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 1	Col. 2	Col. 3	Col. 4	Col. 5

Weight of Batch		Allowable Error (%)		Allowable Error	Meets Specifications	
	x	0.005	=		Yes	No
	x	0.005	=		Yes	No
	x	0.005	=		Yes	No

Remarks (Including any failure to react to sensitivity tests): ______________________

IX SUMMARY

In this chapter we have covered how a hot-mix asphalt plant works, plant inspection, calibration and accuracy checks of scales and thermometers, and checking the accuracy of batch weights.

More detailed information on how a hot-mix asphalt plant works can be found in the HMA Paving Handbook.

X REVIEW

The following questions are similar to those that will be given on the certification examination. The answers may be found on the page following the last question.

1. How is the gradation controlled in a drum mix plant?
    a. By adjusting the batch weights
    b. The gradation cannot be adjusted
    c. By adjusting the cold feed gates.
2. Aggregate is carried from the dryer to the screens by the _________.
    a. cold elevator
    b. hot elevator
    c. overflow chute
3. Some batch plants do not have asphalt scales. Instead the asphalt is measured by a device called a:
    a. weigh bucket
    b. lifting flight
    c. fluidometer
4. The hot mix asphalt produced at a batch plant contains too much fine aggregate. Carry-over is suspected to be the cause. Where is the best place to take a sample to find out if carry-over really is the cause?
    a. from the truck
    b. from the hot bins
    c. from the cold feed gates
5. If a hot bin runs dry, it is an indication that:
    a. the aggregate is not dry
    b. the production rate is too low
    c. the cold feed is out of balance
6. Asphalt storage tanks are required by the specifications to be:
    a. insulated
    b. equipped with a double set of steam coils
    c. at least 250 gallon capacity

7. In which type of plant is the asphalt added in the dryer?
    a. batch plant
    b. drum mix plant
    c. both of the above
8. Automated batch plants, with digital printout, are not required to have which of the following?
    a. cold bins
    b. hot bins
    c. truck scales
9. High moisture content can cause a paving mix to appear to have:
    a. too much aggregate
    b. too much asphalt
    c. not enough asphalt
10. Ten 50-pound test weights are placed on an asphalt scale. The dial reads 505 pounds. The scale error is which of the following?
    a. 1.0%
    b. 0.1%
    c. 10.0%
11. Trucks that haul hot mix asphalt are required to have which of the following?
    a. A canvas cover
    b. An aluminum bed
    c. At least five axles
12. Asphalt lines must be heated because:
    a. Cold asphalt will not coat the aggregate.
    b. The asphalt will solidify and clog the lines.
    c. Both of the above.
13. The return line, which carries the asphalt back to the storage tank, should discharge below the surface of the asphalt. Why?
    a. To protect the hot asphalt from oxygen in the air.
    b. To keep the tank from overflowing.
    c. Both of the above.
14. On a batch plant, where is the asphalt added?
    a. The hot bins
    b. The weigh hopper
    c. The mixer

XI REVIEW ANSWERS

1) . (c) By adjusting the cold feed gates.
2) . (b) Hot elevator
3) . (c) Fluidometer
4) . (b) From the hot bins
5) . (c) Cold feed out of balance
6) . (a) Insulated
7) . (b) Drum mixer plant
8) . (c) Truck scales
9) . (c) Too much asphalt
10) . (a) 1.0%
11) . (a) A canvas cover
12) . (c) Both of the above
13) . (a) Prevent exposure to air
14) . (c) The mixer

Chapter 6 - Job Mix Formula and Quality Assurance Testing

I JOB MIX FORMULAS

The Job Mix Formula (JMF) formerly referred to as Plant Mix Formula – PMF, is a description of an approved mix design. It references the types of materials, the producer, and sources of the materials, percentages of the component materials, temperatures, design properties, and other important information relating to a specific mix design.

For identifying the various types of asphalt concrete in our systems, the WVDOH uses a set of materials codes to designate the type of asphalt concrete that is used in highway construction. The following table shows material codes that are used for the various asphalt concrete mix types (Marshall & Superpave) and the PG Binders that have been used, on our paving projects. These are not all of the codes that are used. The entire lists of Site Manager codes may be found on the MCS&T website.

Table 19 - Asphalt Concrete Mixture Design Codes for Site Manager

Marshall Mixes	Material Code	Superpave Mixes	Material Code
Base - 1	401.002.001	37.5 mm	401.002.006
Base - 2	401.002.002	25 mm	401.002.007
Wearing - 1	401.002.003	19 mm	401.002.008
Wearing - 3/Ultra-Thin Overlay	401.002.004	12.5 mm	401.002.009
Base - 2/Wearing - 4	401.002.005	9.5 mm	401.002.010
Wearing - 1 Skid	402.002.012	4.75 mm	401.002.011
Wearing - 3 Skid	402.002.018	19 mm Skid	402.002.014
Base - 2/Wearing - 4 Skid	402.002.013	12.5 mm Skid	402.002.015
		9.5 mm Skid	402.002.016
Miscellaneous Mixes		4.75 mm Skid	402.002.017
Asphalt, Cold In-Place Recycled	494.001.001		
Asphalt, Micro-Surfacing	495.001.001	PG Binders	
High-Performance Thin Overlay[#]	402.002.017	PG 58-28	705.005.001
Bituminous Patching Winter Grade	412.002.001	PG 64-22	705.005.003
		PG 64-28	705.005.002
		PG 70-22	705.005.004
*** Polymer Modified**		PG 70-22 PM*	705.005.005
# HPTO (4.75mm Skid)		PG 76-22 PM*	705.005.006

A) AGGREGATE MASTER RANGE

It varies from year-to-year, but there are between 60 and 70 hot mix asphalt plants in and around West Virginia that can produce hot mix asphalt for the West Virginia Division of Highways (WVDOH). These plants use a wide variety of equipment and numerous types and sizes of aggregate. A general specification called the Master Range covers the allowable ranges for gradation for all common mix types produced for the WVDOH. In order to account for the wide variety of equipment and materials, the Master Range has to be very broad and liberal. In fact, the wide variation of the master range alone does not guarantee a good quality mix. Therefore, a stricter specification called the Job Mix Formula was added. The JMF is a specification covering a single mix, produced at a single plant.

The Master Range for a Marshall mix design can be found below in Table 20 or in Table 401.4.2A of the standard specifications. The Master Range Superpave mix design can be found below in Table 21 or Table 401.4.2B in the standard specifications. The master range contains the requirements for all of the commonly used mix types. The requirements of the master range are intended to provide a mix with large enough aggregate for good stability, but not so large that any stone is thicker than the pavement layer in which it will be used. It must also have enough medium and fine aggregate to fill in the spaces between the coarse aggregate particles and provide a dense, durable pavement.

Table 20 - Design Aggregate Gradation Requirements for Marshall Design

TYPE OF MIX	Base-I	Base-II (Patch & Level)	Wearing-IV	Wearing-I (Scratch-I)	Wearing-III (Scratch-III)
SIEVE SIZE	Nominal Maximum Size				
	1 ½ in (37.5 mm)	¾ in (19 mm)	¾ in (19 mm)	3/8 in (9.5 mm)	No. 4 (4.75 mm)
2 in (50 mm)	100				
1 ½ in (37.5) mm)	90 - 100				
1 in (25 mm)	90 max	100	100		
¾ in (19 mm)		90 – 100	90 – 100		
½ in (12.5 mm)		90 max	90 max	100	
3/8 in (9.5 mm)				85 - 100	100
No. 4 (4.75 mm)			47 min	80 max	90 - 100
No. 8 (2.36 mm)	15 – 36	20 – 50	20 – 50	30 – 55	90 max
No. 16 (1.18 mm)	-	-	-	-	40 - 65
No. 30 (600 μm)	-	-	-	-	-
No. 50 (300 μm)	-	-	-	-	-
No. 200 (75 μm)	1.0 – 6.0	2.0 – 8.0	2.0 – 8.0	2.0 – 9.0	3.0 – 11.0

Table 21 - Design Aggregate Gradation Requirements for Superpave Design

Nominal Max. Size	37.5 mm (1 ½ inch)	25 mm (1 inch)	19 mm (3/4 inch)	12.5 mm (1/2 inch)	9.5 mm (3/8 inch)	4.75 mm (No. 4)
Standard Sieve Size	Type of Mix					
	37.5	25	19 Note	12.5	9.5	4.75
50 mm (2”)	100					-
37.5 mm (1½”)	90 – 100	100				-
25 mm (1”)	90 max	90 – 100	100			-
19 mm (3/4”)		90 max	90 – 100	100		-
12.5 mm (1/2”)			90 max	90 - 100	100	100
9.5 mm (3/8”)				90 max	90 - 100	95 - 100
4.75 mm (No.4)					90 max	90 - 100
2.36 mm (No.8)	15 – 41	19 – 45	23 – 49	28 - 58	32 - 67	
1.18mm (No.16)						30 - 60
600 µm (No.30)						-
300µm (No. 50)						-
75 µm (No.200)	0.0 – 6.0	1.0 - 7.0	2.0 - 8.0	2.0 - 10.0	2.0 - 10.0	6.0 – 12.0

Note: When a 19 mm mix is specified for use as a heavy duty surface mix, it shall be designed as a fine graded mix with the additional requirement of a minimum of 47% passing the 4.75 mm (No.4) screen.

B) SELECTING A JOB MIX FORMULA

The design requirements for Marshall mix designs are described in MP 401.02.22 and the requirements for Superpave designs are described in MP 401.02.28. Laboratories that develop mix designs for the WVDOH are required to be inspected by the AASHTO Materials Reference Laboratory (AMRL). These inspections must be periodically updated in accordance with the routine schedule of AMRL (approximately every 18 to 24 months). Also, the design technician must have attended a WVDOH approved class on mix design. The WVDOH Materials Division maintains a list of approved mix design laboratories and technicians.

Using the Marshall design method in accordance with MP 401.02.22, the design technician determines the gradation, asphalt content and temperature at which the asphalt concrete will be produced and submits this data to the WVDOH. These values must be within the limits of the master range. In addition to these requirements the Marshall design criteria in the table below must be met. If the WVDOH approves the technician's proposed design, it becomes the Job Mix Formula, and is the specification to which the contractor must produce the paving mix.

Table 22 - Marshall Method Mix Design Criteria MP 401.02.22 - Table 1

Design Criteria	Medium Traffic Design (Note 2)	Heavy Traffic Design	Base-I (Heavy Traffic Design) (Note 4)
Compaction, number of blows each end of specimen **(Note 3)**	50	75	112
Stability (Newton) minimum	5,300	8,000	13,300
Flow (0.25 mm) **(Note 5)**	8 to 16	8 to 14	12 to 21
Voids Filled With Asphalt (%) (Note 6)	65 to 80	65 to 78	64 to 73
Air Voids (%)	4.0		
Fines-to-Asphalt Ratio	0.6 to 1.2		

Note 2: If the traffic type is not provided in the contract documents, contact the District to obtain this information before developing the mix designs.
Note 3: All Wearing-III mixes shall be designed as a 50 blow mix regardless of traffic type.
Note 4: All Base-I mixes will be designed and tested using 112 blows with six inch diameter specimens in accordance with ASTM D 5581.
Note 5: When using a recording chart to determine the flow value, the flow is normally read at the point of maximum stability just before it begins to decrease. This approach works fine when the stability plot is a reasonably smooth rounded curve. Some mixes comprised of very angular aggregates may exhibit aggregate interlocking which causes the plot to produce a flat line at the peak stability before it begins to drop. This type of plot is often difficult to interpret, and sometimes the stability will even start increasing again after the initial flat line peak. When such a stability plot occurs, the stability and flow value shall be read at the initial point of peak stability.
Note 6: A Wearing-I heavy traffic design shall have a VFA range of 73–78 percent. A Wearing-III mix shall have a VFA range of 75–81 percent.

In addition to Table 22, the percent voids-in-mineral aggregate (VMA) for Marshall designs shall be as shown in Table 23.

Table 23 – Marshall Design Percent Voids in Mineral Aggregate MP401.02.22 - Table 2

Mix Type	Nominal Size Sieve	Percent Voids in Mineral Aggregate (VMA) (minimum)
Wearing-III & Scratch-III	4.75 mm (No. 4)	17.0
Wearing-I & Scratch-I	9.5 mm (⅜ in.)	15.0
Base-II, P&L & Wearing-IV	19 mm (¾ in.)	13.0
Base-I	37.5 mm (1 ½ in.)	11.0

Note: Mixtures designed with the VMA exceeding the minimum value by more than two percent may be susceptible to flushing and rutting problems, especially when used on pavements subjected to slow moving traffic conditions. They may also be difficult to compact as they often have a tendency to shove under the roller.

Similarly, using the Superpave design method in accordance with MP 401.02.28, the design technician determines the gradation, asphalt content and temperature at which the asphalt concrete will be produced and submits this data to the WVDOH. These values, of course, must be within the limits of the master range. In addition to these requirements the Superpave volumetric design criteria in the following table must be met. If the WVDOH approves the technician's proposed design, it becomes the Job Mix Formula, and is the specification to which the contractor must produce the paving mix.

Table 24 - Superpave Method Volumetric Design Criteria MP 401.02.28 - Table 1

<table>
<tr><td colspan="4">Design air void content, percent</td><td colspan="3">4.0</td></tr>
<tr><td colspan="4">Fines-to-effective asphalt (FA) ratio (Note 1)</td><td colspan="3">0.6 – 1.2</td></tr>
<tr><td colspan="4">Tensile strength ratio, percent (T 283) (Note 2)</td><td colspan="3">80 (minimum)</td></tr>
<tr><td rowspan="2"></td><td colspan="6">Nominal Maximum Size, mm (in.)</td></tr>
<tr><td>37.5
(1½)</td><td>25
(1)</td><td>19
(¾)</td><td>12.5
(½)</td><td>9.5
(⅜)</td><td>4.75
(No.4)</td></tr>
<tr><td>Percent Voids in Mineral Aggregate (VMA) (Note 3)</td><td>11.5</td><td>12.5</td><td>13.5</td><td>14.5</td><td>15.5</td><td>16.5</td></tr>
<tr><td>Percent Voids Filled with Asphalt (VFA)</td><td>65 – 75</td><td>68 – 76</td><td>70 – 78</td><td>72 – 79</td><td>74 – 80</td><td>75 – 81</td></tr>
</table>

Note 1: When the design aggregate gradation falls within the coarse graded requirement of Table 4, the FA ratio criteria shall be 0.8 – 1.6. For all 4.75 mm (No. 4) mixes, the FA ratio shall be 0.9 - 2.0.

Note 2: Test specimens shall be compacted using a gyratory compactor in accordance with T 312. If the 80 percent minimum tensile strength ratio is not met, a new design will be required. A Division approved antistripping additive, such as hydrated lime conforming to the requirements of M 303 or a liquid antistripping additive, may be added to the mixture if needed. The additive must be identified on the T400SP Form. T 283 shall be waived when a new mix design is developed using all of the aggregate sizes and sources of a previously approved mix design that has met the required tensile strength ratio of at least 85 percent. This waiver information should be noted on the submitted design package along with the previously approved design T400SP number to inform the MCS&T why T 283 test data has not been included. If the approved design contained an antistripping additive, then the new design must also contain this additive. MCS&T may request the tensile strength ratio be checked at any time on any design that is shown to exhibit signs of stripping.

Note 3: Mixtures designed with the VMA exceeding the minimum value by more than two percent may be susceptible to flushing and rutting, especially when used on pavements subjected to slow moving traffic conditions. They may also be difficult to compact as they often have a tendency to shove under the roller.

On the following pages are examples of Job Mix Formulas for both Marshall and Superpave mix designs. The Job Mix Formula is the specification for a specific paving mix, and is what will be used to determine whether or not samples of the paving mix meet specifications. The differences between the Marshall and Superpave JMF are based on the design criteria for each mix type as indicated on the previous pages.

At the top of the form is listed general information that describes the mix this JMF represents. This includes the individual laboratory number assigned to the mix design, the date the mix was accepted, the type of mix (including material code), producer name, district, type of plant, plant location (including the source code assigned to that specific plant), plant make, the person who designed the mix, design lab, and the traffic type for which the design was developed.

The second section of the form covers the mix composition of the design. There are quality requirements for asphalt and aggregate, and this section provides the information needed to determine if the proposed sources of asphalt and aggregate have been approved. In addition, if the mix is designed to be used as a skid surface mix, the coarse aggregates used in the design must be approved by the WVDOH as polish resistant materials. This section includes the names of the aggregate sources including the source code assigned to them, the type of aggregate from each source (including material code and the percentage of total aggregate), the binder type with material code, the binder source with source code, and the percentage of RAP (Reclaimed Asphalt Pavement) used in the design as well as the percentage of virgin binder in the RAP used. MP 401.02.24 supplements design MP 401.02.22 and MP 401.02.28 with additional design criteria regarding RAP in asphalt concrete.

The percentage of RAP that can be used in a mix is determined by Special Provision 401.4.3. It allows all Marshall Base 1 mixes as well as Superpave 25 mm and 37.5 mm mixes to use up to 25% RAP without a binder grade adjustment. It also allows Marshall Base 2 and Superpave 19 mm mixes to use up to 25% RAP without a binder grade adjustment under specific conditions according to Sections 401.4.3.1, 401.4.3.2, and 401.4.3.3 in Special Provision 401.4.3.

The third section on the JMF includes the Sieve Fraction for the aggregates used for the mix. For each sieve this section lists the target percentage of aggregate that will pass the sieve, as well as the allowable range for percentages passing the control sieves.

The last section on the JMF is the Job Mix Formula Values section. This includes fines to asphalt ratio, the various volumetric requirements, and the various temperature ranges required.

This section includes the accepted target values JMF tolerances for percent asphalt, percent air voids, percent voids-in-mineral aggregate, voids filled with asphalt, and for Marshall designs, stability and flow with all of the production maximum and minimum targets listed for these properties. Also, in this section is the maximum density (G_{mm}) and bulk specific gravity of aggregate (G_{sb}) of the accepted, as well as the number of hammer blows used for compaction for Marshall mixes or the number of gyrations used for compaction for Superpave mixes. For Superpave mixes, the tensile strength ratio of the mix is also listed in this section.

The fines to asphalt ratio is another item included in this section of the JMF. The specifications require a ratio of between 0.6 and 1.2 based on the total asphalt content of the mix for Marshall designs and based on effective asphalt content for Superpave designs. See Superpave design criteria notes on Table 24, for exceptions to this specification range. The high limit is used to control asphalt film thickness. High dust contents will reduce film thickness, which in turn can result in raveling and/or stripping. The low limit is used to assure some dust in the mix to aid coating and make the asphalt mix more cohesive.

The allowable temperature range of the mix is also included in this section. The allowable temperature range of the mix is ± 14 °C (± 25 °F) from the desirable mean temperature established by the Temperature Viscosity Chart of the liquid asphalt. The Temperature-Viscosity Chart is provided by the supplier and must be current. Also listed are the mixing temperature and compaction temperature for the mix, which must also be within the ranges listed on the Temperature Viscosity Chart.

There are 3 other types mix designs worth mentioning; Micro-surfacing, High Performance Thin Overlay, and Ultra-Thin Overlay. These mixes are used primarily as preservation treatments for existing asphalt pavements. The JMF for Micro-surfacing must meet the requirements contained in Special Provision Section 495. Micro-surfacing is a combination of an emulsion, water, fine aggregate and mineral filler. It is used to repair small defects and improve skid resistance.

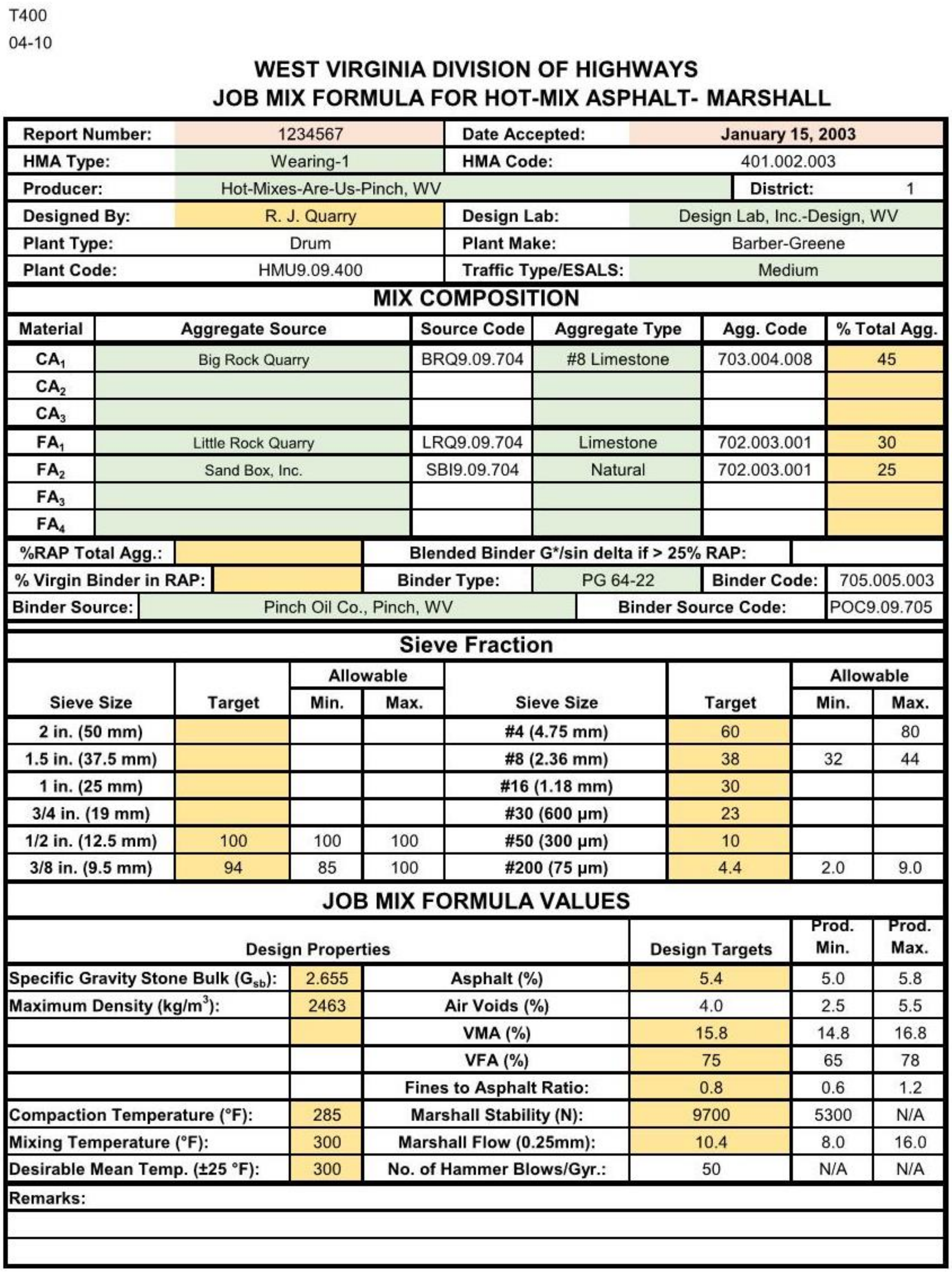
High Performance Thin Overlay (HPTO) is mix design in accordance with the Superpave Design System. The JMF must meet the requirements of Special Provision Section 496. It is used for moderate stresses in existing pavement that doesn’t require structural rehabilitation.

The Ultra-Thin Asphalt Overlay is a single lift ranging from 5/8th to 3/4th of an inch. It also known as a Wearing-3 Heavy mix and must meet the requirements of Special Provision Section 498.

C) JOB MIX VERIFICATIONS

For each JMF, mix design field verifications must be conducted during the first days of plant production for the purpose of demonstrating that the JMF can be produced within the specification tolerances of either MP 401.02.27 for Marshall designs or MP 401.02.29 for Superpave designs.

This verification consists of randomly selected asphalt concrete samples taken in accordance with AASHTO T168 for each three hours of production, with no more than three samples in one day. A minimum of three samples are required for verification, however, three additional samples must be taken if none of the first three samples are completely within the specification limits of Table 401.02.27A for Marshall designs and Table 401.02.29A for Superpave designs, reproduced below in Table 25 and Table 27 respectively. At least one of the first three samples, six if necessary, is required to meet all of the requirements of the corresponding table listed above.



T400
04-10

WEST VIRGINIA DIVISION OF HIGHWAYS
JOB MIX FORMULA FOR HOT-MIX ASPHALT- MARSHALL

Report Number:	1234567	**Date Accepted:**	**January 15, 2003**
HMA Type:	Wearing-1	**HMA Code:**	401.002.003
Producer:	Hot-Mixes-Are-Us-Pinch, WV	**District:**	1
Designed By:	R. J. Quarry	**Design Lab:**	Design Lab, Inc.-Design, WV
Plant Type:	Drum	**Plant Make:**	Barber-Greene
Plant Code:	HMU9.09.400	**Traffic Type/ESALS:**	Medium

MIX COMPOSITION

Material	Aggregate Source	Source Code	Aggregate Type	Agg. Code	% Total Agg.
CA$_1$	Big Rock Quarry	BRQ9.09.704	#8 Limestone	703.004.008	45
CA$_2$					
CA$_3$					
FA$_1$	Little Rock Quarry	LRQ9.09.704	Limestone	702.003.001	30
FA$_2$	Sand Box, Inc.	SBI9.09.704	Natural	702.003.001	25
FA$_3$					
FA$_4$					

%RAP Total Agg.:		**Blended Binder G*/sin delta if > 25% RAP:**			
% Virgin Binder in RAP:		**Binder Type:**	PG 64-22	**Binder Code:**	705.005.003
Binder Source:	Pinch Oil Co., Pinch, WV			**Binder Source Code:**	POC9.09.705

Sieve Fraction

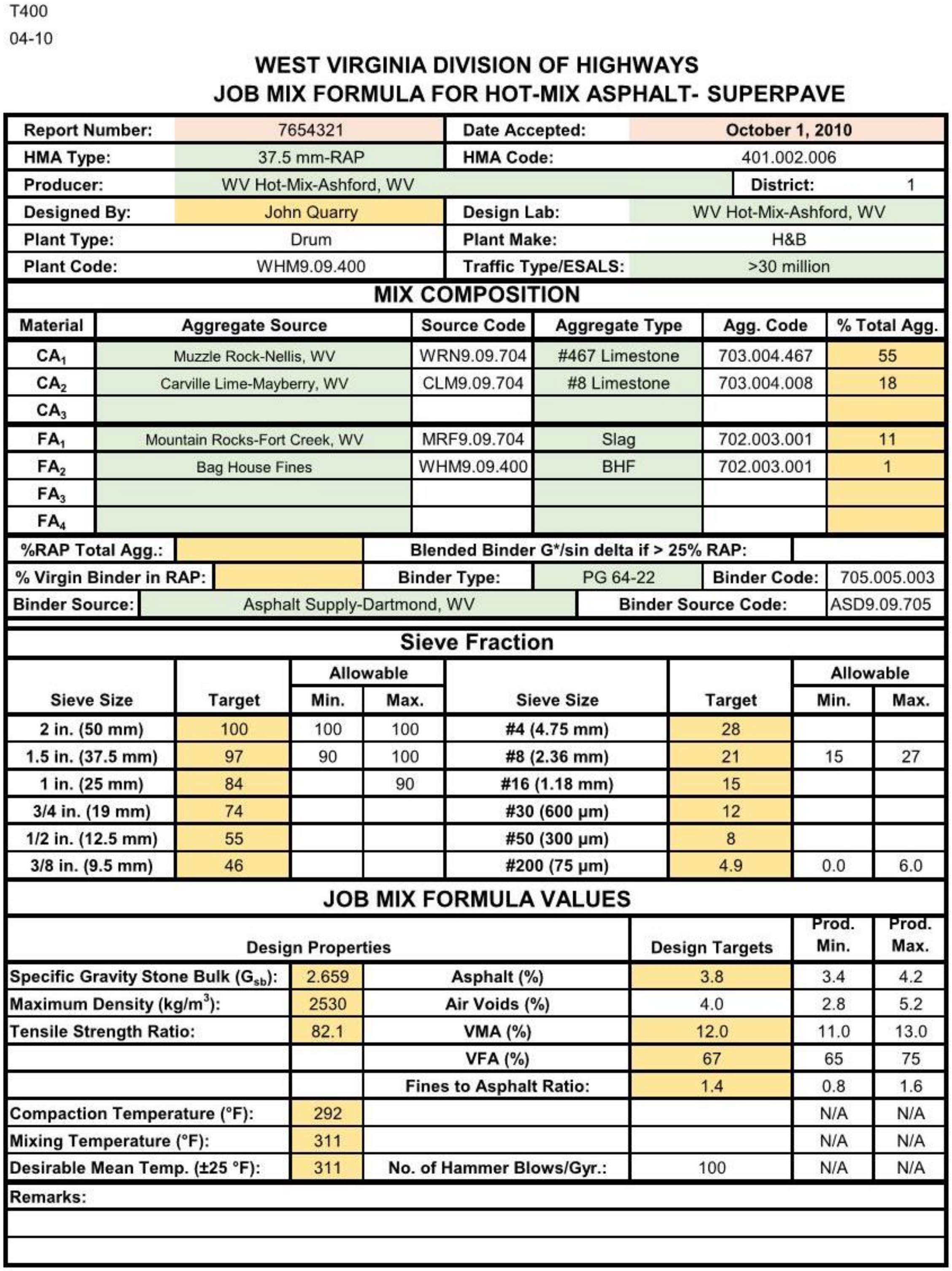
		Allowable				Allowable	
Sieve Size	Target	Min.	Max.	Sieve Size	Target	Min.	Max.
2 in. (50 mm)				#4 (4.75 mm)	60		80
1.5 in. (37.5 mm)				#8 (2.36 mm)	38	32	44
1 in. (25 mm)				#16 (1.18 mm)	30		
3/4 in. (19 mm)				#30 (600 μm)	23		
1/2 in. (12.5 mm)	100	100	100	#50 (300 μm)	10		
3/8 in. (9.5 mm)	94	85	100	#200 (75 μm)	4.4	2.0	9.0

JOB MIX FORMULA VALUES

Design Properties			Design Targets	Prod. Min.	Prod. Max.
Specific Gravity Stone Bulk (G_{sb}):	2.655	Asphalt (%)	5.4	5.0	5.8
Maximum Density (kg/m^3):	2463	Air Voids (%)	4.0	2.5	5.5
		VMA (%)	15.8	14.8	16.8
		VFA (%)	75	65	78
		Fines to Asphalt Ratio:	0.8	0.6	1.2
Compaction Temperature (°F):	285	Marshall Stability (N):	9700	5300	N/A
Mixing Temperature (°F):	300	Marshall Flow (0.25mm):	10.4	8.0	16.0
Desirable Mean Temp. (±25 °F):	300	No. of Hammer Blows/Gyr.:	50	N/A	N/A

Remarks:

Figure 78 - Marshall Mix Design T400



T400
04-10

WEST VIRGINIA DIVISION OF HIGHWAYS
JOB MIX FORMULA FOR HOT-MIX ASPHALT- SUPERPAVE

Report Number:	7654321	**Date Accepted:**	**October 1, 2010**
HMA Type:	37.5 mm-RAP	**HMA Code:**	401.002.006
Producer:	WV Hot-Mix-Ashford, WV	**District:**	1
Designed By:	John Quarry	**Design Lab:**	WV Hot-Mix-Ashford, WV
Plant Type:	Drum	**Plant Make:**	H&B
Plant Code:	WHM9.09.400	**Traffic Type/ESALS:**	>30 million

MIX COMPOSITION

Material	Aggregate Source	Source Code	Aggregate Type	Agg. Code	% Total Agg.
CA_1	Muzzle Rock-Nellis, WV	WRN9.09.704	#467 Limestone	703.004.467	55
CA_2	Carville Lime-Mayberry, WV	CLM9.09.704	#8 Limestone	703.004.008	18
CA_3					
FA_1	Mountain Rocks-Fort Creek, WV	MRF9.09.704	Slag	702.003.001	11
FA_2	Bag House Fines	WHM9.09.400	BHF	702.003.001	1
FA_3					
FA_4					

%RAP Total Agg.:		**Blended Binder G*/sin delta if > 25% RAP:**			
% Virgin Binder in RAP:		**Binder Type:**	PG 64-22	**Binder Code:**	705.005.003
Binder Source:	Asphalt Supply-Dartmond, WV			**Binder Source Code:**	ASD9.09.705

Sieve Fraction

		Allowable				Allowable	
Sieve Size	**Target**	**Min.**	**Max.**	**Sieve Size**	**Target**	**Min.**	**Max.**
2 in. (50 mm)	100	100	100	**#4 (4.75 mm)**	28		
1.5 in. (37.5 mm)	97	90	100	**#8 (2.36 mm)**	21	15	27
1 in. (25 mm)	84		90	**#16 (1.18 mm)**	15		
3/4 in. (19 mm)	74			**#30 (600 µm)**	12		
1/2 in. (12.5 mm)	55			**#50 (300 µm)**	8		
3/8 in. (9.5 mm)	46			**#200 (75 µm)**	4.9	0.0	6.0

JOB MIX FORMULA VALUES

Design Properties			Design Targets	Prod. Min.	Prod. Max.
Specific Gravity Stone Bulk (G_{sb}):	2.659	**Asphalt (%)**	3.8	3.4	4.2
Maximum Density (kg/m^3):	2530	**Air Voids (%)**	4.0	2.8	5.2
Tensile Strength Ratio:	82.1	**VMA (%)**	12.0	11.0	13.0
		VFA (%)	67	65	75
		Fines to Asphalt Ratio:	1.4	0.8	1.6
Compaction Temperature (°F):	292			N/A	N/A
Mixing Temperature (°F):	311			N/A	N/A
Desirable Mean Temp. (±25 °F):	311	**No. of Hammer Blows/Gyr.:**	100	N/A	N/A

Remarks:

Figure 79 - Superpave Mix Design T400

The verification test results will be recorded on Form T408 for Marshall designs and T422 for Superpave designs, reproduced in Table 29 and Table 31 respectively. Samples used for the gradation analysis during the Marshall design verification process may be obtained from hot bins, cold feeds, extracted asphalt concrete samples via the asphalt ignition oven. Superpave verification process requires that material for gradation analysis be obtained from the asphalt ignition oven samples (AASHTO T308). If there is a problem with aggregate breakdown which affects the gradation test results when using the ignition oven, gradation samples may be obtained from hot bins, cold feeds, or extracted asphalt concrete samples. Gradation results for either Marshall or Superpave verification will be recorded on Form T421 reproduced in Table 30. Field verification gradation requirements for Marshall and Superpave are listed in Table 401.02.27B and Table 401.02.29B which have been reproduced below as Table 26 and Table 28 respectively. The gradation results must fall within the limits of each listed control point with the exceptions as noted on the No. 8 and No. 16 sieves.

If all of the requirements of the Marshall verification (Tables 401.02.27A and 401.02.27B) or the Superpave verification (Tables 401.02.29A and 401.02.29B) are met on at least one of the three, six if necessary, field verification samples then the design verification can be approved. If approved, a new target maximum density for field compaction will be established. This target shall be determined by multiplying the average maximum specific gravity (AASHTO T209) of the three, or six, field verification samples by 1000 kg/m3 the density of water- and rounding the value to the nearest whole number. For example if the average maximum specific gravity was 2.459 then the target maximum density would be 2.459 x 1000 = 2459 kg/m3. If no single field verification sample meet all of the requirements described above for Marshall or Superpave then production must halt and a new mix design is required.

Table 25 - Marshall Designs Mix Property Field Design Verification Requirements - Table 401.02.27A

Property	Field Verification Tolerances
Asphalt Content (%)	JMF ± 0.4 %
Air Voids (%) – Base-I	3.0 – 6.0 %
Air Voids (%)	3.0 – 5.0 %
Voids in Mineral Aggregate (VMA) %	Minimum of 0.5% Below Design Criteria
Stability (Newtons)	Minimum Design Criteria
Flow (0.25 mm)	Limits of Design Criteria

Table 26 - Master Range for Hot-Mix Asphalt Total Percent Passing Each Sieve - Table 401.02.27B

TYPE OF MIX	Base-I	Base-II (Patch & Level)	Wearing IV	Wearing-I (Scratch-I)	Wearing-III (Scratch-III)
SIEVE SIZE	Nominal Maximum Size				
	1 ½ in (37.5 mm)	3/4 in (19 mm)	3/4 in (19 mm)	3/8 in (9.5 mm)	No. 4 (4.75 mm)
2 in (50 mm)	100				
1 ½ in (37.5) mm)	90 - 100				
1 in (25 mm)	90 max	100	100		
¾ in (19 mm)		90 – 100	90 – 100		
½ in (12.5 mm)		90 max	90 max	100	
3/8 in (9.5 mm)				85 - 100	100
No. 4 (4.75 mm)			47 min	80 max	90 - 100
No. 8 (2.36 mm)	15 – 36	20 – 50	20 – 50	30 – 55	90 max
No. 16 (1.18 mm)					40 - 65
No. 30 (600 µm)					
No. 50 (300 µm)					
No. 200 (75 µm)	1.0 – 6.0	2.0 – 8.0	2.0 – 8.0	2.0 – 9.0	3.0 – 11.0

Note 1: Allowable tolerances for each JMF shall be the specified design control points shown in Table 401.02.27B with the exception that a Wearing-III mix shall have a tolerance limit of the JMF ± 5% on the 1.18 mm (No. 16) sieve and all other mix types shall have a tolerance limit of the JMF ± 6% on the 2.36 mm (No.8) sieve. These tolerances shall be applied to both the field design verification testing of the JMF, daily quality control testing, and district verification testing.

Table 27 - Superpave Designs Mix Property Field Design Verification Requirements - Table 401.02.29A

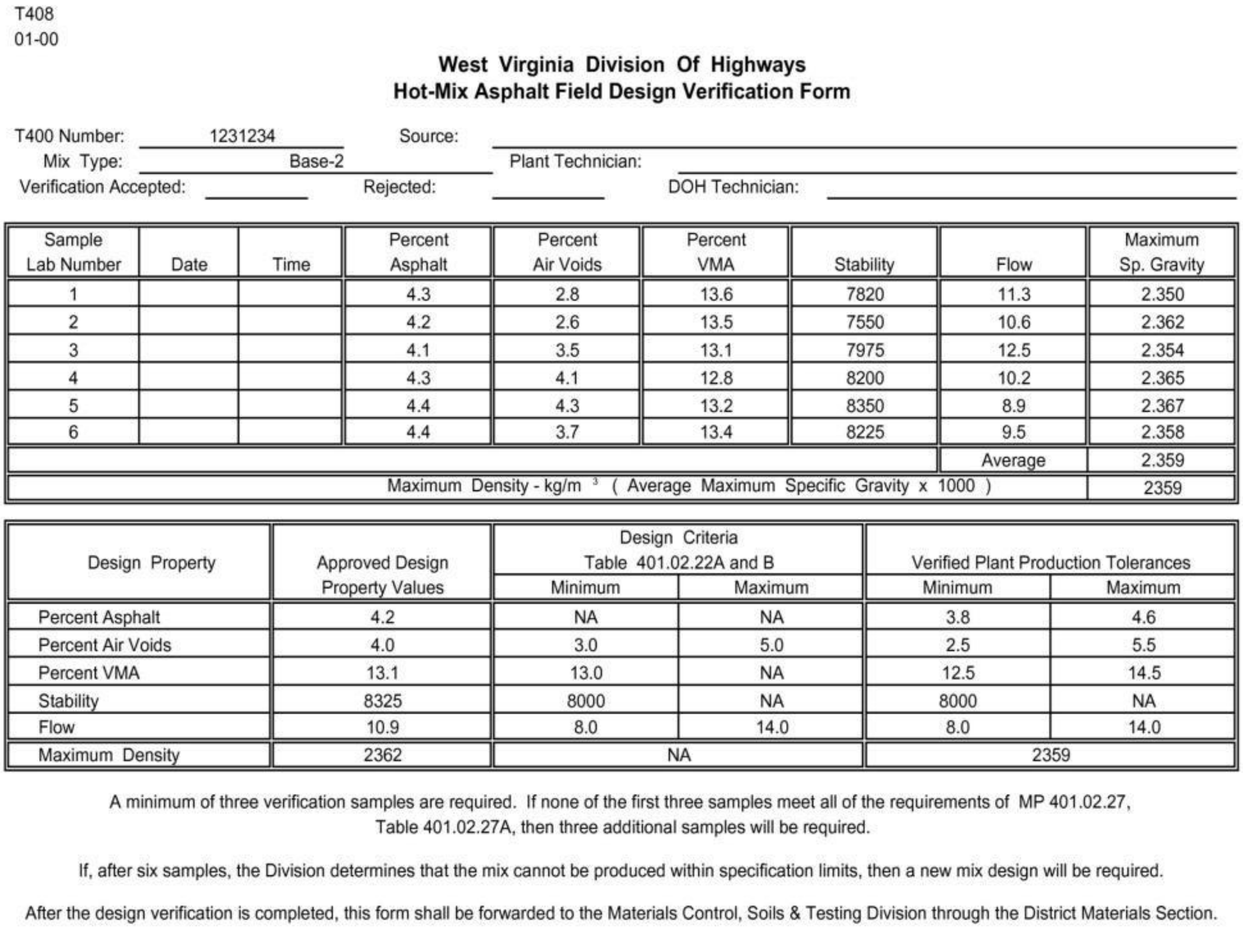
Property	Field Verification Tolerances
Asphalt Content (%)	JMF ± 0.4 %
Air Voids (%)	3.0 – 5.0 %
Voids in Mineral Aggregate (VMA) %	Minimum of 0.5% Below Design Criteria
Voids Filled With Asphalt (VFA) %	For lab information only

Table 28 - Superpave Design Aggregate Gradation Requirements (Note 1) - Table 401.02.29B

Nominal Max. Size	37.5 mm (1 ½ inch)	25 mm (1 inch)	19 mm (3/4 inch)	12.5 mm (1/2 inch)	9.5 mm (3/8 inch)	4.75 mm (No. 4)
Standard Sieve Size	Type of Mix					
	37.5	25	19 (Patch & Level)	12.5	9.5 (Scratch)	4.75 (Scratch)
50 mm (2”)	100					-
37.5 mm (1½”)	90 - 100	100				-
25 mm (1”)	90 max	90 – 100	100			-
19 mm (3/4”)		90 max	90 - 100	100		-
12.5 mm (1/2”)			90 max	90 - 100	100	100
9.5 mm (3/8”)				90 max	90 - 100	95 - 100
4.75 mm (No.4)					90 max	90 - 100
2.36 mm (No.8)	15 - 41	19 – 45	23 – 49	28 - 58	32 - 67	
1.18 mm (No.16)						30 - 60
600 µm (No.30)						-
300 µm (No. 50)						-
75 µm (No.200)	0.0 – 6.0	1.0 - 7.0	2.0 - 8.0	2.0 - 10.0	2.0 - 10.0	6.0 – 12.0

Note 1: Allowable tolerances for each JMF shall be the specified design control points shown in Table 401.02.29B with the exception that a 4.75 mm mix shall have a tolerance limit of the JMF ± 5% on the 1.18 mm (No. 16) sieve and all other mix types shall have a tolerance limit of the JMF ± 6% on the 2.36 mm (No.8) sieve. These tolerances shall be applied to both the field design verification testing of the JMF and the daily contractor quality control testing.

Table 29 - Marshall Field Verification Form T408



T408
01-00

West Virginia Division Of Highways
Hot-Mix Asphalt Field Design Verification Form

T400 Number: 1231234 Source:
Mix Type: Base-2 Plant Technician:
Verification Accepted: Rejected: DOH Technician:

Sample Lab Number	Date	Time	Percent Asphalt	Percent Air Voids	Percent VMA	Stability	Flow	Maximum Sp. Gravity
1			4.3	2.8	13.6	7820	11.3	2.350
2			4.2	2.6	13.5	7550	10.6	2.362
3			4.1	3.5	13.1	7975	12.5	2.354
4			4.3	4.1	12.8	8200	10.2	2.365
5			4.4	4.3	13.2	8350	8.9	2.367
6			4.4	3.7	13.4	8225	9.5	2.358
							Average	2.359
Maximum Density - kg/m ^{3} (Average Maximum Specific Gravity x 1000)								2359

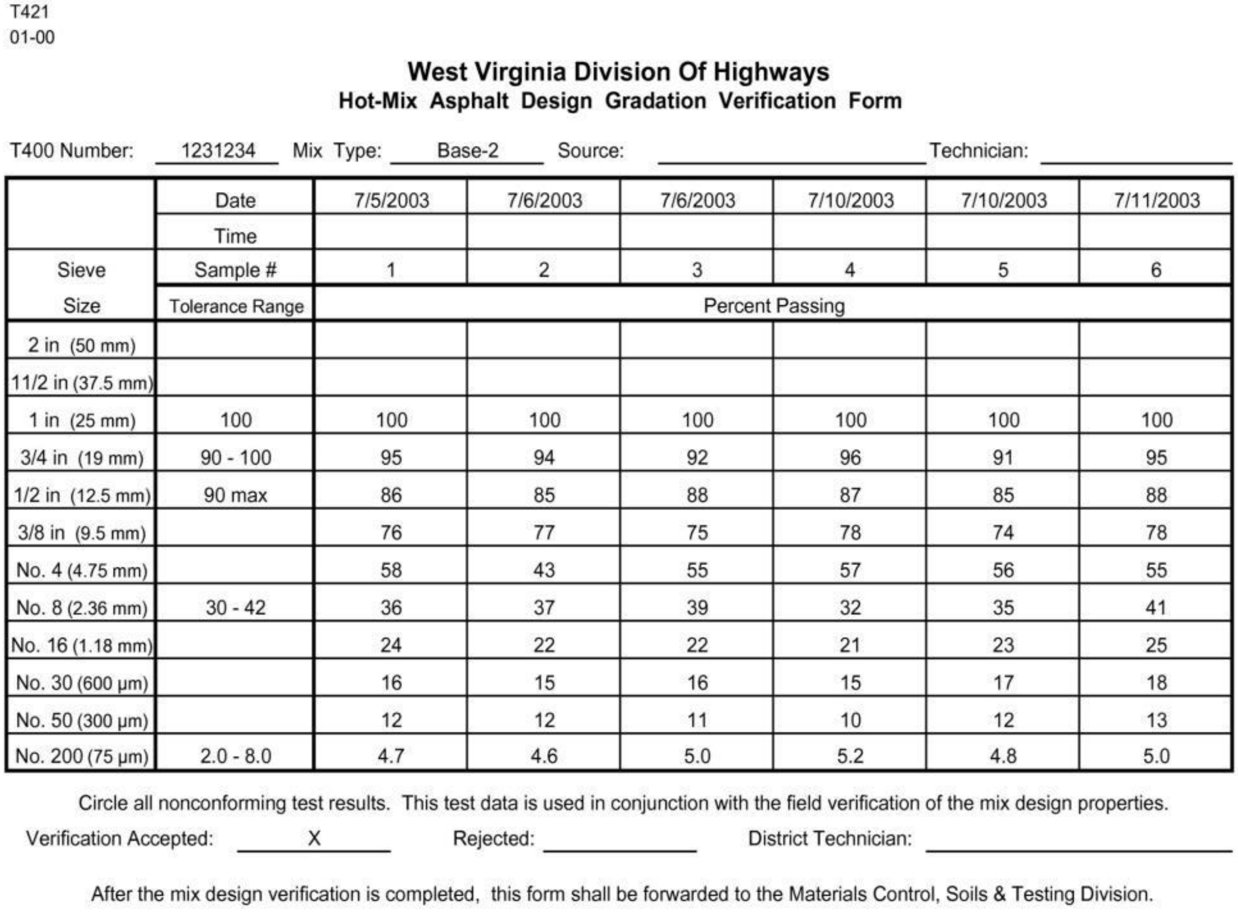
Design Property	Approved Design Property Values	Design Criteria Table 401.02.22A and B		Verified Plant Production Tolerances	
		Minimum	Maximum	Minimum	Maximum
Percent Asphalt	4.2	NA	NA	3.8	4.6
Percent Air Voids	4.0	3.0	5.0	2.5	5.5
Percent VMA	13.1	13.0	NA	12.5	14.5
Stability	8325	8000	NA	8000	NA
Flow	10.9	8.0	14.0	8.0	14.0
Maximum Density	2362	NA		2359	

A minimum of three verification samples are required. If none of the first three samples meet all of the requirements of MP 401.02.27, Table 401.02.27A, then three additional samples will be required.

If, after six samples, the Division determines that the mix cannot be produced within specification limits, then a new mix design will be required.

After the design verification is completed, this form shall be forwarded to the Materials Control, Soils & Testing Division through the District Materials Section.

Table 30 - Field Verification Gradation Analysis Form T421



T421
01-00

West Virginia Division Of Highways
Hot-Mix Asphalt Design Gradation Verification Form

T400 Number: 1231234 Mix Type: Base-2 Source: ________ Technician: ________

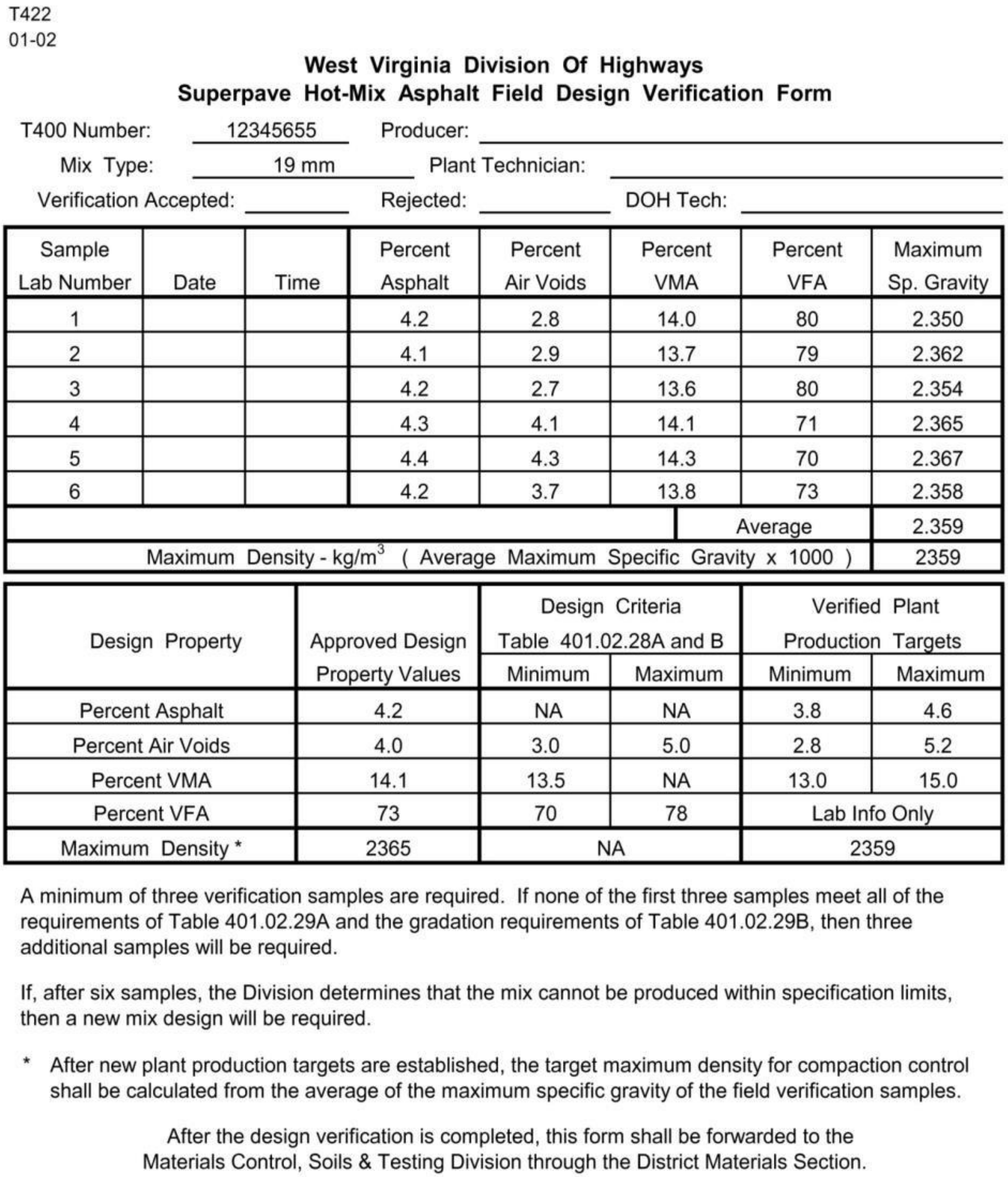
	Date	7/5/2003	7/6/2003	7/6/2003	7/10/2003	7/10/2003	7/11/2003
	Time						
Sieve	Sample #	1	2	3	4	5	6
Size	Tolerance Range	Percent Passing					
2 in (50 mm)							
11/2 in (37.5 mm)							
1 in (25 mm)	100	100	100	100	100	100	100
3/4 in (19 mm)	90 - 100	95	94	92	96	91	95
1/2 in (12.5 mm)	90 max	86	85	88	87	85	88
3/8 in (9.5 mm)		76	77	75	78	74	78
No. 4 (4.75 mm)		58	43	55	57	56	55
No. 8 (2.36 mm)	30 - 42	36	37	39	32	35	41
No. 16 (1.18 mm)		24	22	22	21	23	25
No. 30 (600 µm)		16	15	16	15	17	18
No. 50 (300 µm)		12	12	11	10	12	13
No. 200 (75 µm)	2.0 - 8.0	4.7	4.6	5.0	5.2	4.8	5.0

Circle all nonconforming test results. This test data is used in conjunction with the field verification of the mix design properties.

Verification Accepted: X Rejected: ________ District Technician: ________

After the mix design verification is completed, this form shall be forwarded to the Materials Control, Soils & Testing Division.

Table 31 - Superpave Field Design Verification Form T422



T422
01-02

West Virginia Division Of Highways
Superpave Hot-Mix Asphalt Field Design Verification Form

T400 Number: 12345655 Producer:
Mix Type: 19 mm Plant Technician:
Verification Accepted: Rejected: DOH Tech:

Sample Lab Number	Date	Time	Percent Asphalt	Percent Air Voids	Percent VMA	Percent VFA	Maximum Sp. Gravity
1			4.2	2.8	14.0	80	2.350
2			4.1	2.9	13.7	79	2.362
3			4.2	2.7	13.6	80	2.354
4			4.3	4.1	14.1	71	2.365
5			4.4	4.3	14.3	70	2.367
6			4.2	3.7	13.8	73	2.358
						Average	2.359
Maximum Density - kg/m^3 (Average Maximum Specific Gravity x 1000)							2359

Design Property	Approved Design Property Values	Design Criteria Table 401.02.28A and B		Verified Plant Production Targets	
		Minimum	Maximum	Minimum	Maximum
Percent Asphalt	4.2	NA	NA	3.8	4.6
Percent Air Voids	4.0	3.0	5.0	2.8	5.2
Percent VMA	14.1	13.5	NA	13.0	15.0
Percent VFA	73	70	78	Lab Info Only	
Maximum Density *	2365	NA		2359	

A minimum of three verification samples are required. If none of the first three samples meet all of the requirements of Table 401.02.29A and the gradation requirements of Table 401.02.29B, then three additional samples will be required.

If, after six samples, the Division determines that the mix cannot be produced within specification limits, then a new mix design will be required.

* After new plant production targets are established, the target maximum density for compaction control shall be calculated from the average of the maximum specific gravity of the field verification samples.

After the design verification is completed, this form shall be forwarded to the
Materials Control, Soils & Testing Division through the District Materials Section.

II QUALITY ASSURANCE SYSTEM TESTING

A) MOVING AVERAGE CALCULATIONS

The moving average concept is a relatively simple one and is widely used for Quality Assurance analysis. Test results from the first four QC samples are averaged. When the fifth sample is completed, simply drop the first sample and average the next four (second through fifth) samples. In other words, when a new sample is taken, include this sample and the previous three samples in determining the moving average.

Below is an example of some typical quality control test data for % air voids of a Superpave mix. The design target is 4.0% with an upper limit of 5.2% and a lower limit of 2.8%. The moving average begins with the fourth sample. The district took a verification sample on the same day as the 8th quality control sample. The following quality control chart for % air voids uses all of this data in a graphical form that allow for quick and easy interpretation of the data. Control charts may be prepared in accordance with the guidelines of MP 300.00.51. As an alternative method, the control charts may be prepared with a personal computer using software that can generate such charts and provide a distinct graphic representation of all data points. The example shown is a computer generated chart.

Table 32 - Moving Average Example for Plant Control

Data used to Plot Control Chart for % Air Voids Target Air Voids = 4.0% Upper Limit = 5.2% Lower Limit = 2.8%			
Sample Number	% Air Voids	Moving Average	District Verification Sample
1	3.2		
2	3.1		
3	3.8		
4	4.2	3.6	
5	4.6	3.9	
6	5.0	4.4	
7	3.9	4.4	
8	3.7	4.3	4.6
9	4.2	4.2	
10	4.0	4.0	
11	4.6	4.1	
12	4.8	4.4	

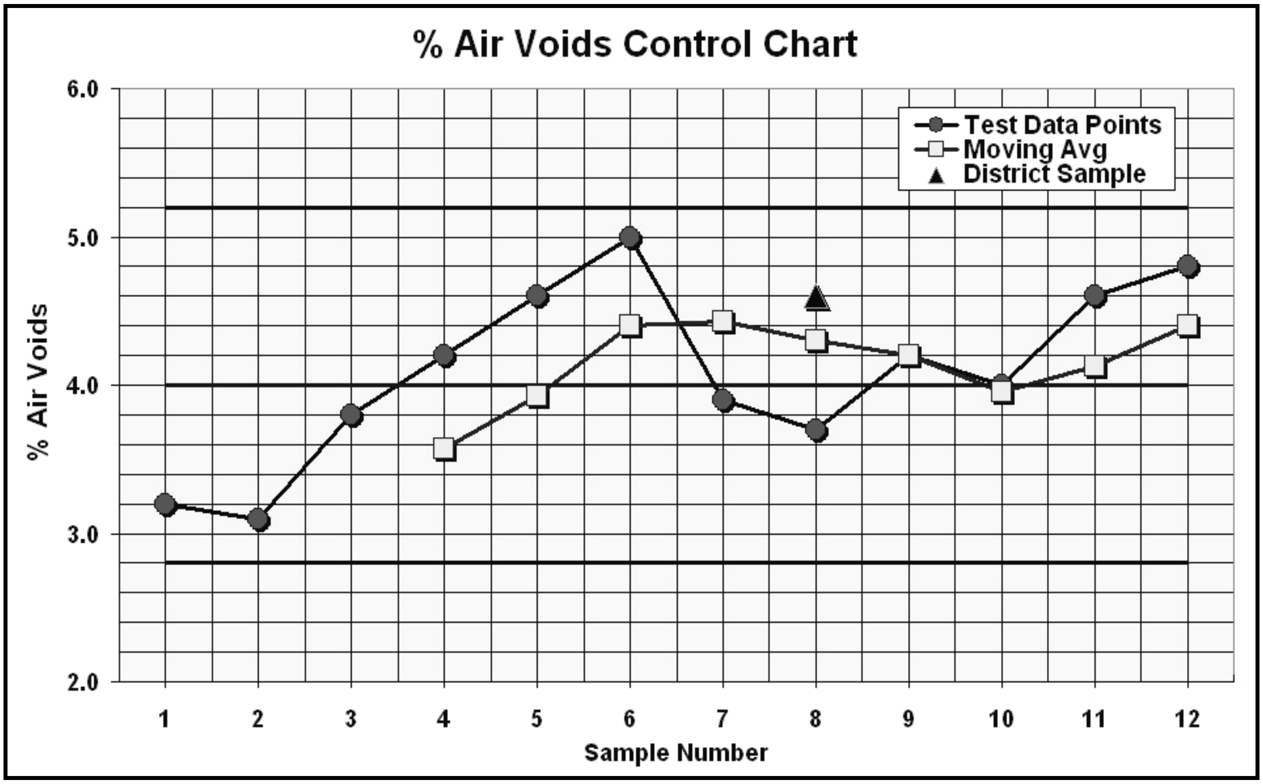


Figure 80 - Example Control Chart

B) QUALITY CONTROL TESTING

After the JMF has been verified and production tolerances have been established for the design properties then daily quality control testing will begin. During each day of plant production the mix shall be tested for all of the design properties referenced in Table 401.02.27C or Table 401.02.29C for Marshall or Superpave designs respectively. These tables have been reproduced as Table 33 and Table 34 below. Any mixture tested shall conform to the production tolerances of these tables.

Table 33 - Marshall Quality Control Mix Property Tolerances Table 401.02.27C

Property	Allowable Deviation From Verified JMF
Asphalt Content (%)	JMF ± 0.4 %
Air Voids (%)	JMF ± 1.5 %
Voids in Mineral Aggregate(VMA)%	Verified JMF ± 1.0% with a minimum of 0.5% below the minimum design criteria
Stability (Newtons)	Minimum Design Criteria
Flow (0.25 mm)	Limits of Design Criteria

Table 34 - Superpave Quality Control Mix Property Tolerances Table 401.02.29C

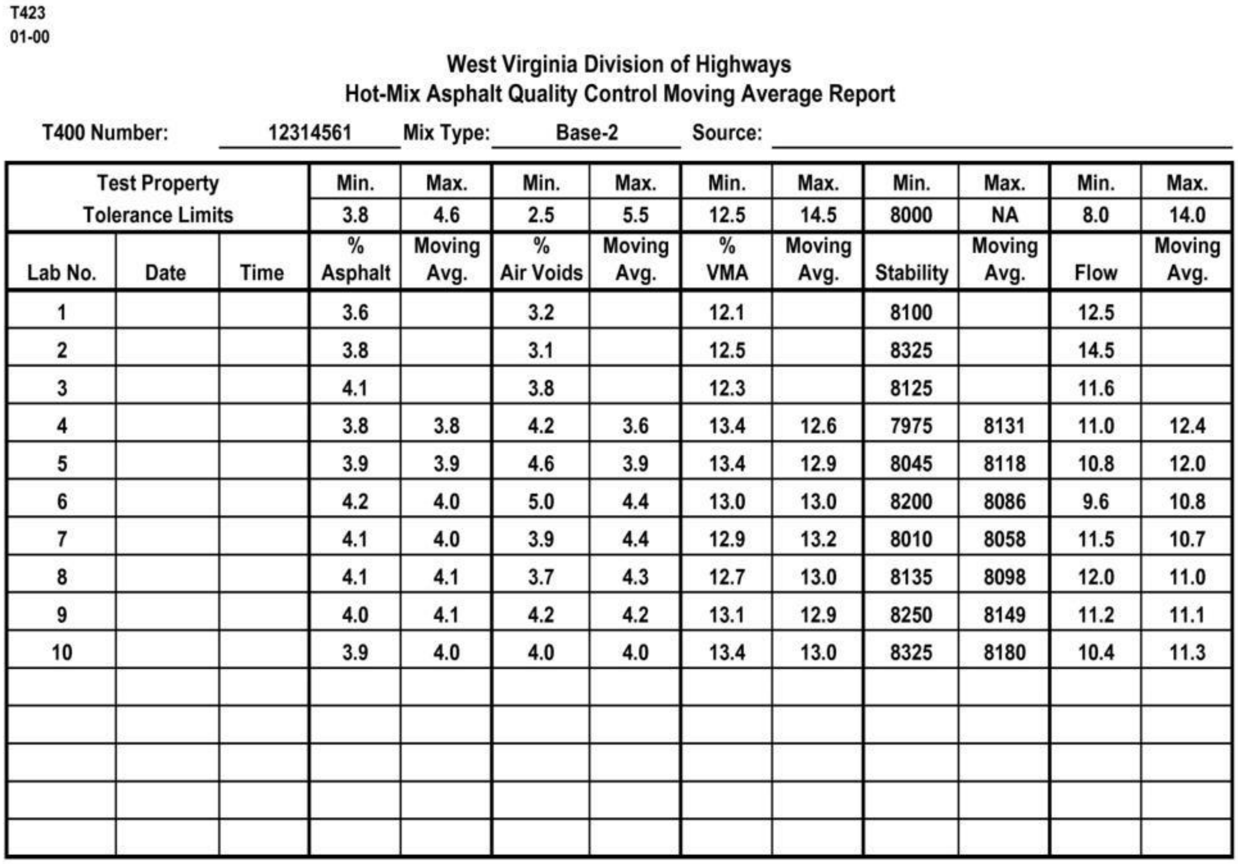
Property	Production Tolerances
Asphalt Content (%)	Verified JMF ± 0.4 %
Air Voids (%)	4.0 ± 1.2 %
Voids in Mineral Aggregate (VMA) %	Verified JMF ± 1.0% with a minimum of 0.5% below the minimum design criteria
Voids Filled With Asphalt (VFA) %	For lab information only

For Marshall designs, a minimum of one sample per day of production shall be tested for quantities up to 3000 tons. When more than 3000 tons of mix is expected to be produced in a single day, the Contractor shall anticipate this additional production and adjust his sampling to one test per half day of production. Aggregate gradation testing shall be conducted at a minimum rate of one test per every 5,000 ton of production or one test every three days of production, whichever occurs first.

For Superpave designs, a minimum of one sample shall be taken for production periods of six hours or less. When the production period exceeds six hours, a minimum of one sample for each half of the production period shall be taken. If the production period exceeds twelve hours, a third sample shall be taken. In addition to the requirements of Table 401.02.29C, an aggregate gradation test shall be conducted on each sample taken.

The Contractor's actual sampling frequency shall be in accordance with his approved Plant Quality Control Plan. A moving average of four samples shall be used for the purpose of determining whether or not the material meets specification requirements with regard to the criteria of Table 401.02.27C or Table 401.02.29C. An example moving average report (Form T423) is shown in Table 35. The Contractor shall maintain daily test reports of each sample and record the moving average of each test property contained in Table 401.02.27C on Form T423 for Marshall designs.

Table 35 - Asphalt Concrete Quality Control Moving Average Form T423



T423
01-00

West Virginia Division of Highways
Hot-Mix Asphalt Quality Control Moving Average Report

T400 Number: 12314561 **Mix Type:** Base-2 **Source:**

Test Property			Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Tolerance Limits			3.8	4.6	2.5	5.5	12.5	14.5	8000	NA	8.0	14.0
Lab No.	Date	Time	% Asphalt	Moving Avg.	% Air Voids	Moving Avg.	% VMA	Moving Avg.	Stability	Moving Avg.	Flow	Moving Avg.
1			3.6		3.2		12.1		8100		12.5	
2			3.8		3.1		12.5		8325		14.5	
3			4.1		3.8		12.3		8125		11.6	
4			3.8	3.8	4.2	3.6	13.4	12.6	7975	8131	11.0	12.4
5			3.9	3.9	4.6	3.9	13.4	12.9	8045	8118	10.8	12.0
6			4.2	4.0	5.0	4.4	13.0	13.0	8200	8086	9.6	10.8
7			4.1	4.0	3.9	4.4	12.9	13.2	8010	8058	11.5	10.7
8			4.1	4.1	3.7	4.3	12.7	13.0	8135	8098	12.0	11.0
9			4.0	4.1	4.2	4.2	13.1	12.9	8250	8149	11.2	11.1
10			3.9	4.0	4.0	4.0	13.4	13.0	8325	8180	10.4	11.3

For Superpave designs, control charts of the moving average (see below) shall be maintained as described in Section 6.10 of MP 401.02.29. Form T424, shown in Table 36, may be used to record the test results and moving average calculations that will be plotted on the moving average charts. For both Marshall and Superpave designs, all required gradation test reports shall be maintained with a summary recorded on Form T425 reproduced as Table 37. The daily test reports, moving average reports (or control charts), and gradation summary reports shall be kept up to date and placed in a location that is easily accessible to the Division for review at any time.

Table 36 - Superpave Quality Control Moving Average Form T424

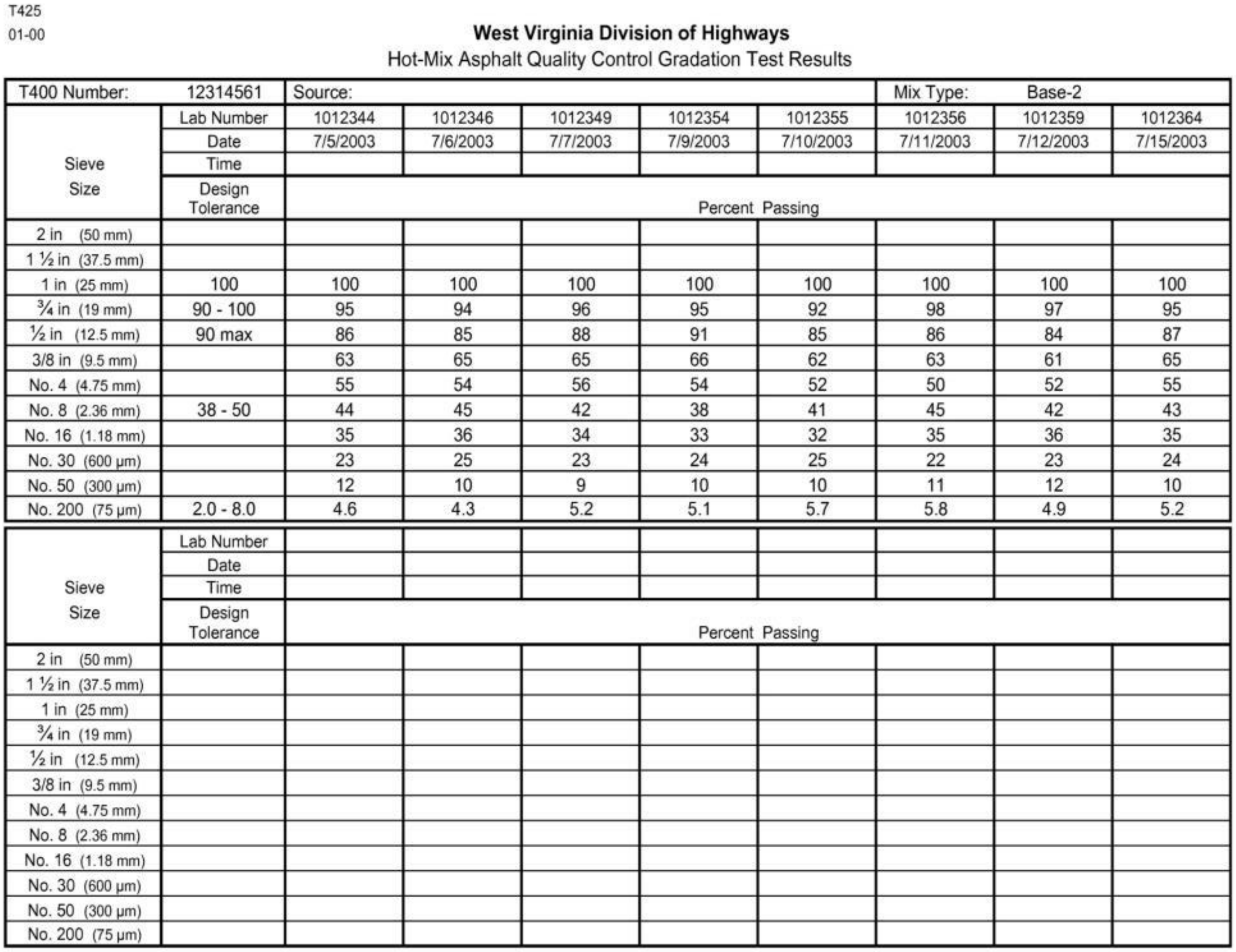
T424
01-00

West Virginia Division of Highways
Superpave Hot-Mix Asphalt Quality Control Moving Average Report

T400 Number: 213544 Mix Type: 9.5 mm Source: ____________________

Test Property Tolerance Limits			Min. 4.5	Max. 5.3	Min. 2.8	Max. 5.2	Min. 14	Max. 16	Min.	Max.
Lab No.	Date	Time	**% Asphalt**	Moving Avg.	**% Air Voids**	Moving Avg.	**% VMA**	Moving Avg.	**% VFA**	Moving Avg.
1			4.8		3		15.8			
2			4.9		3.1		15			
3			4.9		3.5		15.4			
4			5	4.9	3.9	3.4	14.9	15.3		
5			5.1	5.0	3.7	3.6	14.6	15.0		
6			5	5.0	4.2	3.8	15.2	15.0		
7			4.9	5.0	4.5	4.1	14.6	14.8		
8			4.9	5.0	4.1	4.1	15.9	15.1		
9			4.8	4.9	4.3	4.3	14.8	15.1		
10			4.7	4.8	4	4.2	14.6	15.0		
11			4.9	4.8	3.9	4.1	15	15.1		
12			4.6	4.8	3.7	4.0	14.7	14.8		
13			4.9	4.8	4.1	3.9	15	14.8		

Table 37 - Asphalt Concrete Quality Control Gradation Form T425



T425
01-00

West Virginia Division of Highways
Hot-Mix Asphalt Quality Control Gradation Test Results

T400 Number:	12314561	Source:					Mix Type:	Base-2	
Sieve Size	Lab Number	1012344	1012346	1012349	1012354	1012355	1012356	1012359	1012364
	Date	7/5/2003	7/6/2003	7/7/2003	7/9/2003	7/10/2003	7/11/2003	7/12/2003	7/15/2003
	Time								
	Design Tolerance	Percent Passing							
2 in (50 mm)									
1 ½ in (37.5 mm)									
1 in (25 mm)	100	100	100	100	100	100	100	100	100
¾ in (19 mm)	90 - 100	95	94	96	95	92	98	97	95
½ in (12.5 mm)	90 max	86	85	88	91	85	86	84	87
3/8 in (9.5 mm)		63	65	65	66	62	63	61	65
No. 4 (4.75 mm)		55	54	56	54	52	50	52	55
No. 8 (2.36 mm)	38 - 50	44	45	42	38	41	45	42	43
No. 16 (1.18 mm)		35	36	34	33	32	35	36	35
No. 30 (600 µm)		23	25	23	24	25	22	23	24
No. 50 (300 µm)		12	10	9	10	10	11	12	10
No. 200 (75 µm)	2.0 - 8.0	4.6	4.3	5.2	5.1	5.7	5.8	4.9	5.2

Sieve Size	Lab Number								
	Date								
	Time								
	Design Tolerance	Percent Passing							
2 in (50 mm)									
1 ½ in (37.5 mm)									
1 in (25 mm)									
¾ in (19 mm)									
½ in (12.5 mm)									
3/8 in (9.5 mm)									
No. 4 (4.75 mm)									
No. 8 (2.36 mm)									
No. 16 (1.18 mm)									
No. 30 (600 µm)									
No. 50 (300 µm)									
No. 200 (75 µm)									

i) SUPERPAVE PRODUCTION NONCONFORMITY

For Superpave designs there is also a price adjustment specification for material that falls outside of the allowable JMF tolerances. Should the four sample average of test values for percent asphalt, percent air voids, or percent VMA fall outside the verified JMF tolerances by more than the allowable deviation of Table 401.02.29C (MP 401.02.29) then production shall be halted until the Contractor takes necessary steps to bring production under control. Production shall also be halted if three consecutive aggregate gradation tests fall outside the tolerance limits of Table 401.02.29B. Actions taken by the Contractor to bring production back in control shall be documented in the plant diary.

When the four sample average of the Contractor's quality control tests for percent asphalt and/or percent air voids falls outside the JMF tolerances of Table 401.02.29C, the Sublot of material represented by the last individual test value in the moving average shall have its price reduced in accordance with the schedule set forth in Section 7.3 of MP 401.02.29. In the case where the average is nonconforming and the last tested Sublot is conforming, then there would be no price adjustment.

The degree of nonconformance shall be determined using the following relationship:

When the moving average is greater than the upper control limit

$$QU = Xn - UL$$

Equation 1 - Percent of Non-Conformance at Upper Limit

When the moving average is less than the lower control limit

$$QL = LL - Xn$$

Equation 2 - Percent of Non-Conformance at Lower Limit

Where:

- QU = Percent of non-conformance at Upper Limit
- QL = Percent of non-conformance at Lower Limit
- UL = Upper Limit
- LL = Lower Limit
- Xn = Average of four consecutive test values (less than four when production is limited)

If it is decided by the Division that the material is to be allowed to remain in place, then the Sublot shall have its price reduced in accordance with Tables 401.02.29D and/or 401.02.29E as applicable.

Table 38 - Adjustment of Contract Price for Mix Not Within Tolerance Limits Of Percent Asphalt Table 401.02.29D

QU or QL	Percent of Contract Price to be Paid
0.0	100
0.1	98
0.2	96
0.3	92
Greater Than 0.3	Note

Note: The Division will make a special evaluation of the material and determine the appropriate action.

Table 39 - Adjustment of Contract Price for Mix Not Within Tolerance Limits Of Percent Air Voids Table 401.02.29E

QU or QL	Percent of Contract Price to be Paid
0.0	100
0.1	98
0.2	96
0.3	92
Greater Than 0.3	*

Note: The Division will make a special evaluation of the material and determine the appropriate action.

Should the moving average of both the test properties for the same Sublot fall outside of the JMF tolerance, thus resulting in a reduced price for each, then the following procedure shall be used. The quantity of material represented by the last Sublot in the moving average will have an adjusted unit price which is the product of the original price times the percent as a result of non-conformance of the first test property times the percentage unit price as a result of non-conformance of the second test expressed in the following formula.

$$AUP = OUP \times PUPAC \times PUPAV \qquad \text{Equation 3 – Adjusted Unit Price}$$

Where:

- AUP = Adjusted Unit Price
- OUP = Original Unit Price
- PUPAC = Percent Unit Price as a result of Asphalt Content Analysis expressed as a decimal
- PUPAV = Percent Unit Price as a result of Air Void Analysis expressed as a decimal

PUPAC and PUPAV are used in the formula as needed as a single non-conforming item or together for both non-conforming items as shown.

A new moving average will start with the fourth sample that is taken after production is resumed (less than four when production is limited). If, at any time, the Division determines that a mix cannot be consistently produced within the tolerance limits of the verified design properties, approval of the mix may be revoked and the contractor will be required to provide a new mix design.

C) QUALITY CONTROL PLANS

MP 401.03.50 is the quality control guideline for the development of the Contractor's Quality Control Plan for hot mix asphalt. All items listed in the guide are believed necessary to assure adequate product quality control. This guideline specifies a minimum amount of testing per day for the purpose of checking the mix design properties and gradation analysis. This does not mean that a contractor cannot take samples at a higher frequency in order to maintain better control of the mix. In fact, if problems persist with a specific mix design then additional testing may be required in an attempt to bring production back in control. The WVDOH will monitor the activities specified in the quality control plans to verify that they are being performed as indicated.

D) QUALITY ACCEPTANCE

Quality Acceptance, Verification, testing is a function of the Division. The WVDOH takes samples at intervals of a minimum of 10 percent of the contractors testing for the purpose of determining similarity between the WVDOH and the contractor's test results. The Division may decide to take more samples when they suspect a problem with production of a particular mix design. When the Division's tests results are found to be statistically similar to the Contractor's quality control test results the Division can use the Contractor's test data for acceptance purposes. Statistically dissimilar test results require an investigation into the reason why the material is dissimilar. In addition to testing the actual mixture from the Asphalt Concrete plant, the Division also has three additional criteria defined for the acceptance of the in-place pavement: compaction, thickness, and smoothness. These are not covered in this manual since these are performed in the field.

E) INDEPENDENT ASSURANCE

Independent Assurance (IA) Testing is testing conducted by a third party that is not responsible for quality control or making acceptance decisions. The Central Materials Division takes a sample and splits it between our Asphalt Lab and the District's Lab. These results are statistically compared to determine similarity between the two labs. IA testing also may include a comparison between the Central Lab and the Producer Lab, or even a three way comparison between the Central, District, and Producer labs.

The WVDOH uses producer's test results as part of the acceptance plan, so both the producer's QC and the District's QA are critical components to a good Quality Assurance System. It is crucial that both entities use the same standard methods and properly calibrated equipment to eliminate statistical outliers. As well as standard methods and calibrated equipment, all technicians involved must be properly trained in the various standard sampling and testing procedures. Training assures the WVDOH of a reliable quality assurance system.

Chapter 7 - Percent Within Limitations

I INTRODUCTION

Section 410 of the Standard Specifications, Percent within Limits, was implemented during the 2013 paving season as SP 401. It introduces better statistical analysis of material testing results and more manageable square yard paving. Included with the new Special Provision, eight new Materials Procedures were developed to handle new testing, sampling, and payment methods. These MP's are listed below and most are included in the accompanied Workshop Manual.

- MP 401.02.31 - Guide for Quality Control & Acceptance
- MP 401.07.20 - Sampling Loose Asphaltic Mixtures from the Roadway
- MP 401.07.21 -Sampling Compacted Asphaltic Mixtures from the Roadway
- MP 4014.07.22 - Standard Method of Measurement for Thickness of Asphalt Pavement Using Drilled Cores
- MP 401.07.23 - Guide to Determining Interface Bond Shear Strength of Multi-Layered Asphalt Pavement Specimens
- MP 401.07.24 - Standard Test Method for Measuring Pavement Macrotexture Depth Using a Volumetric Technique
- MP 401.07.25 - Guide for Evaluation of Asphalt Pavements with Substandard Properties
- MP 401.13.50 - Guide to Statistical Analysis of Material Using Quality Level Analysis-Percent within Limits

II DEVELOPMENT

In 2012, the WVDOH felt they were not getting the quality and longevity out of its interstates and Appalachian Parkway Development routes. So, they came to the Material's Division (MCS&T) with a mission. This mission was to develop a specification that would put a larger penalty/incentive for quality construction, with an emphasis on longitudinal joint density.

The WVDOH partnered with the FHWA (Federal Highway Administration) and the Asphalt institute to work on the longitudinal joint quality issues. The FHWA helped arrange for a peer review with three other states (PA, DE, & NH) that already had a PWL specification in place. Management from MCS&T visited Penn DOT to view how the specification was implemented. Their model became a framework for the WVDOH to create Special Provision 401.

Unlike a traditional paving project that is paid by the tonnage placed, a PWL project is paid by square yards. This eliminates the payment of "overages" when a project goes above plan quantities. Another way that PWL differs from traditional paving project payment is that penalties/incentives for pay items (asphalt content, gradation, in-place density) are figured using standard deviations and statistical analysis rather than the moving average method. The closer all of the test results can stay to the target, thus creating more uniformity of the finished product. All of the calculations for applying incentives and disincentives are built directly into the digital test data workbook. This PWL test data workbook is an excel spreadsheet designated as Form T-432. For the purposes of this course, the complete understanding of the payment structure is not needed. A guide detailing the entire PWL payment calculations can be found in MP 401.13.50.

III PROJECT LAYOUT OVERVIEW

The project is laid out and divided into 2500 ton lots which consist of five 500 ton sublots. Instructions and step-by-step examples of project layouts can be found in both MP 401.07.20 and MP 401.07.21.

The most important step when setting up the layout for a PWL project is scheduling a pre-paving meeting between the WVDOH and contractor personnel. The main purpose of this meeting is so the contractor and WVDOH can work together on the layout and come to an agreement on such things as paving sequence and pull widths. A site visit is recommended but not required during this meeting.

Even though projects are tested per tonnage they are laid out and paid by square yards. So a conversion from tons to square yards must be made. One of the pieces of information needed from the contractor when performing the project layout conversion is the design maximum theoretical specific gravity of the asphalt mixture to be used. This can be found on the mixtures T-400. The maximum theoretical specific gravity is used to calculate the theoretical application rate of the asphalt mixture at a designed thickness. An example of the conversions and calculations to layout a job can be found in MP 401.07.20 & MP 401.07.21.

Each lot should consist of three samples a loose mixture sample for Asphalt content and gradation determination as well as two cores, one for Density and another for Bond Strength. Both cores are also measured for thickness. These tests will be discussed in Chapter 7 - IV. Once the results are determined they are analyzed for compliance, discussed in Chapter 7 - V.

IV LABORATORY TESTING

Unlike the WVDOH's normal QA/QC, all of the testing of PWL samples for pay determination is tested by DOH personnel. The tests to be performed are Asphalt Content on the loose mixture samples; thickness measurements on mat density and bond cores; bulk gravity by the CoreLok method on mat and longitudinal joint density cores; and interface bond shear strength testing on the bond cores. One randomly sampled loose mix sample shall also be taken per lot for maximum specific gravity testing. This is used as a comparison to the average daily Rice that is provided by the producing plant's laboratory. Part of the requirements of the PWL specifications is that the samples shall be tested and reported in a timely manner, which is typically within 24 hours of sampling.

A) ASPHALT CONTENT & GRADATION

In order to have the most accurate test results possible during the project, hand mixed samples of the design asphalt mixture to be used shall be submitted to the WVDOH district materials laboratory. These samples should be prepared at least two weeks prior to the start of production for the project. The requirements of these calibration samples are specified in section 7 of MP 401.02.31. These oven calibrations shall be applied to all asphalt content and gradation samples for the PWL project.

After the calibration factors for each mix to be placed on the project are established for each NCAT Oven to be used in the laboratory. Testing of the loose mixtures coming from the project can commence. These loose mixture samples shall be quartered and tested as described in Chapter 3 of this manual. The applicable standards for sample reducing by quartering and Asphalt content by ignition oven are AASHTO T-248 Method B and AASHTO T-308, respectively. All test data is recorded on Form T-432.

B) CORE THICKNESS

It is crucial that accurate thickness measurements are taken to ensure that the proper amount of material had been placed on the project and to determine any applicable penalties. On PWL project there are no price adjustments for overages on thickness, although there is the risk of substantial penalties. Thickness measurements for both mat density cores and bond cores are performed in accordance with MP 401.07.22. Thickness is not measured on joint density cores because the overlap of the two mats can have a template that can show a false thickness.

Each core is measured using a minimum 12” steel ruler at four locations around its circumference, approximately 90˚ apart. The cores thickness is measure to the nearest millimeter and converted to inches to be assessed with the design thickness. All test data is recorded on Form T-432.

C) CORE DENSITY

There are several acceptable methods for determining bulk specific gravity of drilled asphalt cores: saturated surface dry, paraffin wax coating, and vacuum sealing. In order to maintain uniformity of testing, the method chosen was the Vacuum sealing method. This method limits the potential of absorption in the porous cut faces of the core. This method is used for both mat and longitudinal joint density cores and is described in AASHTO T-331.

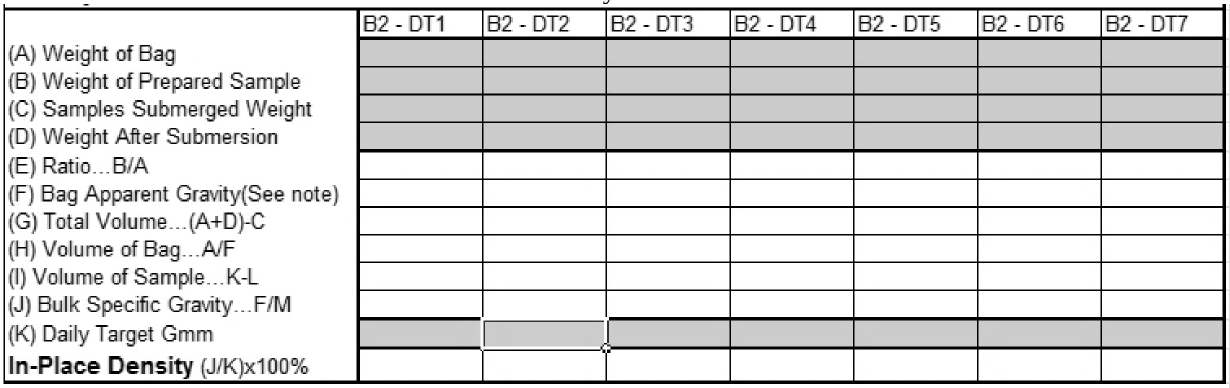
The first step in determining the bulk specific gravity of a drilled core using the vacuum sealing method is to remove any underlying material from the layer that is to be tested. A core saw is used to cut the underlying material away. Be sure that all unwanted material is removed by cutting just barely into the new layer. MAKE SURE ALL THICKNESS MEASUREMENTS HAVE BEEN TAKEN PRIOR TO CUTTING THE CORE.

After trimming the core, the top and bottom edge of the core must be slightly sanded to remove sharp edges that could puncture the bag when vacuum sealed. This can be performed using a masonry rubbing stone. If care is taken, a bench grinder may also be used successfully. The core should now be rinsed in order to remove any dust or friable material that was left by the sawing and sanding operations.

In order to achieve an accurate determination of the bulk specific gravity, the core must be completely dry. Even at a low temperature, drying of the cores in the oven can cause damage which will give inaccurate density results. For this reason, all WVDOH asphalt laboratories are equipped with a vacuum drying apparatuses. The method for using this machine is described in ASTM D7227. When running the vacuum sealing device, the following steps are to be performed. The lines referred to in the list correspond to line items in the From T-432, shown in Table 40.

- Weigh the vacuum bag and recorded in line (A)
- The prepared sample is weighed and recorded on line (B). A “prepared” sample is a core that has been cut, sanded, cleaned, and dried.
- Carefully place the prepared core into the weighed vacuum bag, cut side down.
- Place the sample on the slide plate in the vacuum machine. The bag opening must hang past the heat seal bar by approx. 1” so that a proper seal can be achieved. Adjust bag as needed to make sure the bag is as flat as possible and there are no creases.
- With the machine on and in “Program 1”, close the lid and the sealing process will begin automatically. Make sure the lid’s safety latch is in place during the sealing process.
- Once sealing is complete, carefully transfer the sealed core to the 77˚F water bath. Extra effort must be taken to ensure that when submerging the sample, that no air bubbles get trapped within the folds and creases of the sealed bag. Also, do not set the core on any hard surface, the bag may puncture.
- As soon as the scale stabilizes, record the weight of the submerged sample on line (C).
- Remove the sealed core from the water bath. With a dry hand, remove the core from the bag and reweigh it. Record this weight on line (D).
- These weights are used to calculate the bulk specific gravity of the core automatically in the digital version of Form T-432. The bulk specific gravity is then compared to the average daily maximum specific gravity target, line (K), in order to determine percentage of in-place density. The average daily maximum specific gravity (Gmm) is the average of all the Gmm or “Rice” tests performed by the contractor during that day’s production.

Table 40 – Density Data Form T-432



	B2 - DT1	B2 - DT2	B2 - DT3	B2 - DT4	B2 - DT5	B2 - DT6	B2 - DT7
(A) Weight of Bag							
(B) Weight of Prepared Sample							
(C) Samples Submerged Weight							
(D) Weight After Submersion							
(E) Ratio…B/A							
(F) Bag Apparent Gravity(See note)							
(G) Total Volume…(A+D)-C							
(H) Volume of Bag…A/F							
(I) Volume of Sample…K-L							
(J) Bulk Specific Gravity…F/M							
(K) Daily Target Gmm							
In-Place Density (J/K)x100%							

D) CORE BOND STRENGTH

National studies have shown a link between prematurely failing pavements and the lack of bond in the layers of asphalt pavement. This has also been a major issue with the quality of the state's highway system. Using several other states as models and extensive in house research, the WVDOH devised a method by which to check the interface bond shear strength of our pavements. This test method can be found in MP 401.07.23 "Guide to Determining Interface Bond Shear Strength of Multi-Layered Asphalt Pavement Specimens". The device used for WVDOH testing is shown in Figure 81. This shear device is made specifically for the WVDOH and is currently not available to outside agencies.

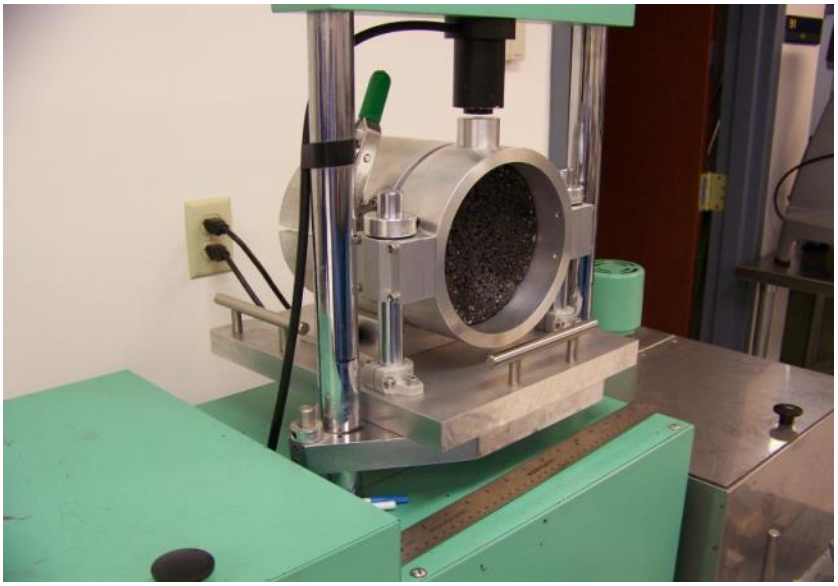


Figure 81 - Shear Bond Strength Device

During the testing process, the load applied to the core must be in the direction of travel to simulate the direction in which the actual stress/strain from traffic will be applied. For this reason, prior to the coring, an arrow must be marked on the core denoting the direction of travel. Also, where the mat density cores are just cored to the depth of the lift of asphalt to be tested, the bond cores are drilled to a depth sufficient enough to allow for underlying material to hopefully remain attached for future bond testing. If during the coring process, the new layer of asphaltic material shears away from the underlying material, this should be documented as zero-bond on Form T-432.

When a bond core arrives in the testing laboratory the thickness must first be measured in accordance with MP 401.07.22 and recorded on Form T-432. The diameter of the bond strength cores must also be measured and recorded on Form T-432 using a 6” micrometer. The diameter is used in the shear strength calculation. Before any additional testing can take place, the internal temperature of the core must be conditioned to room temperature (70˚F to 77˚F). This can be accomplished in several ways: (1) the core can be placed in a watertight container and conditioned in the water bath for several hours; (2) the core can be placed in a draft oven at temperature not to exceed 75˚F for several hours; (3) or the core can be left at ambient lab temperature overnight and tested the next day.

When the core is ready to be tested, load the Marshall Stabilometer with 10,000lb graph paper and change the setting to 10,000. The testing frame must also be lowered in order to fit the shear device. Load the core in the shear device with the direction in the vertical direction as donated by the arrow. Also the interface should be located between the loading and reaction frame, as shown in Figure 82. To assist in lining up the core, mark the cores interface with a paint pen.

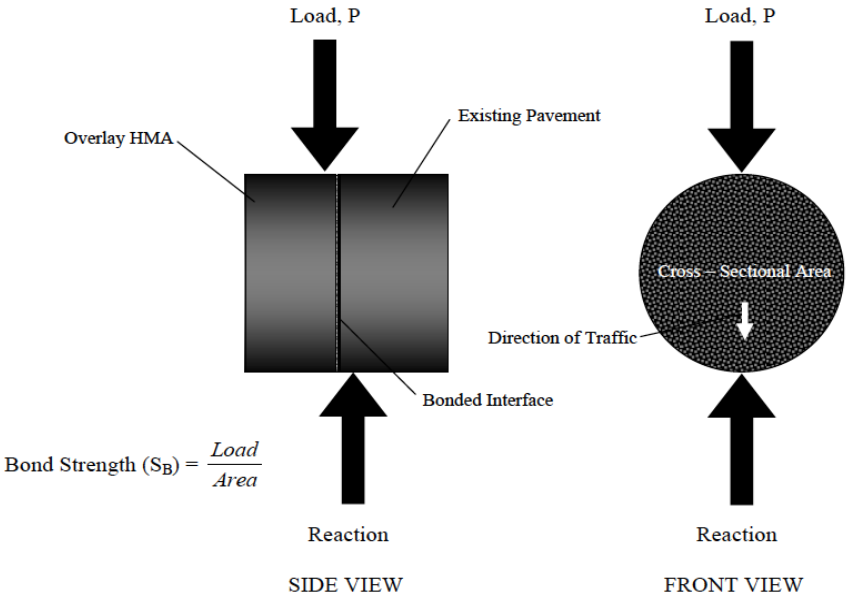
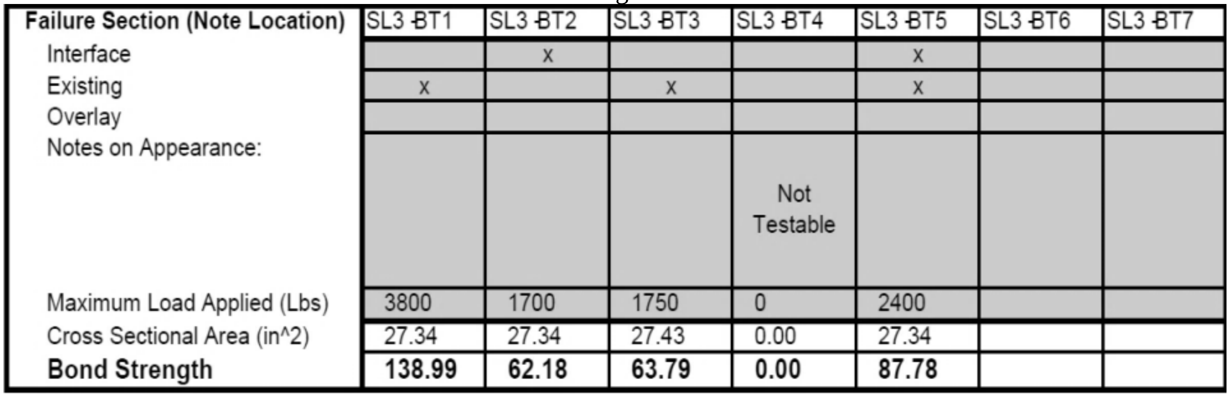


Figure 82 - Bond Core Orientation

Load the device into the Marshall Stabilometer as shown in Figure 81 and press start. The machine will plot a graph similar to a Marshall stability and flow sample. Immediately after the test is completed and the test press has been lowered, the core shall be inspected to see the location where the shear occurred. Record whether the core sheared at the interface, in the existing material, or in overlaid material. The internal temperature should also be measured using an infrared thermometer. The location of shear and internal temperature should be documented on Form T-432. The maximum load applied prior to failure should also be recorded from the graph paper and documented on Form T-432. Table 41 shows an example Form T-432 for bond strength data.

Table 41- Bond Strength Data Form T-432



Failure Section (Note Location)	SL3-BT1	SL3-BT2	SL3-BT3	SL3-BT4	SL3-BT5	SL3-BT6	SL3-BT7
Interface		x			x		
Existing	x		x		x		
Overlay							
Notes on Appearance:				Not Testable			
Maximum Load Applied (Lbs)	3800	1700	1750	0	2400		
Cross Sectional Area (in^2)	27.34	27.34	27.43	0.00	27.34		
Bond Strength	**138.99**	**62.18**	**63.79**	**0.00**	**87.78**		

V PWL ANALYSIS

Once a group or lot of samples is tested they are analyzed according to the formulas in MP 401.13.50. In order to conduct statistical analysis a lot must contain at least three samples. Also, a lot should not contain more than seven samples. In the cases where more than seven samples are needed separate lots should be used. There are five things necessary in order to calculate the Percent within Limits for a group of samples: upper and lower limits, average value and standard deviation of the samples, and the number of samples tested. The upper and lower limits are assigned for each desired test procedure, and are shown in Table 42.

Table 42 - PWL Tolerances

Material Property	Lower Limit	Upper Limit	Notes
Asphalt Content	JMF - 0.4%	JMF + 0.4%	Mixtures with NMAS ≤ 19mm
	JMF - 0.5%	JMF + 0.5%	Mixtures with NMAS > 19mm
Gradations(minus #200)	JMF – 2.0%	JMF + 2.0%	
Mat Density	91.5%	97.0%	
Bond Strength	100 psi	---	
Joint Density	89%	---	

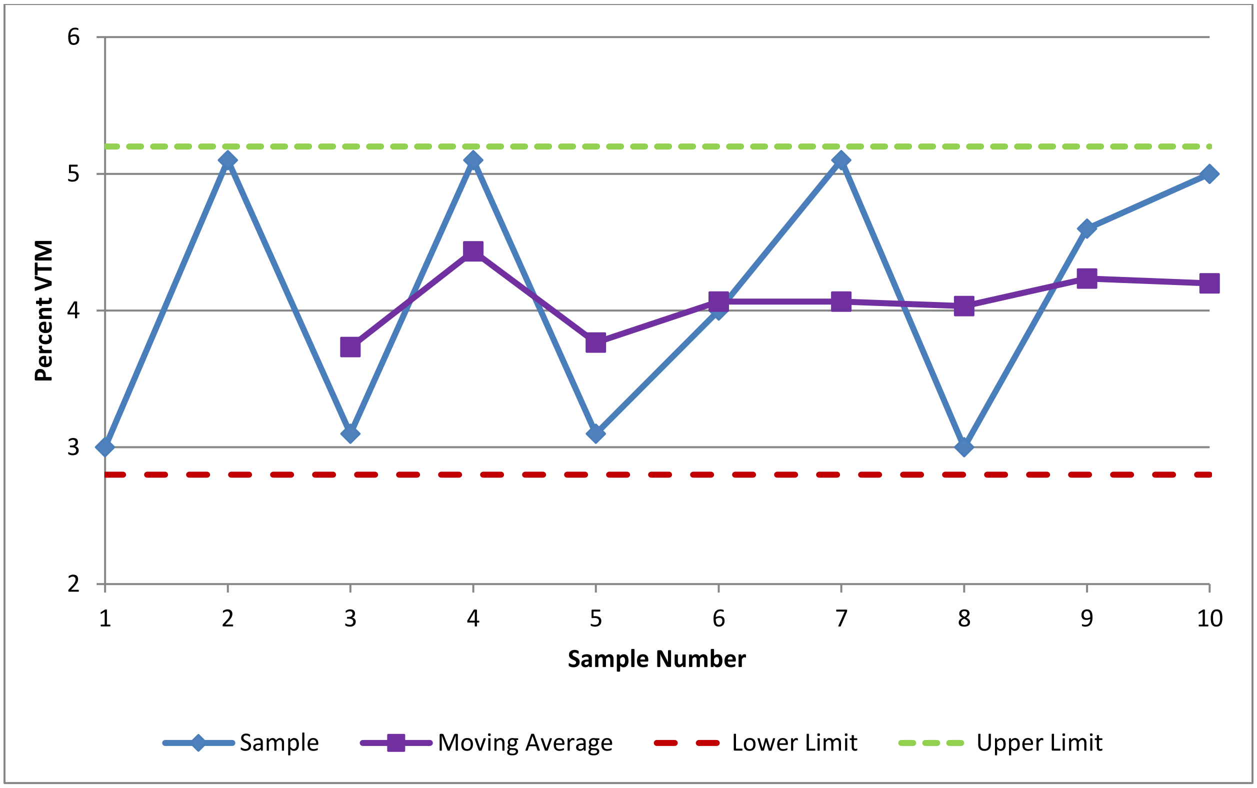


Figure 83 - Moving Average Chart

A PWL analysis better represents the distribution of the material present on the road as compared to a moving average analysis. In a Moving average analysis it is very possible to have constantly varying material that is still considered acceptable. As an example see the moving average graph for VTM in Figure 83. All the data used in the moving average graph would pass specification and would be accepted at full pay. If you take the same data and analysis it using PWL, the producer would incur a penalties due to the large variance in the data. PWL uses the average and standard deviation to construct a normal distribution or Bell curve. The curve is then fitted with the testing limits and the area under the curve outside those limits is considered out of specification. Using the same numbers, Figure 84 demonstrates what the distribution would look.

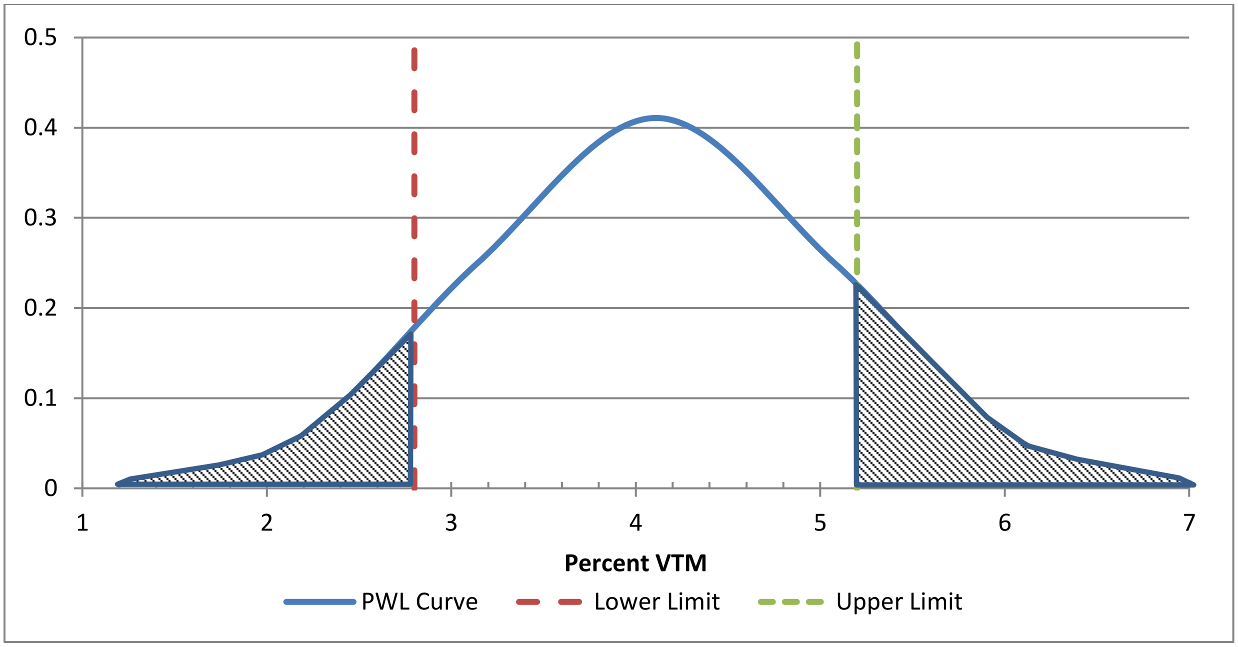


Figure 84 - PWL Distribution

With this example, roughly 20 percent of the distribution is considered to be out of specifications, shown by the shaded areas on the graph. This means that statistically 20 percent of the roadway would have material with air voids outside of the 2.8-5.2 percent range, even though all the lab testing claimed it was acceptable.

A) PENALTY STRUCTURE

The 20 percent from above is calculated using Quality Index values and Table 43 shown below. Quality Index values are calculated using the specified limit, average value of the data, and the standard deviation of the data. For Mat Density, Asphalt Content, and Gradation there are upper and lower quality index values. However, for Joint Density and Bond Strength there is only a lower quality index. Equation 4 and Equation 5 show how to calculate the Quality Index values.

$$Q_U = \frac{(Upper\ Limit - Average)}{Standard\ Deviation}$$ Equation 4 – Upper Quality Index

$$Q_L = \frac{(Average - Lower\ Limit)}{Standard\ Deviation}$$ Equation 5 - Lower Quality Index

Once the Quality Index values are calculated, use Table 43 with each Quality Index and the quantity of samples to determine each of the Percent Within Limits, P_U and P_L. Note that when an upper limit is not specified, P_u shall be 100, and when a lower limit is not specified, P_L shall be 100. When P_U and P_L have been read from the table, use Equation 6 to calculate the PWL value.

$$PWL = (P_U + P_L) - 100$$ Equation 6 – Percent Within Limits

Table 43 - Quality Level Analysis by the Standard Deviation Method

PU or PL % *	**Upper Quality Index (QU) or lower Quality Index (QL)**														
	N=3	**n=4**	**n=5**	**n=6**	**n=7**	**n=8**	**N=9**	**n=10 To n=11**	**n=12 to n=14**	**n=15 To n=18**	**n=19 to n=25**	**n=26 To n=37**	**n=38 to n=69**	**N=70 To N=200**	**n=201 to n=x**
100	**1.16**	**1.50**	**1.79**	**2.03**	**2.23**	**2.39**	**2.53**	**2.65**	**2.83**	**3.03**	**3.20**	**3.38**	**3.54**	**3.70**	**3.83**
99		**1.47**	**1.67**	**1.80**	**1.89**	**1.95**	**2.00**	**2.04**	**2.09**	**2.14**	**2.18**	**2.22**	**2.26**	**2.29**	**2.31**
98	**1.15**	**1.44**	**1.60**	**1.70**	**1.76**	**1.81**	**1.84**	**1.86**	**1.91**	**1.93**	**1.96**	**1.99**	**2.01**	**2.03**	**2.05**
97		**1.41**	**1.54**	**1.62**	**1.67**	**1.70**	**1.72**	**1.74**	**1.77**	**1.79**	**1.81**	**1.83**	**1.85**	**1.86**	**1.87**
96	**1.14**	**1.38**	**1.49**	**1.55**	**1.59**	**1.61**	**1.63**	**1.65**	**1.67**	**1.68**	**1.70**	**1.71**	**1.73**	**1.74**	**1.75**
95		**1.35**	**1.44**	**1.49**	**1.52**	**1.54**	**1.55**	**1.56**	**1.58**	**1.59**	**1.61**	**1.62**	**1.63**	**1.63**	**1.64**
94	**1.13**	**1.32**	**1.39**	**1.43**	**1.46**	**1.47**	**1.48**	**1.49**	**1.50**	**1.51**	**1.52**	**1.53**	**1.54**	**1.55**	**1.55**
93		**1.29**	**1.35**	**1.38**	**1.40**	**1.41**	**1.42**	**1.43**	**1.44**	**1.44**	**1.45**	**1.46**	**1.46**	**1.47**	**1.47**
92	**1.12**	**1.26**	**1.31**	**1.33**	**1.35**	**1.36**	**1.36**	**1.37**	**1.37**	**1.38**	**1.39**	**1.39**	**1.40**	**1.40**	**1.40**
91	**1.11**	**1.23**	**1.27**	**1.29**	**1.30**	**1.30**	**1.31**	**1.31**	**1.32**	**1.32**	**1.33**	**1.33**	**1.33**	**1.34**	**1.34**
90	**1.10**	**1.20**	**1.23**	**1.24**	**1.25**	**1.25**	**1.26**	**1.26**	**1.26**	**1.27**	**1.27**	**1.27**	**1.28**	**1.28**	**1.28**
89	**1.09**	**1.17**	**1.19**	**1.20**	**1.20**	**1.21**	**1.21**	**1.21**	**1.21**	**1.22**	**1.22**	**1.22**	**1.22**	**1.22**	**1.23**
88	**1.07**	**1.14**	**1.15**	**1.16**	**1.16**	**1.16**	**1.17**	**1.17**	**1.17**	**1.17**	**1.17**	**1.17**	**1.17**	**1.17**	**1.17**
87	**1.06**	**1.11**	**1.12**	**1.12**	**1.12**	**1.12**	**1.12**	**1.12**	**1.12**	**1.12**	**1.12**	**1.12**	**1.12**	**1.13**	**1.13**
86	**1.04**	**1.08**	**1.08**	**1.08**	**1.08**	**1.08**	**1.08**	**1.08**	**1.08**	**1.08**	**1.08**	**1.08**	**1.08**	**1.08**	**1.08**
85	**1.03**	**1.05**	**1.05**	**1.04**	**1.04**	**1.04**	**1.04**	**1.04**	**1.04**	**1.04**	**1.04**	**1.04**	**1.04**	**1.04**	**1.04**
84	**1.01**	**1.02**	**1.01**	**1.01**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**0.99**	**0.99**	**0.99**
83	**1.00**	**0.99**	**0.98**	**0.97**	**0.97**	**0.96**	**0.96**	**0.96**	**0.96**	**0.96**	**0.96**	**0.96**	**0.95**	**0.95**	**0.95**
82	**0.97**	**0.96**	**0.95**	**0.94**	**0.93**	**0.93**	**0.93**	**0.92**	**0.92**	**0.92**	**0.92**	**0.92**	**0.92**	**0.92**	**0.92**
81	**0.96**	**0.93**	**0.91**	**0.90**	**0.90**	**0.89**	**0.89**	**0.89**	**0.89**	**0.88**	**0.88**	**0.88**	**0.88**	**0.88**	**0.88**
80	**0.93**	**0.90**	**0.88**	**0.87**	**0.86**	**0.86**	**0.86**	**0.85**	**0.85**	**0.85**	**0.85**	**0.84**	**0.84**	**0.84**	**0.84**
79	**0.91**	**0.87**	**0.85**	**0.84**	**0.83**	**0.82**	**0.82**	**0.82**	**0.82**	**0.81**	**0.81**	**0.81**	**0.81**	**0.81**	**0.81**
78	**0.89**	**0.84**	**0.82**	**0.80**	**0.80**	**0.79**	**0.79**	**0.79**	**0.78**	**0.78**	**0.78**	**0.78**	**0.77**	**0.77**	**0.77**
77	**0.87**	**0.81**	**0.78**	**0.77**	**0.76**	**0.76**	**0.76**	**0.75**	**0.75**	**0.75**	**0.75**	**0.74**	**0.74**	**0.74**	**0.74**
76	**0.84**	**0.78**	**0.75**	**0.74**	**0.73**	**0.73**	**0.72**	**0.72**	**0.72**	**0.71**	**0.71**	**0.71**	**0.71**	**0.71**	**0.71**
75	**0.82**	**0.75**	**0.72**	**0.71**	**0.70**	**0.70**	**0.69**	**0.69**	**0.69**	**0.68**	**0.68**	**0.68**	**0.68**	**0.68**	**0.67**
74	**0.79**	**0.72**	**0.69**	**0.68**	**0.67**	**0.66**	**0.66**	**0.66**	**0.66**	**0.65**	**0.65**	**0.65**	**0.65**	**0.64**	**0.64**
73	**0.76**	**0.69**	**0.66**	**0.65**	**0.64**	**0.63**	**0.63**	**0.63**	**0.62**	**0.62**	**0.62**	**0.62**	**0.62**	**0.61**	**0.61**
72	**0.74**	**0.66**	**0.63**	**0.62**	**0.61**	**0.60**	**0.60**	**0.60**	**0.59**	**0.59**	**0.59**	**0.59**	**0.59**	**0.58**	**0.58**
71	**0.71**	**0.63**	**0.60**	**0.59**	**0.58**	**0.57**	**0.57**	**0.57**	**0.57**	**0.56**	**0.56**	**0.56**	**0.56**	**0.55**	**0.55**
70	**0.68**	**0.60**	**0.57**	**0.56**	**0.55**	**0.55**	**0.54**	**0.54**	**0.54**	**0.53**	**0.53**	**0.53**	**0.53**	**0.53**	**0.52**
69	**0.65**	**0.57**	**0.54**	**0.53**	**0.52**	**0.52**	**0.51**	**0.51**	**0.51**	**0.50**	**0.50**	**0.50**	**0.50**	**0.50**	**0.50**
68	**0.62**	**0.54**	**0.51**	**0.50**	**0.49**	**0.49**	**0.48**	**0.48**	**0.48**	**0.48**	**0.47**	**0.47**	**0.47**	**0.47**	**0.47**
67	**0.59**	**0.51**	**0.47**	**0.47**	**0.46**	**0.46**	**0.46**	**0.45**	**0.45**	**0.45**	**0.45**	**0.44**	**0.44**	**0.44**	**0.44**
66	**0.56**	**0.48**	**0.45**	**0.44**	**0.44**	**0.43**	**0.43**	**0.43**	**0.42**	**0.42**	**0.42**	**0.42**	**0.41**	**0.41**	**0.41**
65	**0.52**	**0.45**	**0.43**	**0.41**	**0.41**	**0.40**	**0.40**	**0.40**	**0.40**	**0.39**	**0.39**	**0.39**	**0.39**	**0.39**	**0.39**
64	**0.49**	**0.42**	**0.40**	**0.39**	**0.38**	**0.38**	**0.37**	**0.37**	**0.37**	**0.37**	**0.36**	**0.36**	**0.36**	**0.36**	**0.36**
63	**0.46**	**0.39**	**0.37**	**0.36**	**0.35**	**0.35**	**0.35**	**0.34**	**0.34**	**0.34**	**0.34**	**0.34**	**0.33**	**0.33**	**0.33**
62	**0.43**	**0.36**	**0.34**	**0.33**	**0.32**	**0.32**	**0.32**	**0.32**	**0.31**	**0.31**	**0.31**	**0.31**	**0.31**	**0.31**	**0.31**
61	**0.39**	**0.33**	**0.31**	**0.30**	**0.30**	**0.29**	**0.29**	**0.29**	**0.29**	**0.29**	**0.28**	**0.28**	**0.28**	**0.28**	**0.28**
60	**0.36**	**0.30**	**0.28**	**0.27**	**0.27**	**0.27**	**0.26**	**0.26**	**0.26**	**0.26**	**0.26**	**0.26**	**0.26**	**0.25**	**0.25**
59	**0.32**	**0.27**	**0.25**	**0.25**	**0.24**	**0.24**	**0.24**	**0.24**	**0.23**	**0.23**	**0.23**	**0.23**	**0.23**	**0.23**	**0.23**
58	**0.29**	**0.24**	**0.23**	**0.22**	**0.21**	**0.21**	**0.21**	**0.21**	**0.21**	**0.21**	**0.20**	**0.20**	**0.20**	**0.20**	**0.20**
57	**0.25**	**0.21**	**0.20**	**0.19**	**0.19**	**0.19**	**0.18**	**0.18**	**0.18**	**0.18**	**0.18**	**0.18**	**0.18**	**0.18**	**0.18**
56	**0.22**	**0.18**	**0.17**	**0.16**	**0.16**	**0.16**	**0.16**	**0.16**	**0.16**	**0.15**	**0.15**	**0.15**	**0.15**	**0.15**	**0.15**
55	**0.18**	**0.15**	**0.14**	**0.13**	**0.13**	**0.13**	**0.13**	**0.13**	**0.13**	**0.13**	**0.13**	**0.13**	**0.13**	**0.13**	**0.13**
54	**0.14**	**0.12**	**0.11**	**0.11**	**0.11**	**0.10**	**0.10**	**0.10**	**0.10**	**0.10**	**0.10**	**0.10**	**0.10**	**0.10**	**0.10**
53	**0.11**	**0.09**	**0.08**	**0.08**	**0.08**	**0.08**	**0.08**	**0.08**	**0.08**	**0.08**	**0.08**	**0.08**	**0.08**	**0.08**	**0.08**
52	**0.07**	**0.06**	**0.06**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**
51	**0.04**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.02**
50	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**

NOTE: For negative values of QU or QL, PU or PL is equal to 100 minus the table value for PU or PL. If the value of QU or QL does not correspond exactly to a figure in the table, use the next higher figure.

* Within limits for positive values of QU or QL.

With all the PWL factors pay factors can be calculated as per Table 44, which is also located in Table 410.13.3.1. Finally, the pay factors for Asphalt Content, Gradation, and Mat Density are combined and a single price adjustment is calculated, as shown in Equation 7.

Table 44 - Percent within Limits Pay Factors

Percentage of Material Within Specification Limits (PWL)	**Lot Pay Factor (Percent of Contract Unit Price)**
96-100 note 1	102 note 1
90-95	100
75-89	[(0.5)PWL]+55
55-74 Note 2	[(1.4)PWL]-12

Note 1 Payment of 102% for mat density shall be subject to additional requirement of the average compaction for the lot being evaluated to be a minimum of 93% density.

Note 2 Material with a PWL less than 55 is considered defective, and will be considered for removal and replacement of the lot. If only one lot characteristic has a percent within limits less than 55, the Engineer, may allow the Contractor to leave the defective lot in place. The decision to remove and replace the subject lot shall include evaluation of all lot characteristics for pay and surface characteristics as per guidelines set forth in MP 401.07.25. If the material is left in place, the Department will pay for the defective lot at a value not to exceed 50% of the contract unit price of asphalt per square yard.
(ie Contract unit price = \$10/sy therefore, \$5/sy max pay)

$$Lot\ Payment = CP\,(2PD + PB + PA)\,/\,400$$

Equation 7 – PWL Price Adjustment

Where:

- CP = Contract unit price per lot (unit price times lot quantity)
- PD = Payment Factor Percentage for mat density
- PB = Payment Factor Percentage for asphalt content.
- PA = Payment Factor Percentage for percent passing the 75 µm (No. 200) sieve

Chapter 8 - Study Guide and Review

I INTRODUCTION

The purpose of this study guide is to serve as a review and reference to those who are preparing to take the written examination for certification as an Asphalt Plant Technician. The example questions and problems in this guide are typical of those that will be included on the examinations. This guide contains information on how the test is given, the subjects covered, materials that will aid in the preparation for the test, and a practice test.

The quality control representatives of a contractor or producer must be certified as an Asphalt Plant Technician. Any industry personnel directly involved in sampling and/or testing activities related to HMA must also be certified as an Asphalt Plant Technician. See MP 106.03.50 for additional information on all of the technician and inspector programs.

II EXAMINATION

The Asphalt Plant Technician examination will be given in a one-part, three hour exam covering the material in the Asphalt Plant Technician Manual and Part-II of the HMA Paving Handbook-2000, both which are reference material given out at the Asphalt Plant Technician School. The written Asphalt Plant Technician examination is an open book test. You may bring books and reference material with you and refer to them during the test. All questions and problems are the multiple choice type.

III PRACTICAL EXAMINATION

After successful completion of the written examination the applicant will be required to pass a practical examination demonstrating their proficiency in conducting tests common to hot-mix asphalt (HMA) quality control. The practical exam currently consists of the following:

- Make a Marshall plug from a hot-mix sample in accordance with AASHTO T245
- Determine the stability and flow of a Marshall specimen in accordance with AASHTO T245 and MP 401.02.22, Table-1, Note 5
- Make a gyratory compactor specimen in accordance with AASHTO T312
- Perform a bulk specific gravity test in accordance with AASHTO T166
- Perform a maximum specific gravity test in accordance with AASHTO T209 using the bowl method
- Calculate the percent air voids and percent VMA of an HMA sample.

The practical exam is subject to periodic updates, and any changes will be noted in the scheduling letter sent out to all persons eligible to take the exam.

IV ADDITIONAL REFERENCE MATERIAL

The publications listed below contain useful reference material for asphalt technicians; these are not required to take the asphalt plant technician written test.

- **Asphalt Mix Design Methods (MS-2),** published by the Asphalt Institute. This manual is a comprehensive guide to designing asphalt mixtures.
- **The Asphalt Handbook (MS-4),** published by the Asphalt Institute. This manual is a comprehensive guide to asphalt Concrete and all of its components.
- **Principles of Construction of HMA Pavements (MS-22),** published by the Asphalt Institute. The four sections in this manual on materials, mix design, plant types and operations, and compaction, plus the appendices contain useful information for the HMA Technician.
- **Asphalt Binder Testing (MS-25)**, published by the Asphalt Institute. This is an in-depth manual developed as a supplement for specification testing of performance graded binders.
- **Performance Graded Asphalt Binder Specification and Testing (SP-1)**, published by the Asphalt Institute. This manual covers the asphalt property measurements of the performance graded asphalt binders that were developed for use in the Superpave System.

Table 45 - Common Materials Test Procedures

Test Method	AASHTO	ASTM	Materials Procedure
Sampling Bituminous Materials	T-40		
Sampling Hot-Mix Asphalt	T-168		
Reducing Samples of HMA to Testing Size	R-47		
Asphalt Content by the Extraction Method	T-164		
Asphalt Content of HMA by the Ignition Method	T-308		
Moisture Content of HMA by the Oven Method	T-329		
Resistance to Plastic Flow Using the Marshall Apparatus	T-245		
Resistance to Plastic Flow Using the Marshall Apparatus [152 mm (6 inch) Specimens]		D-5581	
Preparing & Determining the Density of HMA by Means of the Gyratory Compactor	T-312		
Mixture Conditioning of Hot-Mix Asphalt	R-30		
Bulk Specific Gravity of HMA	T-166		
Maximum Specific Gravity of HMA	T-209		
Percent Air Voids in HMA	T-269		
Resistance of Compacted HMA to Moisture Induced Damage	T-283		
Sampling Aggregate			700.00.06
Reducing Field Samples of Aggregates to Testing Size	T-248		
Moisture Content of Aggregate by Drying	T-255		
Sieve Analysis of Extracted Aggregate	T-30		
Sieve Analysis of Coarse & Fine Aggregate	T-27		
Amount of Material Finer Than 75 µm Sieve in Aggregate	T-11		
Specific Gravity & Absorption of Fine Aggregate	T-84		
Specific Gravity & Absorption of Coarse Aggregate	T-85		
Plastic Fines in Graded Aggregates & Soils by Use of the Sand Equivalent Test	T-176		
Uncompacted Void Content of Fine Aggregate	T-304		
Determining the Percentage of Fractured Particles in Coarse Aggregate		D-5821	
Flat & Elongated Particles in Coarse Aggregate		D-4791	

V REVIEW QUESTIONS

The following questions and problems are typical of the type of material that will be covered on the examination. However, on the exam, all questions and problems are the multiple choice type.

1) Overheated hot-mix asphalt can cause which of the following?
    a. A brittle mix with a shortened pavement life.
    b. Uncoated aggregate in the mix.
    c. A soft pavement which may rut.
2) Which of the following PG Binders has the best resistance to cold weather?
    a. PG 76-22
    b. PG 64-22
    c. PG 58-28
3) Which of the following PG Binders would work best for pavements with very heavy truck traffic?
    a. PG 76-22
    b. PG 64-22
    c. PG 58-28
4) A paving mix that contains too much asphalt is likely to do which of the following?
    a. Ravel
    b. Shove
    c. Flush
    d. Shove or flush, or both
5) How does the viscosity of the asphalt change during mixing?
    a. It usually stays the same.
    b. It becomes lower.
    c. It becomes higher.
6) Fine aggregate will hold more moisture than coarse aggregate. (True or False)
   Answer: ___________
7) The test that measures the temperature at which an asphalt give off vapors that could ignite if exposed to an open flame is called the ______________ test.
8) The asphalt film on aggregate is hardened by exposure to fire and heat. (True or False)
   Answer: ___________
9) The maximum specific gravity test is one of the tests used to find the _____________ of a paving mix.
    a. Stability
    b. Air voids
    c. Viscosity

10) The ignition oven is used to find which of the following?
   a. Flash Point
   b. Asphalt Content
   c. Asphalt Penetration
   d. Viscosity

11) When quartering a sample of hot mix asphalt, the sample is separated into four equal quarters and any two _______________ quarters are discarded.
   a. Random
   b. Adjacent
   c. Opposite

12) An HMA sample consists of 1000 grams of aggregate and 50 grams of asphalt. Find the percent asphalt. ______________

13) An aggregate sample consists of 1000 grams of aggregate and 50 grams of water. Find the percent moisture.___________

14) Calculate the gradation of the following sample. Actual total sample mass is 164.9 grams. .

Sieve Size	Mass Retained	Percent Retained	Percent Passing	Reported Percent Passing
#4	0			
#8	8.2			
#16	60.5			
#30	38.7			
#50	25.2			
#200	25.2			
Pan	6.7			

15) BAD Qestion

16) Failing test results can be caused by not securing a representative sample. (True or False) Answer: ___________

17) At a batch plant a good place to obtain an aggregate sample for gradation is from the bin gates as the material falls into the weigh hopper. (True or False) Answer: ___________

18) The best location to obtain an aggregate sample from a drum mixer plant is from the hot bins. (True or False) Answer: ___________

19) The minimum sample size required for a gradation test depends on the size of the aggregate. (True or False) Answer: ___________

20) A stockpile sample of Number 8 aggregate weighed 5230 grams. After oven drying, the sample weighed 5025 grams. What is the moisture content of the stockpile?

a. 4.6%
b. 4.1%
c. 3.9%

21) The maximum specific gravity of a loose mix sample is 2.428. The average bulk specific gravity of the compacted specimens is 2.331. Calculate the percent air voids. Answer: ___________

22) A Wearing I paving mix is composed of #8's and natural sand. 55% of the blended aggregate is #8's with a specific gravity of 2.678. 45% is natural sand with a specific gravity of 2.615. What is the specific gravity of the combined aggregate? Answer: ___________

23) The bulk specific gravity of the combined aggregate in a 19 mm mix is 2.671. The average bulk specific gravity of the compacted test specimens is 2.433. The percent asphalt in the mix is 4.9% based on percent by total mass of mix. Calculate the VMA for the mix. Answer: ___________

24) A main function of the dryer is to remove moisture from the aggregates. (True or False) Answer: ___________

25) Where are gradation adjustments made in a drum mixer plant?

a. At the cold feed.
b. In the hot bins.
c. Either (a) or (b) above.

26) Aggregate scales are required to be accurate within 0.5 percent. During calibration, a set of aggregate scales was loaded with 2500 lb of aggregate and ten 50 lb weights. The scale dial read 2988 lb. What is the error in the scales, and does it meet the accuracy requirement?

a. 20 lb and no
b. 12 lb and no
c. 12 lb and yes
d. 6 lb and yes

27) Which of the answers below (a, b, c, or d) is the correct percent passing for the following gradation data? Actual original total sample mass = 1140 g.

Sieve Size	Mass Retained	<---------- (a)	Percent (b)	Passing (c)	----------> (d)
1/2”	0	100	100	100	100
3/8”	60	100	95	95	95
#4	300	76	68	68	68
#8	240	47	47	52	47
#16	180	32	32	32	32
#30	70	27	28	28	25
#50	50	24	24	21	21
#200	180	5.2	7.3	5.2	5.2
PAN	59				
Total					

28) Given the Master Range for a Marshall Wearing I below, does the gradation from question 27 meet a Wearing I requirements?

Sieve Size	Requirement
1/2”	100
3/8”	85-100
#4	80 Max
#8	30-55
#200	2.0-9.0

29) According to WVDOH specification, what is the accepted Quality Control tolerance range for air voids of a Base-1 mix? Hint: MP 401.02.27 table C

a. ± 2.5%
b. ± 1.5%
c. ± 1.0%

30) Under heated aggregate could be caused by which of the following:
   a. Wet stockpiles
   b. Overloaded dryer
   c. Clogged burner
   d. Any of the above

31) Which type of plant does not have a screening unit?
   a. Drum mixer
   b. Continuous
   c. Batch

32) Why should cone shaped stockpiles be avoided?
   a. The end loader has trouble loading from a cone shaped pile.
   b. The aggregate tends to segregate because the coarse aggregate collects at the outer edge of the pile.
   c. The stockpile tends to hold moisture.

33) Undersized aggregate in a hot bin might be caused by:
   a. Carry over
   b. Hole in Screen
   c. Either of the above

34) Moisture in the aggregate can be ignored when setting the cold feed gates because it is removed in the dryer. (True or False) Answer: ___________

35) Cyclone collectors, wet scrubbers and baghouses are types of:
   a. Dryers
   b. Dust collectors
   c. Storage silos

36) In a drum mixer plant, the asphalt added near the ___________ of the dryer.
   a. burner end
   b. discharge end
   c. middle

37) Aggregate is delivered from the cold feed to a drum mixer at 2800 lb per minute. The average moisture content of the aggregate is 4.0 percent. Asphalt is added at 120 lb per minute. What is the asphalt content of the paving mix?
   a. 4.1%
   b. 4.3%
   c. 4.5%
   d. 4.7%

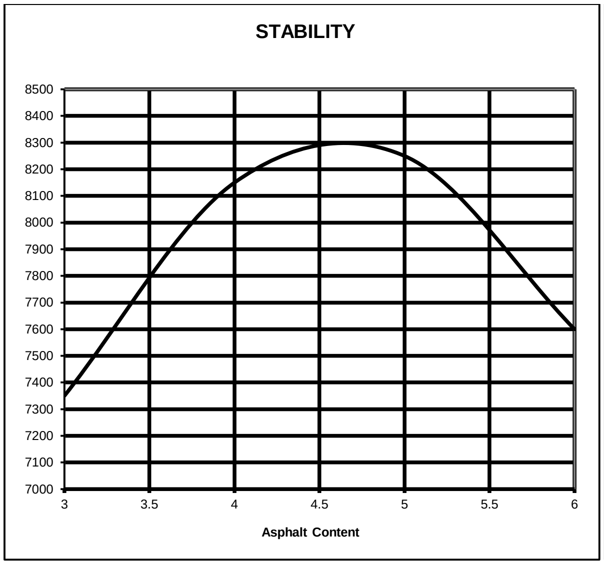
38) Below are plots of a Marshall Design data for a medium traffic paving mix. With the specification limits are listed below; Determine:

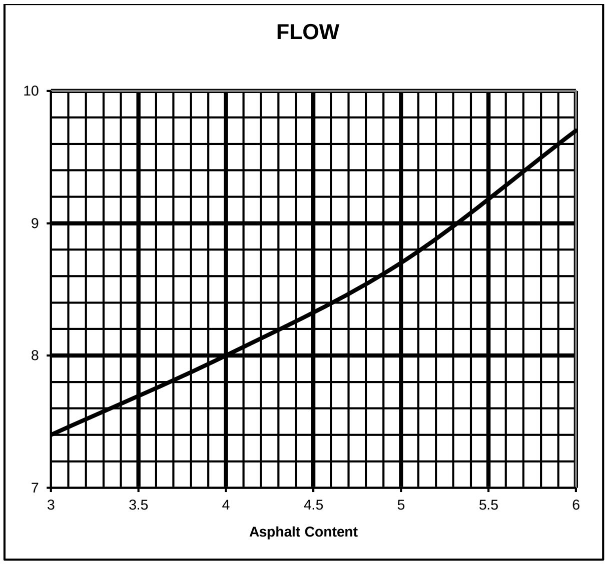
A) What the stability is if the asphalt content is 5.0 percent

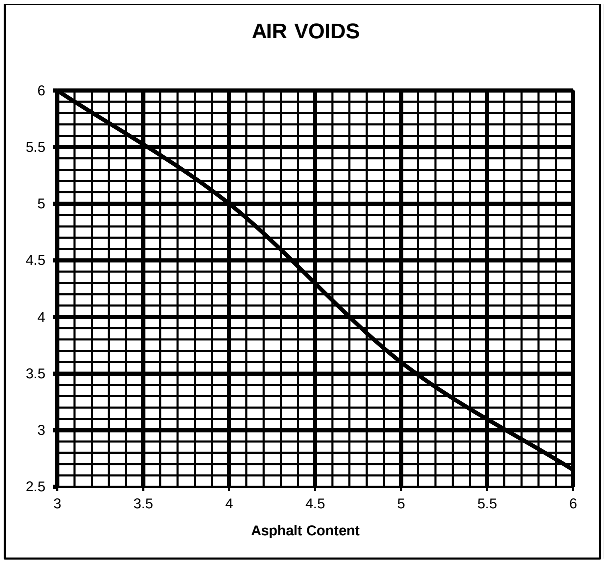
B) What the lowest asphalt content that will provide a mix design within the limits of the above specified requirements

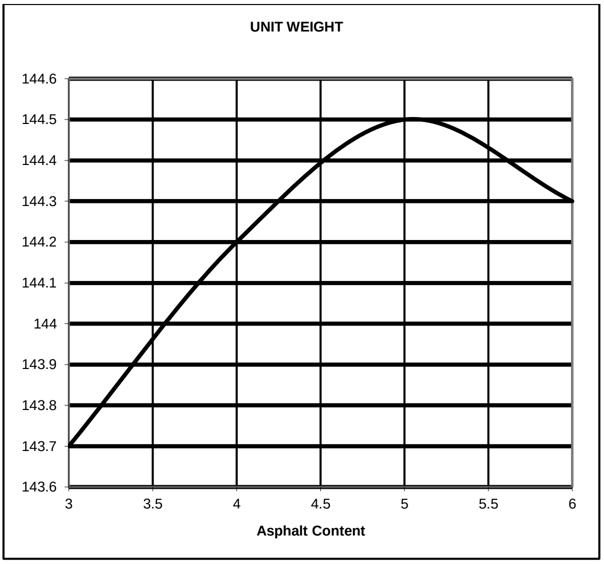
C) Which of the following is closest to the optimum asphalt content using the criteria of MP 401.02.22

Stability	5300 Newtons minimum
Flow (0.25mm)	8.0 to 16.0
Air Voids	3.0 to 5.0 percent









39) Listed below is the gradation data for the aggregates to be used in a Wearing-I mix. Calculate the combined gradation if the aggregates are combined in the following percentages:

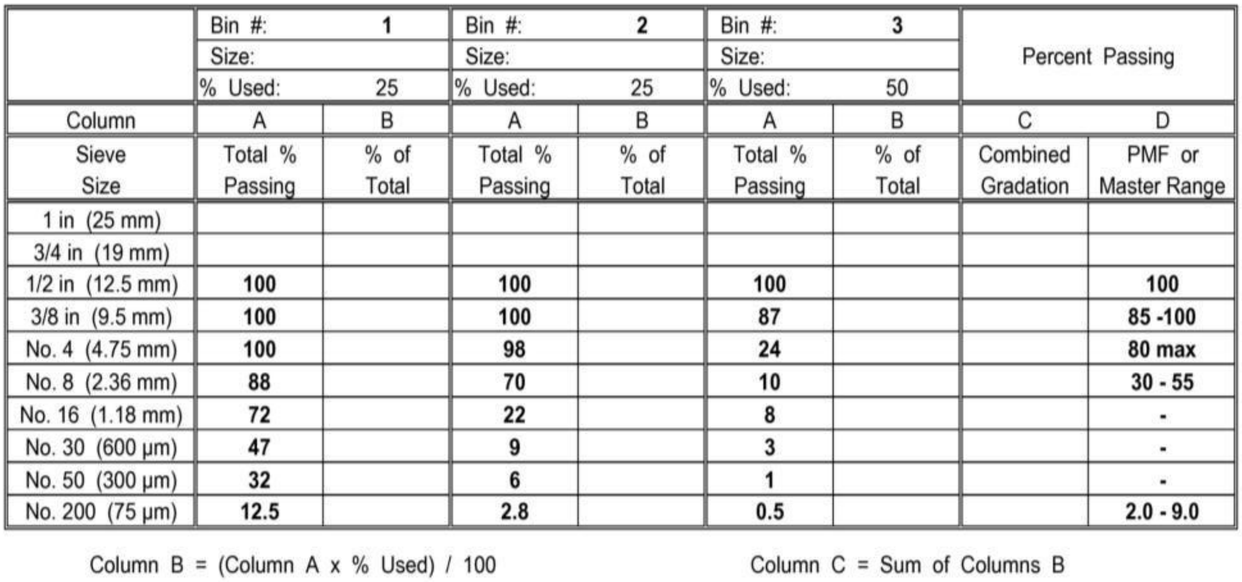
Bin #1 - 35% Bin #2 - 30% Bin #3 - 20% Bin #4 - 15%

SIEVE SIZE	Bin #1	Bin #2	Bin #3	Bin #4	% Passing
1/2”	100	100	100	100	
3/8”	100	100	92	23	
# 4	100	76	16	6	
# 8	98	21	4	2	
# 16	65	10	3	0	
# 50	27	2	2	0	
# 200	9	0	0	0	

40) A conveyor belt carries aggregate from the cold feed to a dryer. The belt speed is 25 feet per minute. Aggregate removed from a section of the belt 2.0 feet long weighs 48.0 lb. How many pounds of aggregate per minute are delivered to the dryer?

a. 570
b. 580
c. 590
d. 600

41) Using the table below determine if the percent of each aggregate listed meets the specification requirements. (True/False)



	Bin #: 1		Bin #: 2		Bin #: 3		Percent Passing	
	Size:		Size:		Size:			
	% Used: 25		% Used: 25		% Used: 50			
Column	A	B	A	B	A	B	C	D
Sieve Size	Total % Passing	% of Total	Total % Passing	% of Total	Total % Passing	% of Total	Combined Gradation	PMF or Master Range
1 in (25 mm)								
3/4 in (19 mm)								
1/2 in (12.5 mm)	**100**		**100**		**100**			**100**
3/8 in (9.5 mm)	**100**		**100**		**87**			**85 -100**
No. 4 (4.75 mm)	**100**		**98**		**24**			**80 max**
No. 8 (2.36 mm)	**88**		**70**		**10**			**30 - 55**
No. 16 (1.18 mm)	**72**		**22**		**8**			**-**
No. 30 (600 µm)	**47**		**9**		**3**			**-**
No. 50 (300 µm)	**32**		**6**		**1**			**-**
No. 200 (75 µm)	**12.5**		**2.8**		**0.5**			**2.0 - 9.0**

Column B = (Column A x % Used) / 100

Column C = Sum of Columns B

42) The acronym VMA stands for the following:
   a. Volumetric Mix Analysis
   b. Voids in Mineral Aggregate
   c. Volume of Mixed Asphalt
   d. Video Music Awards

43) An NCAT ignition oven works by burning the asphalt from a mix sample at a temperature of ___________
   a. 538˚C
   b. 489˚C
   c. 872˚F
   d. 1200˚F

44) Under the Performance grade binder system, what does the “76” in a PG 76-22 represent?
   a. How many gyrations the mix requires
   b. The highest yearly temperature (˚C)
   c. The unit weight of the binder
   d. The average 7-day max. pavement design temperature (˚C)

45) According to Table 2 of MP401.02.28, how many gyrations are required on a PG 64-22 mix for a 1.5 million ESAL road?
   a. 100
   b. 65
   c. 80
   d. 50

46) According to MP 401.02.22 Table 1, How many blows should be used to compact a Heavy Traffic Design Wearing III? Hint:table 1 note 3 MP 401.02.22

    a. 75
    b. 65
    c. 50
    d. None of the above

47) As part of its standard equipment, each plant which proportions aggregate by weight shall provide a minimum of ten _____ pound test weights for the purpose of maintaining the continued accuracy of weighing equipment.
    a. 50
    b. 25
    c. 100
    d. 20

48) A PG76-22 is not required to have a modifier. (True or False)

49) Which of the following is NOT a benefit of using Warm Mix Asphalt (WMA)?
    a. Paving in cooler temperatures
    b. Reduces fuel consumption
    c. Able to use higher RAP
    d. Less compaction required

50) The most abundant virgin aggregate used in asphalt mixes in the state of WV is:
    a. Shale
    b. Limestone
    c. Granite
    d. Slag

51) What type of Aggregate Specific Gravity is defined as the mass of the stone divided by the volume of the solid stone plus the internal voids plus the volume of the external voids?
    a. Apparent
    b. Effective
    c. Bulk

52) If using “Best Practices”, how many drops should be used when loading a dump truck with HMA?
    a. 5
    b. 1
    c. 3

53) According to Chapter 3 sampling, how many levels of Quality Control are there for liquid asphalt suppliers?
    a. 5

    b. 2
    c. 1
    d. 3

54) Which of the following is a Coarse Aggregate Source Property required for all mixes under the 401 Specifications?
    a. % Toughness
    b. % Soundness
    c. % Deleterious Materials
    d. All of the above

55) During the construction process, _____________ is considered the most important factor that contributes to the performance of the pavement.
    a. Gradation
    b. Mix design
    c. Size of the paver
    d. Compaction
    e. All equally important

VI REVIEW ANSWERS

1) A
2) C
3) A
4) D
5) C
6) TRUE
7) FLASH POINT
8) TRUE
9) B
10) B
11) C
12) 4.76%
13) 5.0%
14)

Sieve Size	Mass Retained	Percent Retained	Percent Passing	Reported Percent Passing
#4	0	0	99.86	100
#8	8.2	5	94.86	95
#16	60.5	36.7	58.16	58
#30	38.7	23.5	34.66	35
#50	25.2	15.3	19.36	19
#200	25.2	15.3	4.06	4.1
Pan	6.7	4.06		

15) --------
16) TRUE
17) TRUE
18) FALSE
19) TRUE
20) B
21) 4.0
22) 2.649
23) 13.4
24) TRUE
25) A
26) C
27) D
28) YES
29) B
30) D
31) A
32) B
33) A
34) FALSE
35) B
36) C
37) B
38)

A. 8250
B. 4.0 %
C. 4.7%

39)

12.5 mm	100
9.5 mm	87
4.75 mm	62
2.36 mm	42
1.18 mm	26
300 µm	10
75 µm	3.2

40) D
41) True
42) B
43) A
44) D
45) B
46) C
47) A

48) FALSE
49) D
50) B
51) C
52) C
53) B
54) D
55) D