WEST VIRGINIA DIVISION OF HIGHWAYS

INSTRUCTION MANUAL

ASPHALT PLANT TECHNICIAN

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Chapter 1 - Background

I HISTORY OF ASPHALT CONCRETE

Even though many advanced technologies are used 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 until 1869 in London, England. 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. 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 producer's 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, verifying scale checks, monitoring plant operations and mixing time, observe condition of mix in the truck, load tickets for proper information, and reviewing 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, the 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, a positive or negative charged 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 result, only about 25% of the petroleum refineries in the US produce asphalt.

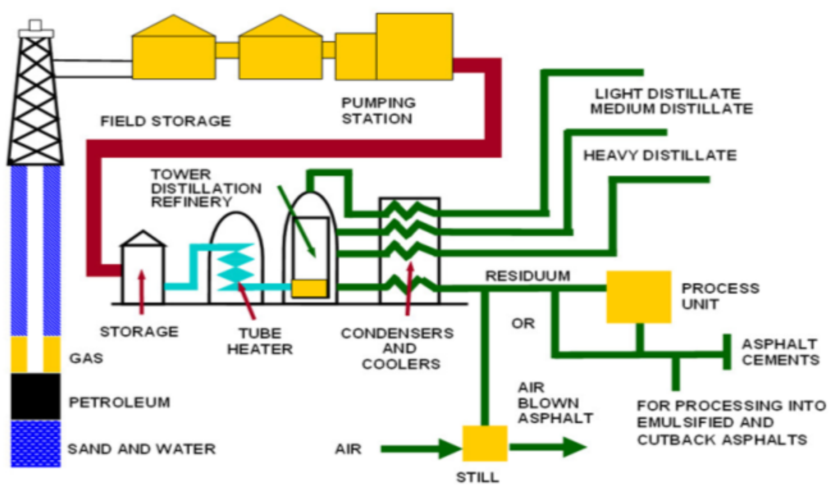


Figure 5 - Refinery Operation

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 porosity can entrap water and can be a problem during asphalt production. These also soak up additional 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) Reclaimed Asphalt Pavements (RAP)

Reclaimed Asphalt Pavement (RAP) is asphalt pavement that has been pulverized, usually by milling, and is used like an aggregate in the 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 so 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 - Aggregates for Asphalt 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. 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 to conduct a technician's day to day tasks are as follows: Standard Asphalt concrete production and placement is covered in Sections 401, while section 402 covers Skid Resistant Asphalt Concrete, and section 410 covers Asphalt concrete production under a Percent within Limitation specification; 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, 402, and 410 reference AASHTO and/or ASTM standard test methods. Copies of the latest versions of these test methods will be required to properly conduct these tests. Also, within these Section are references to various Materials Procedures (MP's) for designing Asphalt concrete mixtures, and the quality control and quality assurance requirements of production. Copies of these MP's will be required 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 is 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 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 Performance Graded Binder, PG 64E-22, in lieu of the standard PG 64H-22 or PG 64S-22 at a certain intersection. If the intersection was on a low volume road it would not normally spec a PG 64E-22, but if there was a large amount of trucks like at a coal loading facility it may be necessary to combat rutting from the large trucks.

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 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 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 MATERIAL

A) Types of Liquid 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 mixtures. They are mostly solid at ambient temperatures and must be heated to make them fluid enough to mix with stone into a paving mix.
- Asphalt Emulsions are asphalt globules suspended in water with an emulsifying agent. Since asphalt and water do not go into solution with one another, 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, or in the use of Cold mix asphalt
- 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, however they are still used in Cold Mix Asphalt.

B) Performance Graded Binders

The Performance Grade specification is the current method for grading asphalt binders. These have names like PG 64S-22. All grades start with the letters PG, which stands for "Performance Graded". The numbers (64 & -22) are temperatures in degrees Celsius where: the 64 represents a maximum value for a seven (7) day average road temperature has than 64° Celsius and the -22 denotes that the roadway will not expected to have a single day temperature lower than -22° Celsius, as shown in Figure 6. Lastly, there is a letter between the two temperatures, this letter designates the traffic leveling that the binder is to be used with. There are three descriptive letters used in WV; S for Standard Traffic, H for Heavy Traffic, and E for Extreme traffic loads.

WV's standard high and low temperature environmental conditions for West Virginia are 64°C and -22°C respectively. There is one exception to this rule, which is the high elevation mountainous areas in the east, in these mountainous regions 58°C and -28°C are considered the environmental conditions the due to the colder temperatures.

WV's specifications state the Standard grade of binder to be used on WVDOH projects is to be PG 64S-22. The state also specifies the use of a PG 64H-22 and PG 64E-22 for the use on roadways with increasingly higher traffic levels, and a PG 58S-28 for the mountainous regions.

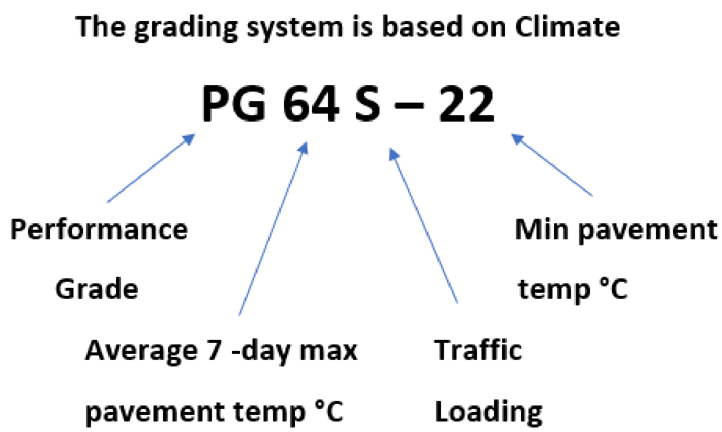


Figure 6 - Performance Graded Binder System

The Performance Grade specification covers several grades for use in a variety of climatic and traffic conditions. Some of these grades are considered neat or virgin, meaning they are produced from standard crude oils without additives. To meet specification however some binder grades require modifying additives, these additives are usually various types of polymers, or acids. For instance, a PG 64E-22 must be a modified binder while a PG 64S-22 may be produced from standard crude.

C) Asphaltic Products

Hot-Mix Asphalt 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 (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 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. Nowadays, Cold mix is used primarily for patching material during winter months when the mixing plants are shut down and hot-mix is not available.

II AGGREGATE

A) Storage/Handling

Since the majority of Asphalt mixtures are comprised of aggregates, aggregate management is crucial for consistent production of asphalt mixtures. 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 8. 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 9 or Figure 10 respectively, rather than a single large stockpile. Stockpiles can also be made using a telescoping conveyer as shown in Figure 11.

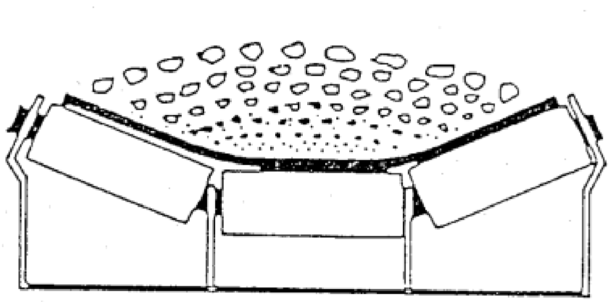


Figure 7 - - Belt Segregation

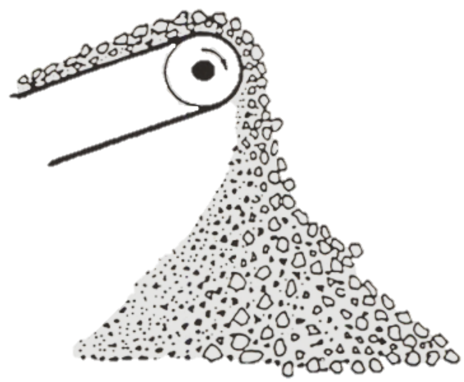


Figure 8 - Stockpile Segregation off a Belt

Figure 9 - Building a Stockpile in Layers

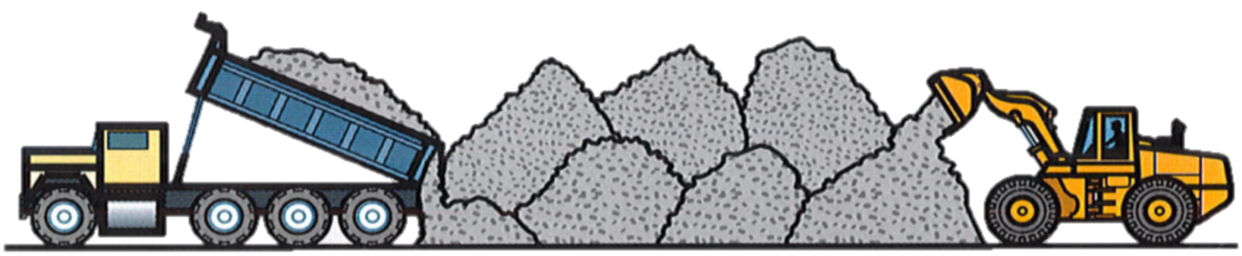


Figure 10 - Building a Stockpile with Smaller Piles

Figure 11 - 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 overestimate 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 12 below.

Figure 12 - 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 No. 30 screen has 30 openings in a linear inch of screen.

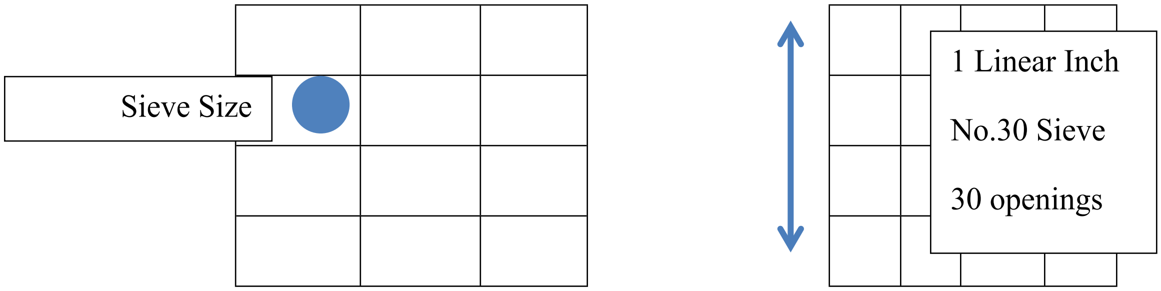


Figure 13 - Sieve Screen Openings

Table 1 – 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 14.

Sieve	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	

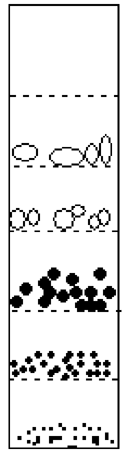


Figure 14 - Example Gradation

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 T 30, while belt samples or hot bin samples from a plant are tested according to AASHTO T 27. AASHTO T 30 includes a procedure for washing the aggregate before the sieving operation is performed. A separate wash test method, AASHTO T 11, is used along with the T 27 sieve analysis. The only major differences in the T 27 procedure from T 30 are in the sample sizes and the method for splitting down the minus 4.75 mm (No. 4) material before sieving. AASHTO T 27 and T 11 are thoroughly covered in the Aggregate Inspector Manual.

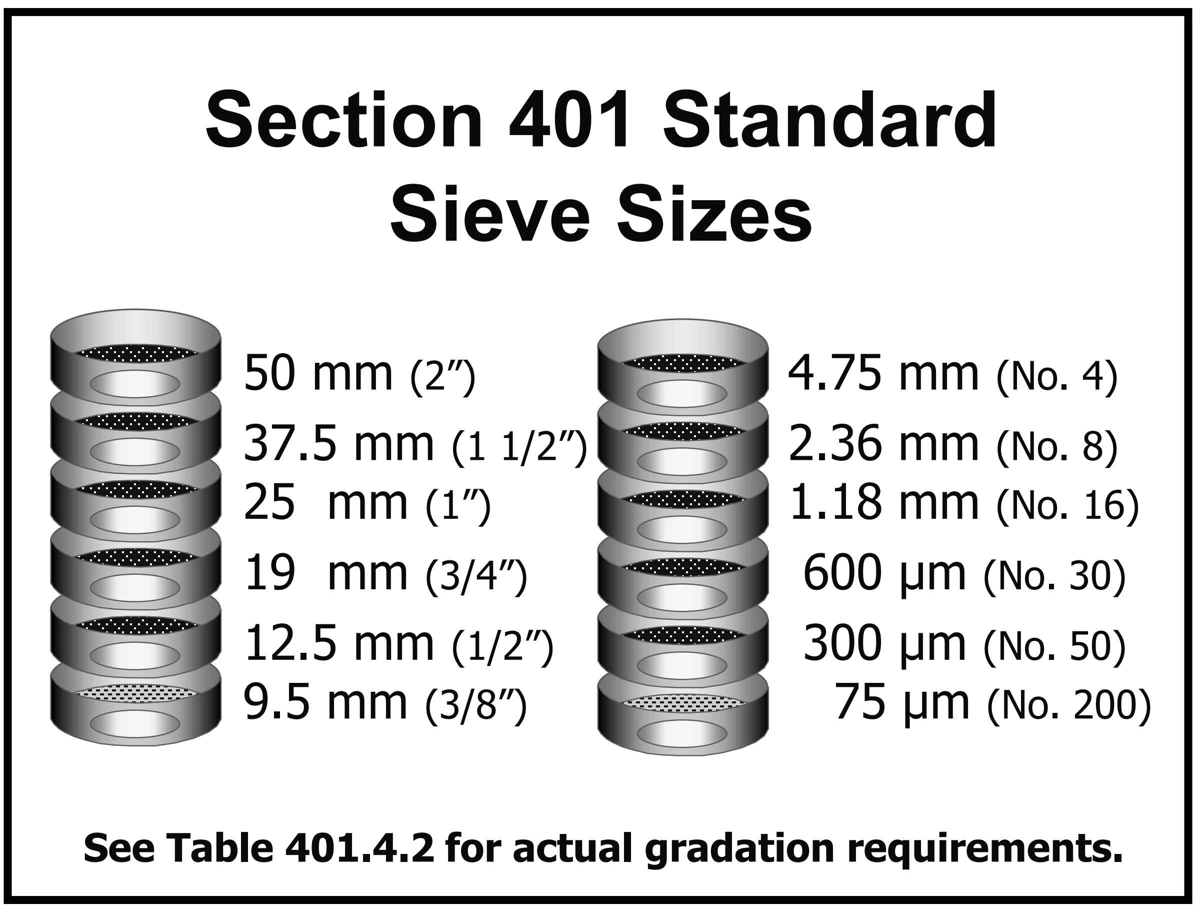
Gradation limits are often placed on aggregates in hot-mix asphalt because when mixes are designed in a lab the percentages of aggregate and asphalt components are controlled very tightly in order to establish the required design criteria. The mix that comes out of the plant must be controlled as close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



After taking an appropriately sized sample in accordance with MP 700.00.06, the sample is reduced to the approximate test portion size in accordance with AASHTO T 248 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. Coarse 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 T 27 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 T 11). 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 2. 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 2 – 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.			

a) 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 T30 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.

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			**100.00 = 100**
9.5 mm	**74.3**	**6.90**	**93.10 = 93**
4.75 mm	**374.4**	**34.77**	**58.33 = 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

iv) Gradation Charts

In WV, all the standard asphalt 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 15. 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.

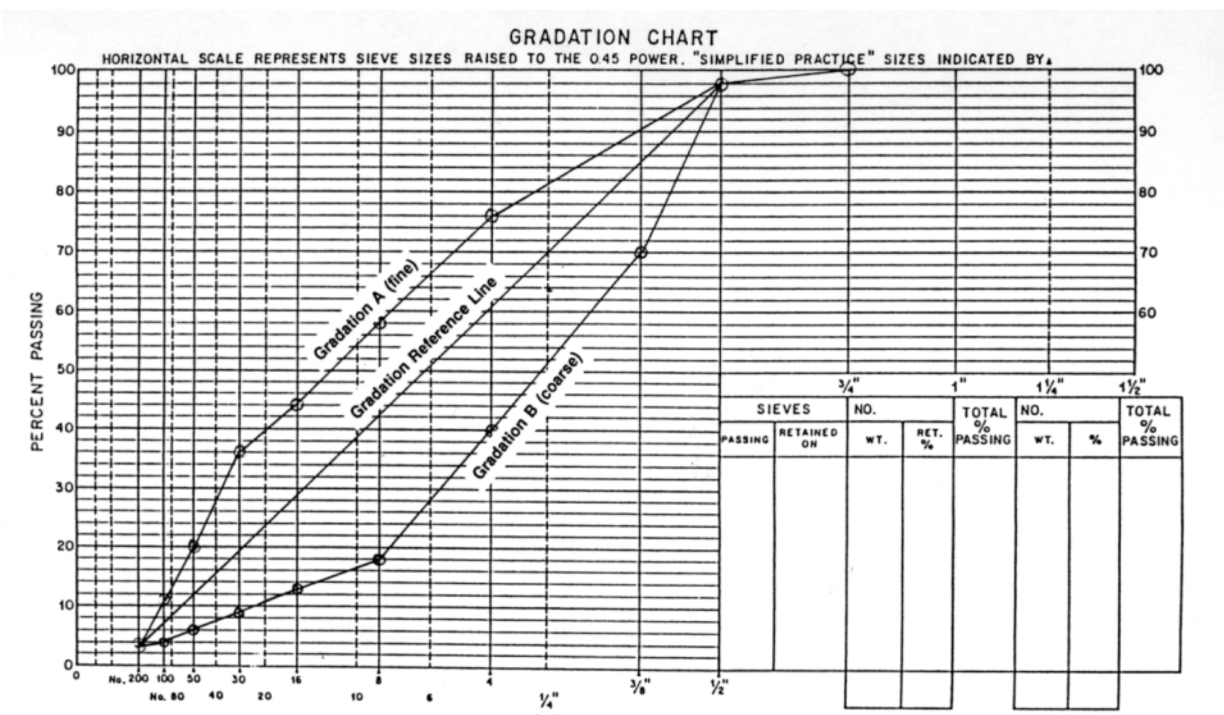


Figure 15 - Example Gradation Chart

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).

iv) 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 16 - Difference between river gravel before and after crushing

v) 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.

vi) Sand Equivalency (AASHTO – T 176)

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 17.

vii) Fine Aggregate Angularity (AASHTO – T 304)

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 18.

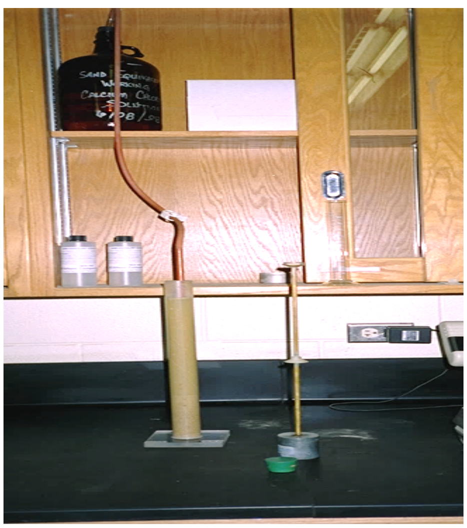


Figure 17 – Sand Equivalency

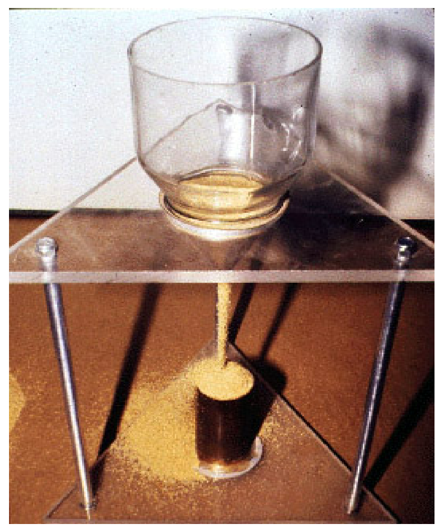


Figure 18 - Fine Aggregate Angularity

viii) Unit Weight (AASHTO – T 19)

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.

ix) 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.

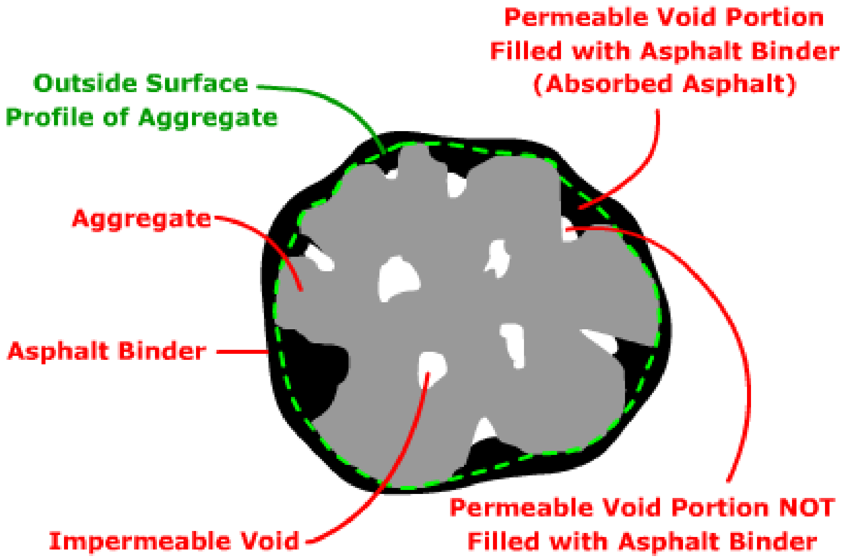


Figure 19 – Definition Rock for Specific Gravity

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.

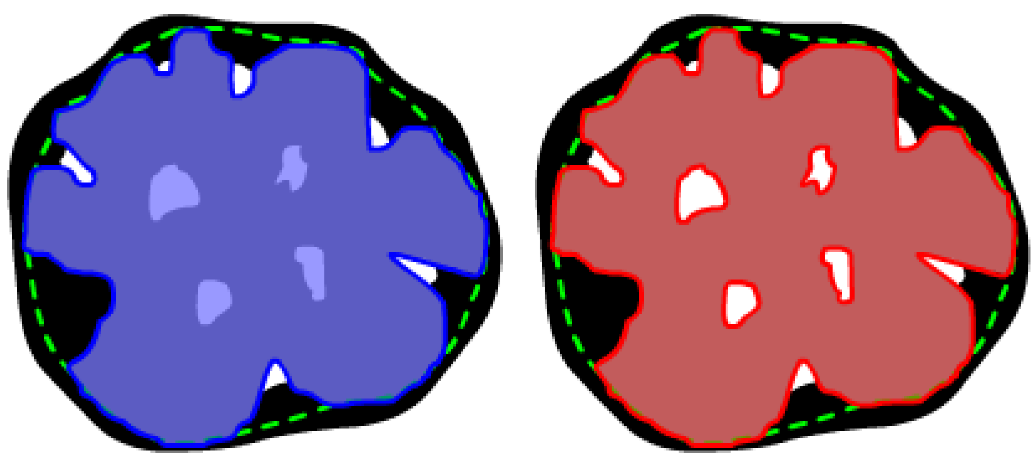


Figure 20 - Apparent Specific Gravity

- **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.

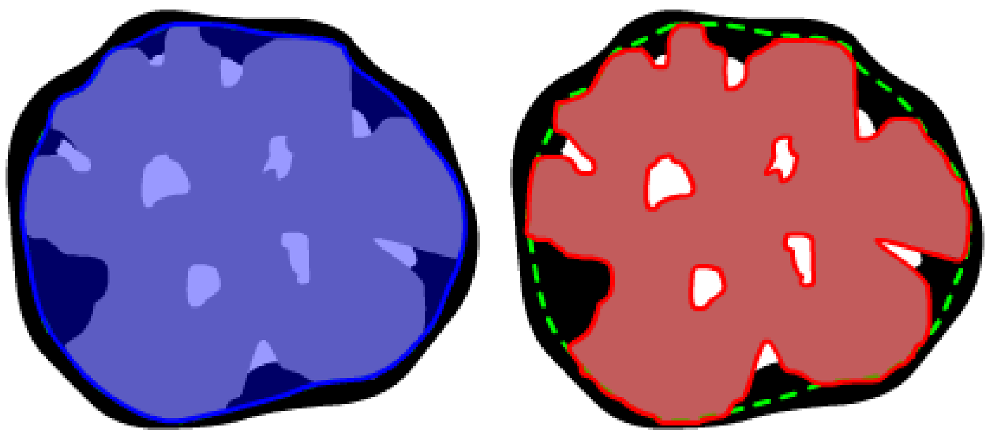


Figure 21 - Apparent Specific Gravity

- **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.

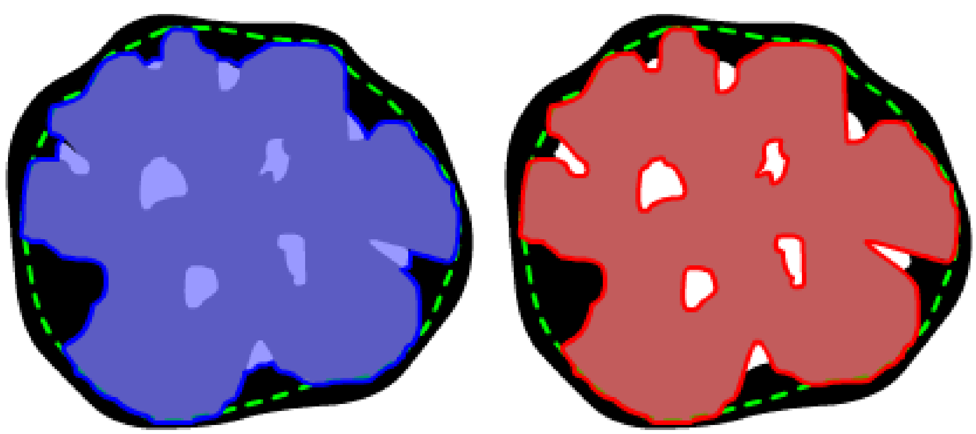


Figure 22 - Apparent Specific Gravity

The specific gravity test for coarse aggregate is covered under AASHTO T 85 and the specific gravity test for fine aggregate is covered under AASHTO T84.

a) Specific Gravity of Coarse Aggregate (AASHTO T 85)

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 (G_{sb}) = A / (A - C)
Bulk Sp. Gravity (G_{sb}) = 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:

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

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

b) Specific Gravity of Fine Aggregate (AASHTO T 84)

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] x 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}) $= \dfrac{503.5}{670.3 + 511.4 - 987.9} = 2.598$

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

III ASPHALT MIXTURES

A) Design Method 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 production of an approved mix design. 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.

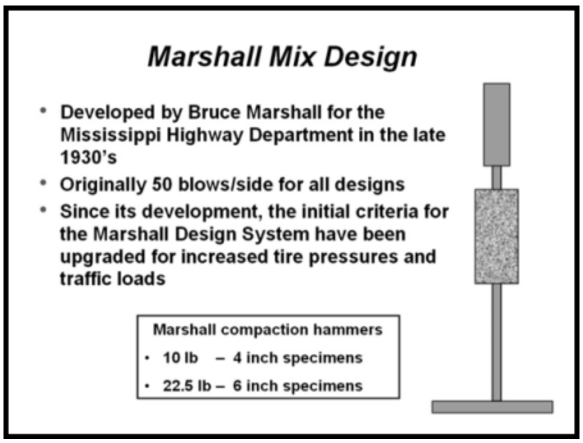
To design a proper Marshall or Superpave mixture, knowledge of the design methods, calculations, and laboratory procedures are required. To ensure that mix designs are properly performed, the mix designs must be prepared by a certified technician for both the Marshall and Superpave methods. Certification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

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, conditioned, and then compacted to a standard cylindrical specimen size of 2½ inches in height by 4in. diameter or 3¾ in. in height by 6in for Base-1 mixtures. The sample is compacted using a Marshall Compaction Hammer Figure 23, at a certain number of blows, depending on traffic levels. For standard 4in samples and medium traffic – 50 blows is required and for heavy traffic – 75blow. Base-1, 6in. samples are compacted with ASTM D5581 at 112 blows regardless of the traffic level. Once compacted and cooled the samples are tested for bulk specific gravity and then tested for stability and flow using the Marshall Stabilometer Figure 24. A sample's Stability is a measure of maximum load resistance and the Flow is a measure of cumulative deformation until maximum load occurs.



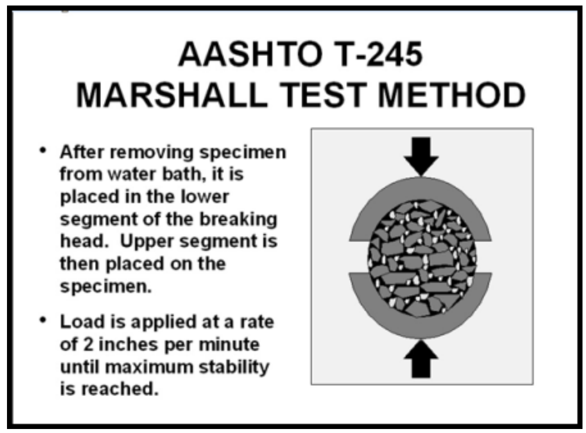


Figure 23 - Marshall Compaction Hammer

Figure 24 - 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 25. 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 25 - Superpave Gyratory Compactors

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 recording.

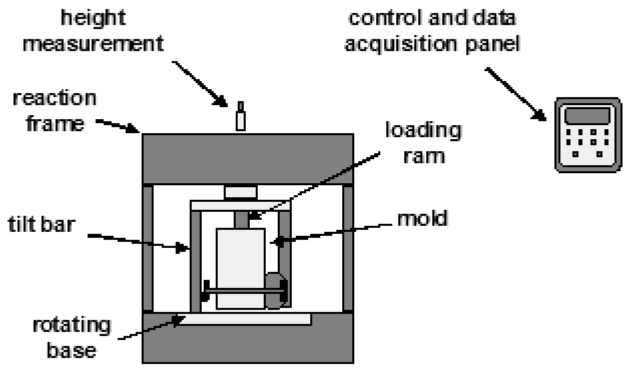


Figure 26 - Key Components of a Gyratory Compactor

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, 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 27, 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 27, 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.

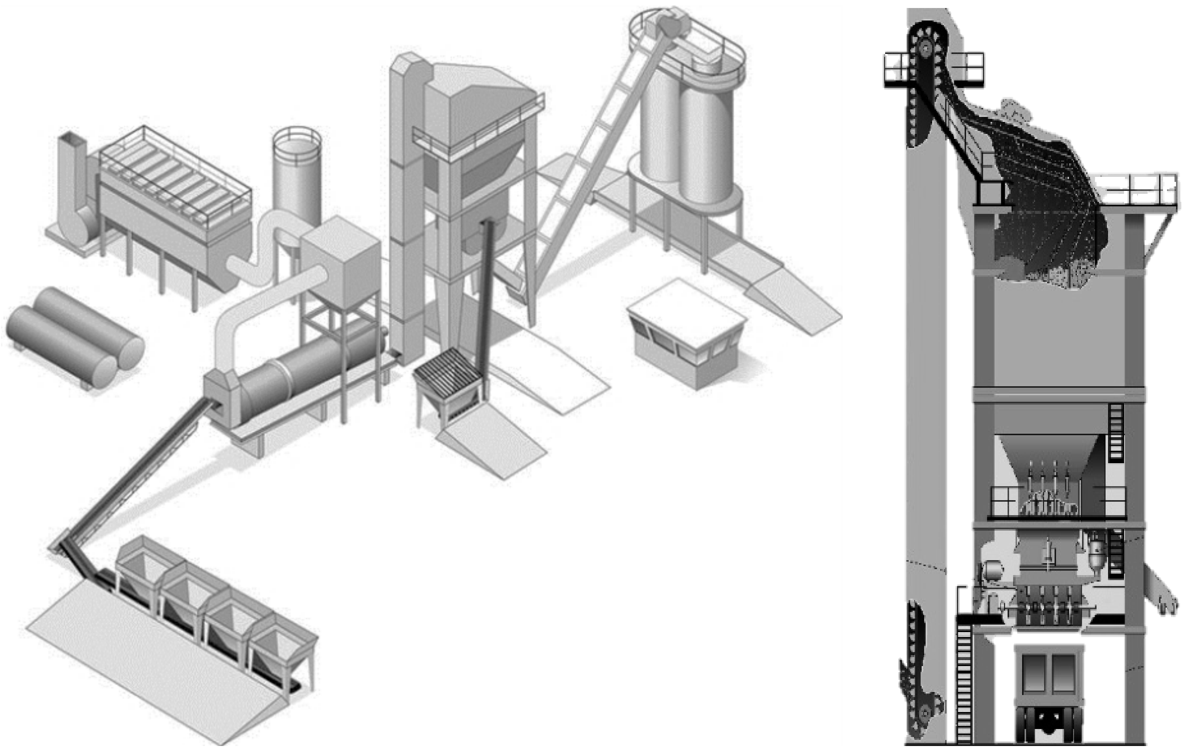


Figure 27 – Batch Mixing Plant and Batch Tower

With a drum mixing plant, shown in Figure 28, 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 29. 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.

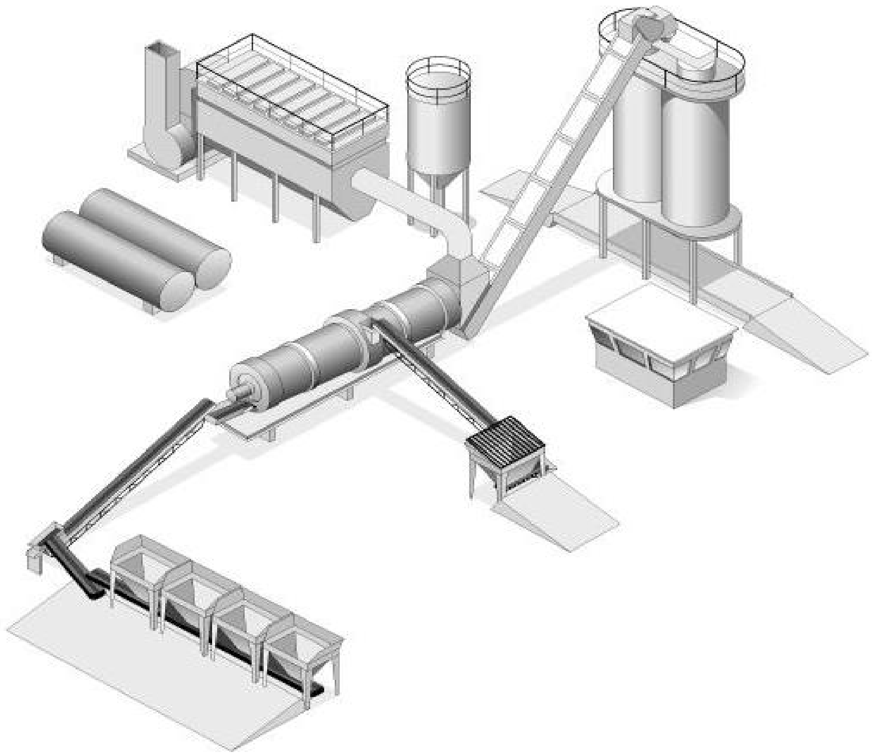


Figure 28 - Drum Mixing Plant

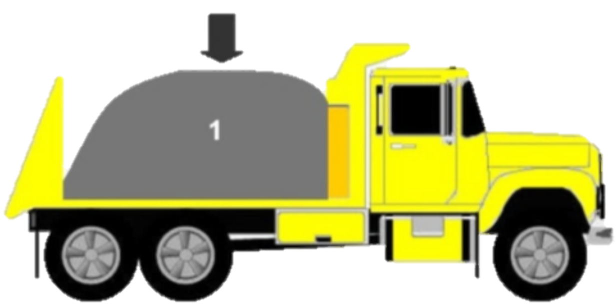


Figure 29 – Incorrect Truck Loading Scenarios

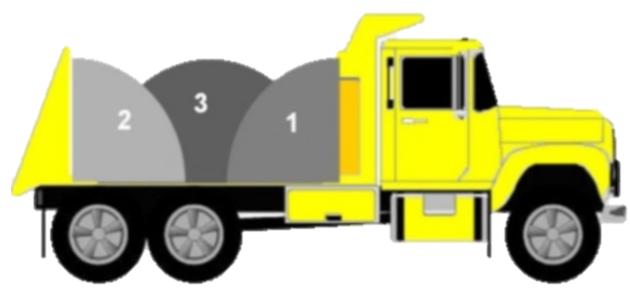


Figure 30 – Correct Truck Loading Scenarios

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 31. Also shown in Figure 31, a Materials Transfer Device (MTD) 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 31 – Asphalt Paving Train

Once laid by the paver the asphalt concrete is further compacted using compaction rollers, shown in Figure 32. There are three general types of rollers; Static Steel Wheel, Vibratory Steel Wheel, and Pneumatic-Tired 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 being used by the driving public.

Figure 32 - 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 64S-22.

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.

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 many 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 an 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 ensure 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.

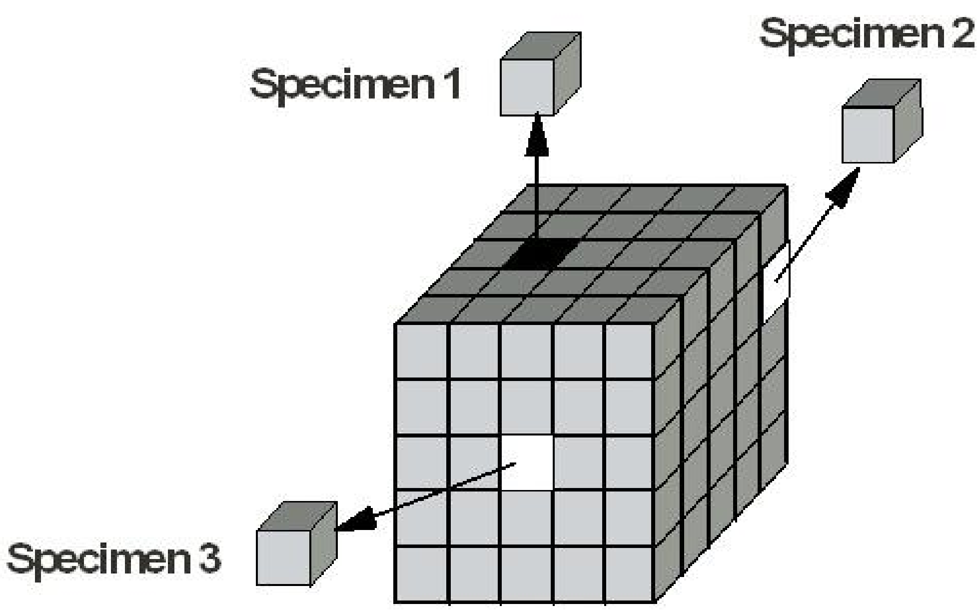


Figure 33 - Sampling Cube

Sampling locations can be determined by 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 3. 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 unbi ased 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 3 - 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.

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

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

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.

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

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

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

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

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

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

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

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

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 3 and you proceeded right with the five random numbers.

Givens:
Production = 2500 tons
Samples = 5
Random Number =
Column 2 & Row 18 from Table 3

Unknowns:
Sample tonnage = ??

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

$Sample1 = 2500tons \times 0.917 = 2292.5tons$ $Sample2 = 2500 tons \times 0.942 = 2355.0tons$

$Sample3 = 2500tons \times 0.985 = 2462.5tons$

$Sample4 = 2500tons \times 0.838 = 2095.0tons$

$Sample5 = 2500tons \times 0.805 = 2012.5tons$

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 34 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.

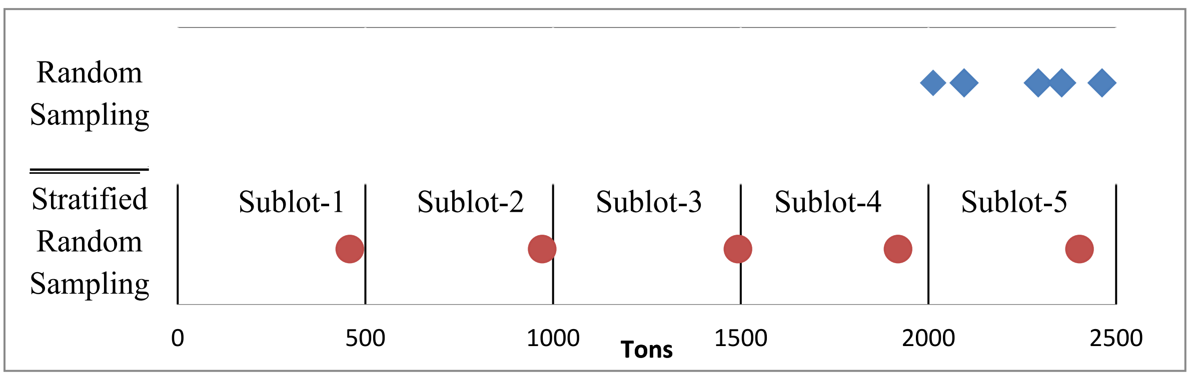


Figure 34 - Stratified Random Sampling Example

II 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 35). 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. To obtain a truly representative sample of stockpiled material, all levels of the stockpile should be included in a field sample (Figure 36). 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.

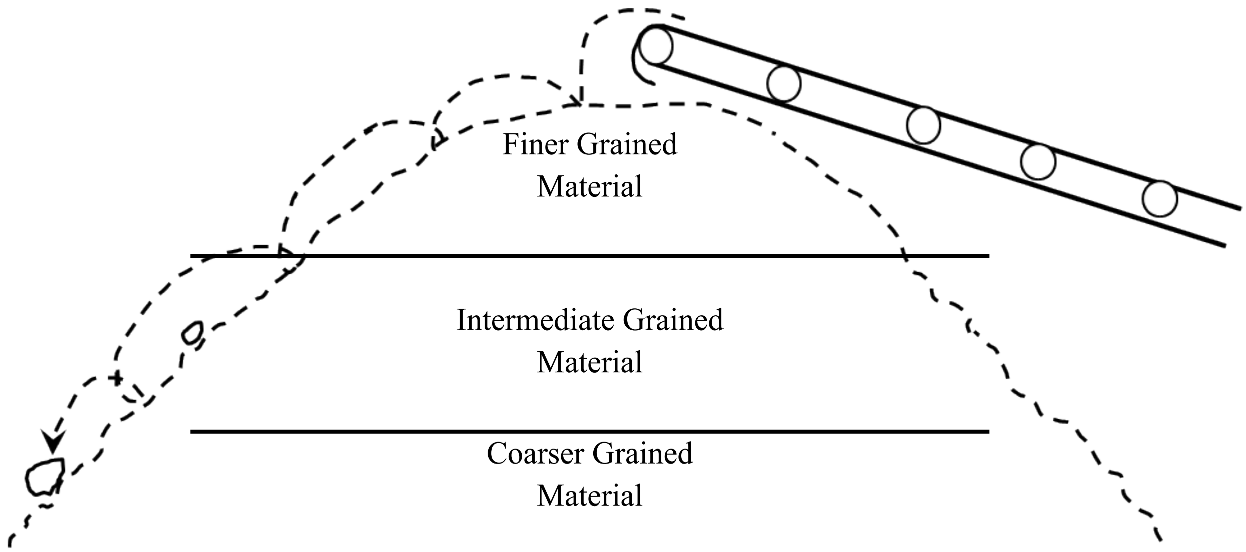


Figure 35 - Stockpile Segregation

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 36).

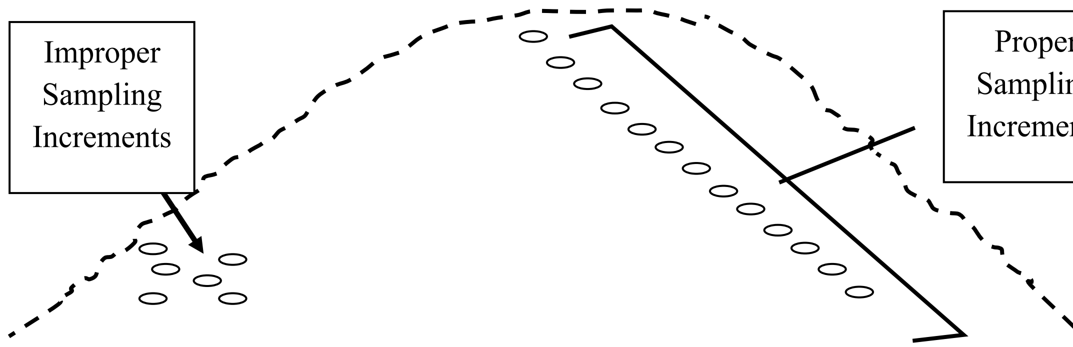


Figure 36 - Stockpile Sampling

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 like 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.

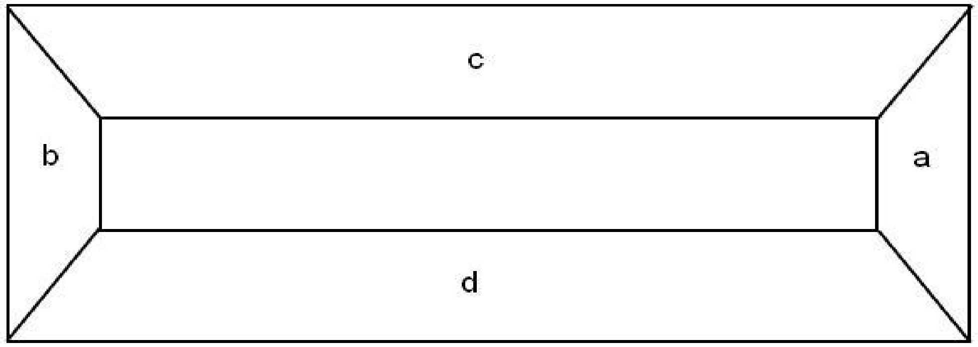


Figure 37 - Aggregate Sampling Device

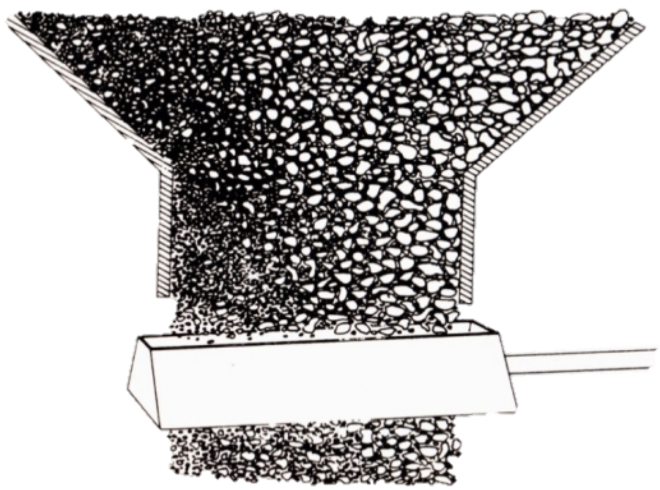


Figure 38 - Aggregate Sampling Device (Side View)

III 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 mixture 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 39 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 39 – 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 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 40 for reference.

Figure 40 - 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 41 for reference.

Figure 41 - 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 4 gives estimated minimum sampling quantities by mixture type.

Table 4 - 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

IV 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.

Chapter 4 - Aggregates for Asphalt Mixtures

I PROPERTIES OF ASPHALT MIXTURES

A mix that is properly designed should contain enough 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 these properties is the major goal of the mix design process. No single asphalt content will maximize these properties. Instead, the asphalt content must be selected to optimize 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 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 affect 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.

II AGGREGATE STOCKPILE BLENDING

A) AGGREGATES

High quality asphalt requires using high quality aggregates, for this reason we test the different aggregates to be used in an Asphalt Concrete mixture in multiple ways, these tests have already been described in Chapter 2. Some of these aggregate requirements are place on the individual stockpiles, while others are placed on the blend of stockpiles used for the mixture. Individual stockpile tests are referred to as Source Property tests while Consensus properties are tested on the blend. Many of the Source requirements are similar between both Marshall and Superpave however Superpave requires the Consensus property tests, where Marshall does not.

i) Stockpile\Blend Requirements for Asphalt Concrete

The materials used in a design must conform to the requirements set forth in the Agency Standard Specifications. Asphalt Concrete is covered in Sections 401 and 402 of the WVDOH Standard Specifications. Fine aggregate specifications are covered under Section 702 and simply state 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 mixtures are:

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

Table 5 - Marshall Coarse Aggregate Source Properties

WVDOH Coarse Aggregate Source Properties Section 703	Maximum Percent by Mass
Shale content (MP 703.00.27)	1
Coal and other lightweight deleterious material (MP 702.01.20)	1.5
Friable particles (MP 703.01.20)	0.25
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 <u>Marshall Only</u>	5

The WVDOH places requirements for shale content, coal and other lightweight deleterious material, and friable particles, soundness, percent wear, and thin or elongated pieces as indicated in Table 5 and Table 6 for Marshall and Superpave mixes.

Table 6 - Superpave Aggregate Consensus Properties

Superpave Mix Design MP 401.02.28						
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 the necessary testing required to determine the acceptability of polish resistant aggregates for use in skid resistant asphalt mixture.

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 T 27) 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

T415 found on page 77,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 42 - ASTM Standard Sizes of Coarse Aggregates

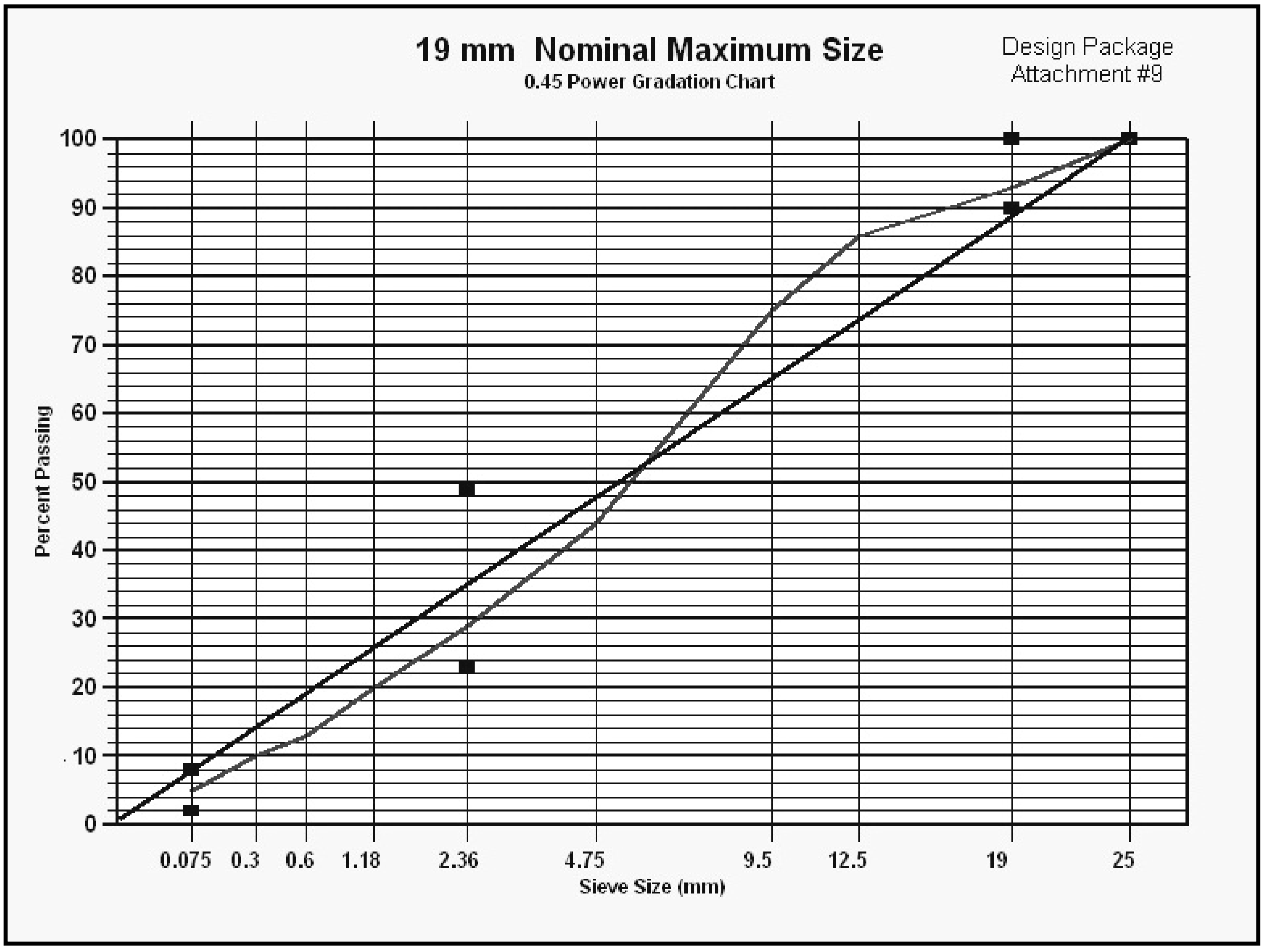


Figure 43 - Power 45 Chart for a 19mm NMAS

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 #:		Bin #:		Bin #:		Bin #:		Bin #:		Percent Passing	
	Size:		Size:		Size:		Size:		Size:			
	% Used:		% Used:		% Used:		% Used:		% Used:			
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.

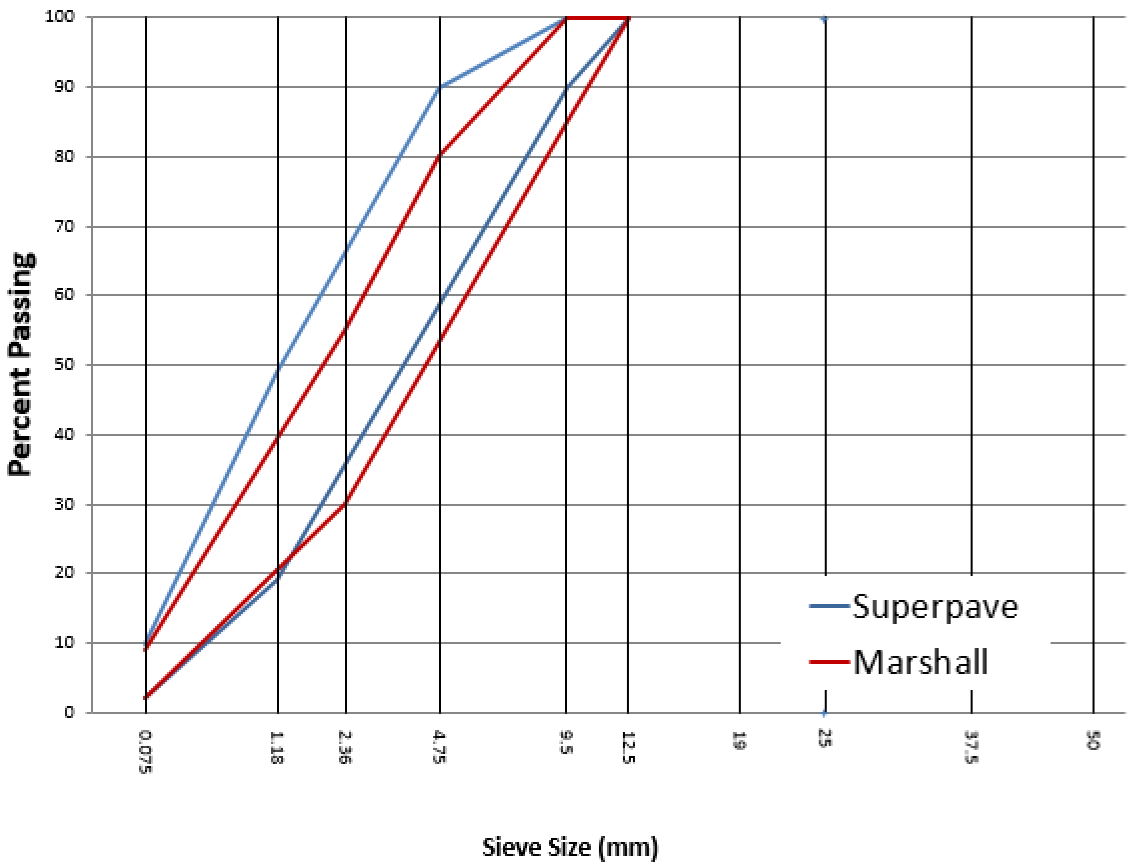


Figure 44 - Control Points for Asphalt Mix designs with 9.5mm NMAS

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:

$$G_{sb} = \frac{100}{\frac{P_1}{G_1} + \frac{P_2}{G_2} + \ldots + \frac{P_n}{G_n}} = \frac{100}{\frac{52}{2.684} + \frac{48}{2.627}} = \frac{100}{19.374 + 18.272} = 2.656$$

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 T 304, using Method A.

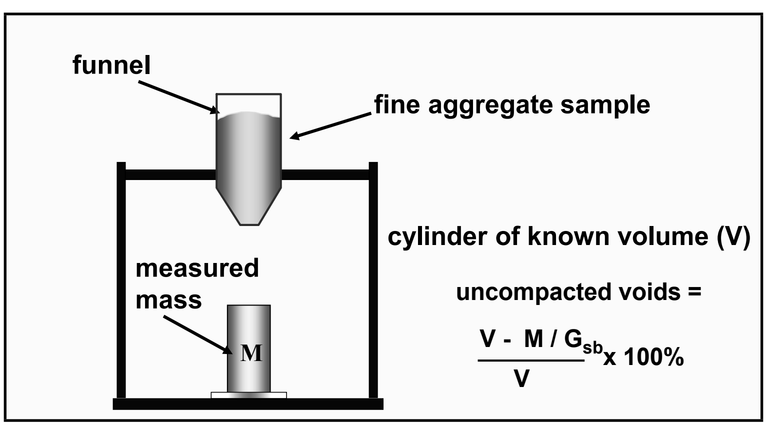


Figure 45 - Fine Aggregate Angularity

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 T 176, 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.

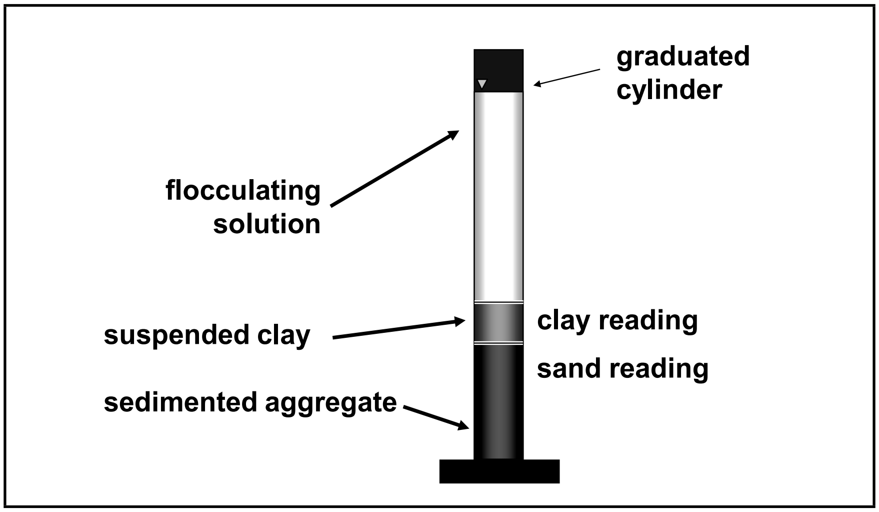


Figure 46 - Clay Content

Chapter 5 - Asphalt Mixing Plants

I INTRODUCTION

In this chapter is meant to demonstrate how to inspect an asphalt plant and how to calibrate some of the plant equipment. For basic information related to asphalt plants, the specific components and how they work please refer to sections 5-12 in the "Hot-Mix Asphalt Paving Handbook 2000" (HMA Paving Handbook). In addition, Section 401 of the Standard Specifications 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 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.

II AGGREGATE MANAGMENT

Aggregate should be stored on a clean surface and the various sizes should be separated. Information regarding the storage and handling of Aggregate can be found in Section 6 of the HMA Handbook, however, here 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.

III 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.
- Hot bin samples are also quick indicators of holes in the screens. Screens should be checked occasionally for holes and excessive wear.
- 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 Ross Count tests show that a shorter mixing time gives a satisfactory asphalt coating. A time lock is required to ensure 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.

IV 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.

Stockpiles of reclaimed asphalt pavement (RAP) 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 in the area that will be loaded into the plant. 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) 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 returns to normal. Using a vibratory feeder can help 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 ensure 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.

C) 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 going into the baghouse should be no more than about 20° F higher than the mix temperature, except that higher temperature differences may be unavoidable if a high percent of RAP 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 for the dryer include gases (natural gas or LP 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. If high percentages of RAP (30% +) are continuously used, these adjustments may be necessary as well.

D) 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.

E) 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 mix plants do not have hot bins. The aggregates are mixed entirely from 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.

F) 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.

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)

COMPONENT	PURPOSE	BATCH PLANT	DRUM PLANT
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.

V 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.

- Thermometers for the liquid asphalt at the plant are required to be calibrated a minimum of once per season for the Annual Plant Inspection by the DOH.
- Aggregate Discharge Temperature Indicators (Pyrometers) are required to be calibrated a minimum of once per season for the Annual Plant Inspection by the DOH.
- All Lab / Plant thermometers are also required to be calibrated a minimum of once per season.

B) Batch Plant Asphalt 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 49 pounds. 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 placing weights on the scales at 50 pound at a time, until the total mass is slightly above the mass of the maximum liquid asphalt expected to be put in a single batch. This is usually done twice a year.

C) Batch Plant 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 12 - 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): ____________________

D) Batch Plant Cold Feed Bin Calibrations

Although the screened material in the hot bins is weighed up per batch, it is important that the aggregate going into the plant to be dried and screened is proportioned correctly as well. Poorly proportioned aggregate can cause one hot bin to overfill and another to run empty. This also changes the gradation within the mix and effects the volumetric properties.

Each Cold Feed Bin needs to be calibrated for each material that will be ran through it. This is typically done at 3 to 4 different belt speed settings. Material is run at each setting for a set amount of time. The material is weighed and the dry tons per hour is calculated and plotted on a graph. This process is repeated for the rest of the belt speeds. Once all the points are plotted on the graph they are connected, and the belt speed setting can be found for any ton per hour aggregate desired. Repeat this process for each cold feed bin and material.

E) Drum Plant Aggregate Scale Calibration

The Weigh Bridge as well as each Cold Feed Bin on a Drum Plant need to be calibrated at least one per season for the Annual Plant Inspection by the DOH. This calibration is a two-phase process. The Weigh Bridge must be calibrated first and is typically calibrated at 2 or 3 different run speeds, depending on the make of the plant. The Weigh Bridge must be accurate to within 0.5% before being accepted.

The second phase is calibrating each of the Cold Feed Bins. Each bin must be calibrated for each material that will be run through it. Again, depending on the plant make, this calibration is run at one or two different speed settings. To be considered calibrated, each of these trials must be accurate to within 0.5%.

F) Drum Plant Liquid Asphalt Calibration

Unlike Batch Plants, Drum Plants do not weigh the liquid asphalt for individual batches. The liquid asphalt is pumped into the drum at a continuous flow, the same as the aggregate. The pump that sends the liquid asphalt to the drum must be calibrated at least once a season for the Annual Plant Inspection by the DOH. The calibration is typically done at two different flow rates and must be accurate to within 0.5%. Although it is not required, it is recommended that a separate calibration is run when switching to a polymer modified liquid asphalt.

G) Truck Scales Calibration

As part of the Annual Plant Inspection, the truck scales must be calibrated a minimum of once per season. This calibration is done by the Department of Weights & Measures and usually observed by the DOH. The scales must be accurate to within 0.5% on an entire range of weights up to the weight of a fully loaded truck to pass inspection.

VI 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.

Chapter 6 - Asphalt Mixture Tests and Volumetric Analysis

I INTRODUCTION

This chapter discusses the general procedures for how to conduct tests on asphalt materials, this chapter however does not replace or override in any way the procedures written by AASHTO which the state specifies.

II TESTING PRECISION

Testing accuracy and precision is incredibly important, without accuracy and precision test results have little meaning. All test procedures involve some amount of testing error. The more difficult the test procedure, the higher the possibility for an error to occur. Much of the testing errors currently experienced are the result of variations in the testing procedures by the technicians either from the lack of experience or in an attempt to make the test "easier" or quicker to complete. 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.

III COMPACTION SAMPLE PREPERATION

A) MARSHALL PILL

To create a Marshall pill, samples are batched of sufficient size (approx. 1200g) so when compacted the specimen 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 mixture should be reheated to the predetermined mixing temperature determined from the Binder Temperature-Viscosity chart Figure 47 or the JMF. Before beginning the compaction process, verify the specimen's temperature to assure that it is close to the upper end of the compaction temperature range. Specimen molds, tools, and the compaction hammer are preheated to 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 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 still be within the limits of the established compaction temperature range. Place a paper protection disk on top of the test specimen.

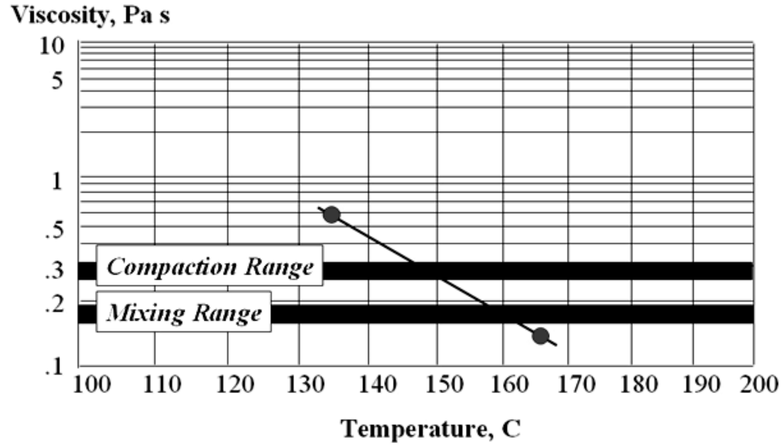


Figure 47 - Binder Temperature - Viscosity Chart

The mold is placed on the compaction pedestal 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 (112 for Base I). Within 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 (in 4 areas approx. 90 degrees apart). These steps are repeated for the remaining two specimens.

B) SUPERPAVE PILL

To create a Superpave pill, WVDOH requires the use of the AASHTO T 312 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. Like the Marshall 6-inch samples this specimen size accommodates larger stone mixes. The compactor operates at 600 ± 18 kPa of vertical pressure, at 30 ± 0.5 gyrations per minute, and at an average internal angle of 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 13 - Gyratory Compaction Criteria (Note 4)

20-Year Projected design ESALs (millions)	Compaction Parameters	
	Gyration Level-1	Gyration Level-2
	N_{design} for Binder < PG 64E-XX	N_{design} for Binders ≥ PG 64E-XX or Mixes Placed Below Top Two Lifts (Note-5)
< 0.3	50	50
0.3 to < 3	65	65
3 to < 30	80	65
≥ 30	80	65

Note 4: Unless otherwise specified in the contract documents, a PG 64S-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.

To begin a Superpave sample, a batch of material of sufficient size so that when compacted the specimen will be 115 ± 5 mm in height should be place in an oven and heated to compaction temperature. This batch varies based on the gravity of the stone but is usually around 4800 grams. The asphalt mixture should be reheated to the predetermined mixing temperature determined from the Binder Temperature-Viscosity chart (Figure 47) or the JMF. After the sample has been heated in the oven, check the temperature to assure that it is within the compaction temperature range. Unlike Marshall, all specimen molds and tools 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, there is no rodding with Superpave. Place the mold top plate if required by the gyratory compactor manufacturer. Place the mold into the Gyratory compactor with the appropriate setting and initiate the compaction mode. See Table 13 for the correct number of gyrations.

IV SPECIFIC GRAVITY OF ASPHALT MIXTURES

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 T 166) 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 ± 2 °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. The specimen mass must be moted within 15 seconds after removal from the water bath. Repeat the procedure for the other two specimens. The bulk specific gravity of the mix is the average of the test specimens. The bulk 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 damp towel, the specimen mass is 1208.6 grams. Calculate the bulk specific gravity, density, and percent water absorption.

Solution:

Bulk Specific Gravity (G_{mb}) = $\dfrac{1207.9}{1208.6 - 707.2} = 2.409$

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

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

If the percent of water absorbed by the specimen exceeds 2.0 percent, the procedure specifies that AASHTO T 331 (Bulk Specific Gravity and Density of asphalt mixture Using Automatic Vacuum Sealing Method) shall be used to determine the bulk specific gravity.

Figure 48 - 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, G_{mm}, 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 T 209. The bowl method is used by the WVDOH labs, but the other methods referenced in T209 are also acceptable. The same procedure is used for Marshall and Superpave mixtures.

After the sample has been sufficiently heated to make workable, 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 as the material is cooling. Make sure that the fine aggregate portion of the mix contains no pieces larger than 1/4 in.

Allow the sample to cool to room temperature and place it in the tared bowl to determine the sample mass. Cover the sample with water at approximately 77 °F and place the cover on the bowl. Gradually apply a vacuum until the residual pressure manometer reads 30 mm of Hg ± 5mm of Hg. Maintain this pressure for 15 ± 1 minute. 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. Release the vacuum at a rate not to exceed 60 mm of Hg per second, suspend the bowl and contents in a 77± 2 °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 T 209 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:

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

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:

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

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 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 G_{se} = effective specific gravity of aggregate
P_{mm} = % by mass of total loose mixture = 100%
P_b = asphalt, % by total mass of mix
G_{mm} = maximum specific gravity of mix
G_b = 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 G_{mm} = maximum specific gravity of mix
P_{mm} = % by mass of total loose mixture = 100%
P_s = aggregate, % by total mass of mix
P_b = asphalt, % by total mass of mix
G_{se} = effective specific gravity of aggregate
G_b = 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.

$$G_{se} = \frac{100 - 5.0}{\frac{100}{2.488} - \frac{5.0}{1.025}} = \frac{95}{40.193 - 4.878} = 2.690$$

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

$$G_{mm} = \frac{100}{\frac{94.0}{2.690} + \frac{6.0}{1.025}} = \frac{100}{34.944 + 5.854} = 2.451$$

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

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

Where V_a = % air void in the compacted mix
G_{mm} = maximum specific gravity of the paving mix
G_{mb} = 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 (V_a) = $\frac{2.492 - 2.405}{2.492} \times 100 = 3.5\%$

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:

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

where G_{sb} = bulk specific gravity of aggregate
G_{mb} = bulk specific gravity of compacted mix
P_s = 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%

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

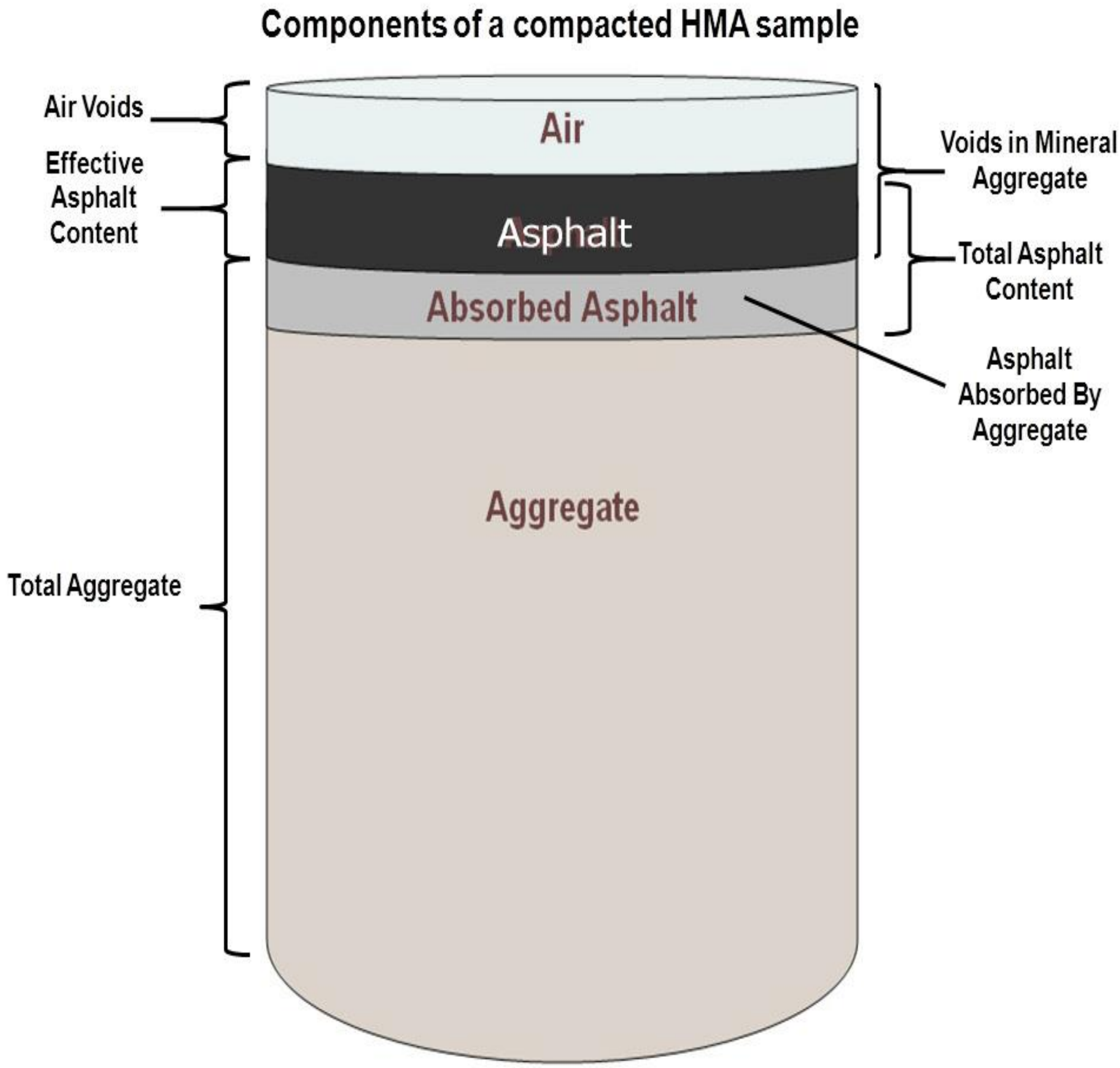
C) PERCENT VOIDS FILLED WITH ASPHALT (VFA)

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:

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

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.

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

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 T 245 or ASTM D5581) are 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 T 245 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 114) 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 T 166) must be run 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 140 ± 2°F water bath for 30 to 40 minutes [45 to 60 minutes for 6 in. specimens]. One at a time they are removed from the bath, excess water is removed with a towel, 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 49 for an example on the next page.

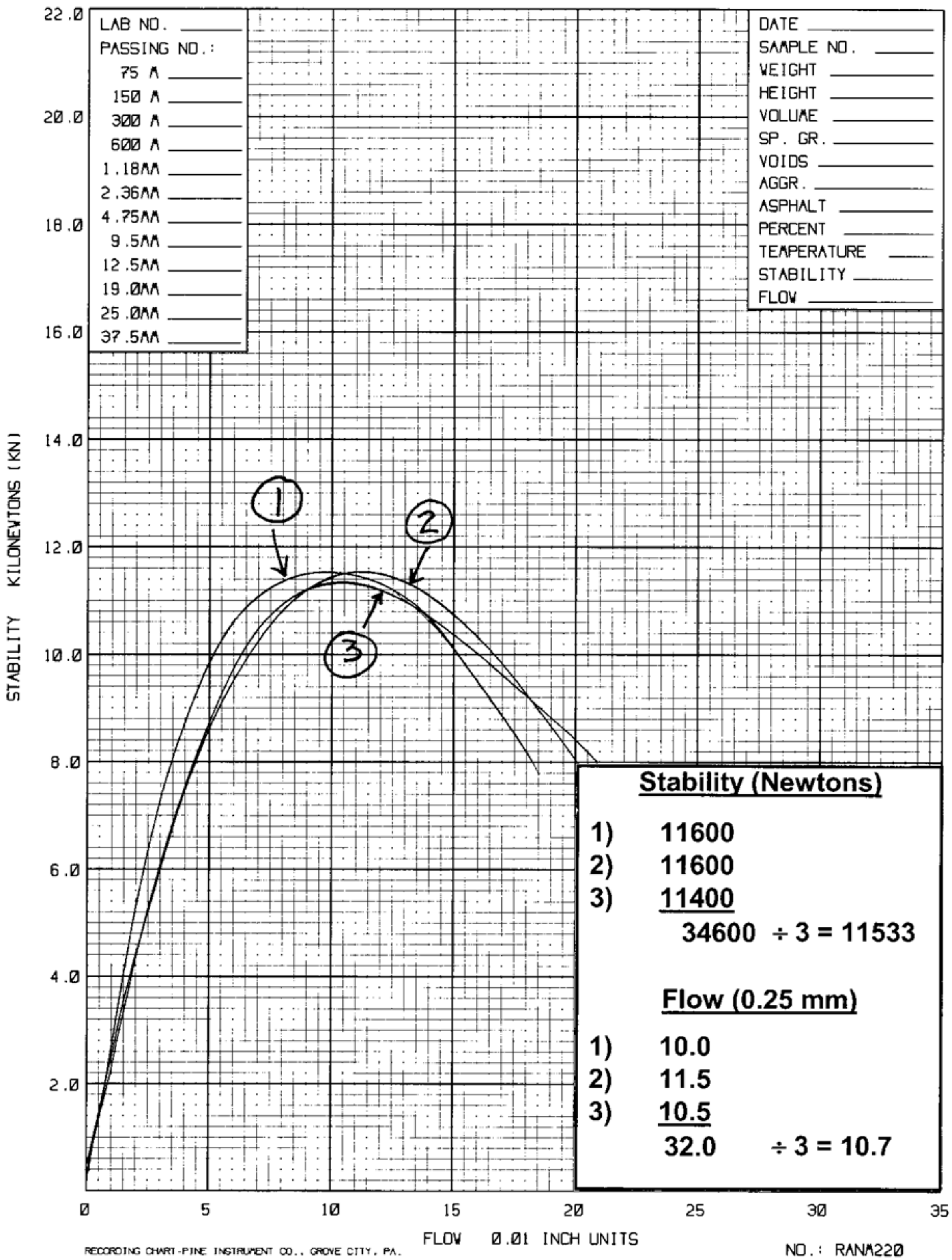


Figure 49 - Marshall Stability and Flow Chart

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

VII DETERMINING ASPHALT CONTENT

A) 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 T 164 which covers the reflux, centrifuge, and vacuum extraction procedures, and AASHTO T 308 which uses the asphalt content ignition oven for burning off the asphalt in the test sample.

The AASHTO T 164 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 T 30, 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 non-chlorinated 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 T

164 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 the sample, the remaining aggregate can be washed and graded using the AASHTO T 30 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 T 308. The actual burning process usually takes less than one hour to complete.

i) Asphalt Content by The Ignition Method

The ignition oven method of determining the asphalt content of hot-mix asphalt is covered in AASHTO T 308. 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 must 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 50 - 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.

a) 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 T 30) 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 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 14, 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 14 - 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 %

b) 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 15 - 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 pre-weighed 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.

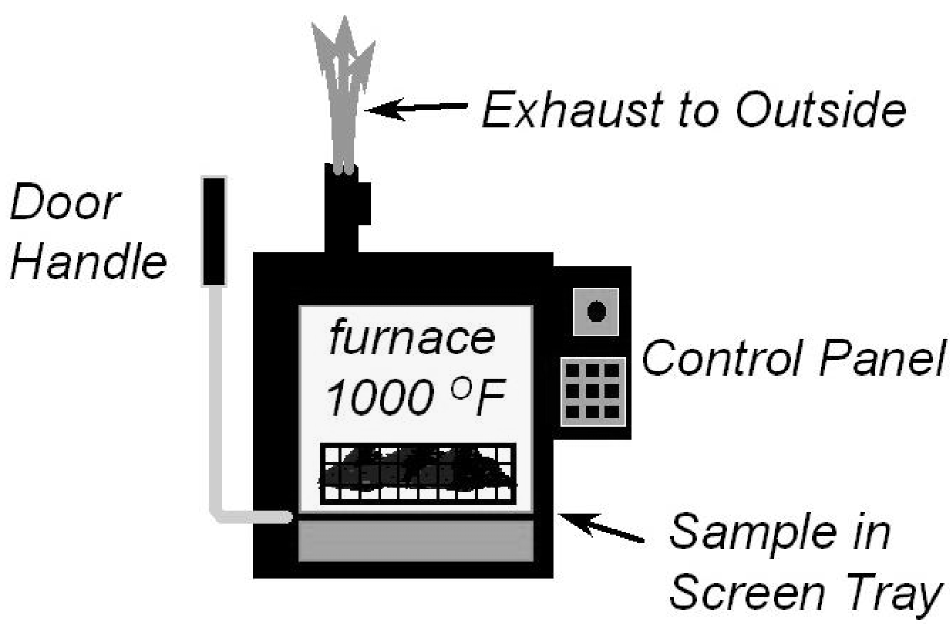


Figure 51 - Asphalt Ignition System Schematic

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	Correctio n
		% Passing	Difference	% Passing	Difference	Difference	Factor (±)
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) And
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.

VIII 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 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 T 255, 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; 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.

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

or

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

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 T 329 – 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 T 329, 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?

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

Chapter 7 - Job Mix Formulas and Quality Assurance Systems

I JOB MIX FORMULAS

The Job Mix Formula (JMF) formerly referred to as Plant Mix Formula – JMF, 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 16 - 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 58S-28	705.005.010
Bituminous Patching Winter Grade	412.002.001	PG 58H-28	705.005.011
		PG 64S-22	705.005.008
*** Polymer Modified**		PG 64H-22	705.005.009
# HPTO (4.75mm Skid)		PG 64E-22 PM*	705.005.007

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 17 or in Table 401.4.2A of the standard specifications. The Master Range Superpave mix design can be found below in Table 18 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 17 - 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 18 - 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 AASHTO re:source. These inspections must be periodically updated in accordance with the routine schedule of AASHTO (approximately every 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 19 - 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 19, the percent voids-in-mineral aggregate (VMA) for Marshall designs shall be as shown in Table 20.

Table 20 – 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 21 - Superpave Method Volumetric Design Criteria MP 401.02.28 - Table 1

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.

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 II 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 21, for exceptions to this specification range. The high limi t 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

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 shall 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 is part of a quality control system designed to assure the quality of the plant produced mix. 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. The testing required on plant produced asphalt mixture is basically the same as what is required in a mix design. Tests include stability and flow (AASHTO T 245) (Marshall only), bulk specific gravity (AASHTO T 166), maximum specific gravity (AASHTO T 209), percent air voids (AASHTO T 269), VMA calculations (Asphalt Institute MS-2 Manual), Asphalt Content (AASHTO T 308), and Gradation (AASHTO T 30).

Unlike during mix designing, where samples are created in a laboratory-controlled area, verification samples are randomly selected asphalt mixture samples taken in accordance with AASHTO T 168 for each three hours of production. During verification one is limited to no more than three samples in one day. To complete a verification a minimum of three samples are required, 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 22 and Table 24 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

WEST VIRGINIA DIVISION OF HIGHWAYS
MARSHALL JOB MIX FORMULA

Report Number:	9876543	**District:**	1
HMA Type:	Wearing-1 RAP	**HMA Code:**	401.002.003
Producer:	Hot Asphalt Inc-Anytown, WV		
Designed By:	Tom Philpott	**Design Lab:**	Lab Services of WV-Trimble, WV
Plant Type:	Drum	**Plant Make:**	ASTEC
Plant Code:	HAI5.05.400	**Traffic Type/ESALS:**	3 to <30 million

MIX COMPOSITION

Material	Aggregate Source	Source Code	Aggregate Type	Agg. Code	% Total Agg.
CA_1	Rocks R Us-Charleston, WV	RRU5.05.704	#8 Limestone	703.004.008	45
CA_2					
CA_3					
CA_4					
FA_1	Little Rock Co.-Westfall, PA	LRC5.05.704	Limestone (D)	702.003.001	40
FA_2					
FA_3					
FA_4					
BHF					

% Virgin Binder in Mix:	6.0	**%RAP Total Agg.:**	15

Binder Code:	705.005.008	**Binder Type:**	PG 64S-22	**Specific Gravity of Binder (G_b):**	1.024
Binder Source:	We Have Asphalt LLC-Pomdale, OH			**Binder Source Code:**	WHA5.05.705

SIEVE FRACTION

Sieve Size	Target	Allowable Min.	Allowable Max.	Sieve Size	Target	Allowable Min.	Allowable Max.
2 in. (50 mm)				#4 (4.75 mm)	69		80
1.5 in. (37.5 mm)				#8 (2.36 mm)	47	41	53
1 in. (25 mm)				#16 (1.18 mm)	34		
3/4 in. (19 mm)				#30 (600 μm)	26		
1/2 in. (12.5 mm)	100	100	100	#50 (300 μm)	15		
3/8 in. (9.5 mm)	96	85	100	#200 (75 μm)	6.7	2.0	9.0

JOB MIX FORMULA VALUES

Design Properties			Design Targets	Min.	Max.
Specific Gravity Stone Bulk (G_{sb}):	2.652	Asphalt (%)	6.0	5.6	6.4
Maximum Density (kg/m^3):	2456	Air Voids (%)	4.0	2.5	5.5
		VMA (%)	16.4	15.4	17.4
		VFA (%)	76		
		Fines to Asphalt Ratio:	1.1	0.6	1.2
Compaction Temperature (°F):	290	Marshall Stability (N):	13967	5300	N/A
Mixing Temperature (°F):	310	Marshall Flow (0.25mm):	12.0	8.0	16.0
Desirable Mean Temp. (±25 °F):	310	No. of Hammer Blows	80		

Remarks:	

Figure 52 - Marshall Mix Design T400

T400

WEST VIRGINIA DIVISION OF HIGHWAYS
SUPERPAVE JOB MIX FORMULA

Report Number:	9876543	**District:**	1
HMA Type:	9.5 mm Skid RAP	**HMA Code:**	402.002.016
Producer:	Hot Asphalt Inc-Anytown, WV		
Designed By:	Tom Philpott	**Design Lab:**	Lab Services of WV-Trimble, WV
Plant Type:	Drum	**Plant Make:**	ASTEC
Plant Code:	HAI5.05.400	**Traffic Type/ESALS:**	3 to <30 million

MIX COMPOSITION

Material	Aggregate Source	Source Code	Aggregate Type	Agg. Code	% Total Agg.
CA_1	Rocks R Us-Charleston, WV	RRU5.05.704	#8 Limestone	703.004.008	45
CA_2					
CA_3					
CA_4					
FA_1	Little Rock Co.-Westfall, PA	LRC5.05.704	Limestone (D)	702.003.001	40
FA_2					
FA_3					
FA_4					
BHF					

% Virgin Binder in Mix:	6.0	**%RAP Total Agg.:**	15		
Binder Code:	705.005.008	**Binder Type:**	PG 64S-22	**Specific Gravity of Binder (G_b):**	1.024
Binder Source:	We Have Asphalt LLC-Pomdale, OH			**Binder Source Code:**	WHA5.05.705

SIEVE FRACTION

Sieve Size	Target	Allowable Min.	Allowable Max.	Sieve Size	Target	Allowable Min.	Allowable Max.
2 in. (50 mm)				#4 (4.75 mm)	69		90
1.5 in. (37.5 mm)				#8 (2.36 mm)	47	41	53
1 in. (25 mm)				#16 (1.18 mm)	34		
3/4 in. (19 mm)				#30 (600 μm)	26		
1/2 in. (12.5 mm)	100	100	100	#50 (300 μm)	15		
3/8 in. (9.5 mm)	96	90	100	#200 (75 μm)	6.7	2.0	10.0

JOB MIX FORMULA VALUES

Design Properties			Design Targets	Min.	Max.
Specific Gravity Stone Bulk (G_{sb}):	2.652	Asphalt (%)	6.0	5.6	6.4
Maximum Density (kg/m^3):	2456	Air Voids (%)	4.0	2.8	5.2
Tensile Strength Ratio:	93.2	VMA (%)	16.4	15.4	17.4
		VFA (%)	76	74	80
		Fines to Eff. Asphalt Ratio:	1.0	0.6	1.2
Compaction Temperature (°F):	290				
Mixing Temperature (°F):	310				
Desirable Mean Temp. (±25 °F):	310	No. of Gyrations	80		

Remarks:

Figure 53 - Superpave Mix Design T400

The verification volumetric and Asphalt content test results shall be recorded on Form T408 for Marshall designs or T422 for Superpave designs, reproduced in Table 26 and Table 28 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 T 308). 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 27. 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 23 and Table 25 respectively. The gradation results must fall within the limits of each listed control point with the exceptions as noted on the No. 8 and/or 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 T 209) 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 meets all of the requirements described above for Marshall or Superpave then production must halt and a new mix design is required.

In addition to the field verification, daily mix verification testing, while not required can provide an early warning by indicating if the mix properties deviate from the specifications. Daily verification is a good 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.

Table 22 - 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) %	For Lab Info Only
Stability (Newtons)	Minimum Design Criteria
Flow (0.25 mm)	Limits of Design Criteria

Table 23 - Master Range for Hot-Mix Asphalt Total Percent Passing Each Sieve - Table 401.02.27B

TYPE OF MIX	Base-I	Base-II (Patch & Level)	W e a r i n g I V	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 24 - 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 25 - 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 26 - 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 27 - 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 28 - 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 29 - 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	

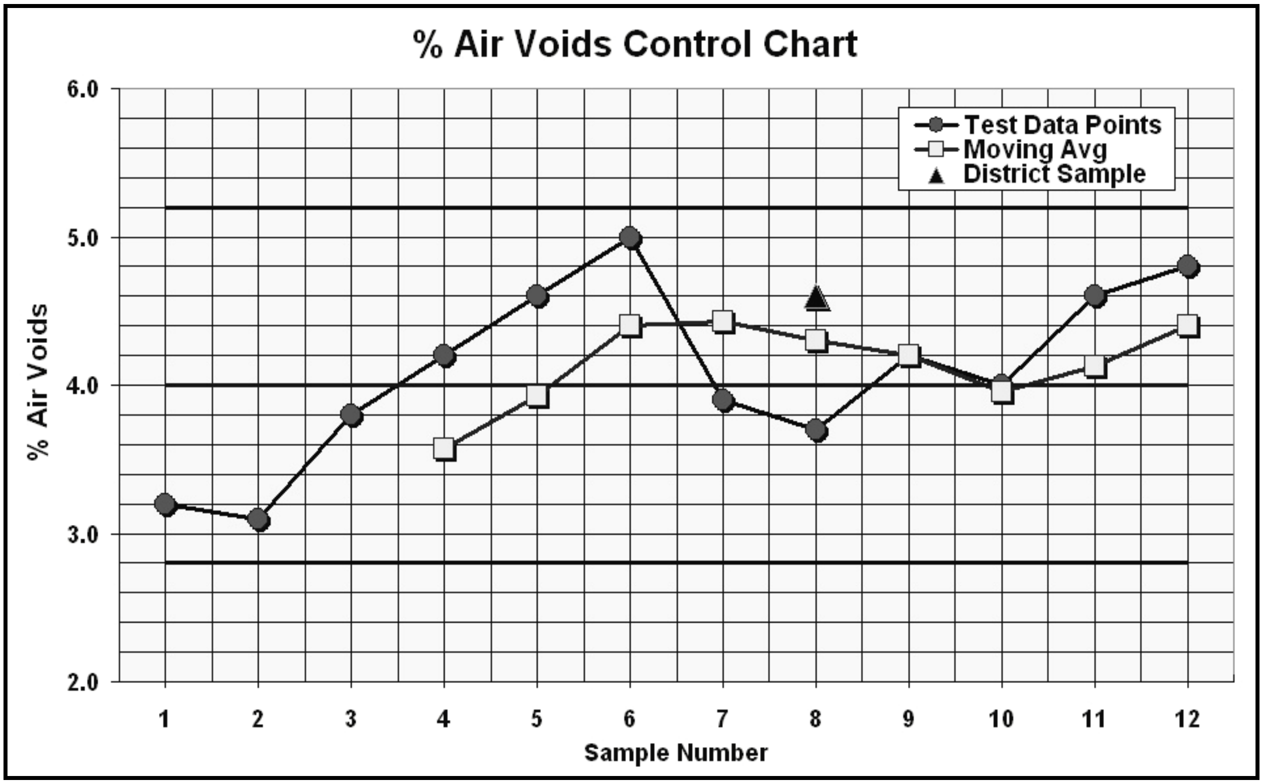


Figure 54 - Example Control Chart

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 30 and Table 31 below. Any mixture tested shall conform to the production tolerances of these tables.

Table 30 - 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 31 - 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 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.

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 32. 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.

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 33, 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 34. 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 32 - 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

Table 33 - 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			Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Tolerance Limits			4.5	5.3	2.8	5.2	14	16		
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 34 - 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) Production Nonconformity

For Superpave and Marshall 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 401.02.27C or Table 401.02.29C (MP 401.02.27 for Marshall or MP 401.02.29 for Superpave) 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 401.02.27 B or 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 these tables, 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 the applicable MP. 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
- X_n = 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 the applicable table.

Table 35 - Adjustment of Contract Price for Mix Not Within Tolerance Limits Of Percent Asphalt Table

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 36 - Adjustment of Contract Price for Mix Not Within Tolerance Limits Of Percent Air Voids Table

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.

$$AUP = OUP \times PUPAC \times PUPAV$$ 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 8 - Percent Within Limits (PWL)

I INTRODUCTION

Section 410 of the Standard Specifications, Percent within Limits, was implemented during the 2013 paving season as Special Provision 401. It introduces a higher level of statistical analysis of material testing results and more manageable square yard paving. Included with the new Specification, eight new Materials Procedures were developed to handle new testing, sampling, and payment methods. These MPs 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 401.07.22 - 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 interstate and highway 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 QUALITY CONTROL

A) Field Verification

For PWL projects the contractor is still required to follow a standardized plant production quality control system much like that followed during a standard 401 job. While similar the procedures for field verification and QC are slightly different than a 401 job. For PWL, to achieve an approved field verification the following applies (Except from MP 401.02.31):

> This field design verification shall consist of a randomly selected asphalt mixture sample taken in accordance with the AASHTO T 168 truck bed sampling method for each 750 tons delivered to the project with a maximum of three samples in one day. A minimum of three samples are required for verification, however, up to three additional samples are required if none of the first three individual samples and the average of the three samples are completely within the tolerance limits.
>
> If, after three samples the design criteria and gradation requirements of at least one of the samples plus the average of the three samples is within all of the allowable tolerance limits of Table 37 then verification of the design is complete. If the criteria are not met, then up to an additional three samples shall be tested. If the fourth, fifth, or sixth sample plus the average meet all testing requirements, then field design verification is complete. If, after six samples, the Division determines that the mix cannot be produced within specification limits, then production of this mix design shall be discontinued, and a new mix design will be required.

B) Quality Control

Once a field verification is accepted then the contractor shall enter into a quality control mode. Daily quality control testing shall consist of a randomly selected asphalt mixture sample taken in accordance with the AASHTO T 168 truck bed sampling method for each 1000 tons (900 Mg) delivered to the project with a minimum of one sample per day. The material produced shall conform to the single and multiple sample production tolerances of Table-A. If a new target asphalt content for the design was established in accordance with Section 5.10 of the field design verification procedure, then a new moving average for all test requirements of Table-A shall begin with the quality control samples. If the target asphalt content was not changed then the moving average shall continue from the last design verification sample.

Table 37 -Mix Property Field Design Verification and Quality Control Requirements Note-1

Test Property	Single Sample Tolerances	Multiple Sample Tolerance (3 to 5 samples with 5 sample moving average)
Asphalt Content (%) for 25 mm, 37.5 mm, & Base-1 mixtures	JMF ± 0.7 %	JMF ± 0.5 %
Asphalt Content (%) for all other standard mix types	JMF ± 0.6 %	JMF ± 0.4 %
Air Voids (%)	JMF ± 1.8 %	JMF ± 1.5 %
Voids in Mineral Aggregate (VMA) %	JMF ± 2.0 %	JMF ± 1.5 %
Stability (Newtons) Note-2	Minimum Design Criteria	Minimum Design Criteria
Flow (0.25 mm) Note-2	Limits of Design Criteria	Limits of Design Criteria
Percent Passing the Nominal Maximum Sieve for the Design	JMF Lower Target Limit - 2 %	JMF Target Range
Percent Passing the Sieve Below the NMS for the Design Note-3, Note-4 and Note-5	92 % Max	90 % Max
Percent Passing 2.36 mm (No. 8) Sieve Note-6	JMF Target Range ± 2 %	JMF Target Range
Percent Passing the 75 µm (No. 200) Sieve	JMF Target ± 3.0 %	JMF Target ± 2.0 %

Note-1: Targets established on T400 or T400 SP.
Note-2: Marshall mixtures only.
Note-3: For a 4.75 mm mixture the single sample tolerance for the sieve above the nominal maximum sieve shall be the JMF Lower Target Limit - 2 % and the multiple sample tolerance shall be the JMF Target Range.
Note-4: For Wearing-I mixtures the single sample tolerance shall be 82 % Max and the multiple sample tolerance shall be 80 % Max.
Note-5: For Wearing-IV and 19 mm surface mixtures the single sample tolerance shall be 45 % Min and the multiple sample tolerance shall be 47 % Min.
Note-6: These same criteria shall apply to the 1.18 mm (No. 16) sieve on 4.75 mm and Wearing-III mixtures.

IV QUALITY ACCEPTANCE

With PWL the payment for the material is no longer based on the quality control tests completed by the Contractor, instead it is based upon samples taken from the roadway and tested by the division. Below is the overview of how this is achieved.

A) 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. 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 8 - IVB) . Once the results are determined they are analyzed for compliance, discussed in Chapter 8 - IVC) .

B) Laboratory Testing

Unlike 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.

i) 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 T432.

ii) 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.

iii) 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 apparatus. 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 Form T432, shown in Table 38.

- 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 38 – 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%							

iv) 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 55. This shear device is made specifically for the WVDOH and is currently not available to outside agencies.

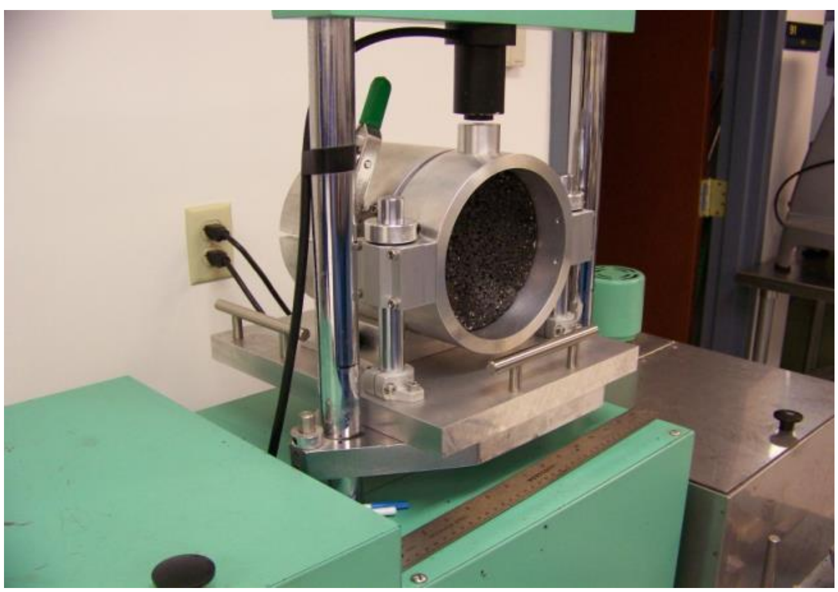


Figure 55 - Shear Bond Strength Device

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 56. To assist in lining up the core, mark the cores interface with a paint pen.

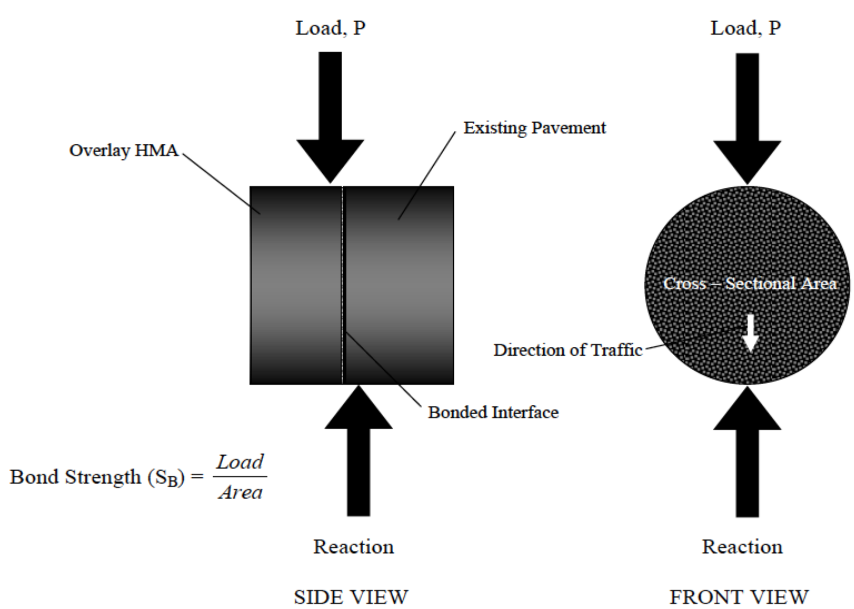


Figure 56 - Bond Core Orientation

Load the device into the Marshall Stabilometer as shown in Figure 55 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 exis ting 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 T432. The maximum load applied prior to failure should also be recorded from the graph paper and documented on Form T432. Table 39 shows an example Form T432 for bond strength data.

Table 39- Bond Strength Data Form T432

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**		

C) 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 40.

Table 40 - PWL Tolerances

Material Property	Lower Limit	Upper Limit	Notes
Asphalt Content	JMF - 0.4%	JMF + 0.4%	Mixtures with NMAS ≤ 19mm
Asphalt Content	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%	---	

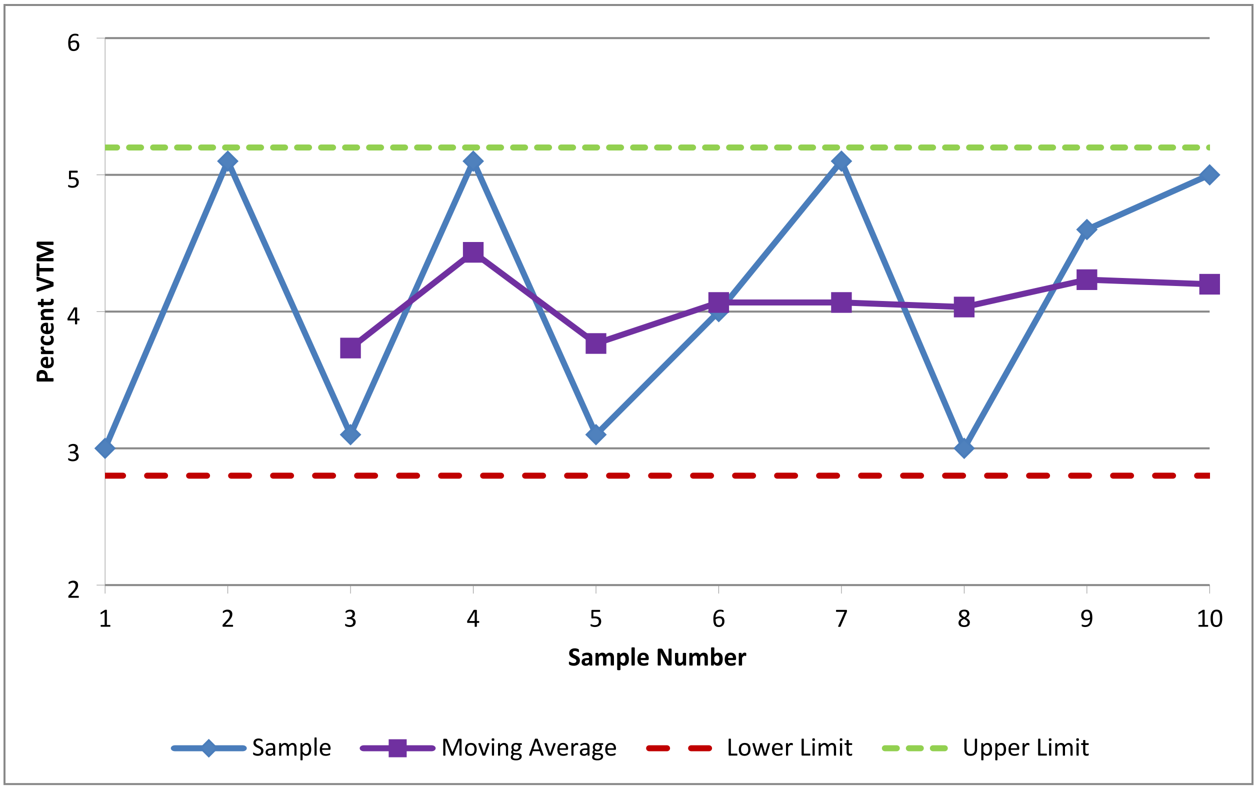


Figure 57 - Moving Average Chart

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 57. 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 analyze it using PWL, the producer would incur 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 58 demonstrates what the distribution would look.

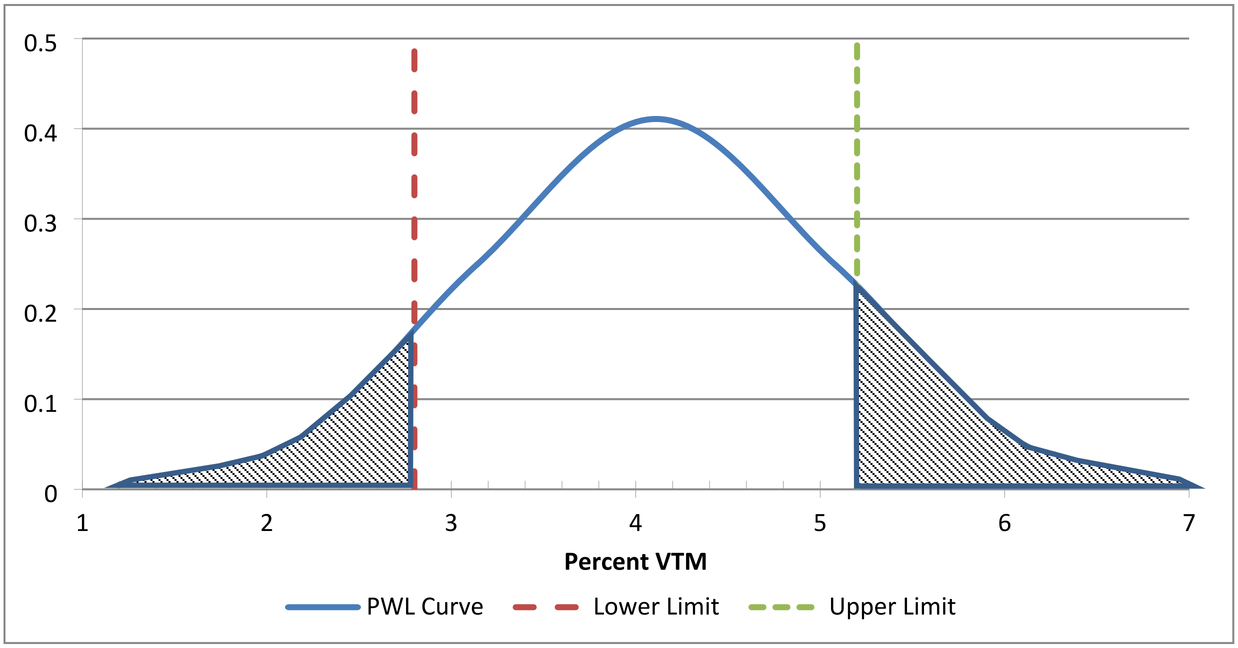


Figure 58 - PWL Distribution

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.

i) Penalty Structure

The twenty percent from above is calculated using Quality Index values and Table 41 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 41 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 41 - 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 42, 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 42 - Percent within Limits Pay Factors

Percentage of Material Within Specification Limits (PWL)	Lot Pay Factor (Percent of Contract Unit Price)
90-100	100
75-89	[(0.5)PWL]+55
55-74 Note 1	[(1.4)PWL]-12

Note 1; 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. (i.e., Contract unit price = $10 sy → $5 sy max)

$$Lot\ Payment = CP\ (2PD + PB + PA)\ /\ 400$$

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