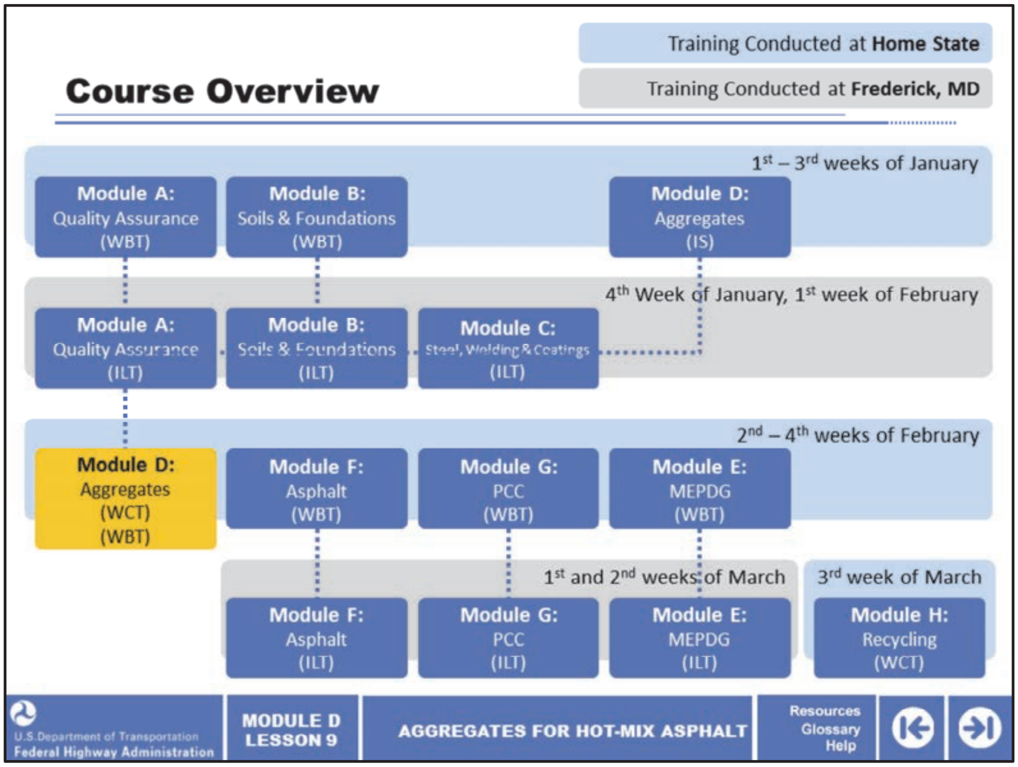
Welcome to the Highway Materials Engineering Course (HMEC), Lesson 9: Aggregates for Hot Mix Asphalt. In this lesson, we are going to focus on the use of aggregates in the asphalt concrete (AC) layer.

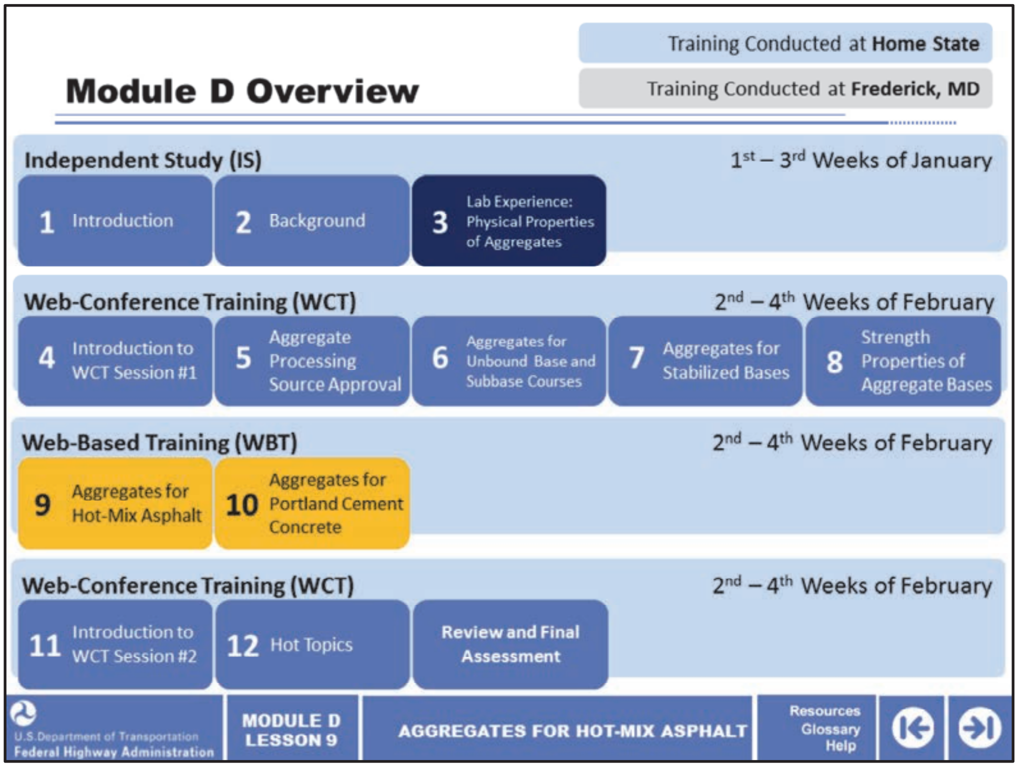
A printer-friendly version of the lesson materials can be downloaded by selecting the paperclip icon. Only the slides for the this lesson are available.

If you need technical assistance during the training, please select the Help link in the upper right-hand corner of the screen.



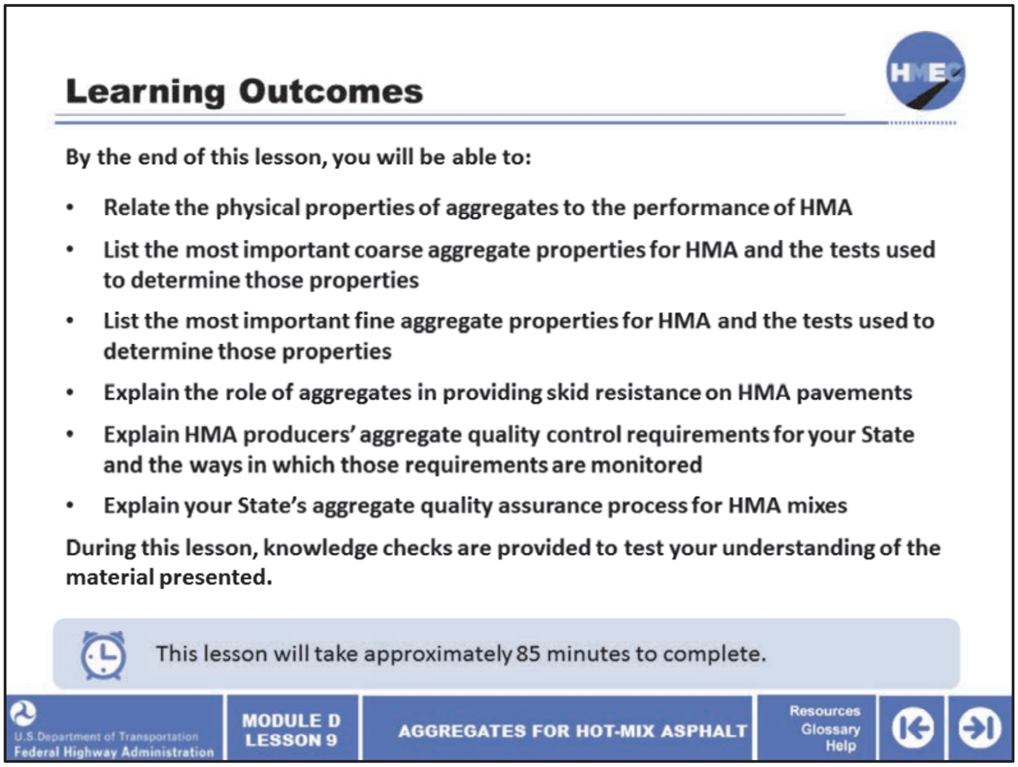
Let's take a moment to review how Module D: Aggregates for Transportation Construction Projects, fits into this course. Module D is the fourth module in the FHWA HMEC. You have already completed Module A, Module B, Module C, and the independent study portion of Module D, along with the Web-conference Lessons 4 and 5.

On the next screen, we'll review the lesson structure of this module in more detail.



Module D consists of 12 lessons. You completed Lessons 1–3 during the independent study portion of this module. You have also completed Lessons 4–8 as Web-conference training (WCT) lessons. You are now working to complete Lessons 9 and 10 as Web-based training lessons, before you reconvene for Lessons 11 and 12 in another scheduled WCT session. During the final WCT, you will complete a brief review and wrap up, before finishing this module with the final assessment.

Let's review the learning outcomes for this lesson.

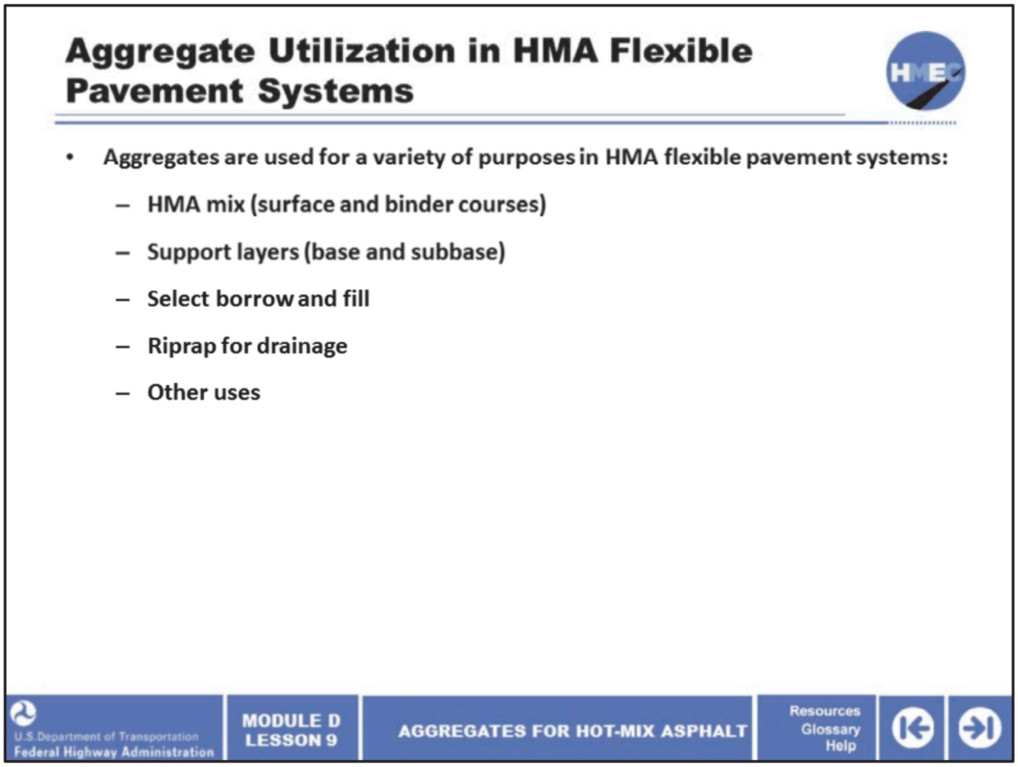


By the end of this lesson, you will be able to:

- Relate the physical properties of aggregates to the performance of hot mix asphalt (HMA);
- List the most important coarse aggregate properties for HMA and the tests used to determine those properties;
- List the most important fine aggregate properties for HMA and the tests used to determine those properties;
- Explain the role of aggregates in providing skid resistance on HMA pavements;
- Explain HMA producers' aggregate quality control requirements for your State and the ways in which those requirements are monitored; and
- Explain your State's aggregate quality assurance process for HMA mixes.

During this lesson, knowledge checks are provided to test your understanding of the material presented.

This lesson will take approximately 85 minutes to complete.

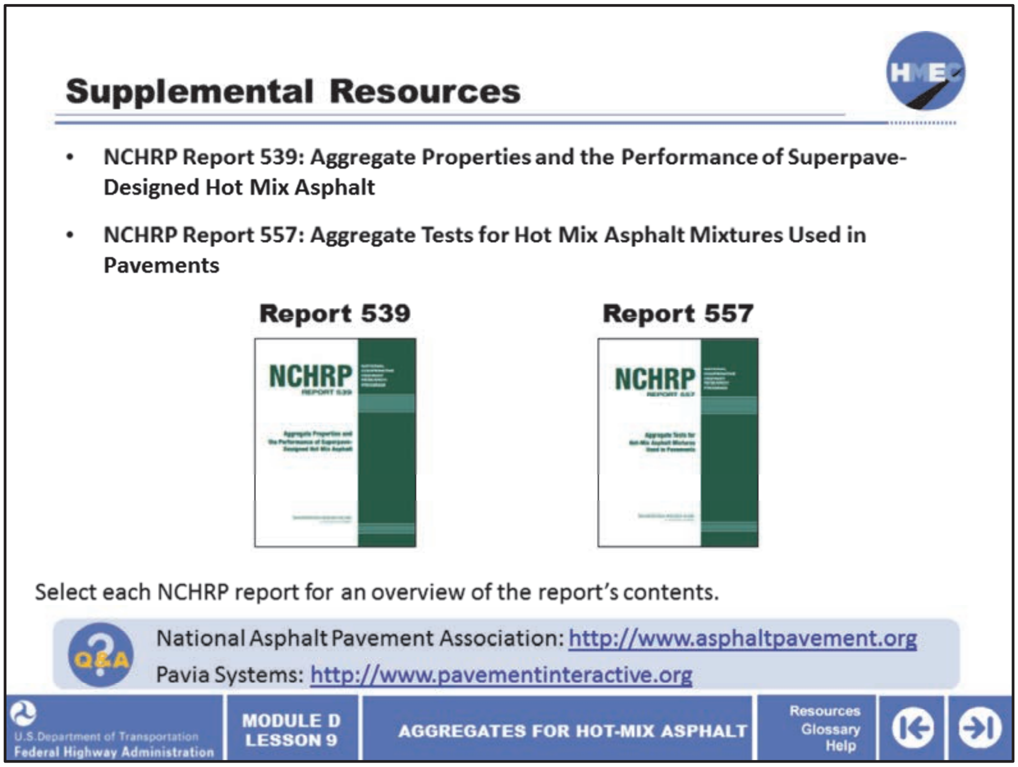


Now let’s get started.

Aggregates are used for a variety of purposes in HMA flexible pavement systems, including:

- HMA mix (surface and binder courses);
- Support layers (base and subbase);
- Select borrow and fill;
- Riprap for drainage; and
- Other uses that are possible depending on the specific pavement design.

In this lesson, we will focus on the use of aggregates in the AC layer.



The following National Cooperative Highway Research Program (NCHRP) resources provide detailed information on aggregate properties and the test procedures required for asphalt mixes:

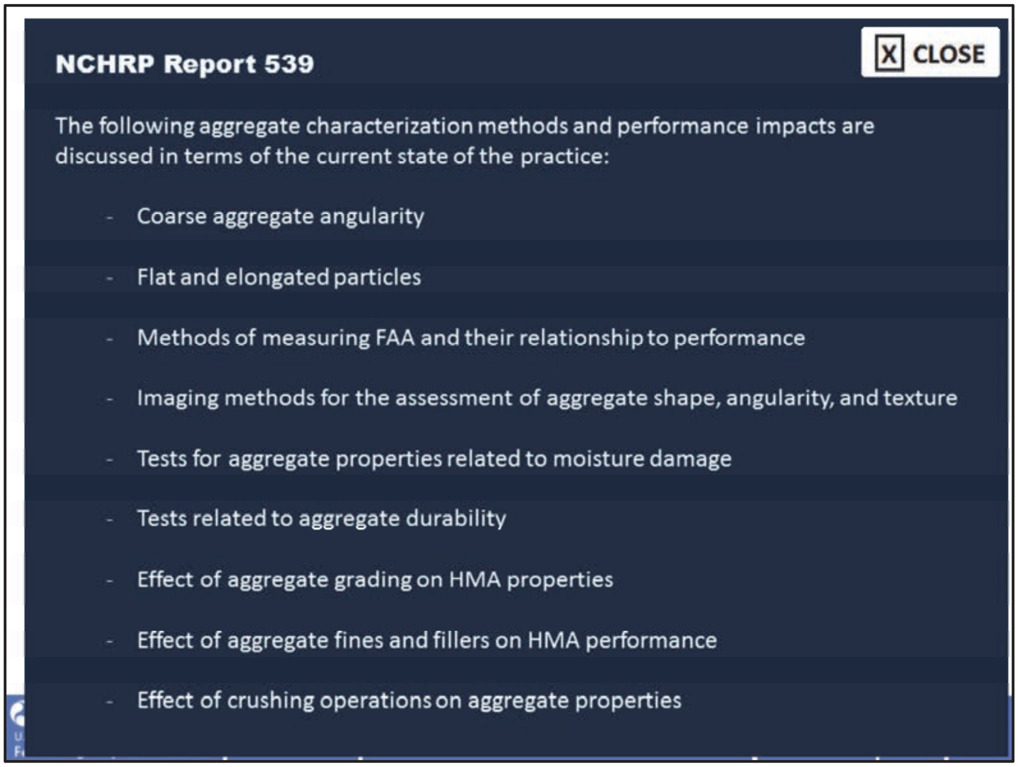
• NCHRP Report 539: Aggregate Properties and the Performance of Superpave-Designed Hot Mix Asphalt; and
• NCHRP Report 557: Aggregate Tests for Hot Mix Asphalt Mixtures Used in Pavements.

Note that there are also numerous resources available online, including the National Asphalt Pavement Association Web site at asphaltpavement.org and the Pavia Web site at pavementinteractive.org. If you require additional information about a specific topic, you are encouraged to visit these Web sites.

Select each NCHRP report for an overview of the report's contents.

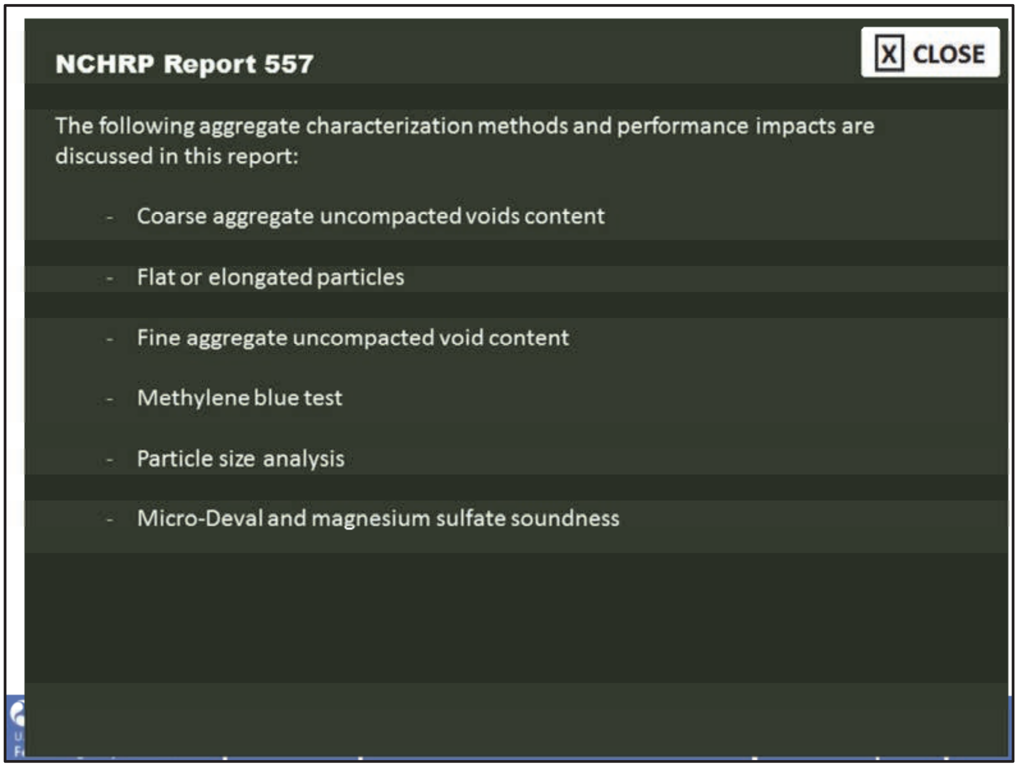
Image description: Cover of the NCHRP Report 539: Aggregate Properties and the Performance of Superpave-Designed Hot Mix Asphalt.

Image description: Cover of the NCHRP Report 557: Aggregate Tests for Hot Mix Asphalt Mixtures Used in Pavements.



The following aggregate characterization methods and performance impacts are discussed in terms of the current state of the practice:

- Coarse aggregate angularity;
- Flat and elongated particles;
- Methods of measuring fine aggregate angularity (FAA) and their relationship to performance;
- Imaging methods for the assessment of aggregate shape, angularity, and texture;
- Tests for aggregate properties related to moisture damage;
- Tests related to aggregate durability;
- Effect of aggregate grading on HMA properties;
- Effect of aggregate fines and fillers on HMA performance; and
- Effect of crushing operations on aggregate properties.



The following aggregate characterization methods and performance impacts are discussed in this report:

- Coarse aggregate uncompacted voids content;
- Flat or elongated particles;
- Fine aggregate uncompacted void content;
- Methylene blue test;
- Particle size analysis; and
- Micro-Deval and magnesium sulfate soundness.

There has been a vast amount of research conducted over the span of many decades regarding aggregate properties and how they relate to the performance of AC, most importantly HMA or warm mix asphalt (WMA). A number of aggregate properties have significant influence during production and placement, such as gradation. Other properties, such as soundness, have long-term performance implications.

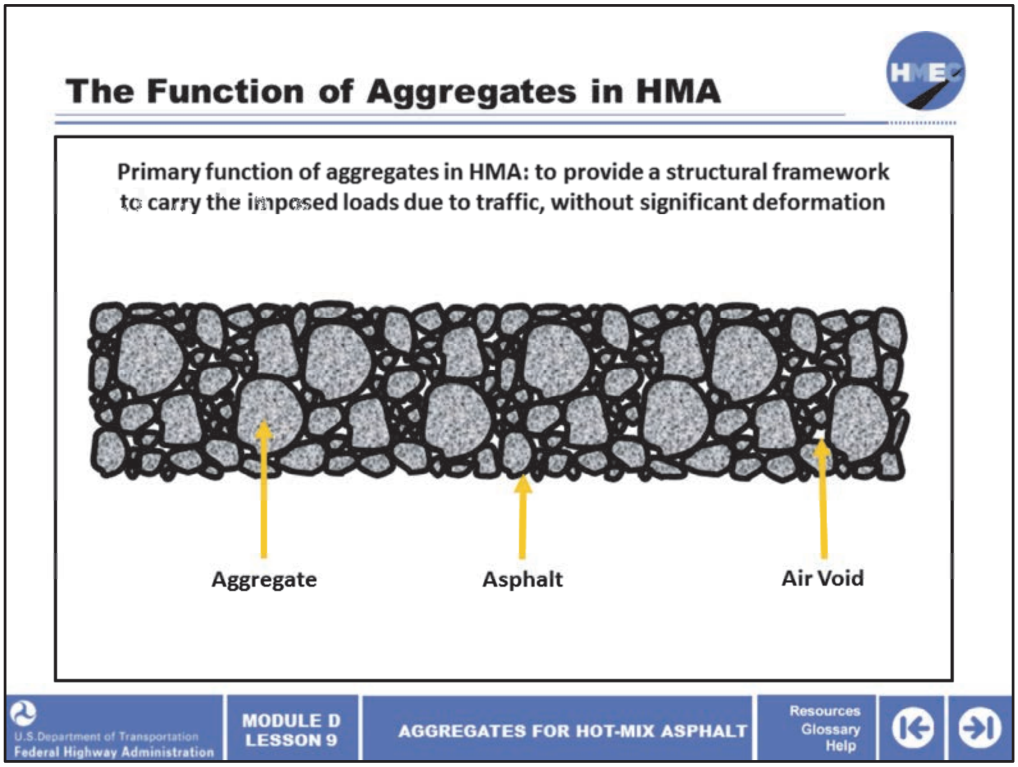
We will concentrate on the most important aggregate properties and how they relate to HMA performance.

Many of the parameters influence mix design and are evident during mixing and placement, while others have long-term effects.

The photos show an HMA surface mix and an HMA binder mix. Although the properties and requirements are different, the aggregates play a key role in the performance of each.

Image description: Photo of an HMA surface mix.

Image description: Photo of an HMA binder mix.

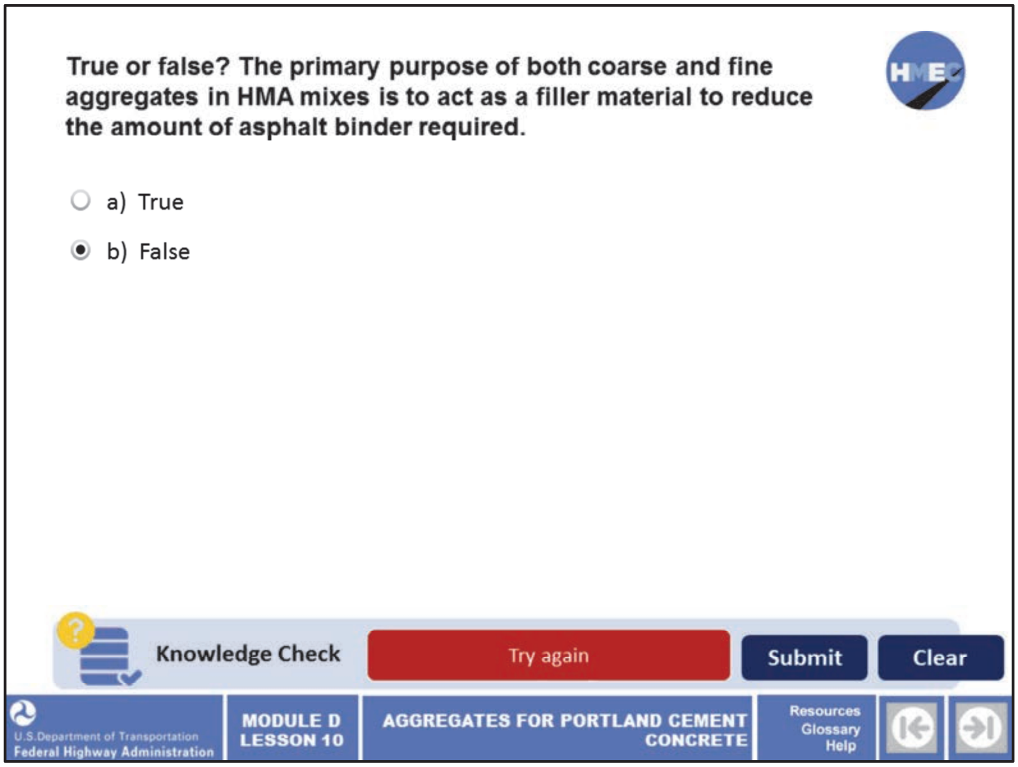


The aggregates play a primary role in the ability of HMA to carry traffic loads. The interaction between the aggregate particles is responsible, in large part, for the strength and deformation characteristics of the HMA.

As can be seen in the figure, the aggregate particles are graded such that they form a continuous matrix with very high levels of particle interaction. Each of the aggregate particles is coated with asphalt cement during the mixing process in order to bind the aggregates into a cohesive material.

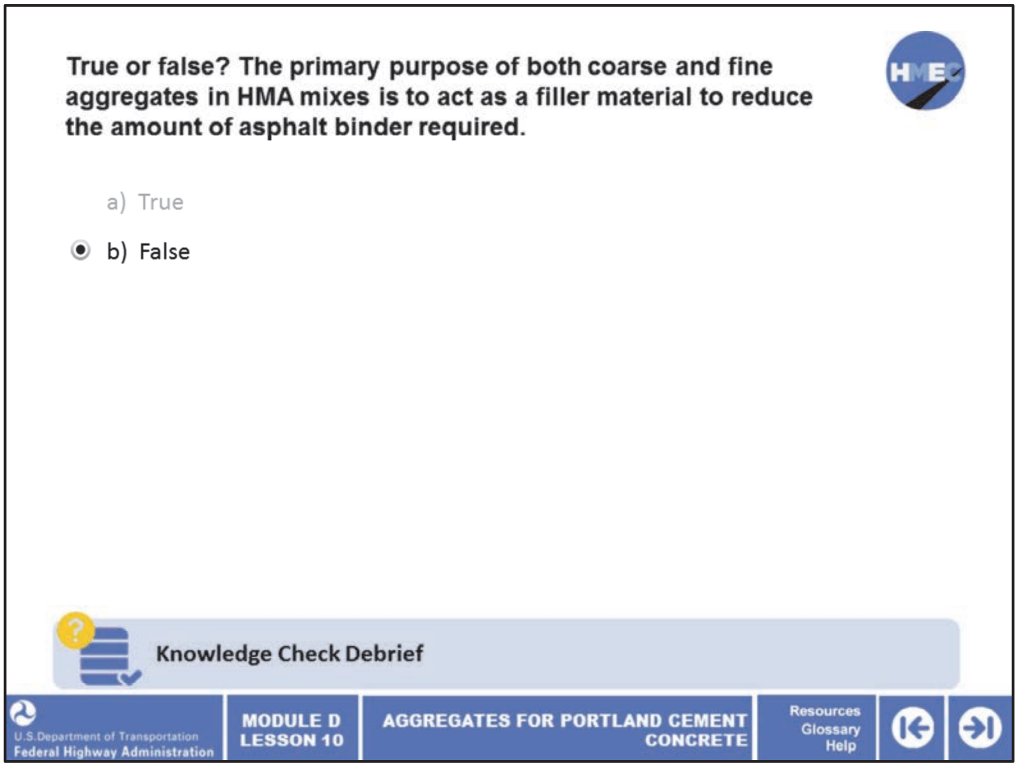
It should be noted that HMA is a ductile material that is designed to deform under load. This deformation can be elastic (recoverable) or plastic (permanent) deformation. We will discuss deformation later in this lesson.

Image description: Illustration of asphalt layer, displaying aggregate, asphalt and air void.

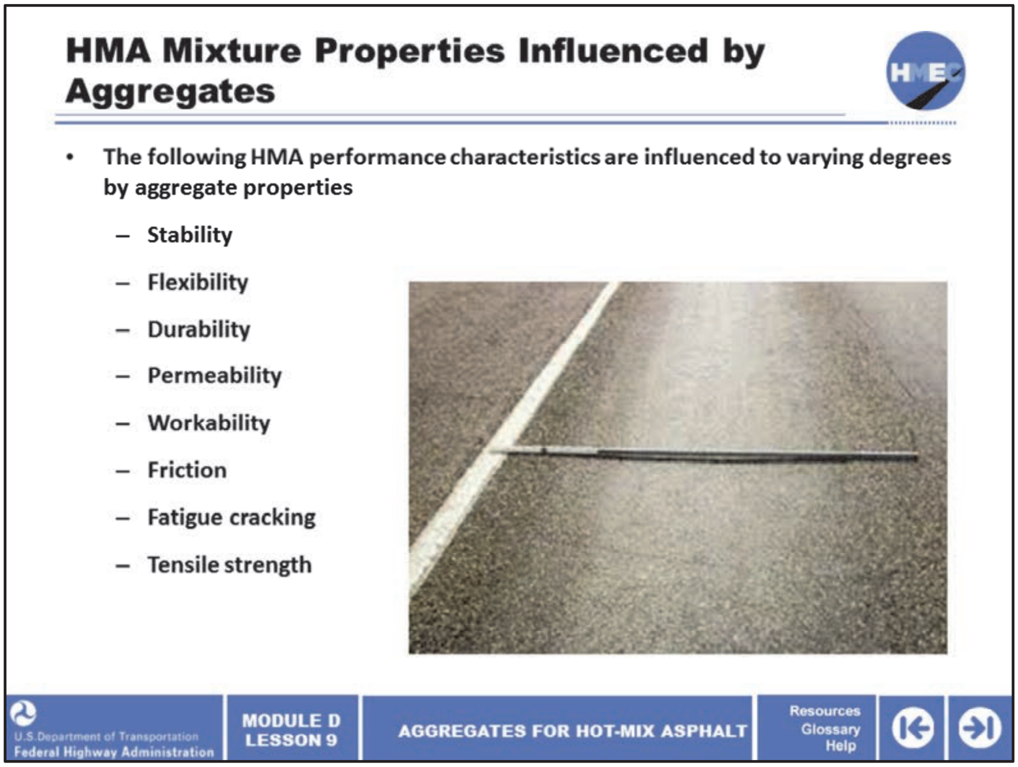


True or false? The primary purpose of both coarse and fine aggregates in HMA mixes is to act as a filler material to reduce the amount of asphalt binder required.

a) True; or
b) False.



The correct answer is b) False. Aggregates are a key structural component and carry the majority of the imposed traffic loads.

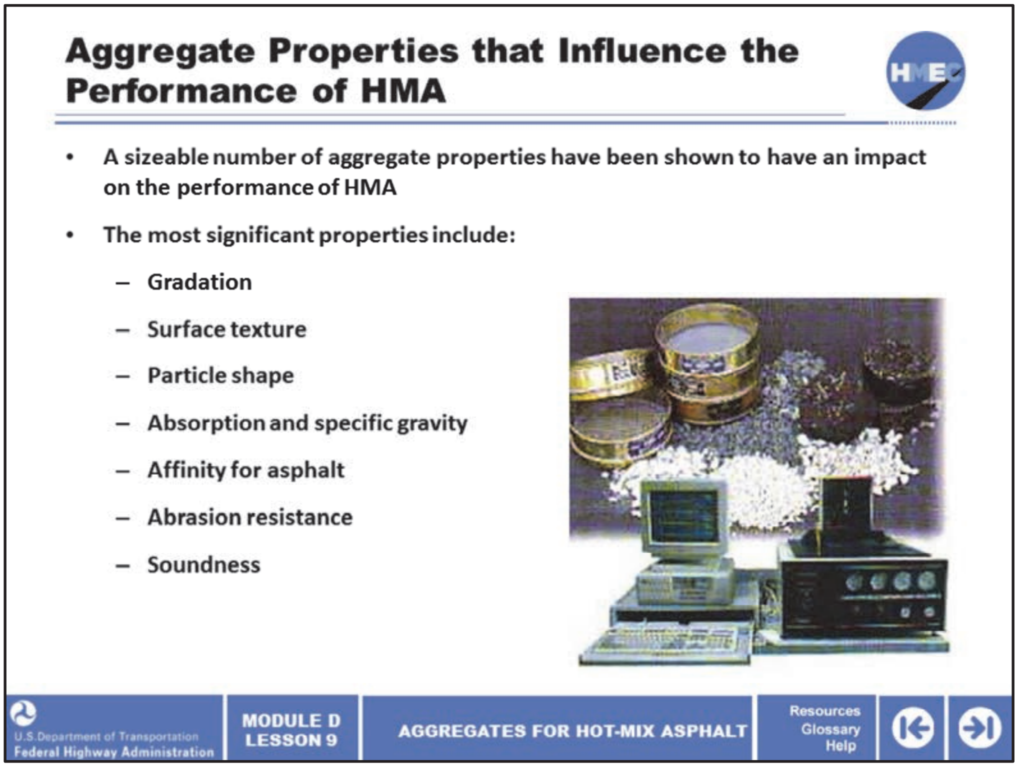


HMA performance characteristics are dependent, to varying degrees, on the aggregate properties that we will discuss in this lesson. The performance characteristics are:

- Stability;
- Flexibility
- Durability;
- Permeability;
- Workability;
- Friction;
- Fatigue cracking; and
- Tensile strength.

The photo shows rutting in a HMA pavement. Although there can be multiple causes for this type of permanent deformation, aggregate properties play an important role in its prevention.

Image description: Photo of rutting in an HMA pavement.



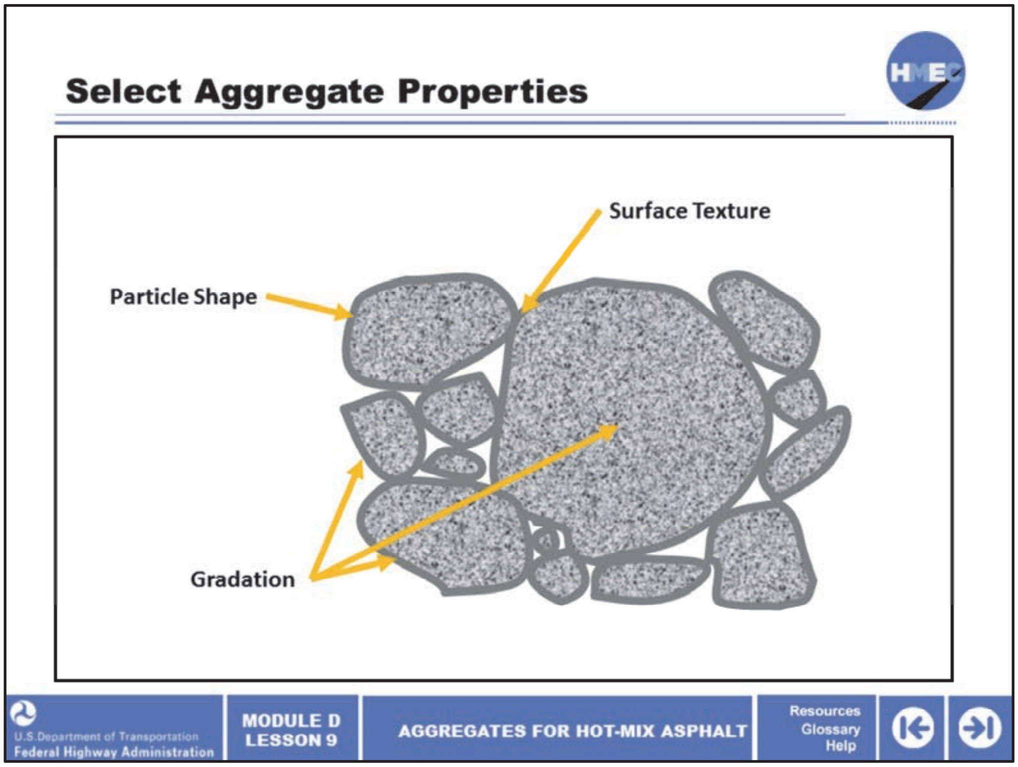
There are many aggregate properties that influence the behavior of HMA. As characterization methods for aggregates and HMA mix design procedures (Superpave) have evolved, these performance links have also undergone revision.

The most important aggregate properties are:

- Gradation;
- Surface texture;
- Particle shape;
- Absorption and specific gravity;
- Affinity for asphalt;
- Abrasion resistance; and
- Soundness.

We will discuss these properties in detail in this lesson.

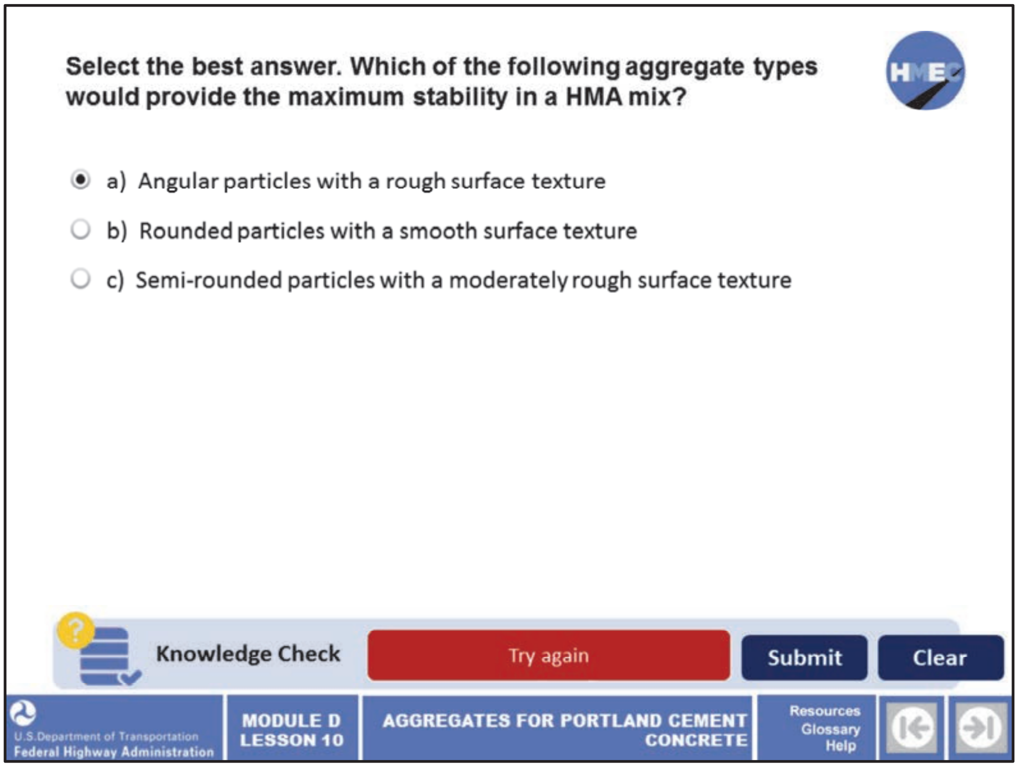
Image description: Photo of sieves, aggregates and testing equipment.



The majority of aggregate properties that effect HMA performance are related to particle interaction. In order to carry traffic loads without significant deformation (potentially resulting in rutting, fatigue cracking, etc.), the aggregates have to develop a stable matrix with solid particle-to-particle interaction.

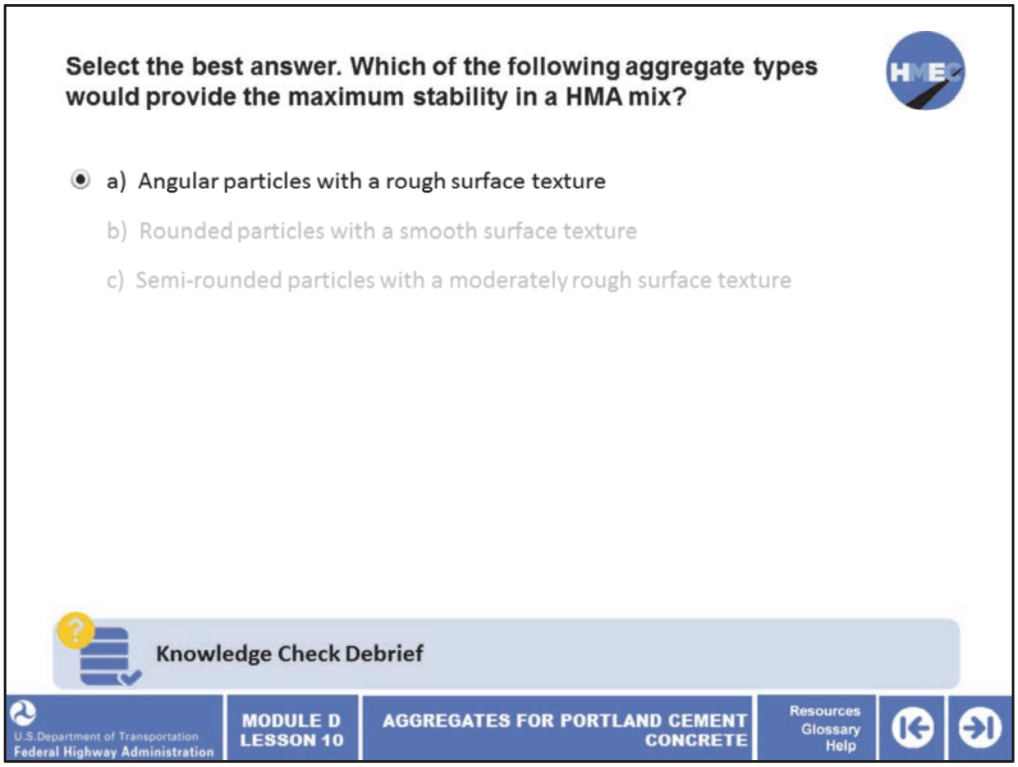
The gradation is one of the most important parameters for dense-graded HMA (minimal voids) mixes as the void space is minimized and the particle interaction is greatest. Particle shape and surface texture are also very important properties in that these control, to a large extent, the interlocking and friction developed between the particles. For instance, smooth, rounded particles are easily reoriented under load and do not provide good stability. Angular particles with rough surface texture provide a very stable aggregate matrix because the particles, once densified, do not readily reorient under load, thereby providing a high level of stability.

Image description: Illustration of aggregates.

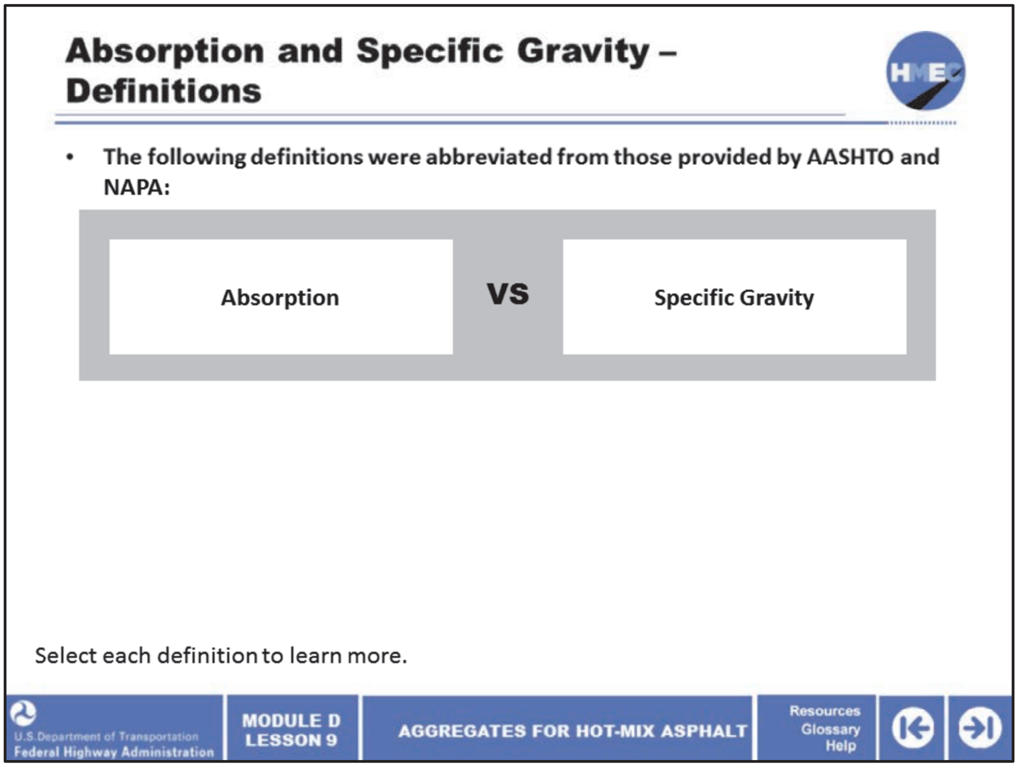


Select the best answer. Which of the following aggregate types would provide the maximum stability in a HMA mix?

a) Angular particles with a rough surface texture;
b) Rounded particles with a smooth surface texture; or
c) Semi-rounded particles with a moderately rough surface texture.

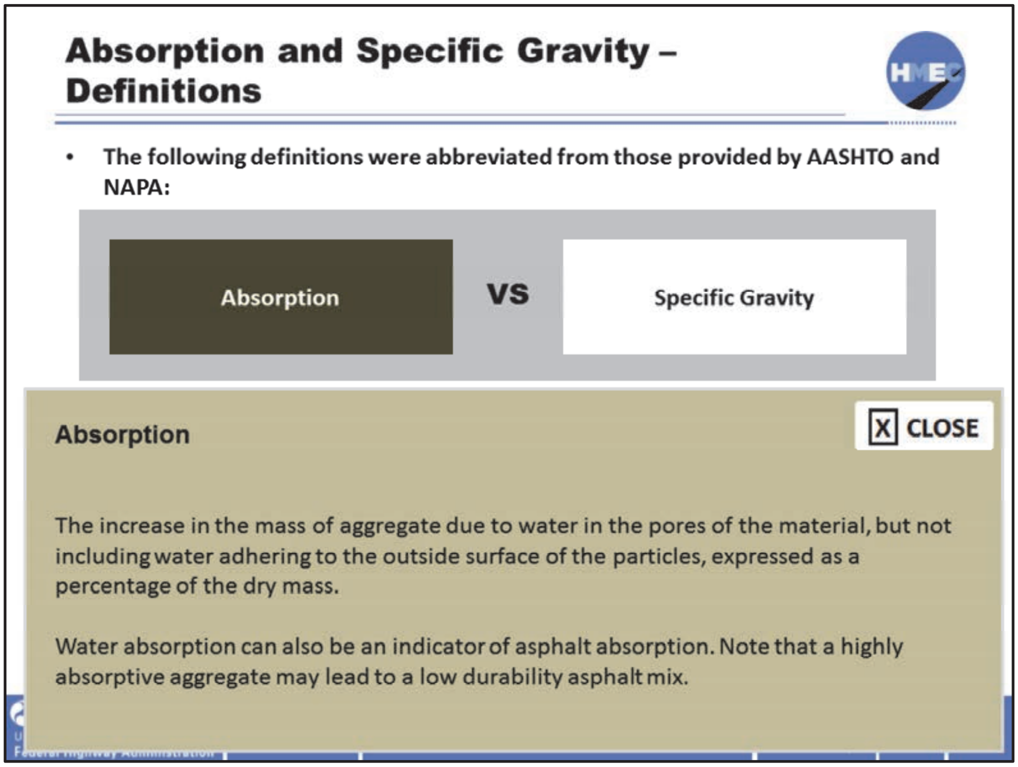


The correct answer is a) Angular particles with a rough surface texture. This type of aggregate would provide good bonding for the asphalt due to the surface texture, and the angular particles would provide good particle interaction.



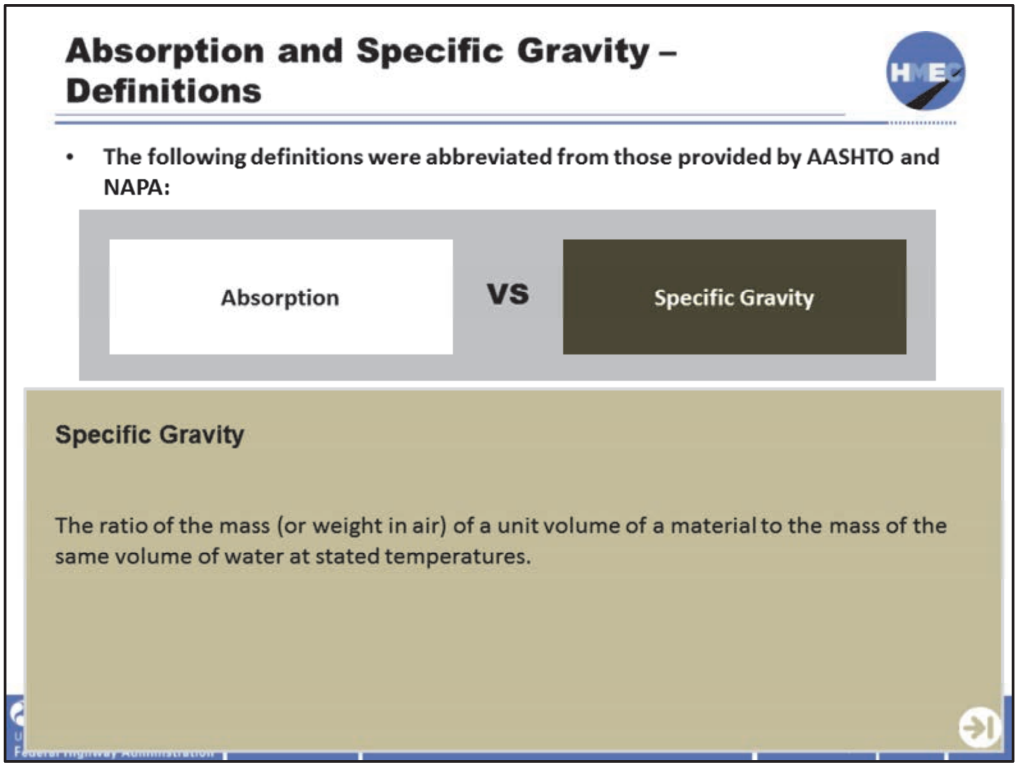
Let's review some definitions. The following definitions were abbreviated from those provided by the American Association of State Highway Transportation Officials (AASHTO) and National Asphalt Pavement Association (NAPA).

Select each definition to learn more.

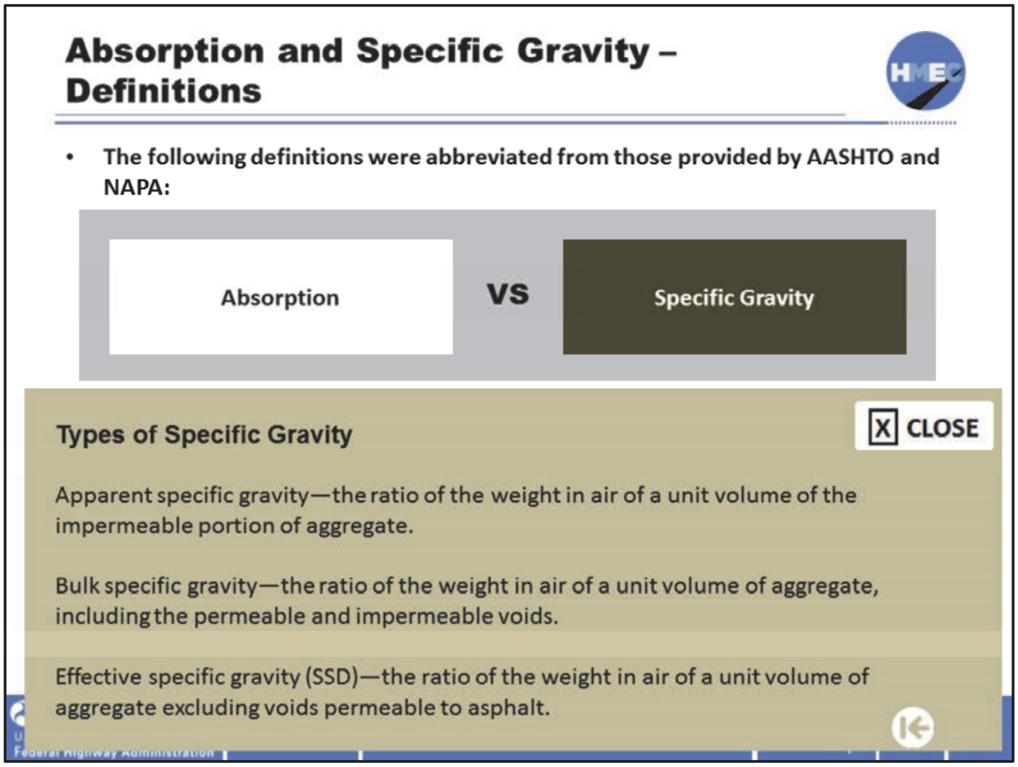


Absorption is the increase in the mass of aggregate due to water in the pores of the material, but not including water adhering to the outside surface of the particles, expressed as a percentage of the dry mass.

Water absorption can also be an indicator of asphalt absorption. Note that a highly absorptive aggregate may lead to a low durability asphalt mix.



Specific gravity is the ratio of the weight of a given volume of aggregate to the weight of an equal volume of water. Water has a specific gravity of 1 at a temperature of 73.4 °F (23 °C). Specific gravity is a critical parameter for the HMA design engineer. The value is used in calculating air voids, voids in mineral aggregate (VMA), and voids filled by asphalt (VFA). All are critical to a well-performing and durable HMA mix.

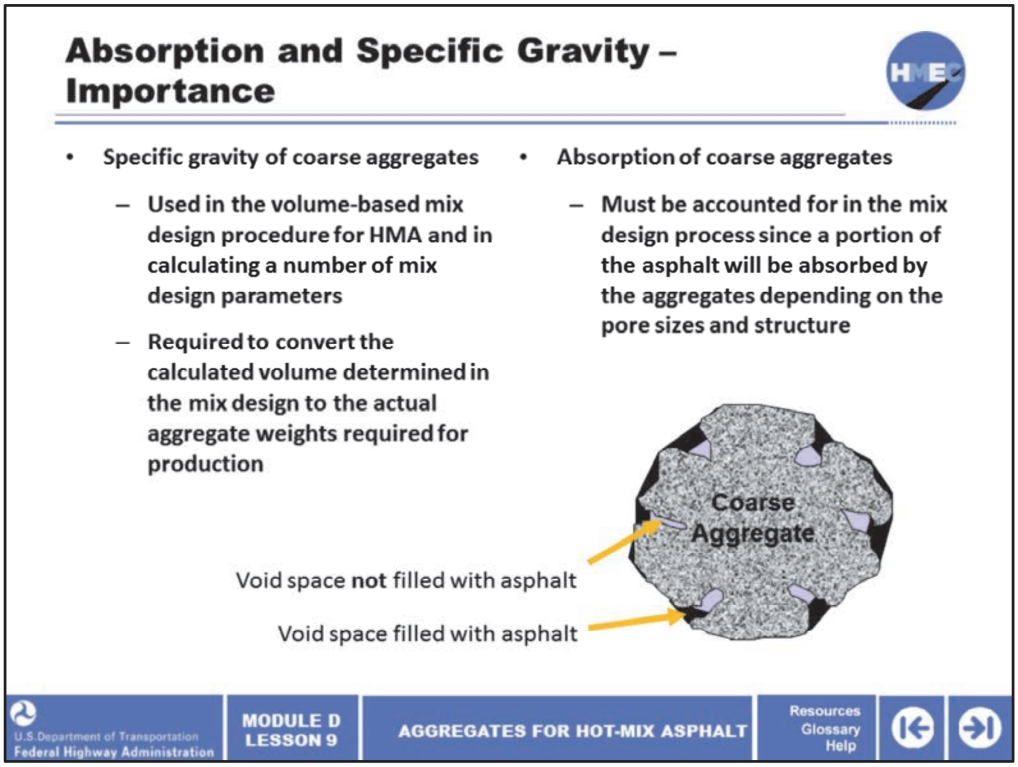


Three types of specific gravities are used in HMA mix design and are covered in detail in Module F:

Apparent specific gravity—the ratio of the weight in air of a unit volume of the impermeable portion of aggregate.

Bulk specific gravity—the ratio of the weight in air of a unit volume of aggregate, including the permeable and impermeable voids.

Effective specific gravity (SSD)—the ratio of the weight in air of a unit volume of aggregate excluding voids permeable to asphalt.

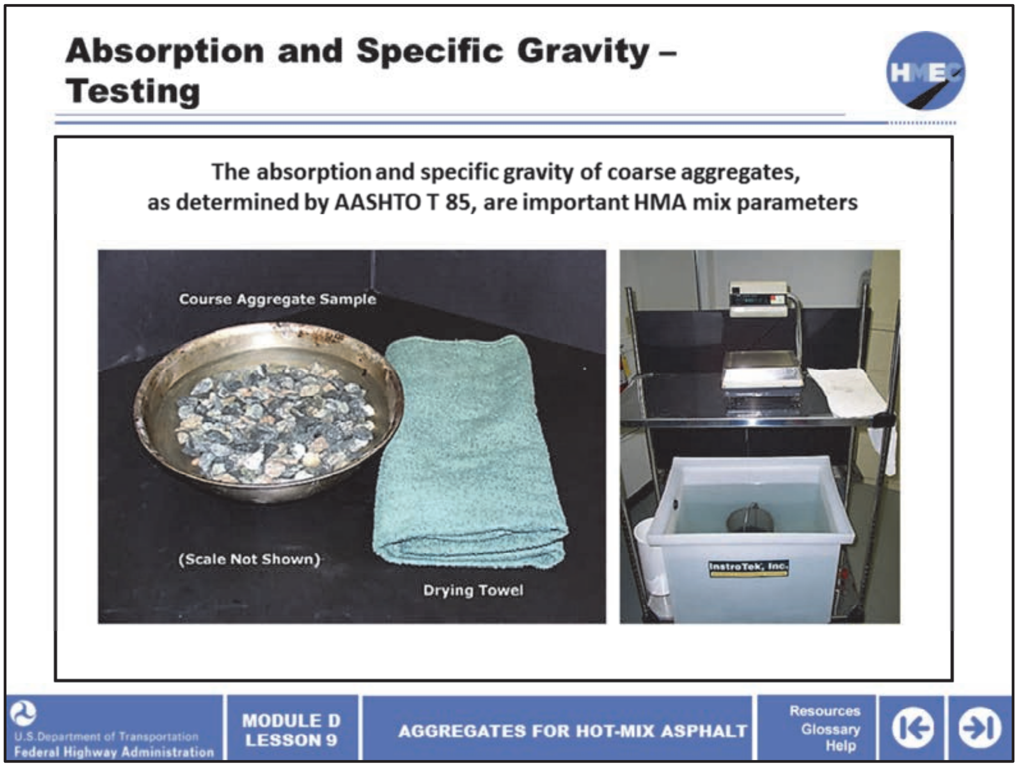


The specific gravity of the coarse aggregates is used in the volume-based mix design procedure for HMA. It is also used in calculating a number of mix design parameters, as well as being required to convert the calculated volume determined in the mix design to the actual aggregate weights required for production.

The absorption of coarse aggregates must be accounted for in the mix design process since a portion of the asphalt will be absorbed by the aggregates depending on the pore sizes and structure.

The figure shows a typical aggregate particle with surface voids that are able to be partially filled with asphalt during HMA production. The amount of asphalt that is likely to be absorbed is estimated by the water absorption.

Image description: Illustration of a piece of coarse aggregate.

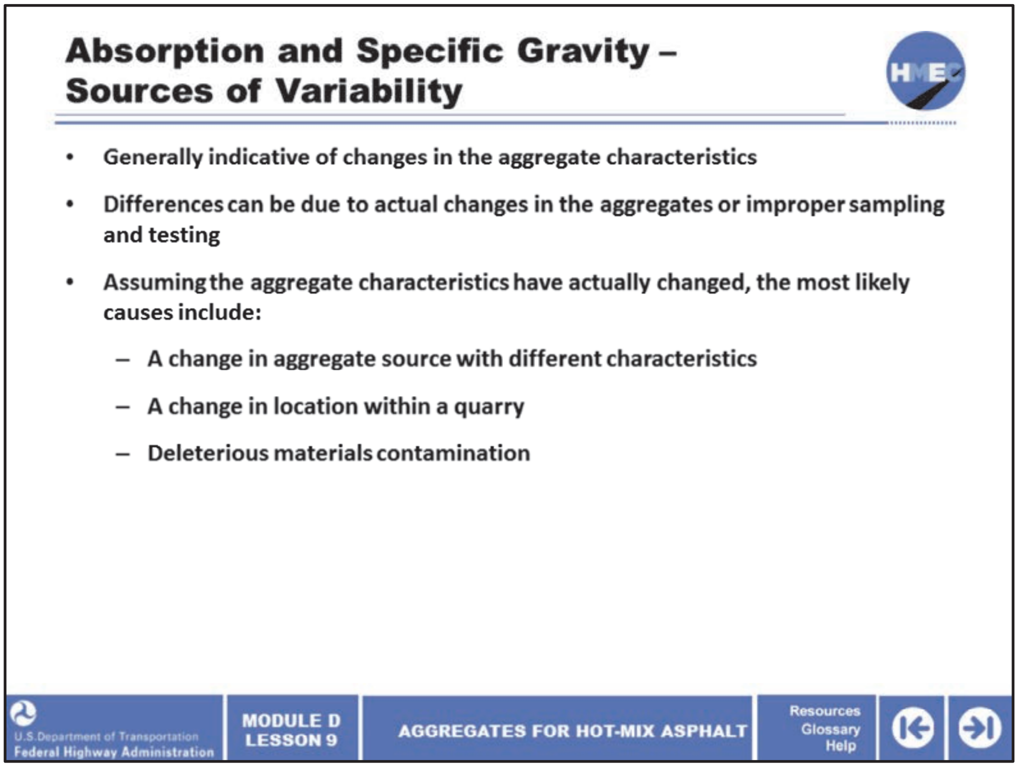


The specific gravity and absorption tests have been previously covered in Lesson 3 and were likely a part of your laboratory experience. The procedure is described in AASHTO T 85.

The photos (obtained from the Pavement Interactive Web site, www.pavementinteractive.org) show two of the basic steps involved in testing, aggregate soaking, and weighing the aggregates while submerged in water.

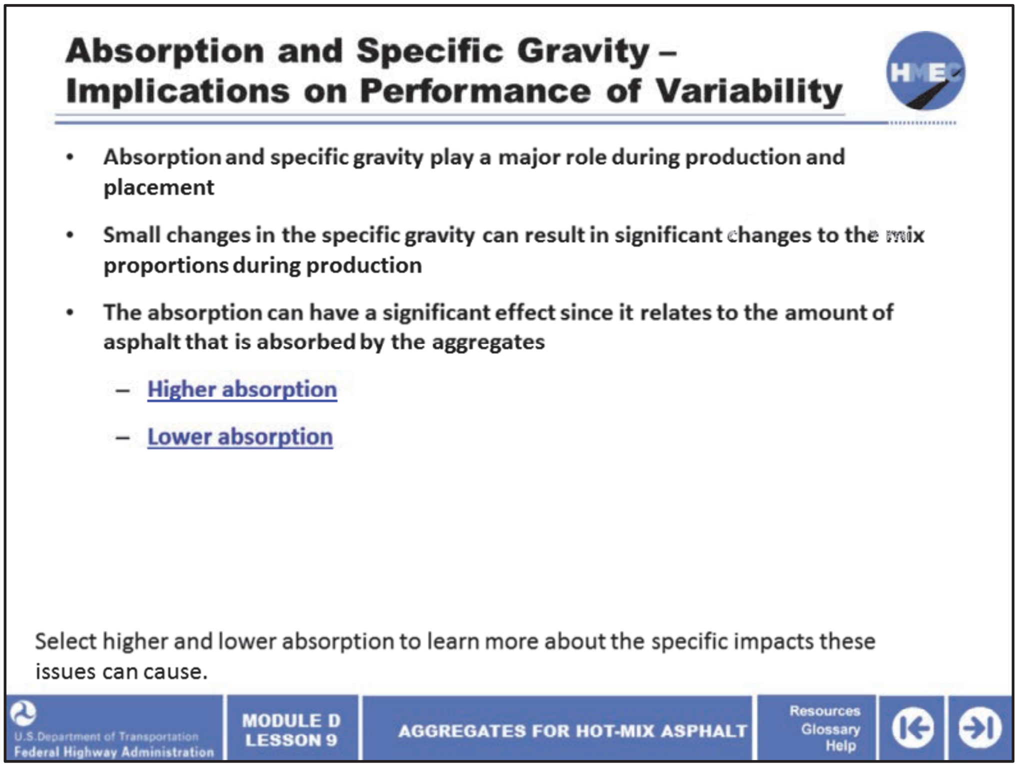
Image description: Photo of coarse aggregate sample in bowl and drying towel.

Image description: Photo of weighing aggregate sample in container of water.



Variability in the specific gravity and absorption are generally indicative of changes in the aggregate characteristics. These differences can be due to actual changes in the aggregates or improper sampling and testing. Assuming the aggregate characteristics have actually changed, the most likely causes include the following:

- A change in aggregate source with different characteristics;
- A change in location within a quarry; and
- Deleterious materials contamination.

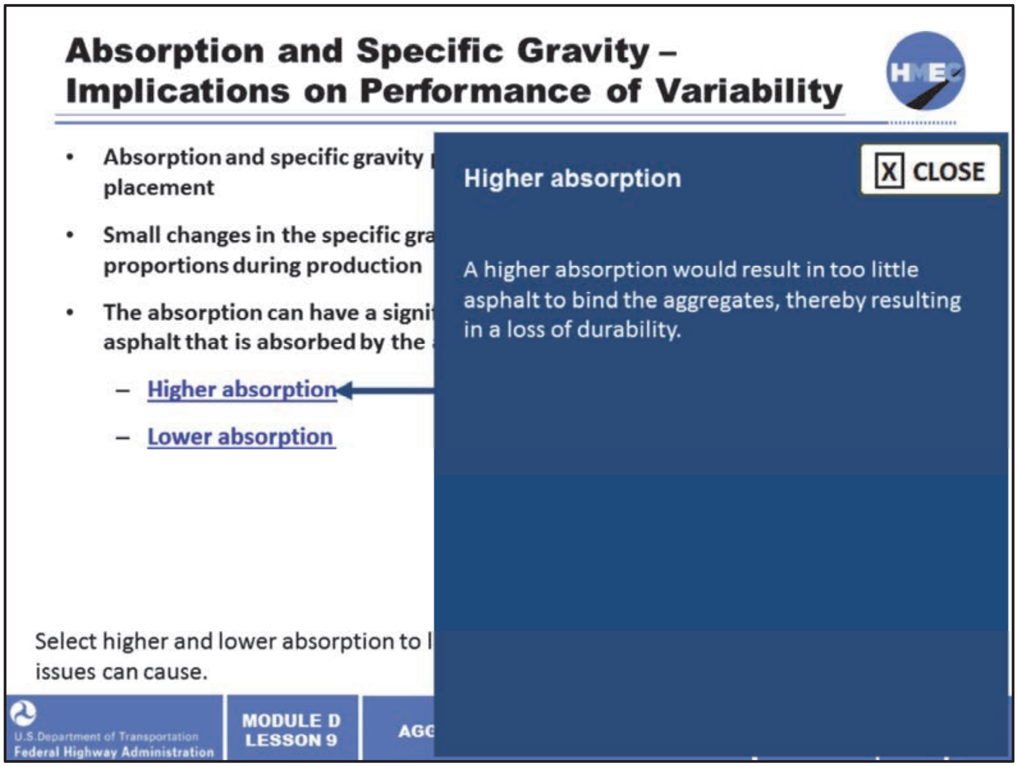


Absorption and specific gravity play a major role in the HMA mix design process, as well as during production and placement. Regardless of the source of the change, it must be quickly identified and resolved so as not to negatively impact the HMA performance.

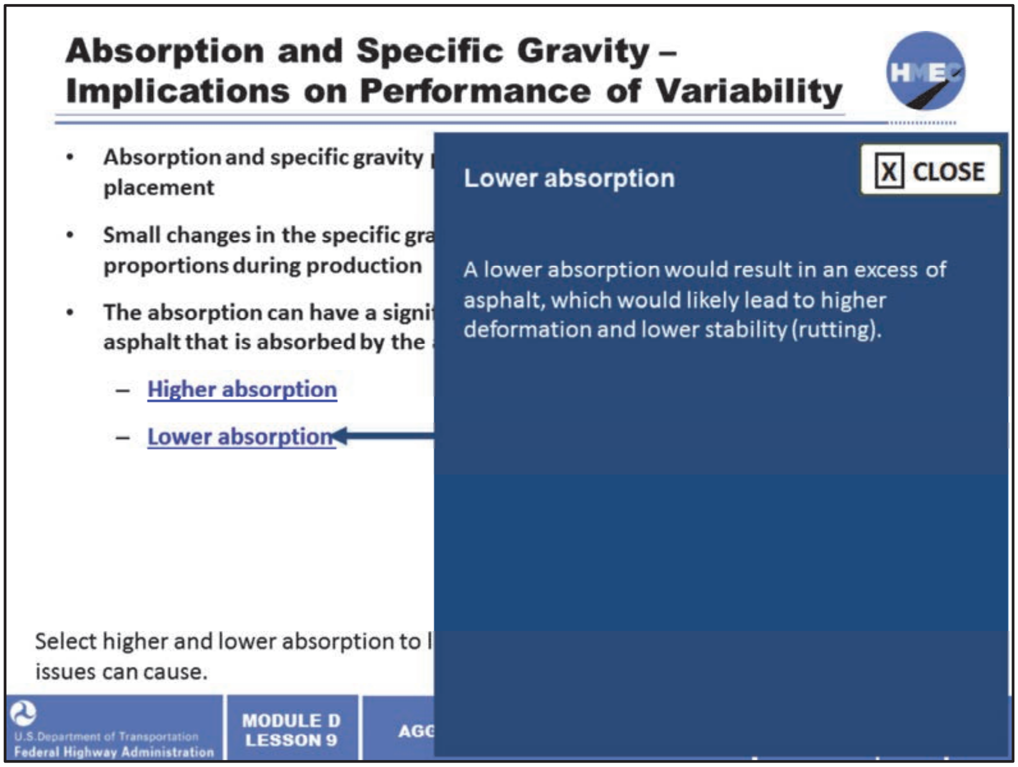
As you will discuss in Module F, relatively small changes in the specific gravity can result in significant changes to the mix proportions during production since the volume to weight conversion is based on this value.

The absorption can have a significant effect since it relates to the amount of asphalt that is absorbed by the aggregates.

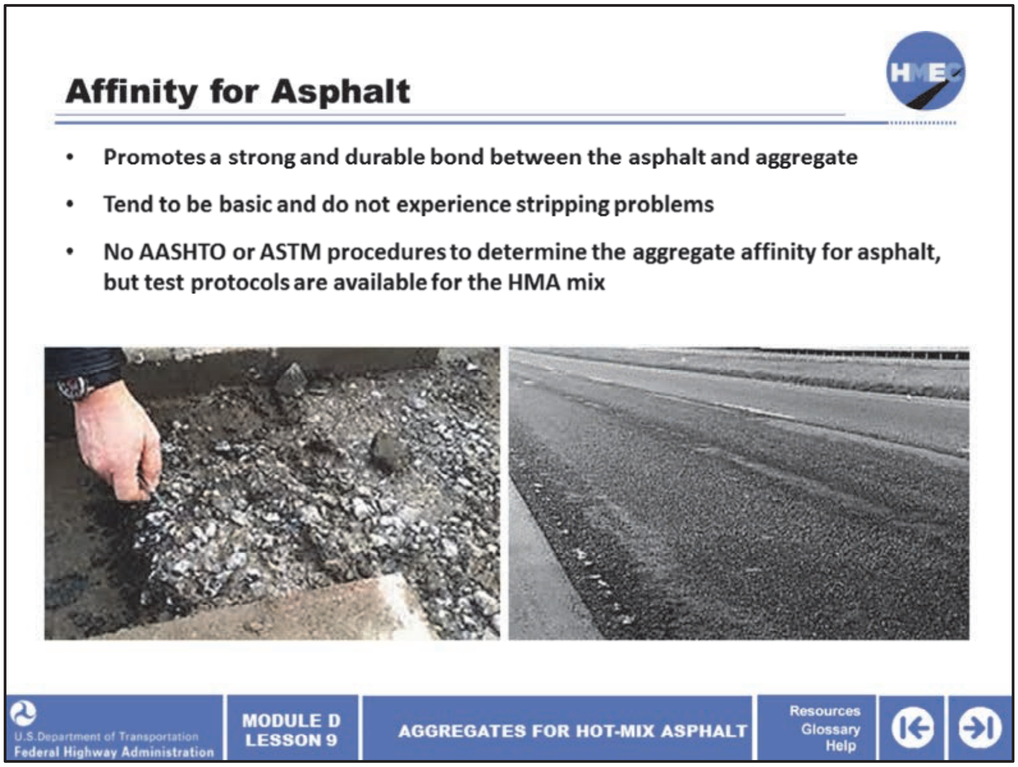
Select higher and lower absorption to learn more about the specific impacts these issues can cause.



A higher absorption would result in too little asphalt to bind the aggregates, thereby resulting in a loss of durability.



A lower absorption would result in an excess of asphalt, which would likely lead to higher deformation and lower stability (rutting).



Now we'll discuss affinity for asphalt. Desirable aggregates for HMA use have an affinity for asphalt that promotes a strong and durable bond between the asphalt and aggregate. The mineralogy and chemical composition of the aggregate have been identified as key properties, although there is still considerable research investigating this very complex interaction.

Some aggregates have an affinity for water over asphalt (hydrophilic). These aggregates tend to be acidic and are prone to stripping (debonding between the asphalt and aggregate) after exposure to water. When stripping begins at the surface and progresses downward, it is usually called raveling.

Aggregates that have an affinity for asphalt tend to be basic and do not experience stripping problems.

The photo on the left shows stripping at the bottom of a HMA layer. The photo on the right illustrates surface raveling. Although these are basically the same phenomena, stripping is more problematic in that it results in a loss of structural capacity that cannot easily be addressed.

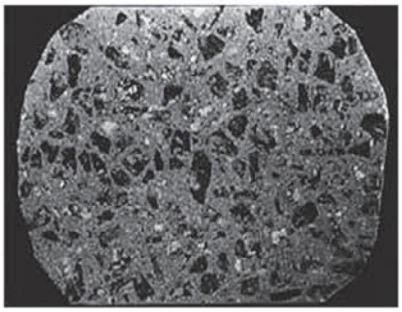
There are no AASHTO or ASTM procedures to determine the aggregate affinity for asphalt, however, test protocols are available for the HMA mix.

Image description: Photo of pavement failure caused by stripping.

Image description: Photo of raveling or weathering of asphalt road.

Gradation

- The maximum aggregate size (MAS), nominal maximum aggregate size (NMAS), and the overall particle size distribution are the key gradation parameters
- According to the Superpave mix design criteria, the following definitions are used
  - Maximum size: 1 sieve size larger than NMAS
  - Nominal maximum size: 1 sieve size larger than the first sieve to retain more than 10%



Standard NMAS Designations	
mm	inches
9.5	3/8
12.5	1/2
19	3/4
25	1
37.5	1.5

As with every other course aggregate application discussed in this module, aggregate gradation has a substantial influence on performance.

The maximum aggregate size (MAS), nominal maximum aggregate size (NMAS) and the overall particle size distribution are the key gradation parameters.

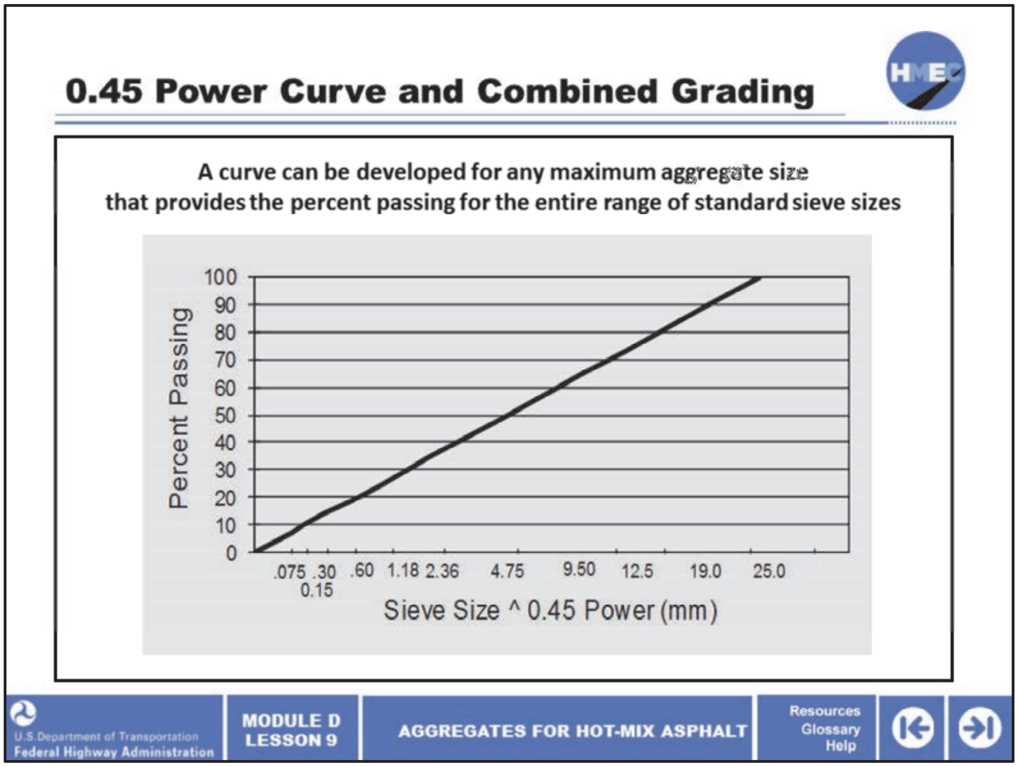
According to the Superpave mix design criteria, the following definitions are used:

- Maximum size: 1 sieve size larger than NMAS; and
- Nominal maximum size: 1 sieve size larger than the first sieve to retain more than 10%.

There are five standard nominal maximum aggregates sizes, including 37.5mm, 25mm, 19mm, 12.5mm, and 9.5mm, or in inches, 1½ inch, 1 inch, ¾ inch, ½ inch, and $^3/_8$ inch. The intended use and pavement design dictates the appropriate NMAS.

Dense graded HMA uses aggregates blended to the 0.45 power curve as shown on the next screen.

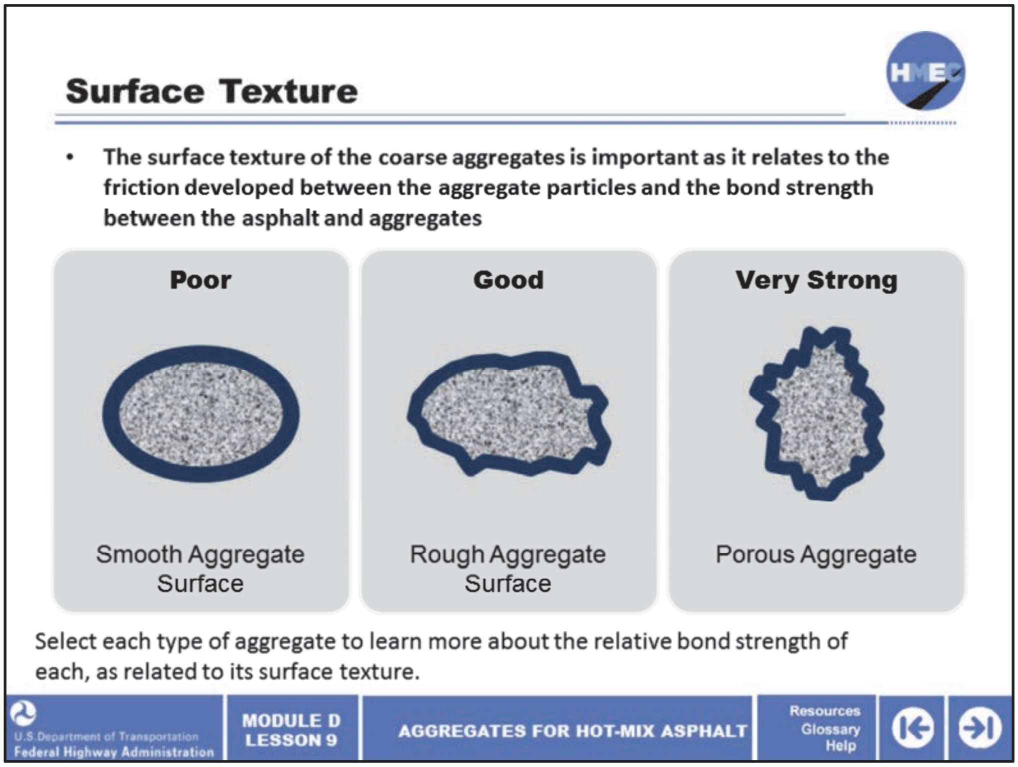
Image description: Photo of concrete fabricated without larger sizes of coarse aggregate.



The 0.45 power curve represents the maximum density of combined aggregate grading. A curve can be developed for any maximum aggregate size that provides the percent passing for the entire range of standard sieve sizes. The combined grading of aggregates used for HMA mixes are based on a modified 0.45 power curve.

Note that the overall combined grading includes the fine, intermediate, and coarse aggregates.

Image description: Graph of 0.45 power curve and combined grading.



Surface texture plays a major role in the development of the internal strength of the HMA mix. The internal friction increases exponentially as the texture of the aggregate progresses from polished to very rough. In addition, the texture of the aggregate greatly influences the skid resistance of the HMA mix.

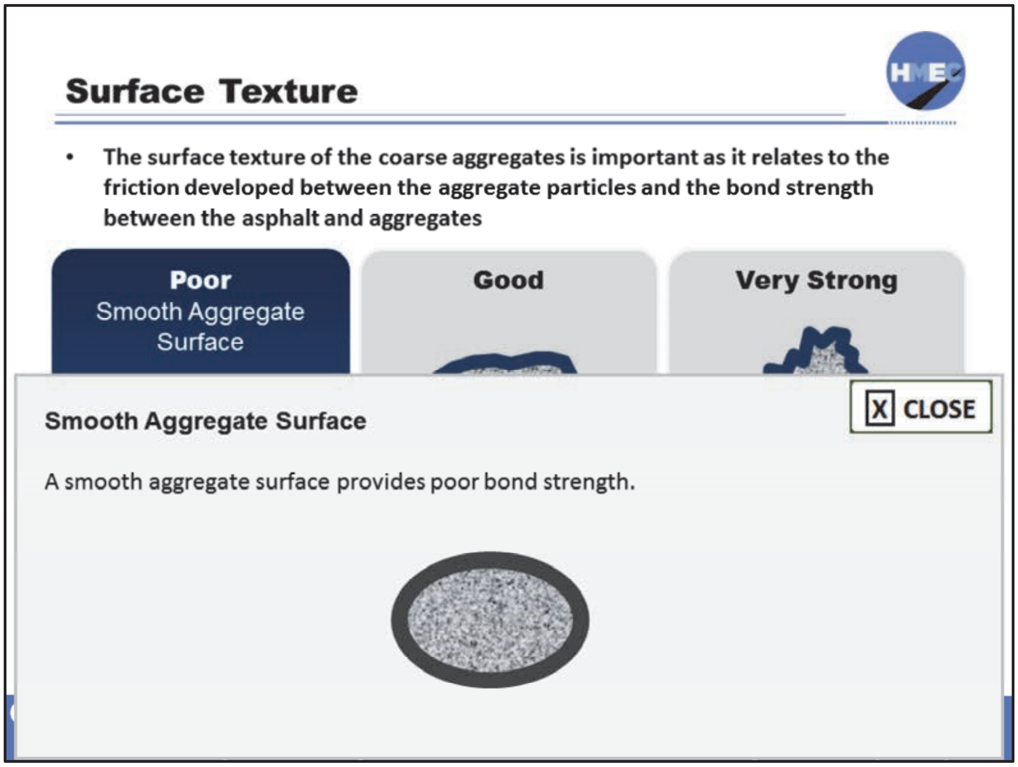
The texture of the aggregate is directly related to the strength of the bond between the aggregate and the asphalt binder. A weak bond would lead to the stripping of the binder from the aggregate surface. A strong bond would lead to high durability of the HMA mix.

Select each type of aggregate to learn more about the relative bond strength of each, as related to its surface texture.

Image description: Illustration of smooth aggregate.

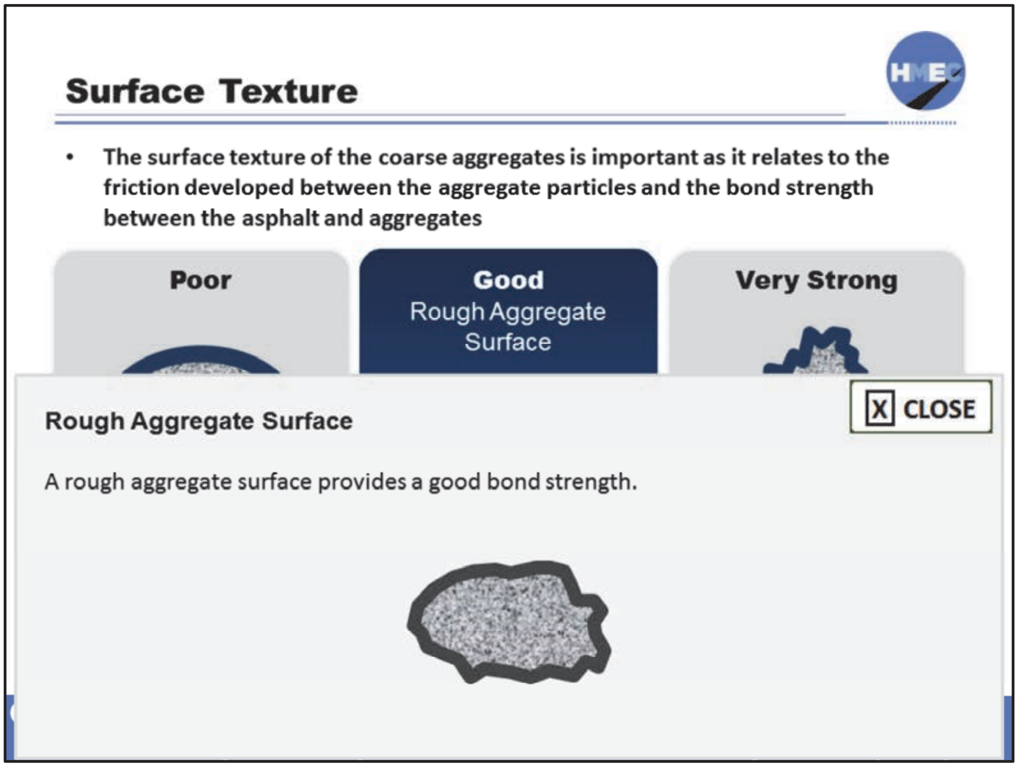
Image description: Illustration of rough aggregate.

Image description: Illustration of porous aggregate.



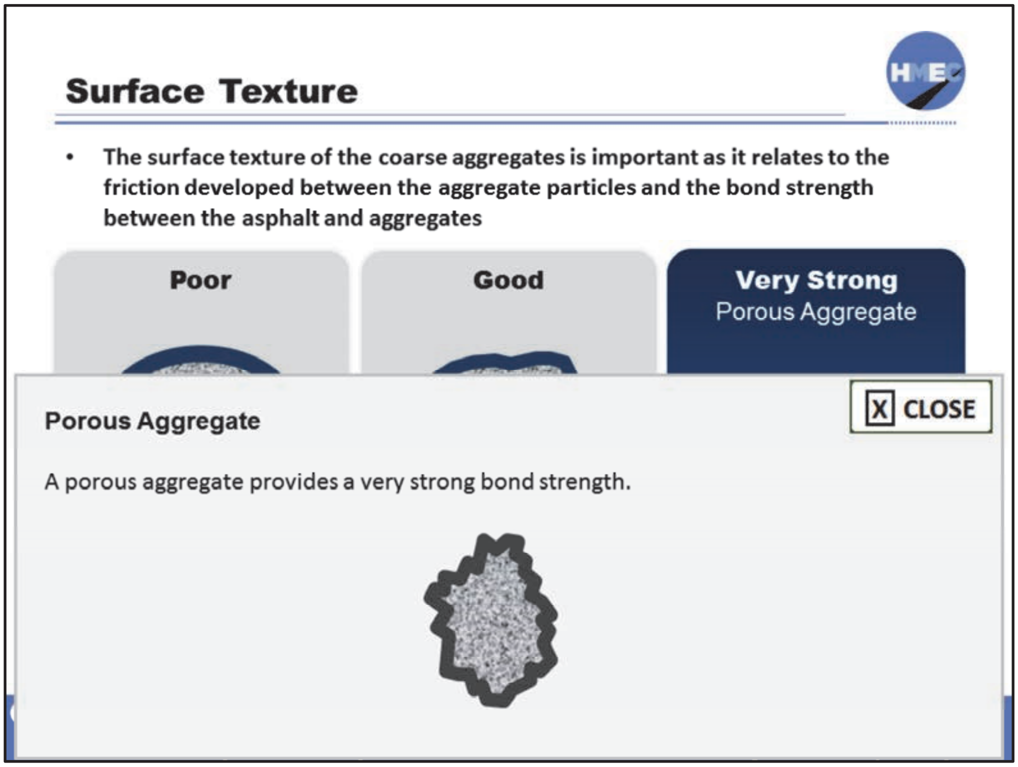
A smooth aggregate surface provides poor bond strength.

Image description: Illustration of smooth aggregate.



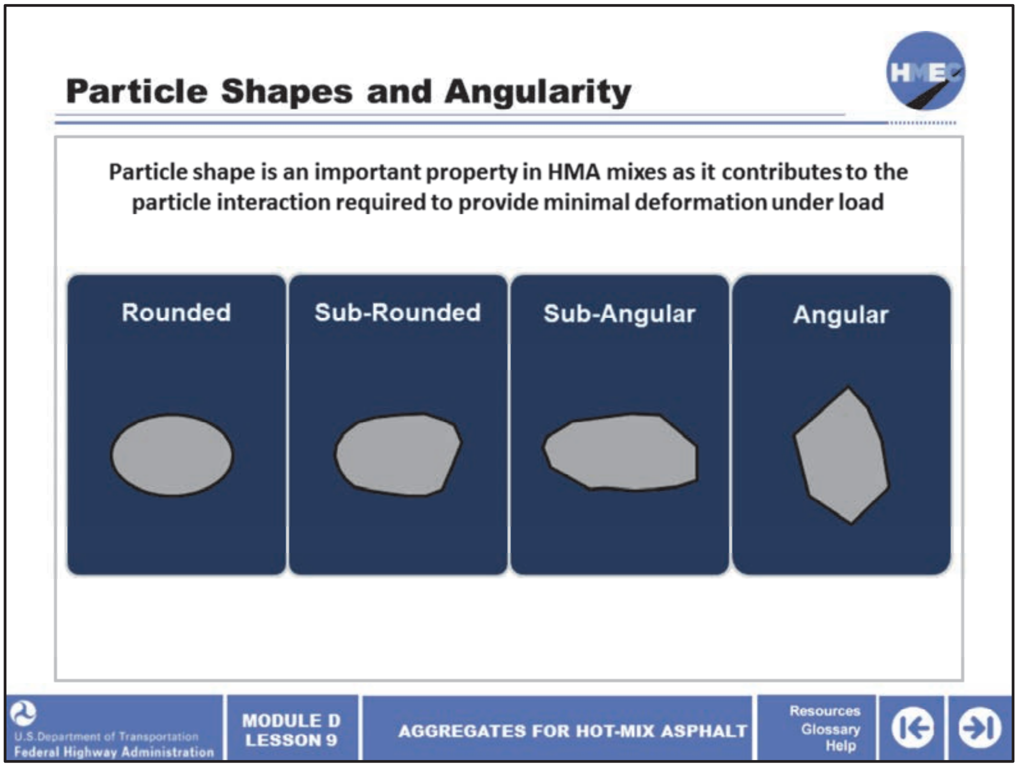
A rough aggregate surface provides a good bond strength.

Image description: Illustration of rough aggregate.



A porous aggregate provides a very strong bond strength.

Image description: Illustration of porous aggregate.



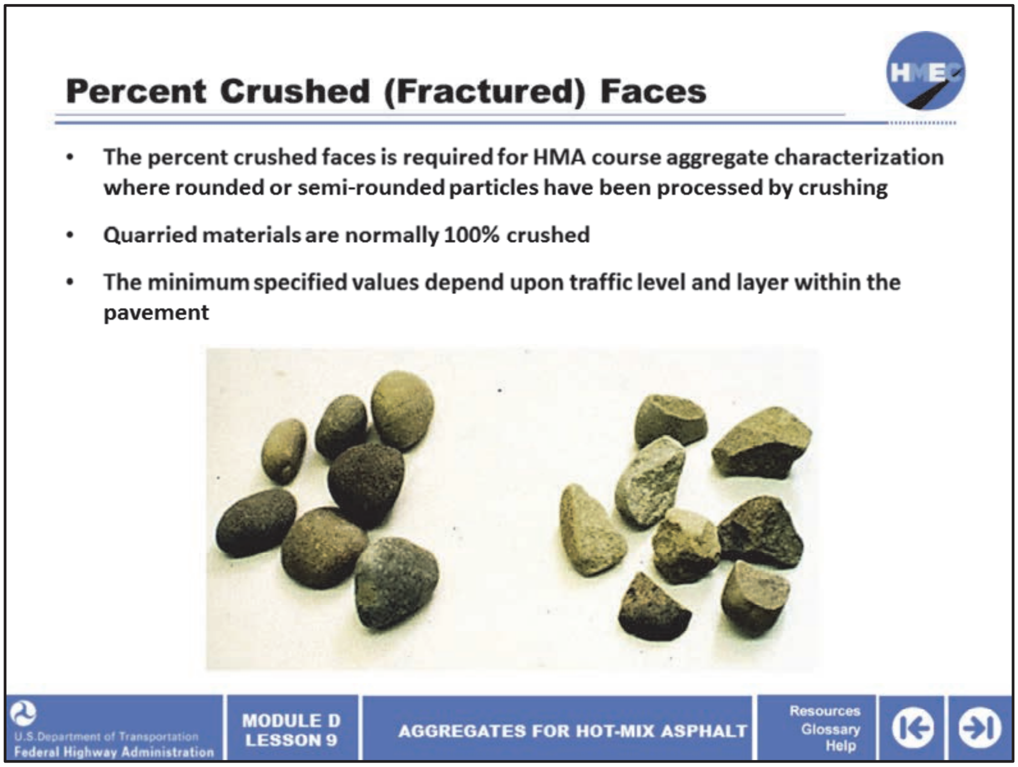
The shape of the aggregate is the first property that can be altered by the manufacturing process. Unprocessed aggregates usually have a rounded shape while fully processed aggregates have an angular shape. The in-between shapes can be obtained through partial processing of the aggregate. The quality of the aggregate is measured by its ability to maintain its processed shape as it is subjected to abrasion during manufacturing, construction, and service life.

Image description: Illustration of rounded aggregate.

Image description: Illustration of sub-rounded aggregate.

Image description: Illustration of sub-angular aggregate.

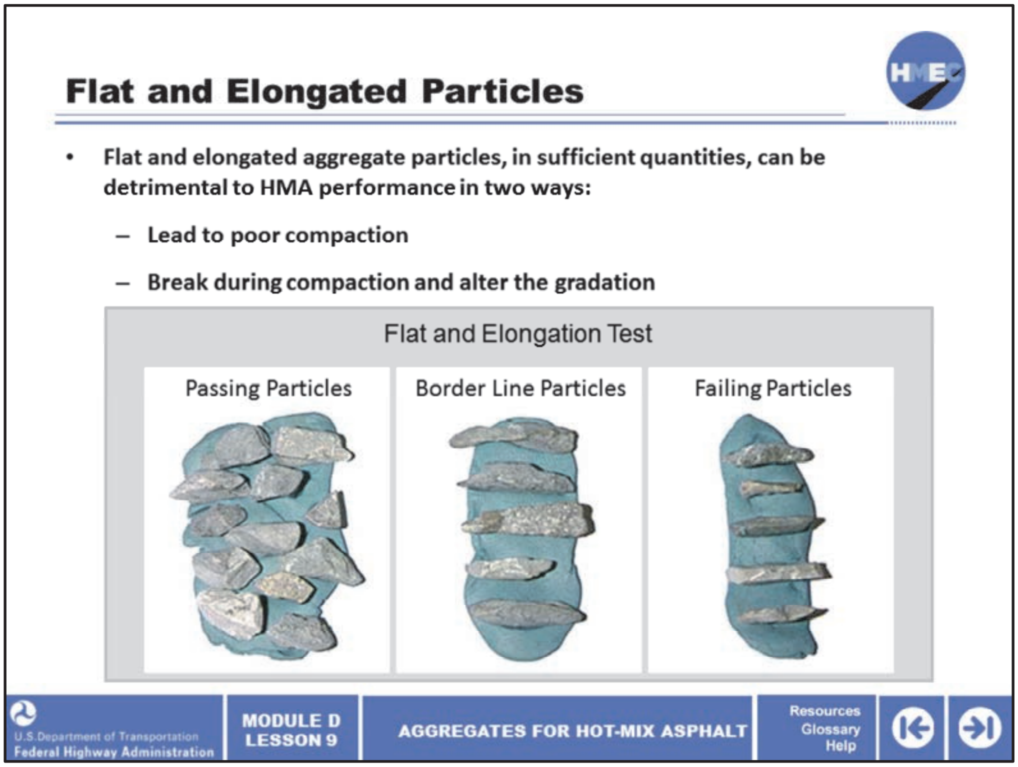
Image description: Illustration of angular aggregate.



Now let's take some time to discuss the percent crushed, or fractured, faces. The percent crushed face test is a process that physically identifies the presence of a fractured face on each aggregate particle. The grading rule is that the face must be a mechanical fracture and must cover at least ¼ of the particle's projected area. The objective of the test is to identify the percentage of coarse aggregates that have a specified number of fractured faces. The test can identify aggregates with one fractured face or two fractured faces. Aggregates are washed, separated on a flat surface, and observed individually.

The aggregate on the left is natural gravel with rounded, smooth particles. The aggregate on the right shows the same type of particles after crushing to produce the required fractured faces for use in HMA.

Image description: Photo of natural gravel with rounded, smooth particles and the same type of particles after crushing.



Flat and elongated aggregates tend to make compaction of the HMA difficult because the particles tend to lock up with adjacent aggregate particles and resist reorientation into a more dense configuration. In other words, significant numbers of flat or elongated particles can increase the compactive effort required to achieve target density for a given HMA mixture.

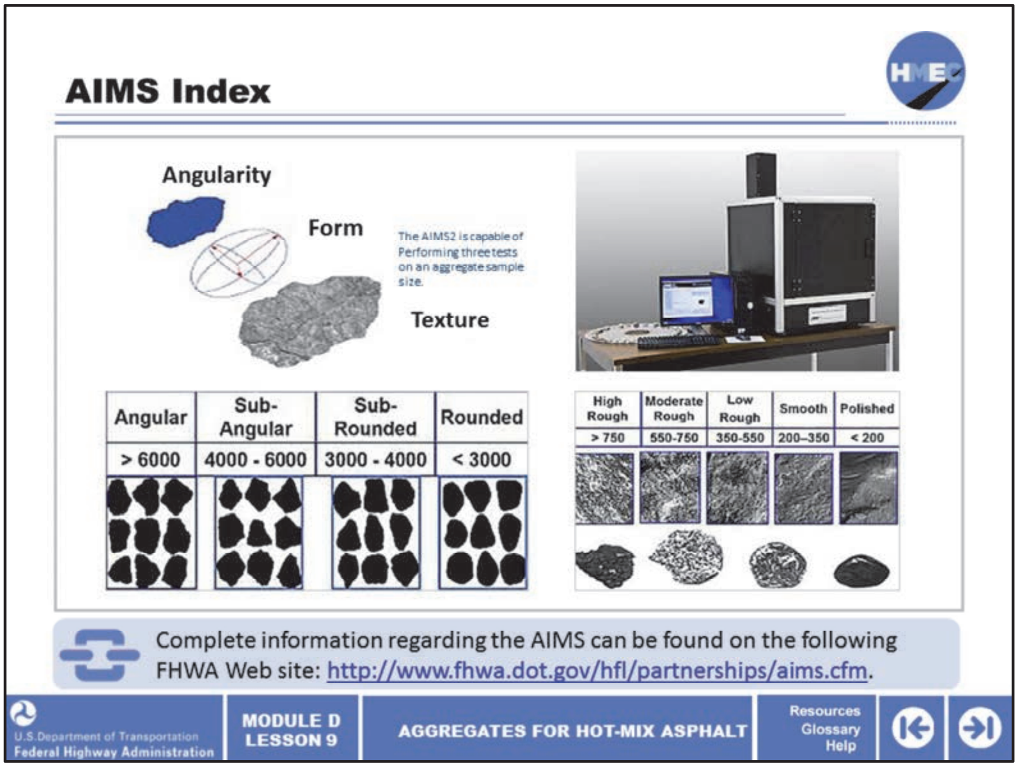
Flat and elongated particles also have a tendency to fracture along their weak, narrow dimension when subjected to compaction loading. If present in sufficient quantity, this can effectively change the aggregate gradation as larger flat and elongated particles are broken into smaller, more cubic particles. The result is that these smaller particles will fill existing void spaces and reduce the voids in the mineral aggregates or VMA.

Ultimately, the result can be HMA mix instability (rutting and shoving), and reduced durability.

Image description: Photo of passing particles.

Image description: Photo of border line particles.

Image description: Photo of failing particles.



The Aggregate Imaging Measurement System (AIMS) was developed in an effort to eliminate the subjective determination of particle shape and texture. The diagram in the upper left depicts the capabilities of the device in measuring particle angularity, form (length, width, and depth), and surface texture. The device is pictured in the upper right and consists of the test chamber and data acquisition system.

The device is capable of characterizing a wide range of particle textures and shapes, as shown in the bottom figures. Prior to development of the AIMS, determining the particle shape and texture was problematic in that the results were highly dependent on the skill and experience of the laboratory technician performing the tests.

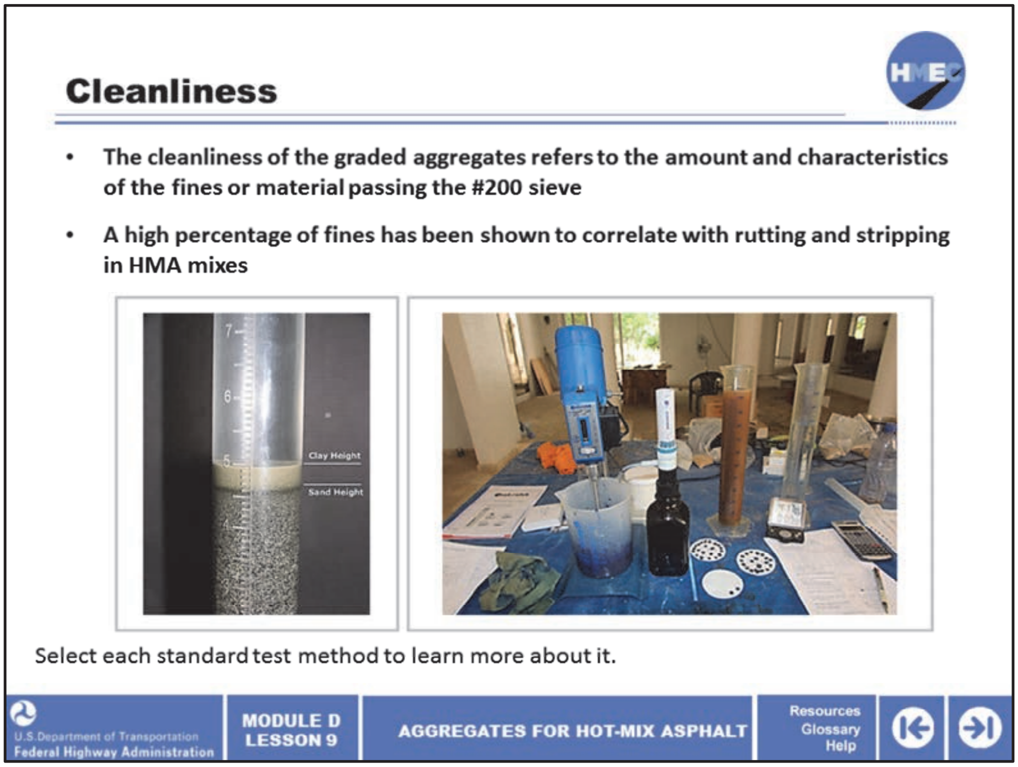
Complete information regarding the AIMS can be found on the FHWA Web site.

Image description: Diagram depicting the capabilities of the device in measuring particle angularity, form (length, width, and depth), and surface texture.

Image description: Photo aggregate imaging system.

Image description: Illustration showing angular aggregate, sub angular aggregate, sub rounded aggregate and rounded aggregate.

Image description: Illustration showing high rough aggregate, moderate rough aggregate, low rough aggregate, smooth aggregate and polished aggregate.

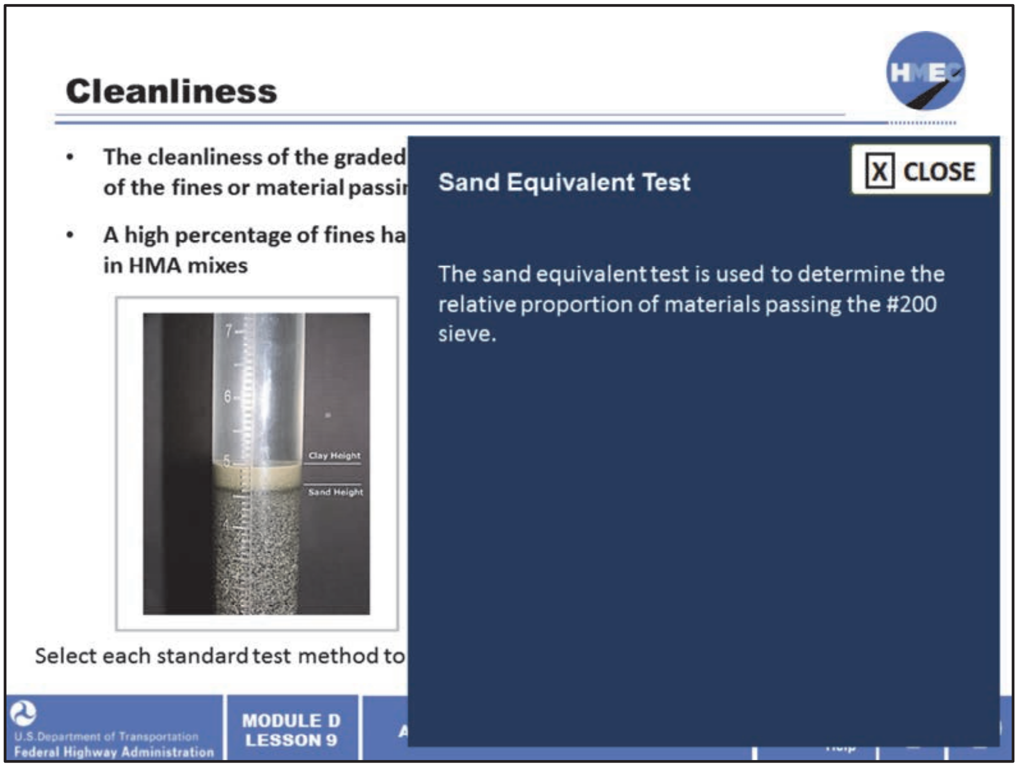


The cleanliness of the graded aggregates refers to the amount and characteristics of the fines or material passing the #200 sieve. Two standard test methods are used to determine the amount and characteristics of the fines present in the graded aggregates.

Select each standard test method to learn more about it.

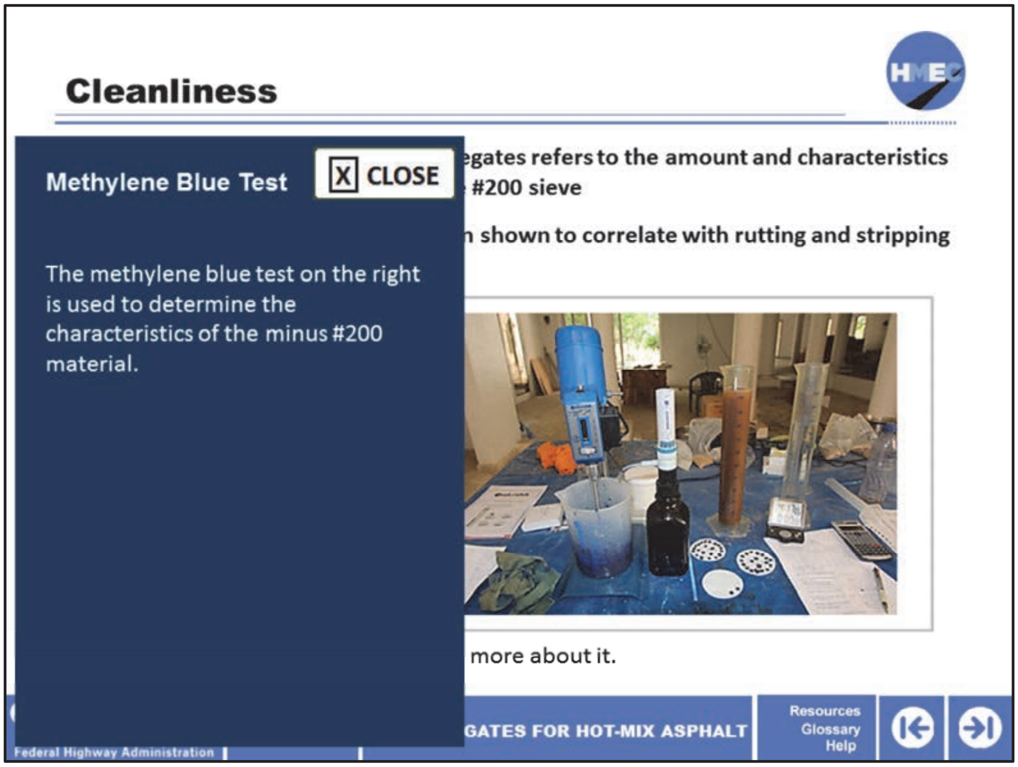
Image description: Photo of sand equivalent test cylinder.

Image description: Photo of methylene blue test.



The sand equivalent test is used to determine the relative proportion of materials passing the #200 sieve.

Image description: Photo of sand equivalent test cylinder.



The methylene blue test on the right is used to determine the characteristics of the minus #200 material.

Image description: Photo of methylene blue test.

The Los Angeles (LA) abrasion test is a measure of degradation of mineral aggregates resulting from a combination of abrasion, impact, and grinding in a rotating steel drum containing a specified number of steel spheres (dependent upon the test sample's grading).

Similar to the LA abrasion test, the Micro-Deval test uses a rotating drum with steel spheres; however, the sample size, drum, and spheres are much smaller, and the sample is run wet. The Micro-Deval test tends to polish aggregate particles, while the LA abrasion test tends to break them.

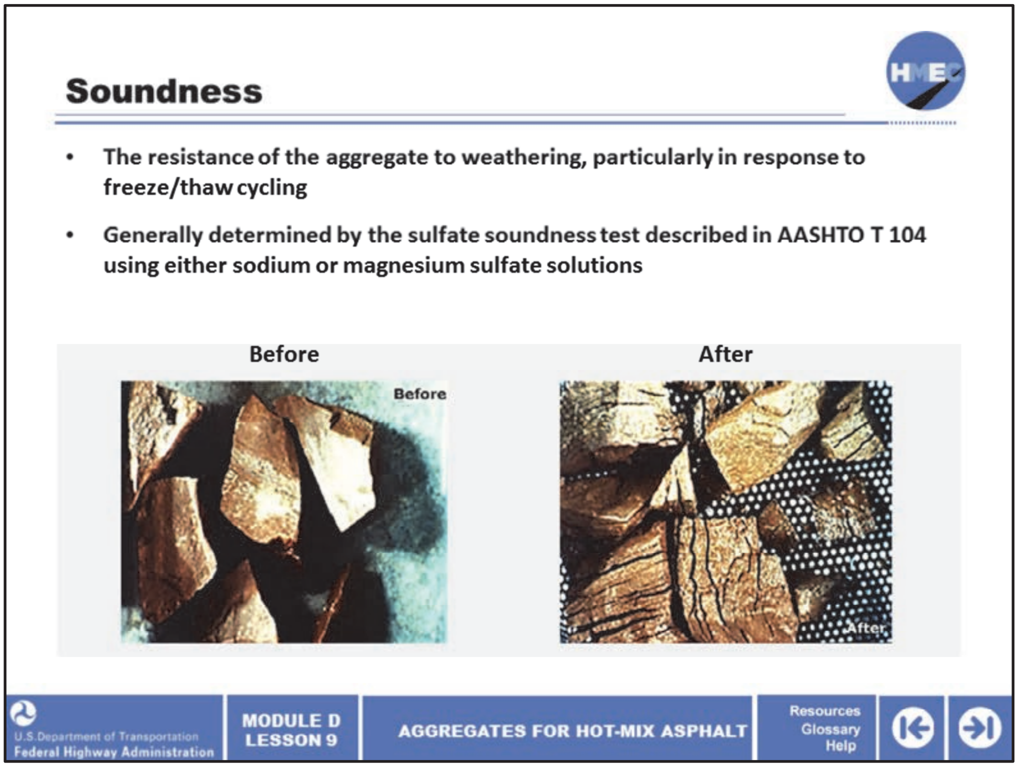
Both the LA abrasion test and the Micro-Deval test are primarily for asphalt mixes, particularly surface courses.

The LA abrasion device is on the left, the Micro-Deval unit is pictured on the right.

The polishing potential of the aggregates can be estimated by the British Wheel test or the insoluble residue test as was described in Lesson 3.

Image description: Photo of LA abrasion test machine.

Image description: Photo of Micro-Deval apparatus.



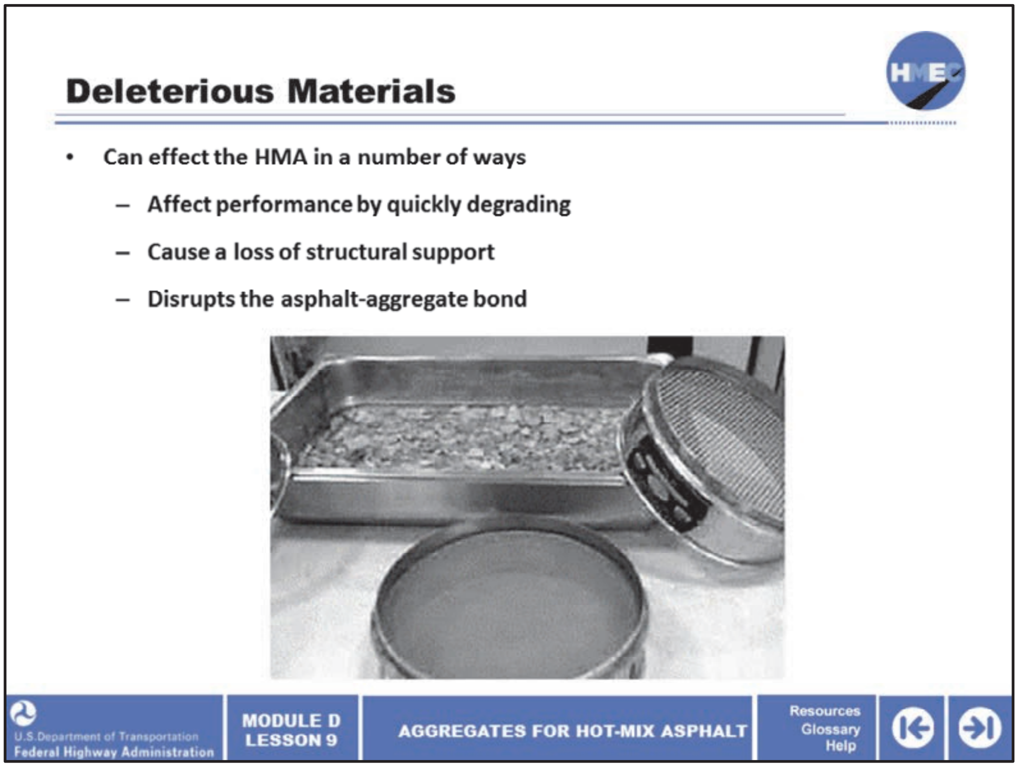
The soundness of aggregates is an important coarse aggregate characteristic in HMA and is defined as its resistance to disintegration under the action of wetting/drying and freezing/thawing. Aggregates are typically subjected to cycles of wetting/drying and freezing/thawing during their service live. The disintegration of the aggregate particles under these conditions would lead to drastic changes in the gradation of the mix and significantly impact its internal strength and long-term durability.

The soundness of the aggregate becomes very critical once the bond between the asphalt binder and the aggregate is broken, leaving easy access for water to penetrate the aggregate.

Disintegration by wetting/drying or freeze/thaw is generally determined by the sulfate soundness test described in AASHTO T 104 using either sodium or magnesium sulfate solutions.

Image description: Photo of aggregates before soundness test.

Image description: Photo of aggregates after soundness test.



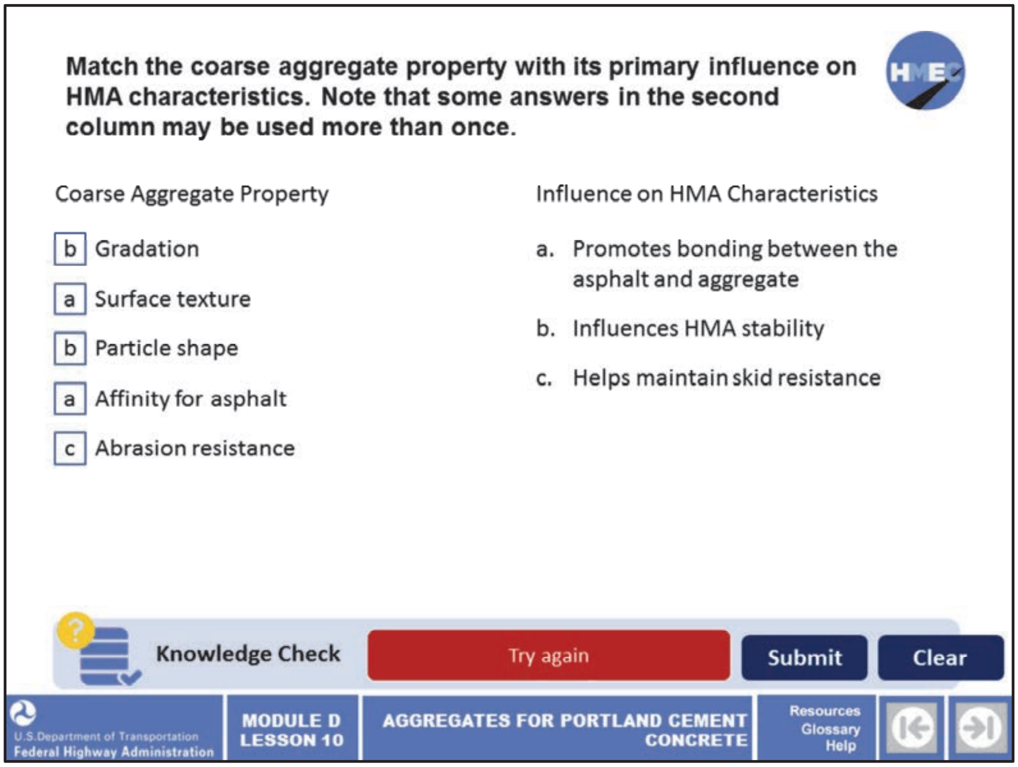
Deleterious material can effect the HMA in a number of ways, and consists of clay lumps, shale, soft, friable, or laminated particles, vegetable matter, or other objectionable material.

Aggregates must be relatively clean when used in HMA. Deleterious materials are not desirable because they generally affect performance by quickly degrading. This degradation causes a loss of structural support and/or disrupts the asphalt-aggregate bond.

To test for clay lumps or friable particles, a sample is first washed and dried to remove material passing the 0.075-mm (#200) sieve. The remaining sample is separated into different sizes and each size is weighed and soaked in water for 24 hours. Particles that can be broken down into fines with fingers are classified as clay lumps or friable material. The amount of this material is calculated by percentage of total sample weight. Specifications usually limit clay and friable particles to a maximum of 1%.

The photo shows testing for clay lumps and friable particles in the coarse aggregates.

Image description: Photo of aggregates in container and sieves.



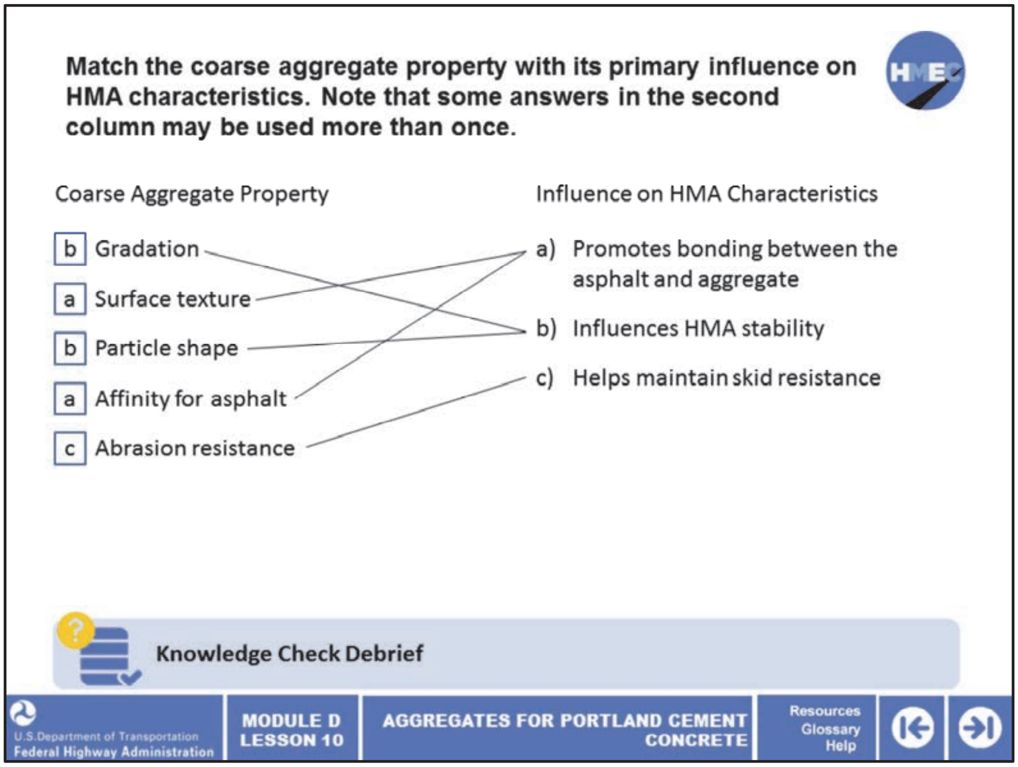
Match the coarse aggregate property with its primary influence on HMA characteristics. Note that some answers in the second column may be used more than once.

Coarse aggregate properties are:

- Gradation;
- Surface texture;
- Particle shape;
- Affinity for asphalt; and
- Abrasion resistance.

Influence on HMA characteristics are:

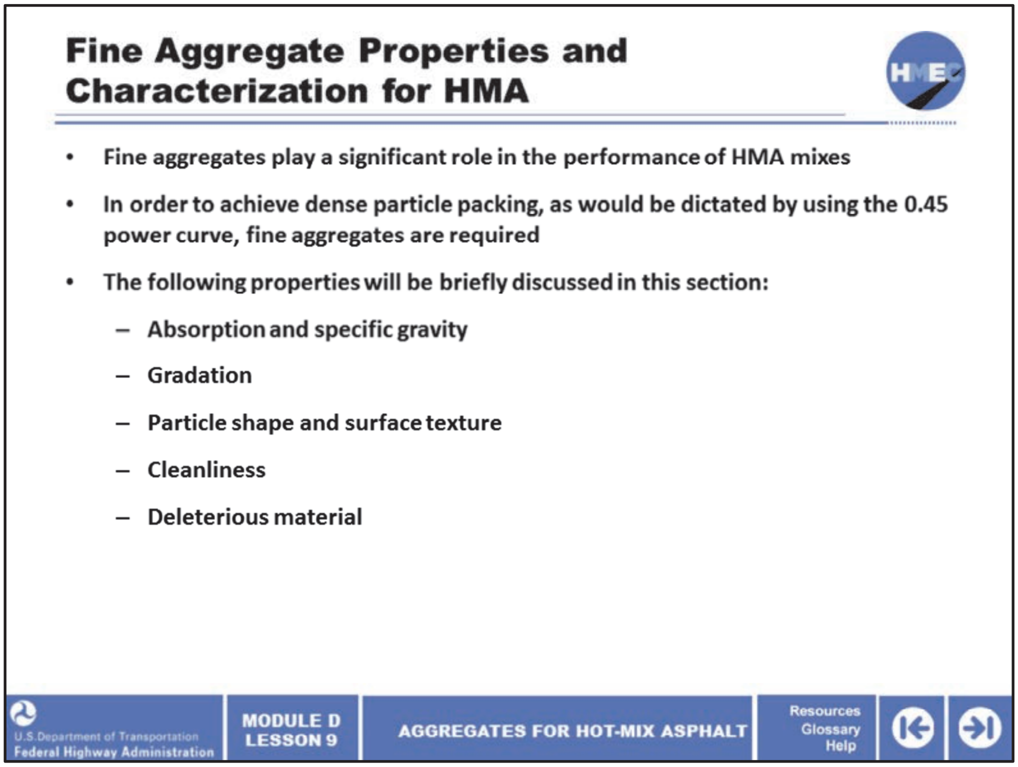
a) Promotes bonding between the asphalt and aggregate;
b) Influences HMA stability; and
c) Helps maintain skid resistance.



The correct answers are as follows:

- Gradation b) Influences HMA stability.
- Surface texture a) Promotes bonding between the asphalt and aggregate.
- Particle shape b) Influences HMA stability.
- Affinity for asphalt a) Promotes bonding between the asphalt and aggregate.
- Abrasion resistance c) Helps maintain skid resistance.

Note that surface texture of the aggregates is responsible for the initial skid resistance of HMA.



Like coarse aggregates, fine aggregates also play a significant role in the performance of HMA mixes. It has long been recognized that the characteristics of the fine aggregate component of HMA can have a significant and sometimes dominant influence on mixture rutting and fatigue cracking resistance.

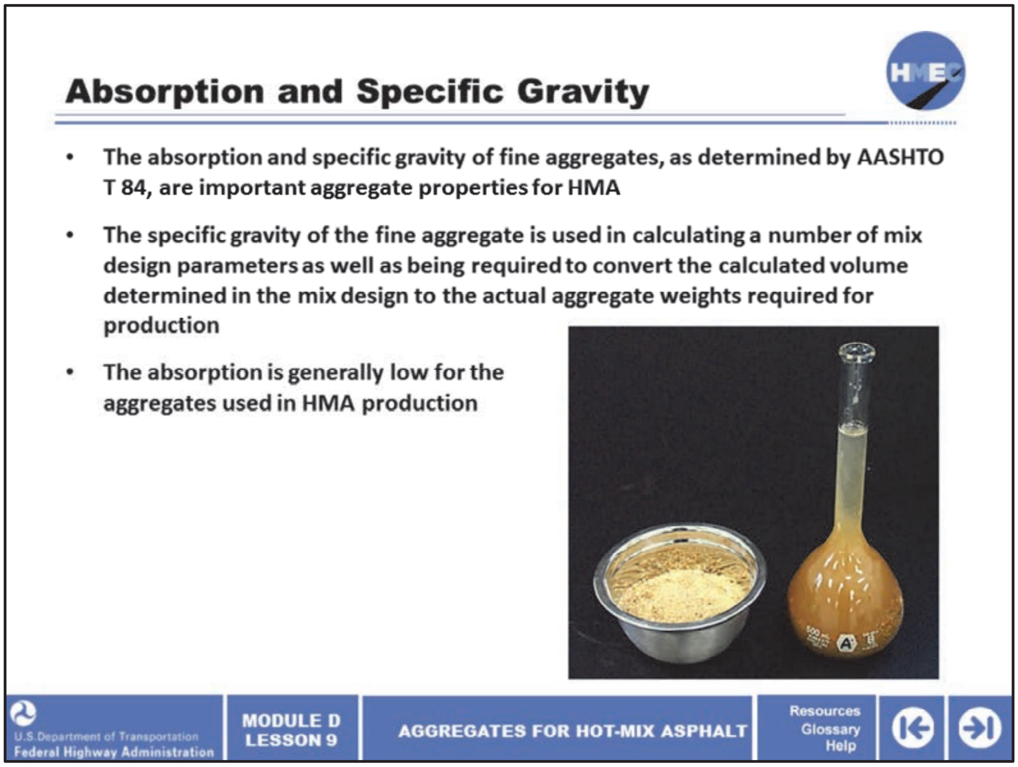
Fine aggregate properties that have been identified as having the most significant effect are the amount, shape, angularity, and surface texture.

In order to achieve dense particle packing, as would be dictated by using the 0.45 power curve, fine aggregates are required.

Note that open-graded mixes use a minimal fines content in order to achieve good permeability.

In this section, we will briefly discuss the following properties:

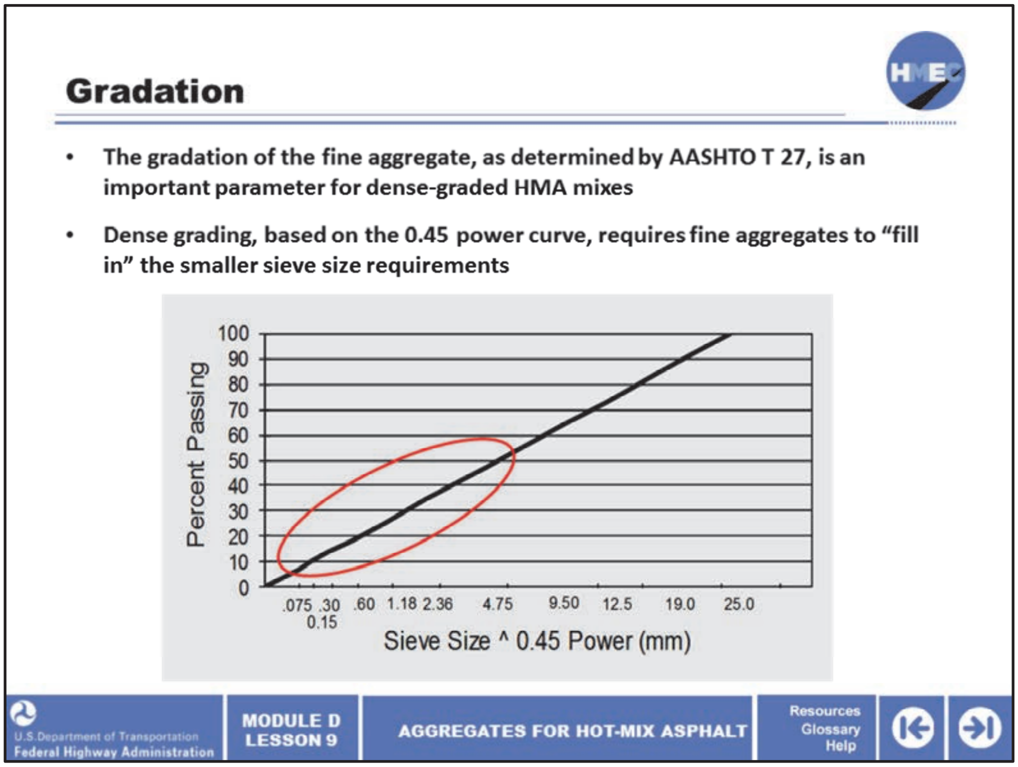
- Absorption and specific gravity;
- Gradation;
- Particle shape and surface texture;
- Cleanliness; and
- Deleterious material.



The specific gravity definitions provided in the coarse aggregate discussion pertain to the fine aggregate as well. It should be noted that the bulk specific gravity (BSG) of aggregates used for HMA are generally in the range of 2.5 to 3.0. Low values of the BSG can be indicative of relatively porous or weak particles.

The absorption of the fine aggregates is also similar to the coarse aggregate and is generally in the range of approximately 0 to 5%. Aggregates with higher absorption are generally not economically feasible to use because of the increased asphalt required to coat the particles.

Image description: Photo of specific gravity sample and pycnometer.



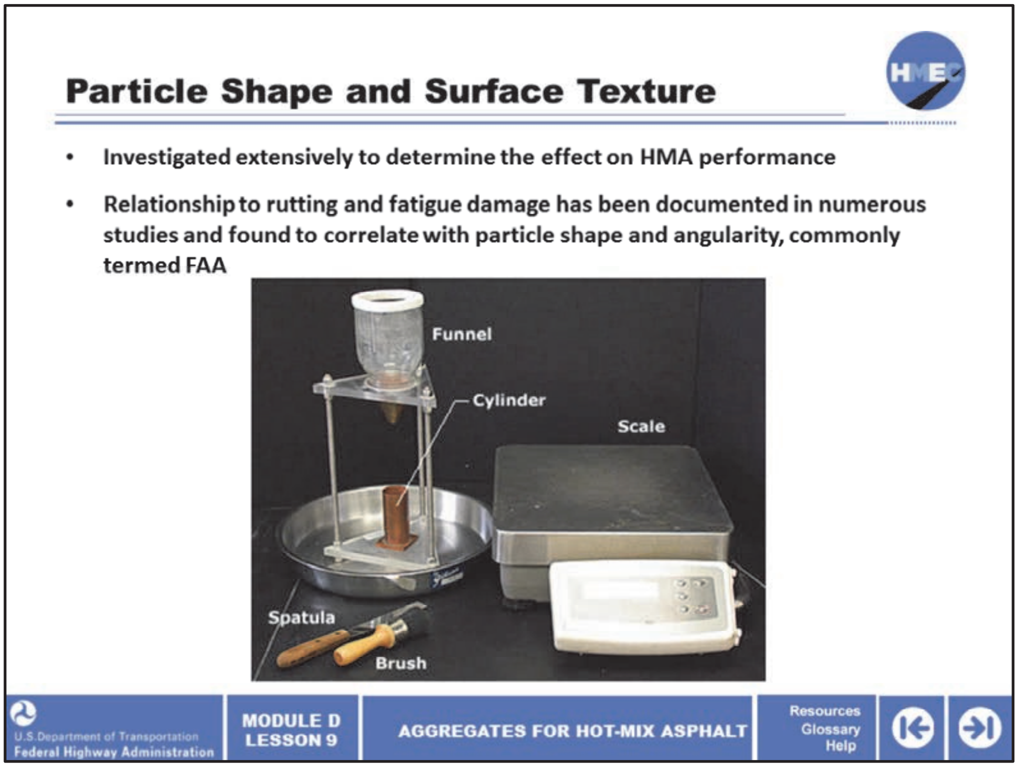
The discussion on gradation for coarse aggregates is also applicable, for the most part, to fine aggregates.

The amount of fines (minus #200) is of high importance as will be discussed on the following screens.

Note that the fine aggregate gradation plays an important role in the gradation range known as the restricted gradation zone (RGZ). The RGZ refers to an area lying along the maximum density line extending from the #50 (0.30-mm) sieve to the #8 (2.36-mm) or #4 (4.75-mm) sieve through which it is undesirable for a mixture gradation to pass.

The RGZ is one of the most controversial components of the Superpave mixture and was adopted primarily to reduce premature rutting. You will discuss this topic in more depth in Module F.

Image description: Graph of 0.45 power curve and combined grading.



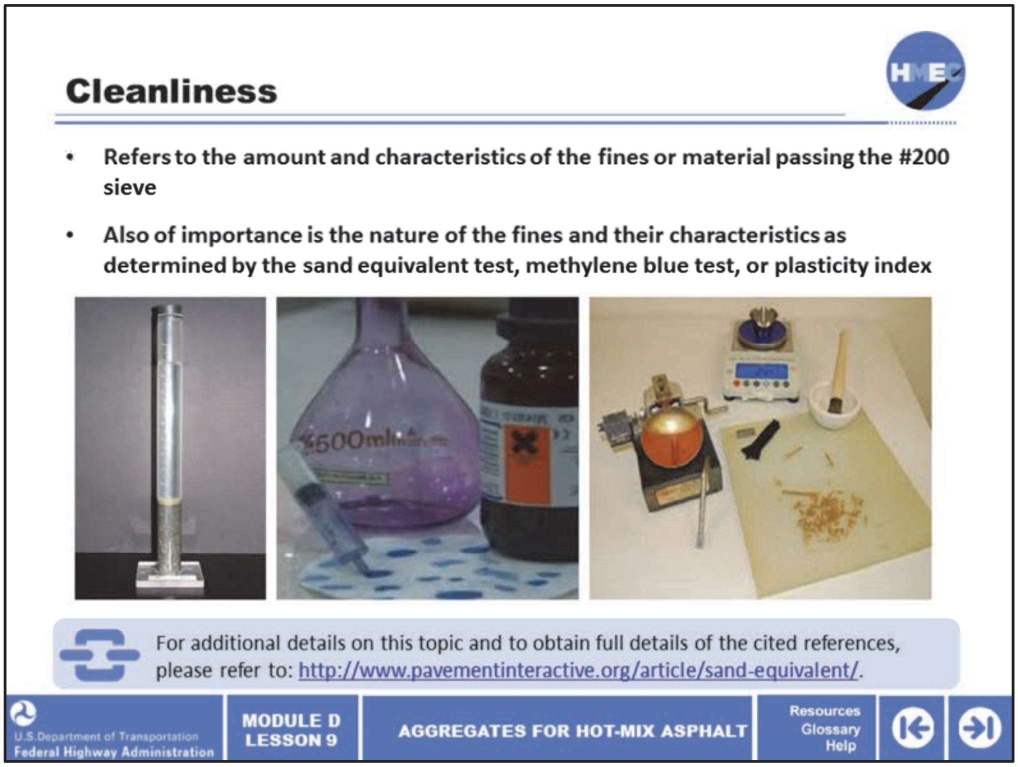
Angular materials are desirable in paving mixtures because they tend to lock together and resist deformation after initial compaction, whereas rounded materials may not produce sufficient inter-particle friction to prevent rutting. The measured uncompacted voids are affected by the shape, angularity, and texture of the fine aggregate, the aggregate grading, and specific gravity. Fine aggregate angularity (FAA) can indicate the effect of the fine aggregate portion of the mixture on the overall properties of the mixture.

It is generally believed that low FAA values will result in an unstable HMA mixture (e.g., potential for rutting and shoving) and high FAA values will result in a stable HMA mixture if all other mixture properties are satisfactory.

The NCHRP research reports listed at the beginning of this lesson should be consulted for further details regarding these relationships.

The photo shows the standard method used to determine the angularity of fine aggregates.

Image description: Photo of the standard method used to determine the angularity of fine aggregates.



As with coarse aggregates, the cleanliness of the fine aggregates refers to the amount and characteristics of the fines or material passing the #200 sieve.

Excessive dust or plastic fines (clay-like fine particles) in HMA aggregate can contribute to a lack of stability (rutting or shoving) or moisture damage and stripping. A simple test to determine whether or not a particular aggregate has enough dust or plastic fines to make a HMA mixture unstable or susceptible to stripping is valuable in preventing the manufacture of poor performing mixtures.

The sand equivalent test separates out a fine aggregate sample’s sand and plastic fines and dust portion to determine the content of the latter.

The plasticity index (PI) can indirectly indicate the type and amount of plastic fines, although several researchers have reported no correlation between the PI and the field performance of HMA.

Based on their test results, Kandhal, Lynn, and Parker (1998) recommended the methylene blue (MB) test over the sand equivalent test as the one that is “best related to stripping in HMA.” However, Woodward, Woodside, and Jellie (2002) point out that the MB test is rock-type specific and its application to rock types other than basalt can be a problem.

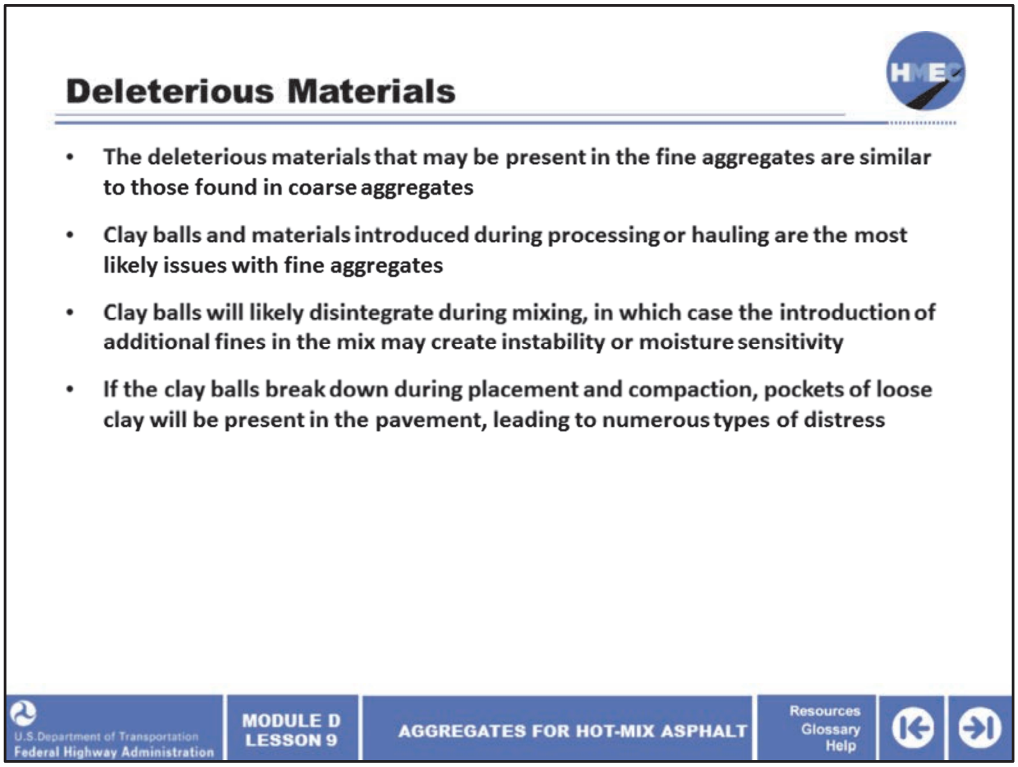
For additional details on this topic and to obtain full details of the cited references, please refer to:

http://www.pavementinteractive.org/article/sand-equivalent/.

Image description: Photo of sand equivalent test.

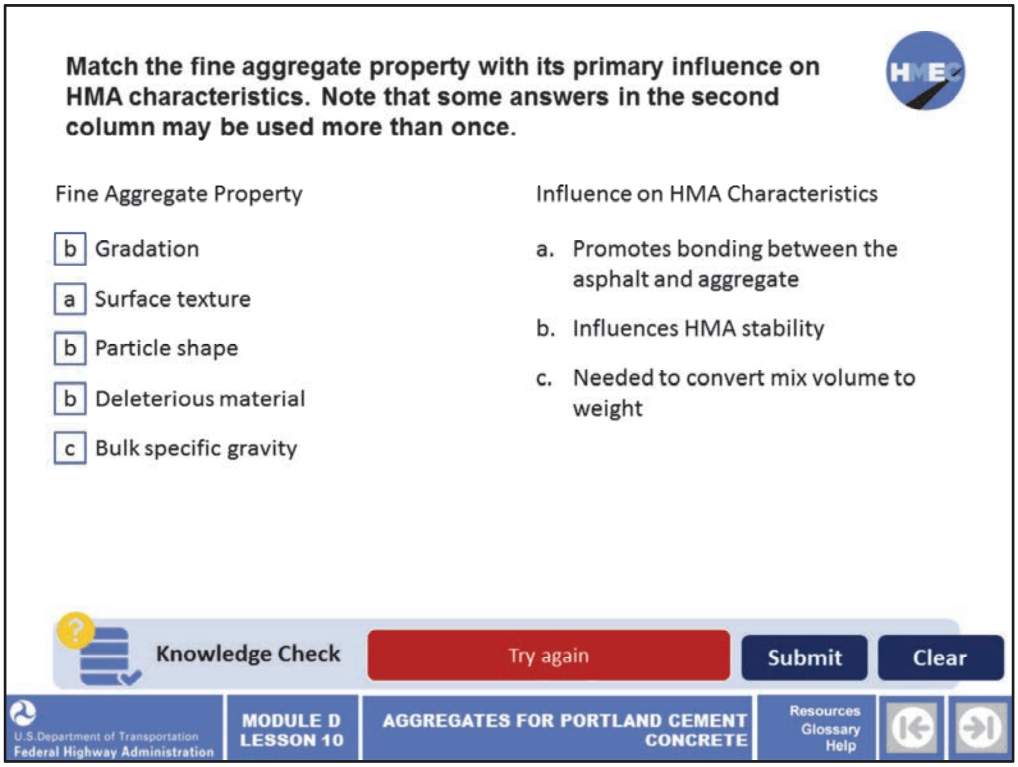
Image description: Photo of methylene blue test.

Image description: Photo of Atterberg limits test.



The deleterious materials that may be present in the fine aggregates are similar to those found in coarse aggregates. However, clay balls and materials introduced during processing or hauling are the most likely issues with fine aggregates. Clay balls will likely disintegrate during mixing, in which case the introduction of additional fines in the mix may create instability or moisture sensitivity.

If the clay balls break down during placement and compaction, pockets of loose clay will be present in the pavement leading to numerous types of distress.



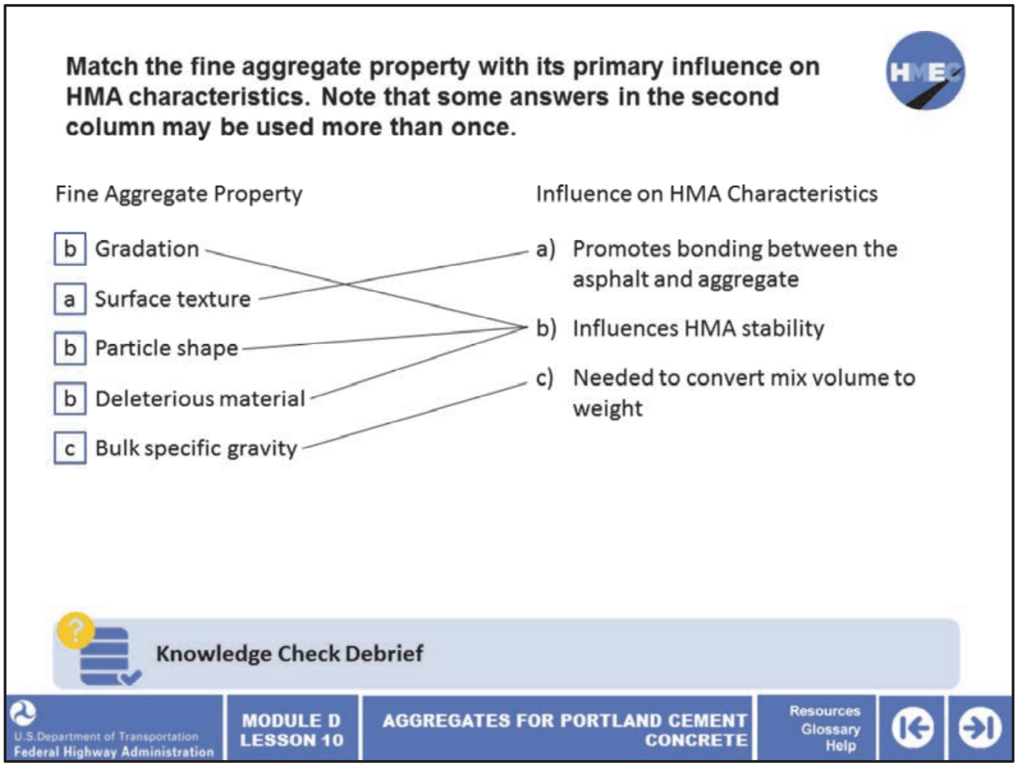
Match the aggregate property with its primary influence on HMA characteristics. Note that some answers in the second column may be used more than once.

Fine aggregate properties are:

- Gradation;
- Surface texture;
- Particle shape;
- Deleterious material; and
- Bulk specific gravity.

The influence on HMA characteristics are:

a) Promotes bonding between the asphalt and aggregate;
b) Influences HMA stability; and
c) Needed to convert mix volume to weight.



The correct answers are as follows.

- Gradation b) Influences HMA stability.
- Surface texture a) Promotes bonding between the asphalt and aggregate.
- Particle shape b) Influences HMA stability.
- Deleterious material b) Influences HMA stability.
- Bulk specific gravity is c) Needed to convert mix volume to weight.

Skid resistance is based on the friction that is developed between the pavement surface and tires. The skid resistance of the roadway is well correlated to accident rates, particularly on curves, at intersections and during wet weather.

Both the coarse and fine aggregates have a role in determining the long-term skid resistance of a HMA pavement. The asphalt does not contribute to the tire/pavement friction or skid resistance.

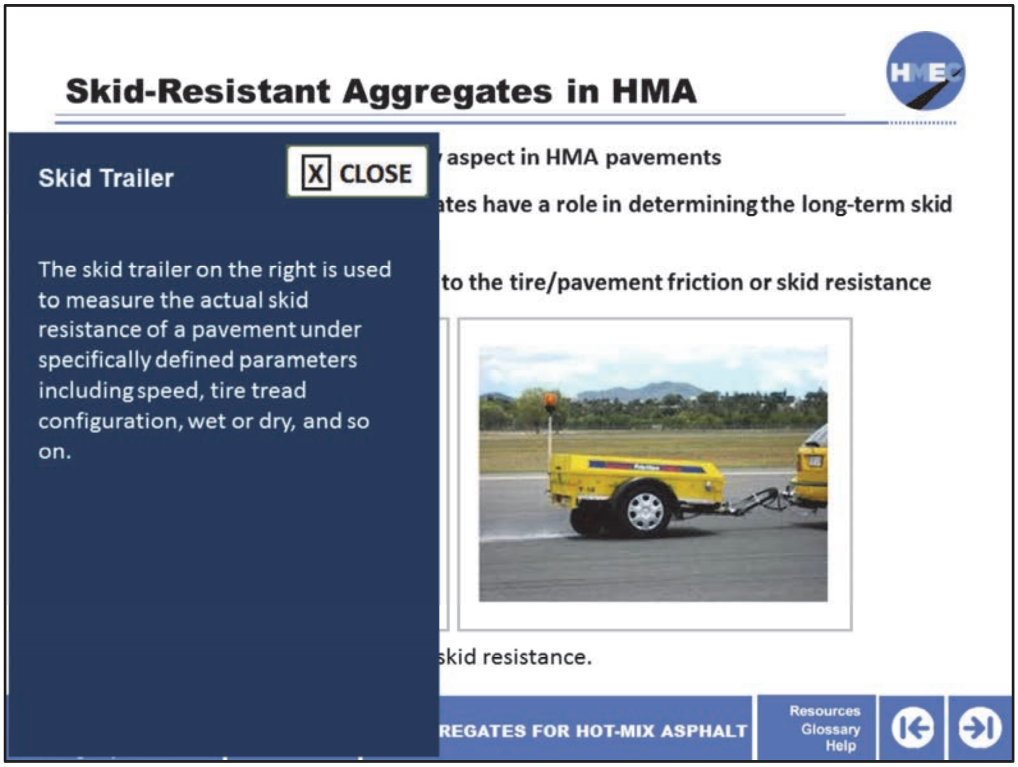
Select each photo to learn more about skid resistance.

Image description: Photo of British pendulum tester.

Image description: Photo of surface friction tester.

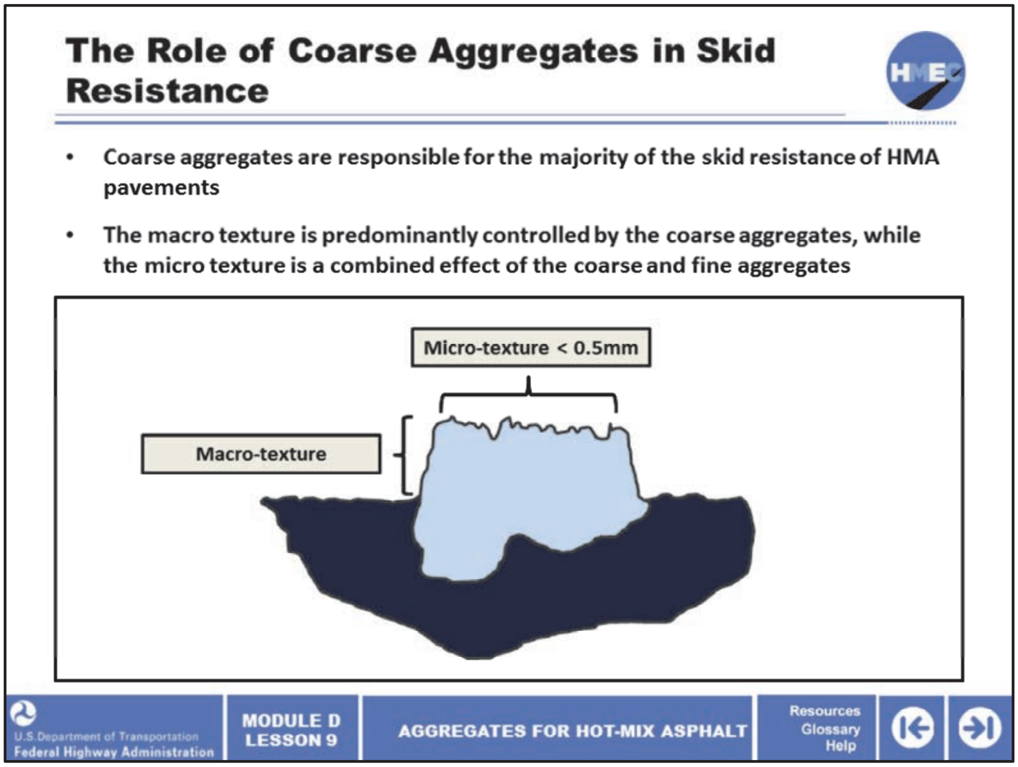
The British Pendulum Tester shown on the left can be used to approximate the frictional resistance of in-service paving materials.

Image description: Photo of British pendulum tester.



The skid trailer on the right is used to measure the actual skid resistance of a pavement under specifically defined parameters including speed, tire tread configuration, wet or dry, and so on.

Image description: Photo of surface friction tester.



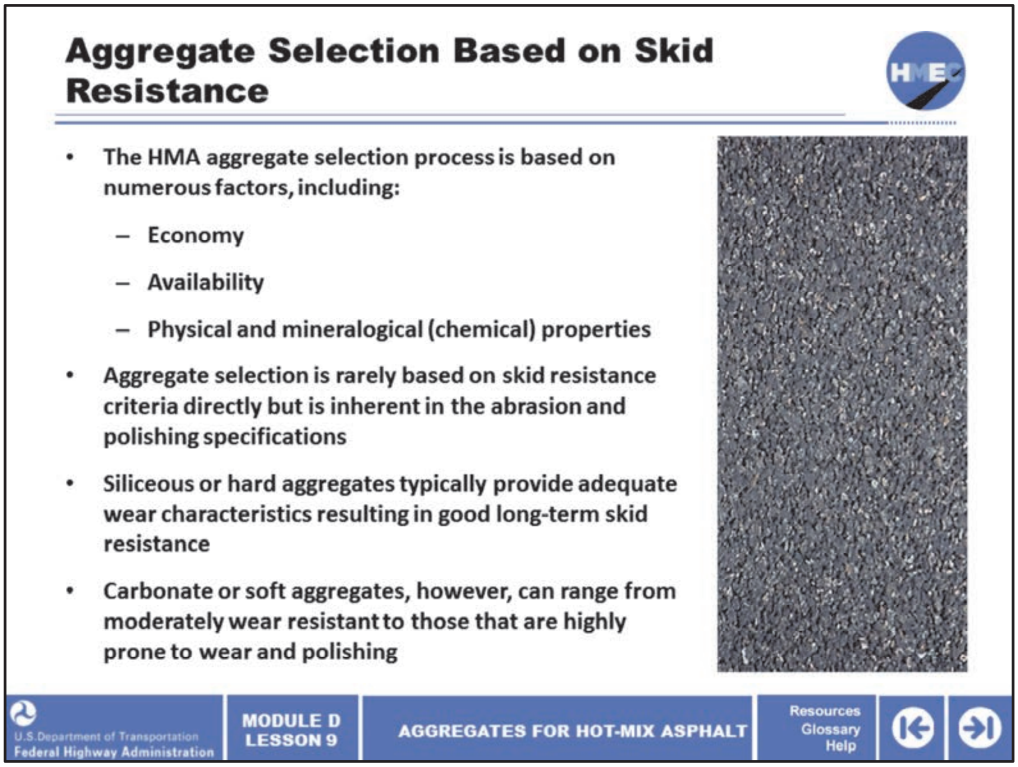
Coarse aggregates are responsible for the majority of the skid resistance of HMA pavements. The macro-texture is predominantly controlled by the coarse aggregates, while the micro-texture is a combined effect of the coarse and fine aggregates.

In order for the skid resistance not to diminish with time, the coarse aggregates used in the HMA mix must be wear resistant. The primary role of the coarse aggregates in this case is to establish and maintain adequate surface friction.

In general, siliceous aggregates are wear resistant while carbonate aggregates are less so and may need to be evaluated prior to use.

The figure represents a simplified version of macro- and micro-texture. Of critical importance is the ability of the aggregates to maintain a desirable texture over an extended period of time.

Image description: Illustration of a simplified version of macro- and micro-texture.

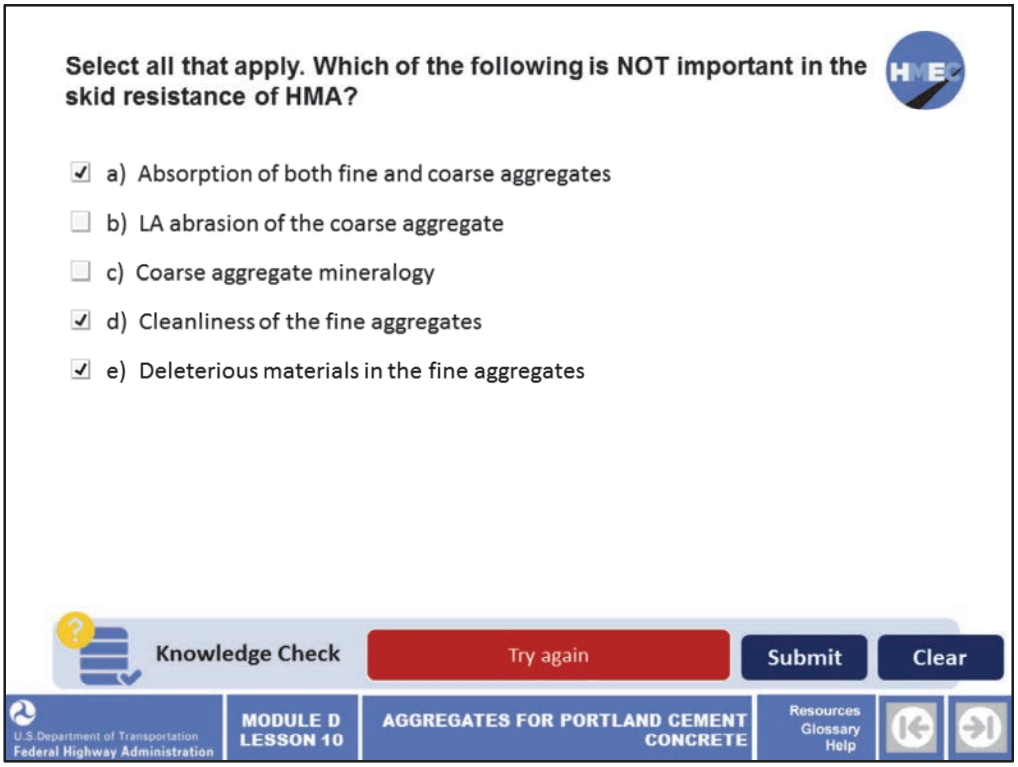


Aggregate selection is based on a number of factors, including the abrasion and polishing characteristics of the coarse aggregates and the insoluble residue for the fine aggregates. Aggregate selection is rarely based on skid resistance criteria directly but is inherent in the abrasion and polishing specifications.

Mineralogy is an important characteristic in estimating the polishing potential and loss of micro-texture. Aggregates containing various minerals tend to wear somewhat differentially and therefore maintain a good micro-texture as the softer minerals abrade while exposing harder materials.

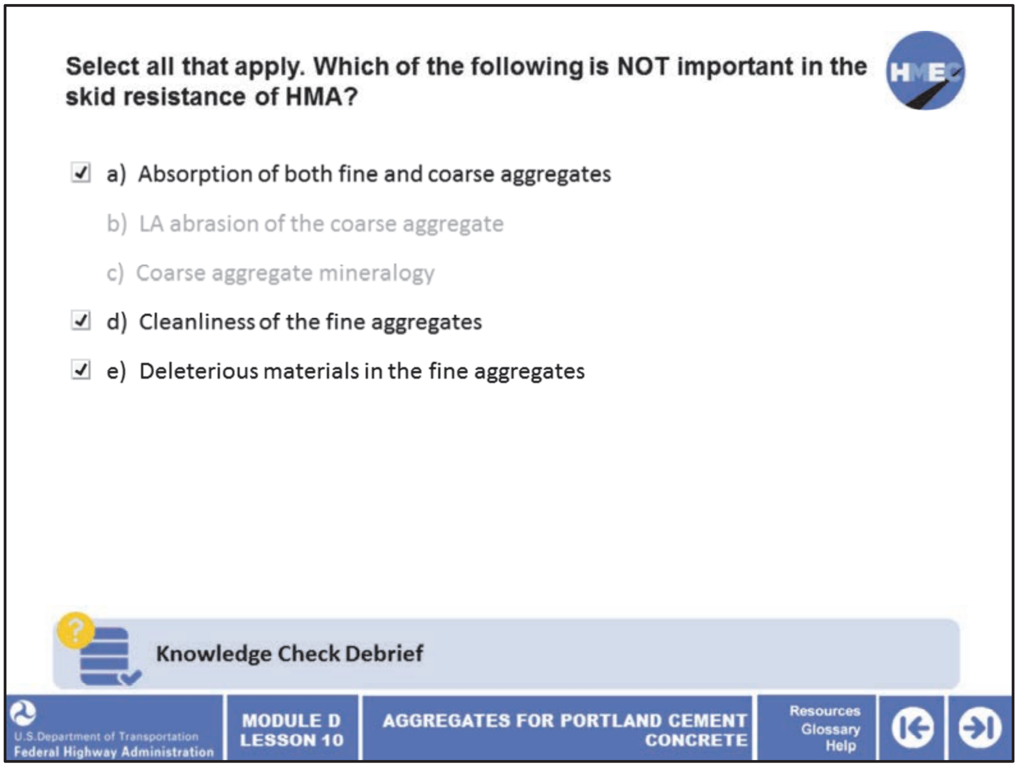
It is also necessary to maintain good macro-texture over time. Soft aggregates tend to wear and polish quickly while hard aggregates are wear resistant and can maintain good texture over many years of service.

Image description: Photo of asphalt.



Select all that apply. Which of the following is NOT important in the skid resistance of HMA?

a) Absorption of both fine and coarse aggregates;
b) LA abrasion of the coarse aggregate;
c) Coarse aggregate mineralogy;
d) Cleanliness of the fine aggregates; and
e) Deleterious materials in the fine aggregates.



The correct answers are a) Absorption of both fine and coarse aggregates, d) Cleanliness of the fine aggregates, and e) Deleterious materials in the fine aggregates.

HMA Mix Producers' Approach to Aggregate Quality Control

- Regardless of the method of storage and delivery, the overall goals are to:
  - Eliminate contamination
  - Minimize degradation
  - Minimize segregation
  - Provide easy access to feed aggregates to the plant

Aggregate quality control is based on providing a consistent graded aggregate for producing the HMA. These overall goals encompass the majority of the considerations.

- Eliminate contamination;
- Minimize degradation;
- Minimize segregation; and
- Provide easy access to feed aggregates to the plant.

Aggregates at HMA production plants are either stored in stockpiles or bunkers. Delivery may be by truck, rail or barges, depending on the size and location of the facility.

The majority of plants that produce HMA for State projects have a high rate of turnover for the aggregates.

A comprehensive quality control plan on the part of the producer is standard operating procedure.

Image description: Photo of conveyors separating RAP.

Importance of Stockpile Sampling and Testing

- **The importance of proper sampling and testing of stockpiled materials cannot be overemphasized**
- **In order to promote the consistent gradation needed to produce uniform HMA properties, the coarse and fine aggregate gradations must be routinely tested, particularly as new aggregate shipments arrive**

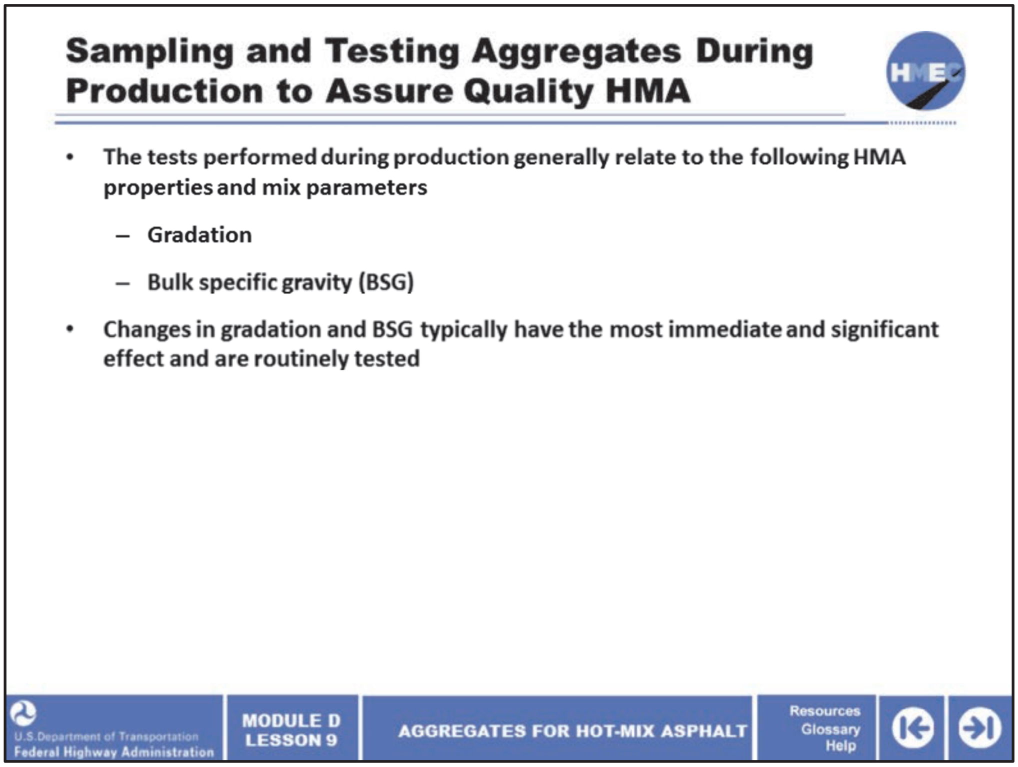
Routine testing of the aggregate stockpiles is required to monitor changes in gradation, unit weight, absorption and other properties that may vary with different shipments or sometimes within the same shipment.

Agencies typically have guidelines that govern when stockpile sampling and testing is required. However, plant operators may sample and test more frequently if changes in the stockpile are evident during batching.

It should be noted that the loader operator plays a key role in providing uniform material to the plant as even the best constructed stockpiles have some measure of non-uniformity.

Image description: Photo of shoveling a stockpile of aggregate.

Image description: Photo of dump truck near aggregate stockpiles.



The importance of both the coarse and fine aggregate properties has been discussed in this lesson. HMA production facilities routinely test the variables over which they have control. In other words, the aggregate gradation and bulk specific gravity (BSG) have significant and immediate implications to the properties of the HMA during placement and compaction.

If stockpile sampling is done correctly, the tests will provide accurate gradation and BSG for that stockpile. By combining the overall results of the various stockpiles, coarse, intermediate, and fine aggregate (or some variation), appropriate adjustments to the batch weights can be made.

QC Practices to Minimize Segregation, Degradation, and Contamination

- Proper stockpile construction and management are necessary to produce uniform HMA with consistent properties
- Best practices include:
  - Firm and stable platform for stockpile construction
  - Site drainage plan that allows water to drain away from stockpiles
  - Stockpiles are sufficiently separated to prevent cross contamination
  - Drop height of aggregates during construction should be minimized
  - Use an end loader to blend the individual stockpiles

This 7-minute video provides stockpile management best practices: http://www.youtube.com/watch?v=KxgkgIde3nY

Proper stockpile construction and management practices are necessary to produce uniform HMA with consistent properties. Proper management begins at the time of construction by providing a firm and stable platform on which to construct the stockpiles. The site drainage plan should allow water to drain away from the stockpiles. The stockpiles should be sufficiently separated so that cross contamination doesn't occur. The drop height of the aggregates during construction should be minimized to prevent segregation and degradation. The use of an end loader to blend the individual stockpiles is also beneficial as shown in the video.

The most effective stockpile management routine will likely not eliminate segregation, degradation, and contamination but will minimize them to reasonable levels. Stockpile segregation, degradation, and contamination should be considered in the initial plant layout.

When sampling and testing indicate that routine problems exist in aggregate management, the source must be identified and corrected. Oftentimes theses issues are due to improper stockpiling of the aggregates rather than changes in the aggregates properties, assuming a consistent aggregate source is used.

Maintaining Aggregate Quality Control Records

- **Quality control (QC) records must be maintained by the plant in order to determine if significant variability is present**
  - **Gradation**
  - **BSG**
- **If the gradation of a particular stockpile has been consistent for the past several weeks and now is fluctuating significantly on a daily basis, an immediate investigation as to the cause is warranted**

Aggregate quality control (QC) records must be maintained by the plant in order to determine if significant variability is present. By routinely monitoring the gradation and BSG, decisions in regards to stockpile management are simplified.

For instance, if the gradation of a particular stockpile has been consistent for the past several weeks and now is fluctuating significantly on a daily basis, an immediate investigation as to the cause is warranted.

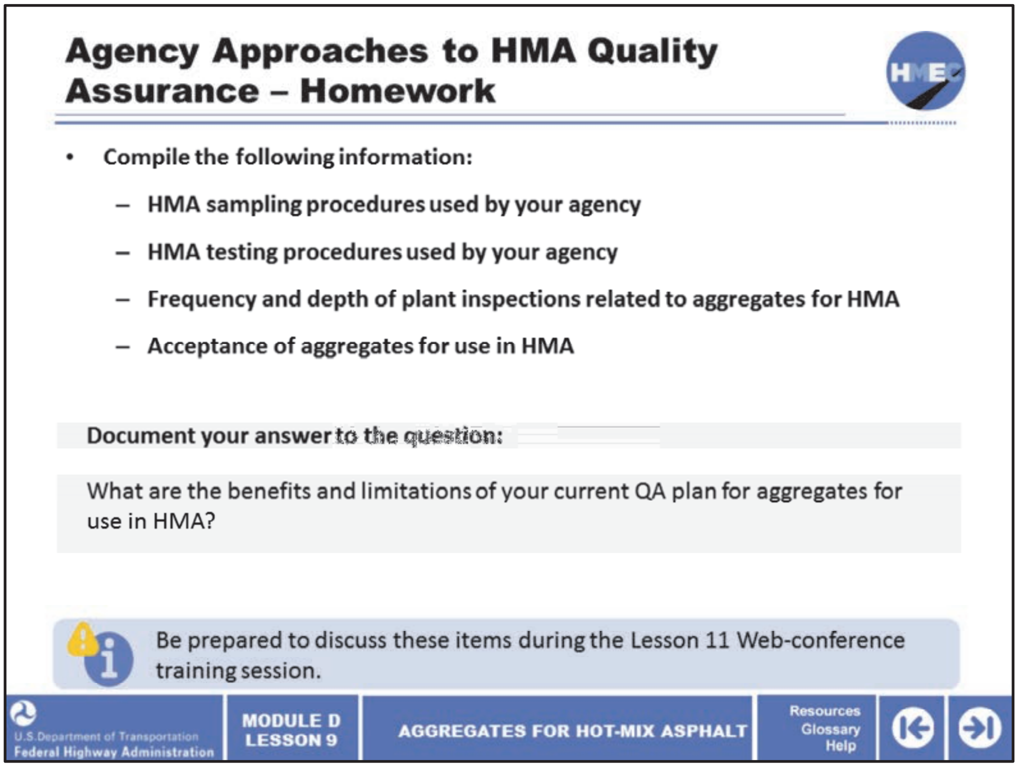
Image description: Photo of front-end loader depositing material in dump truck.

Quality assurance (QA) is important to verify compliance with the specifications. Agency approaches to aggregate QA differ substantially depending on location, aggregate types, sources, and myriad other factors, and may include:

- Required testing;
- Plant inspection and certification;
- Record keeping; and
- Acceptance.

We are not going to discuss details in this lesson because of these differences.

Image description: Photo of conveyors stockpiling material.

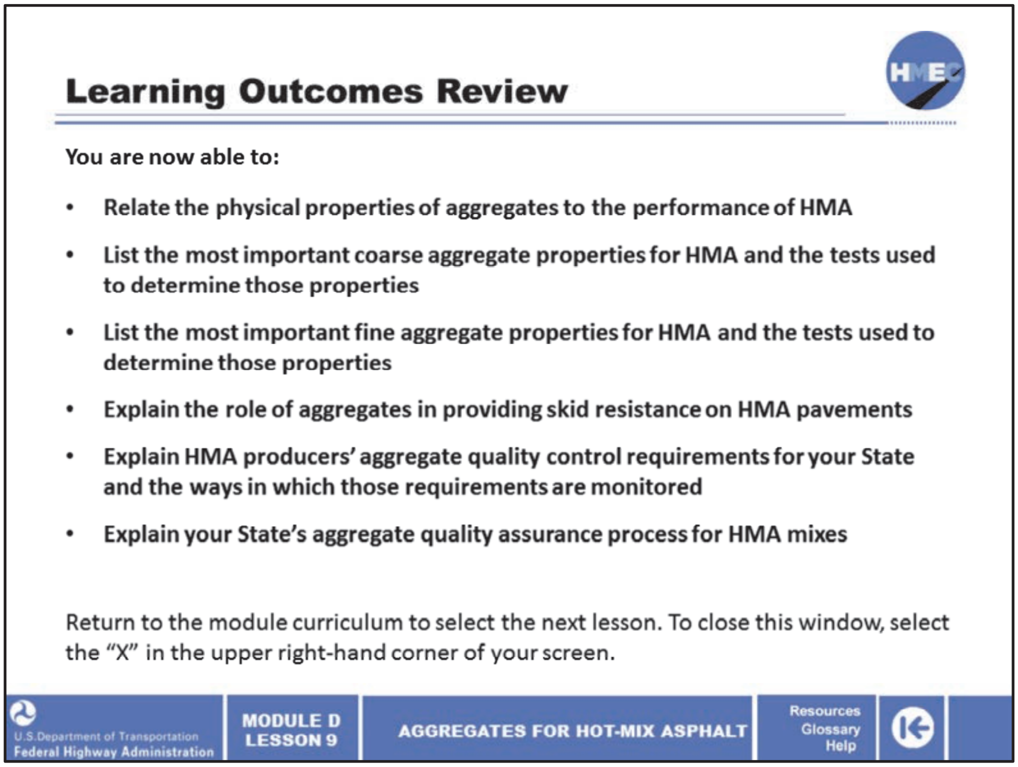


Most agencies have their own protocols that are followed in terms of QA plans. In preparation for the next Web-conference training session, you are requested to compile information on the following:

- HMA sampling procedures used by your agency;
- HMA testing procedures used by your agency;
- Frequency and depth of plant inspections related to aggregates for HMA; and
- Acceptance of aggregates for use in HMA.

In addition, what are the benefits and limitations of your current QA plan for aggregates for use in HMA?

Document this information in your participant workbook or compile as appropriate from your agency's documentation. Be prepared to discuss these items during the Lesson 11 Web-conference training session.



You have completed Module D, Lesson 9: Aggregates for Hot-Mix Asphalt. You are now able to:

- Relate the physical properties of aggregates to the performance of HMA;
- List the most important coarse aggregate properties for HMA and the tests used to determine those properties;
- List the most important fine aggregate properties for HMA and the tests used to determine those properties;
- Explain the role of aggregates in providing skid resistance on HMA pavements;
- Explain HMA producers' aggregate quality control requirements for your State and the ways in which those requirements are monitored; and
- Explain your State's aggregate quality assurance process for HMA mixes.

Close this lesson, and return to the module curriculum to select the next lesson. To close this window, select the "X" in the upper right-hand corner of your screen.