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CHAPTER 1 – INTRODUCTION

INTRODUCTION

This manual is designed to provide guidance for the sampling, testing, and reporting of test results for aggregate materials as standardized by the Michigan Department of Transportation (MDOT). We will cover many, but not all, situations the technician encounters. Adherence to the procedures contained herein should ensure that tests performed by numerous individuals on the same lot of aggregate materials will be in substantial agreement.

The technician conducting the inspection can be a Department employee or a consultant under contract to the Department and is the authorized representative of the Michigan Department of Transportation. It is the duty of all technicians to acquaint themselves in full with the specifications and instructions applying to their work. A thorough familiarity with the appropriate tests conducted on properly selected samples is essential for satisfactory performance of the Technician’s duties.

The American Association of State Highway and Transportation Officials (AASHTO), and the American Society for Testing and Materials (ASTM) publish many construction standards. The United States government agencies, state agencies, local governmental agencies, and individual companies may develop their own standards. Agencies may adopt published standards, or parts of published standards, and rename them as a test method. Therefore, it is important to know which testing standards are being used.

Conformance to requirements can be determined by quality control testing. If something being measured does not meet, then you have nonconformance.

Many of the federal and state agencies have adopted Quality Control, Quality Assurance, Total Quality Management and ISO-9000:2000 (International Organization for Standardization) programs. To be successful these programs need much more than adoption and verbal commitment by management. It takes an active leadership and participation in the quality process by all members of the organization. A commitment to training is also a major component of these programs.

Product quality control is a direct reflection of the organization’s leadership and attitude. This attitude also affects the external image of the organization as perceived by many individuals. Quality control is more than a product shipped or service provided. Quality control techniques can be applied to customer relations, product production, laboratory procedures and documentation, to name a few.

One of the biggest challenges any technician may face is communication. The technician must know and understand how to use the applicable quality control standards. Individuals may interpret the written procedures differently when it comes to performing a certain procedure. Arguments develop about a standard’s correct interpretation and whether a procedure is being carried out correctly.

Every business must establish clear communications, from the president or owner, down to the newest employee and right back up to the president or owner. Information must flow smoothly between parties, in a form acceptable and understandable to everyone.

In business, the buyer and seller also should establish mutual confidence through a relationship based on clear communication.
Before production starts, schedule a meeting to discuss expectations, such as sample taking or the running of the test. Work through the first procedure together, making sure you reach agreement on how procedures will be done. Don’t lock yourself into thinking the old ways are the best ways. As technology changes, procedures change. Let your views reflect technology’s positive progress.

**DEFINITIONS**

An aggregate is a produced product having specific physical and gradational properties and is created by manipulation of material through a processing operation. The material may be from natural sand and/or gravel deposits, quarried bedrock, slag from steel mills or copper refineries, debris from mining operations, or crushed Portland cement concrete.

*Natural Gravel Aggregates* - These aggregates occur in natural, unconsolidated deposits of granular material which are derived from rock fragments such as boulders, cobbles, pebbles and granules and may be rounded, crushed or a combination of both. These deposits may be found either above or below the water table. Natural gravel aggregates consist predominantly of particles larger than the No. 4 sieve (4.75 mm).

*Crushed Stone Aggregates* - These aggregates are derived from the crushing of quarried bedrock.

*It should be noted that Natural Gravel Aggregates and Crushed Stone Aggregates are both included in the Standard Specifications for Construction under the definition of Natural Aggregates.*

**Sands**

**Natural Sand** - An accumulation of unconsolidated rock fragments or detrital particles derived from the chemical and/or physical disintegration of rocks as part of the natural weathering process which is uniformly graded and consists predominantly of particles smaller than the No. 4 sieve (4.75 mm).

**Stone Sand** - A fine aggregate produced from quarried rock which is uniformly graded and consists predominantly of particles smaller than the No. 4 sieve (4.75 mm).

**Stamp Sand** – A fine aggregate which is the end result of a stamp-mill crushing operation. This aggregate is composed of hard, durable particles, uniformly graded in size and consists predominantly of particles smaller than the No. 4 sieve (4.75 mm).

**Slag Aggregates** - Those aggregates produced as a co-product of the refining operations that turn iron and copper ore into refined metals.

**Crushed Portland Cement Concrete Aggregates** - Those aggregates obtained by crushing salvaged Portland cement concrete. Coarse, dense-graded and open-graded aggregates manufactured from salvaged Portland cement concrete must conform to the grading requirements in Table 902-1, and the physical requirements for gravel and stone in Table 902-2 of the most current Standard Specifications for Construction.

**Coarse Aggregates** - Those aggregates having particle sizes basically finer than 3 inches (75 mm) in diameter and containing negligible amounts of material finer than the No. 4 sieve (4.75 mm). The highest quality aggregates are used in Portland cement concrete and hot mix asphalt (HMA) pavements.

**Fine Aggregates** - Those aggregates composed of rock fragments finer than the No. 4 sieve (4.75 mm) and coarser than the No. 200 sieve (0.075 mm). Generally, these
are blended with coarse aggregates to produce Portland cement or HMA mixtures.

**Dense-Graded Aggregates** - Those aggregates composed of rock fragments finer than 1½ inches (37.5 mm) in diameter and are uniformly graded to finer than the No. 200 sieve (0.075 mm). When properly produced, these aggregates can achieve high density and stability. They are generally used for base courses and shoulders.

**O.G.D.C.- Open-Graded Drainage Course Aggregate** - These aggregates consist of coarse, including pea gravel, gradations with minor amounts of material finer than the No. 200 sieve (0.075 mm). They may be gravel, stone, crushed concrete or slag. They are used as drainable base material immediately below Portland cement concrete and HMA pavements.

**Pre-Qualified Aggregate Suppliers** - Aggregate producers with histories of continuous production of specification materials, who are willing to comply with MDOT procedures, are permitted by the Construction and Technology Division to furnish aggregates to federally funded projects by attesting the aggregates meet specification requirements based on their own quality control. Samples are obtained by MDOT personnel from material shipped to project sites or plants for quality assurance verification and payment.

**Acceptance Tests** - Tests conducted on produced material for acceptance or rejection. These tests may be conducted any time prior to final incorporation in the finished work. These tests also include the Department’s quality assurance tests and are sometimes referred to as Pre-Qualified Supplier or Reduced Acceptance tests.

**Independent Assurance Tests** - Tests conducted to evaluate both the technician’s sampling and testing procedures and the condition of the testing equipment. The initial sample is split into two halves. One half is tested by the technician and the other half is tested by the independent assurance inspector. The independent assurance inspector cannot be involved in the project and must use different equipment to test the aggregate. The Independent Assurance Test should be completed and compared to the results of the Acceptance Test within two days. These samples may be submitted to the Central Testing Laboratory for processing if necessary.

**Information Test** - These tests are for information only and not intended for acceptance or rejection of aggregate materials. If a technician feels that an aggregate material has changed substantially from when it was accepted, or suspects an aggregate’s quality, the technician may perform an Information Test. Based on the test results, two courses of action are available: 1) If the material is out of specification requirements, the technician may require additional Acceptance Tests; or 2) If the material is substantially within specification requirements, no further action is required. However, these passing results should not change the sampling frequency.

**Quality Control Tests** - These are tests run by a material supplier for his own information and used to control the quality of material being produced. The frequency of testing is dependent upon the uniformity of the production operation. If the quality control tests are part of the Pre-Qualified Aggregate Supplier Program, they must conform to the frequency stated in the producer’s quality control plan. Each quality control plan is reviewed and approved by both the controlling MDOT Region and Construction and Technology Division.

**HEALTH AND SAFETY**

Prior to entering a construction zone, processing area, pit or quarry, make sure you have all the necessary personal protective
equipment. This equipment includes, but is not limited to; steel-toed work boots, reflective vest or clothing, hard hat, safety glasses, hearing and dust protection. It is the technician’s responsibility to make sure their personal protective equipment meets current Michigan and Federal Occupational Health and Safety Administration standards.

When entering a construction zone, processing area, pit or quarry, check in with the person in charge of the operation. Never enter an operation to take samples without informing someone on-site. Observe traffic patterns and park your vehicle in a safe location. Ask for permission before you climb onto equipment or venture around to observe the operation.

People working with equipment day after day may become too accustomed to their work environment. If their job has become a repetitive routine, they might not notice what’s going on around them. Family problems, after-work plans or an inattentive attitude can contribute to a lack of concentration and, potentially, cause an accident.

Accidents cost much more than money. In addition to increased insurance premiums, medical bills, workman’s compensation, and, in the most tragic cases, death benefits, the company loses time during the accident investigation, reputation in the local community, and morale among employees. Also, it’s costly to educate new employees to take the place of their injured counterparts.

In addition to safety, health issues are important to the employee. What you do today will affect your “Quality of Life” in the future. Spending the rest of your life with a work related injury or illness is not part of the “American Dream.”

Working around processing equipment and in laboratories with constant exposure to dust may lead to long term lung related health issues. The Occupational Health and Safety Administration has published exposure limits.

Experts generally agree that sound levels below 80 decibels (dB) are considered to be safe. However, many pieces of equipment in the work environment exceed this sound level. Exposure to a level of 85 dB over an 8 hour work day can cause permanent hearing loss. A typical leaf blower generates enough dB’s to damage your hearing is less than one minute.

Repetitive activities or awkward postures can be cumulative over time and result in long term musculoskeletal problems. As you age, your body’s ability to repair itself decreases. An example of this could be the development of lower back or leg pain from repetitive lifting of heavy objects.

Think about your actions and what you want your “Quality of Life” in the future to be before it is too late.

Everyone agrees that health and safety is an important part of the work environment.

In addition, health and safety standards change. Be sure you’re aware of the current government health and safety regulations and company safety policies on your job.
CHAPTER 2 – SAMPLING AND STOCKPILING

**SAMPLING FREQUENCY**

To properly sample materials, you must have a clear understanding of how materials are stockpiled, blended or placed. This will help you obtain representative samples of the material being tested.

In General, the Michigan Department of Transportation’s definitions for quality control and quality assurance for aggregates are: Quality Control is all the processes used by the contractor or supplier to ensure specification material is provided to the project: Quality Assurance is the procedures and tests conducted by the Department to verify and accept for payment purposes that the material meets specifications.

Sampling for acceptance by MDOT can be done anywhere from the production site to just prior to use of the aggregate in the finished product. The justification for this is found in the “2003 Standard Specifications for Construction” under Division 1, General Provisions, Section 105.05 Approval of Materials Incorporated into the Work.

The minimum sampling frequency for non-pre-qualified suppliers or sources is printed in the Department’s “Materials Source Guide” under “Materials Acceptance Requirements”. This document also lists the pre-qualified suppliers, their sources, and materials participating in the Pre-Qualified Aggregate Supplier Program. This information is located in the Approved Manufacturers section. These manuals are only updated annually. Therefore, the Pre-Qualified Aggregate Supplier list may not be all inclusive. If you have any questions, the supplier should be able to produce a letter granting them pre-qualified status. This information can be confirmed by contacting either the MDOT Region where the source is located or Construction and Technology Division, Aggregate Quality Control Group in Lansing, Michigan. The minimum sample frequency for pre-qualified aggregate suppliers can be found in the Department’s “Materials Quality Assurance Procedures Manual” under Section C-6, Part 7. In addition, Special Provisions may be added to contracts which change the location or sample frequency. The basic sampling frequencies are presented in the following table.

<table>
<thead>
<tr>
<th>Material</th>
<th>Non-Pre-Qual.</th>
<th>Pre-Qualified</th>
<th>Visual Insp.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fine Agg.</td>
<td>1 per 1000 ton</td>
<td>1 per 10,000 ton</td>
<td>1 per 100 ton</td>
</tr>
<tr>
<td>Coarse Agg.</td>
<td>1 per 1000 ton</td>
<td>1 per 10,000 ton</td>
<td>1 per 100 ton</td>
</tr>
<tr>
<td>Dense Graded</td>
<td>1 per 1000 ton</td>
<td>1 per 10,000 ton</td>
<td>1 per 500 ton</td>
</tr>
<tr>
<td>Open Graded</td>
<td>1 per 1000 ton</td>
<td>1 per 10,000 ton</td>
<td>1 per 100 ton</td>
</tr>
<tr>
<td>Class I</td>
<td>1 per 1000 ton</td>
<td>1 per 10,000 ton</td>
<td>1 per 100 ton</td>
</tr>
<tr>
<td>Class II &amp; IIA</td>
<td>1 per 3000 cyd</td>
<td>1 per 10,000 cyd</td>
<td>1 per 500 cyd</td>
</tr>
<tr>
<td>Class III</td>
<td>1 per 10,000 cyd</td>
<td>1 per 30,000 cyd</td>
<td>1 per 500 cyd</td>
</tr>
<tr>
<td>Class IIIA</td>
<td>1 per 1000 cyd</td>
<td>1 per 3000 cyd</td>
<td>1 per 100 cyd</td>
</tr>
</tbody>
</table>

Closely examine the contract proposal for special provisions or supplemental specifications. Special provisions generally deal with how to do something or alter material specifications on a project specific basis. However, frequently used special provisions become part of the contract documents when a specific set of criteria is met. Supplemental specifications are added to every project and usually replace or alter material specifications, procedures or introduce new materials.

No matter how much planning is put into acquiring a sample, it all becomes worthless if the sample does not truly represent the total material. Discard any non-representative samples.

**FIELD SAMPLE SIZE**

The MDOT’s Michigan Test Method (MTM) 107, titled “Sampling Aggregates”, lists minimum aggregate field sample sizes.
Fine aggregates and Granular Material Class IIIA for independent assurance or acceptance test - approximately 25 lbs. (11 kg)

Coarse, Dense-Graded, Open-Graded aggregates and Granular Materials (except Class IIIA) for independent assurance or acceptance test - approximately 50 – 60 lbs. (25 kg) (one full bag)

Aggregates for abrasion test (as produced) - approximately 100 lbs. (50 kg) (two full bags)

Aggregates for concrete mix design - approximately 50 – 60 lbs. (25 kg) (one full bag)

For both abrasion and mix design - approximately 100 lbs. (50 kg) (two full bags)

ASTM and AASHTO standards have guidelines for the minimum field sample sizes for laboratory testing based on the maximum nominal size of aggregates. When collecting a field sample for MDOT the minimum field sizes listed above apply unless altered by special provision or supplemental specification. Local government agencies and private contractors may have different requirements. Therefore, you can see the necessity of verifying proper field and test sizes before collecting the sample.

**SAMPLING TOOLS**

Some common field sampling tools are:

- Canvas Bags, Plastic or Steel Pails capable of holding approximately 50 pounds
- Square Nosed Scoops
- Square Point Shovels (Round Point Shovels are not allowed)
- A Sample Thief made from 1½ to 2 inch diameter by approximately 30 inches long thin wall electrical conduit to sample fine aggregates (sand) only
- 5 foot T-handle Bucket Auger made from thick walled galvanized iron pipe with blades welded on either a 3 or 4 inch outside diameter foot long thin walled pipe.
SAMPLING

MTM 107 explains the approved sampling procedures in detail. The basic procedure will be summarized in the following paragraphs of this manual. To obtain a sample increment of an aggregate product using a scoop or square point shovel: (1) remove the surface area of the material to be sampled; (2) dig down into the material approximately one foot or the thickness of the material if has been placed on the grade. If geo-textile separator is used be careful not to tear or punch a hole in it.

As illustrated in Figure 1, insert the shovel or scoop at the base of the hole. Push the shovel into the material and pull it upward to fill the shovel or scoop. Empty it into the sample container. This represents one sample increment. Do this in as many different areas as necessary to obtain the recommended representative field size sample.

Figure 2 illustrates a typical random sample pattern in a back-bladed “mini” stockpile. Observe the flattened surface for signs of segregation. If the surface appears uniform, it is not necessary to dig into the flattened surface to create a vertical face as shown in Figure 1 prior to obtaining your sample increment.

The three areas back-bladed in Figure 3 are arranged from the fine to coarse sides of the stockpile. The area selected should be approximately where the future shipping face will be located. After the front end loader operator has pulled material down, distribute your samples equally between the three locations. Figure 3 shows six randomly selected sample increment sites. As with the “mini” stockpile, it is not necessary to dig into the flattened surface to create a vertical face prior to obtaining your sample if there is no observable segregation.

A “sample thief” may be used only to sample fine aggregates (sand). First, remove the loose surface material from the sampling area. Push the sample thief into the stockpile 12 to 18 inches. Then, remove the tube and empty it into the sampling container. Continue this process randomly until you
obtain the proper field sample size. A sample thief inserted into a stockpile is illustrated in Figure 4.

**Figure 4: Thief Taking Sample**

Although seldom used, the bucket auger can be employed to obtain aggregate samples. This method works best on stockpiles of material with low percent crushed or finer gradation. The size of the auger opening will limit the maximum size of aggregate particle that can be sampled.

If the sample is to be obtained from truck, front end loader, or dumpster built stockpiles before they have been bladed flat prior to adding the next layer, remove the dry surface material from the area of the sample site, turn the auger until it reaches sufficient depth to obtain a sample increment. Empty the auger into a sample container. Repeat the procedure in several locations to obtain a representative field sample.

If the dumps have been prepared for the next layer, use the sample pattern for bottom dump earth-movers and there is no need to remove material before augering into the surface of the stockpile. With truck built stockpiles, the layers of material are two to four feet deep. Bottom dump earth-movers spread their loads over a much larger area. When sampling with the auger, take care not to bore into previously sampled material.

**SOURCES OF SEGREGATION**

When moving materials to or from stockpiles, segregation of the aggregates can be a problem. All aggregates are subject to segregation.

Conveyors carrying material to the stockpiles vibrate causing the fine material to separate and settle to the bottom, as illustrated in Figure 5. Also, the distance between the rollers and the length of the conveyor system affects aggregate separation or segregation.

**Figure 5: Conveyor Cross Section**

The degree of aggregate segregation depends on how the operator sets up the machinery. If a pre-screening operation is planned where the oversized stone is diverted to a separate crusher, extra care must be taken to blend the crushed oversize stone back with the fine material. Usually, the operator deposits the sized, crushed stone back on top of the conveyor as it travels to the stockpile. This can also happen with a single portable plant containing a vibrating screen and crushers combined into one unit.

If segregated material continues to stockpiles, bins, trucks or bottom dump earth-movers without any correction, segregation can become a major problem. The material’s gradation will not be consistent. The stockpile may look similar to Figure 6 with the fine material falling towards the conveyor and the coarse material falling away from the conveyor.

**Figure 6: Conveyor Dumping on Ground Without Baffle**
Placing baffles and other mechanical devices in the ends of conveyors can help control segregation problems. A typical mechanical device is illustrated in Figure 7.

![Image of conveyor with baffle](image)

**Figure 7: Conveyor With Baffle**

Before taking the sample, overview the operation to observe how the material is flowing into the stockpile. Walk around the pile. Look for signs of segregation.

If the machinery has already left the pit or quarry area, walk around the stockpiled material. Look for signs of segregation. Try to figure out how the material will be loaded for shipping.

If the stockpile has a small shipping face, one sample may be adequate. If the stockpile has a shipping face larger than what will be loaded on one truck, it will be necessary to take several samples and conduct sieve analyses to determine how much variation is present across the shipping face. If the variation is greater than 5 percent on any sieve with an opening larger than No. 200 sieve, the variation may cause problems. The variation in the No. 200 sieve will depend on the maximum permissible amount passing.

**WASH PLANT CONTAMINATION**

Wash plants producing coarse aggregates (stone) may have a buildup of contaminated aggregate in their stockpile’s center. The loader operator may not reach the center of the pile for several days or weeks because new processed aggregate may have been added to the stockpile or, perhaps, the plant may have been down for repairs or weather conditions.

Fine material, such as clay, silt and fine stone dust from the stone crushing process may not completely wash off the aggregate as it flows through the wash operation. This fine material is suspended in the water coating the larger aggregate particles. This excess water drips onto the conveyor belt and then drips from the end of the stacking conveyor onto the stockpile. Over time this small amount of the clay, silt and dust from the crushed stone builds up in the center of the pile. When the loader operator reaches this point, this “contaminated” material will be loaded. This is illustrated in Figure 8.

![Image of contaminated core of stockpile](image)

**Figure 8: “Contaminated” Core of Any Stacker Built Stockpile**

The technician must be aware this problem may exist. Retesting the aggregate in the pile’s center can ensure that the loss by wash and gradation meets specifications or if the pile’s center must be washed again.

**OTHER SOURCES OF CONTAMINATION**

When using earth-movers or dump trucks for stockpiling aggregate, the equipment’s tires will carry undesirable material from the pit or quarry floor up on the stockpile causing contamination, especially after a rain or in the spring or fall when the ground is wet. In addition, heavy equipment traveling on the stockpiles will compact the aggregate and cause breakdown.

Another source of contamination is the wind during summer dry periods. Dust cast
into the air by moving equipment will settle on the surface of the stockpile and increase the loss by wash.

**CONVEYOR BELT SAMPLING**

Sampling from a conveyor belt can produce a very representative sample of aggregate if done properly. Merely obtaining a sample at the beginning or end of production does not provide a representative sample.

If you decide to take a sample from a conveyor, keep safety in mind. Closely observe the material on the conveyor. How is it flowing to the stockpile? It is extremely important to inspect the belt returning under the conveyor. Noting how much fine material sticks to the belt as it makes its cycle around the conveyor.

It is recommended that a minimum of three approximately equal increments be sampled from the stopped conveyor belt to obtain a representative sample. To do this, you will need two templates formed to the conveyor curvature as illustrated in Figure 9.

![Figure 9: Conveyor with Templates](image)

Push the templates through the aggregates at the selected site. The distance between the templates will depend upon the width of the conveyor belt and the size of the field sample needed. Use a scoop to remove the aggregate between the templates and place it in the sample container. Use a brush to remove the small amount of aggregate between the templates that the scoop missed. Take care not to remove aggregate sticking to the belt as the belt makes its cycle around the conveyor.

Some conveyors have a mechanical sampling device attached to their end, as illustrated in Figure 10.

![Figure 10: Mechanical Sampling Device](image)

Push the pan mounted on a pair of sliding mechanisms all the way across the stream of flowing aggregate and return it to the starting point. Through a door in the bottom of the pan, the material empties into a pail or bag. It is recommended that this procedure be done a minimum of three times to obtain a representative sample.

Another method of sampling from a radial stacking conveyor can be done by repositioning the conveyor to discharge into a loader bucket, as shown in Figure 11. Move the loader away from the stockpiling area to a safe working area. Dump the bucket on the ground. Obtain a sample from this “mini” stockpile with a square point shovel or scoop.

![Figure 11: Conveyor Dumping into Loader](image)

This method works well when the conveyor discharges close to the ground or the loader operator can reasonably raise the bucket to catch the discharge stream from the conveyor. When the material falls several feet, the wind may blow some of the fine material away from the loader. This may cause the material to test coarser than its actual gradation. In addition, a large free fall from the conveyor belt to the front end loader bucket may lead to segregation.
Asphalt plants have many cold feed bins that must be controlled to blend the aggregates. After blending, a sieve analysis will establish that the bins are feeding in the correct proportions. Some plants have an ejection device for sampling a chute or conveyor as illustrated in Figure 12. If not, a belt sample must be taken.

![Figure 12: Sampling Device](image)

Small amounts of the aggregate can be ejected by closing a gate across a feed belt. This allows the aggregate to fall on the ground, into a wheelbarrow or loader bucket. Use a scoop or square point shovel to obtain a representative field aggregate sample.

**CONE SHAPED STOCKPILE**

To obtain a representative sample from a cone shaped stockpile with no shipping face, the technician must obtain samples from at least six sites and distribute them according to the stockpile’s volumetric proportions. Figure 13 represents a typical cone shaped stockpile.

![Figure 13: Cone Stockpile Proportion](image)

If ten sample increments, are collected to form the composite field sample, seven would be from the bottom third of the stockpile and three from the middle third of the stockpile. Since the top third only contains 4 percent of the aggregate in the stockpile, you would not collect any sample increments from that portion of the stockpile. If, on the other hand, you decide that six sites are sufficient, the distribution would be four from the bottom third, two from the middle third and none from the top third.

Looking down on the top of the stockpile, the sampling pattern may be similar to Figure 14.

![Figure 14: Top View of Cone Stockpile](image)

If the stockpile has a shipping face, the sample pattern may be similar to Figure 15.

![Figure 15: Loading from Cone Shaped Stockpile](image)
Notice that the material is loaded at right angles to the aggregate’s flow. If segregated, loading in this manner will help prevent all the coarse or fine material from being loaded first. The loading becomes more uniform.

**RADIAL STACKER BUILT STOCKPILES**

Always load out aggregate from the end of a radial built stockpile. This will reduce the segregation and provide a more uniform product, see Figure 16.

There are four approved methods for obtaining representative samples from radial or fixed stacker stockpiles. The first one to be discussed is hand sampling.

If there is no front end loader available and it is safe to scale the stockpile’s shipping face, a sample may be obtained by hand using a square point shovel, square nosed scoop, or sample thief (depending on the size of the material) and sample container(s) with enough capacity to hold the required amount of aggregate. The volumetric distribution of aggregate within a radial stockpile is slightly different than a fixed stacker stockpile, see Figure 17.

The technician may want to obtain the sample sites as illustrated in Figure 18.

The second method can be used prior to load out. This approach uses a front end loader to pull material down the future shipping face by tilting the bucket downward and reaching as high as possible to place the bucket on the stockpile. The front-end loader operator applies a downward force while backing away from the pile, pulling aggregate down, as illustrated in Figure 19. Repeat this procedure at least three times around the future shipping face to obtain a representative sample. Take the sample increments from the aggregate pulled down. This sample may be slightly coarser than material located deeper within the stockpile depending on the presence of internal segregation.
The third approved method is also done before material has been shipped out. The loader operator first removes a bucket full of aggregate from at least three different locations along the future shipping face. The loader operator then goes back to the previous locations and removes a second bucket full. Place this second bucket full of material from each location into one “mini” stockpile in a safe place. The loader operator then thoroughly mixes the “mini” stockpile. The “mini” stockpile is then back-bladed to create a large sampling surface.

The final approach is the preferred method to use to obtain a representative shipping face sample for any type of aggregate or stockpile. A front end loader operator removes enough material to represent one truck load of aggregate from across the shipping face. This material is separated from the stockpile, thoroughly mixed and then back-bladed to create a large sampling area.

TRUCK, FRONT END LOADER, AND DUMPSTER BUILT STOCKPILES

When building a stockpile with dump trucks, front-end loaders, or dumpsters, dump loads of aggregate side by side until the desired width is obtained. Once one row is complete, move forward and add another row of aggregate. Repeat the process until the desired stockpile length is completed. Additional layers may be placed on top of the first layer. Care should be taken that the material in the successive layers does not spill over the edge of the stockpile. In addition, while placing successive layers on the stockpile, contamination from the material stuck to the vehicle tires may fall onto the stockpile. An example of a truck built stockpile is shown in Figure 20.

Obtain sample aggregate increments from several locations on the pile. Take samples from the top of one truck dump, the right side of another truck dump, the left side of another truck dump, the front of another truck dump, and the back of another truck dump, as shown in Figure 21. Use sufficient sample sites for a representative sample. At each sample site follow the procedure in Figure 1.

Another way to sample a truck built stockpile is to obtain the sample increments from the flatten top of the previous layer. The
technician may take a sample diagonally across the top of the pile as shown in Figure 22 or use a random number process to obtain sample locations.

![Figure 22: Diagonal Sample Pattern - Top View](image)

When loading the material from dump truck stockpiles, it is recommended to load the aggregate at right angles to the truck dumping. This helps to re-blend the material uniformly and consistently.

Occasionally, trucks dump over pit or quarry walls. This practice can lead to segregation problems due to the pile’s height and the product’s gradation. Larger materials have a tendency to roll down the outside, accumulating at the base of the stockpile, see Figure 23.

![Figure 23: Aggregate Dumped Over Wall](image)

The best solution for sampling aggregate stockpiles in this manner is to construct a “mini” stockpile.

**BOTTOM DUMP OR EARTH-MOVER BUILT STOCKPILES**

Bottom dump earth-movers build stockpiles in successive relatively thin layers placed one on top of the other. The equipment operator should alternate the direction of travel across the stockpile. Alternating the direction of travel will reduce the aggregate’s segregation and increase the likelihood a uniform product will be shipped.

A typical sampling pattern consisting of ten locations diagonally across the stockpile is shown in Figure 24. If fewer sample sites are selected, make sure the full width of the stockpile’s surface is covered. A random number process to locate sites and times for taking sample increments could also be developed.

![Figure 24: Top View of Pan Dump Stockpile](image)

**ON GRADE SAMPLING**

Both the aggregate and asphalt industries sample material after placement in roadbeds or on road surfaces. All parties should agree on sampling procedures before starting the project.

One method of sampling uses fixed locations. A typical composite sample pattern consists of selecting a 1000 foot length and
the full width of the roadway. First divide the length into ten 100 foot increments. One sample increment is obtained from each 100 foot section. The layout for the fixed location is illustrated in Figure 25. If the 1000 feet section ends in an odd size increment of less than 500 feet, add that partial section to the previous full section. If the odd size section is 500 feet or more in length, consider it as another section. Depending on the layer’s thickness, the length of the sample area can be adjusted.

**Figure 25: On Grade Sample Points**

D = distance to sampling points from the start of the increment, your choice, but must be the same for each increment.

T = distance from centerline to sampling point*
  = 2 feet from edge of pavement
  = 7 feet from edge of pavement
  = on centerline
  = 7 feet from edge of pavement
  = 2 feet from edge of pavement

*Distances to the sampling points may be determined by pacing.

A random number process may be used to obtain the location of sample sites. Sample aggregate with a square point shovel or scoop. Take care not to dig into the other aggregate layers lying under the sample location. Also, avoid cutting a hole into the geotextile fabric that separates the layers of aggregate.

**TRUCKS AND RAILROAD CARS**

When sampling from trucks or railroad cars, the decision will have to be made if the entire sample will be taken from one shipping unit or as a composite sample from several shipping units. Generally, samples are taken from one shipping unit.

If the sample will be obtained from inside the hauling unit, randomly select at least six sites. Dig down about one foot at each location. Bring the shovel or scoop up the “vertical” face collecting one sample increment. It is important to realize that coarse and open-graded aggregates sampled in this manner may yield coarser gradations.

If you elect to sample a hauling unit after it has discharged the aggregate, empty the material separate from any other aggregate loads. Sample this individual dump as if it was a “mini” stockpile.
ASTM and AASHTO have established their standards for the minimum sample sizes for laboratory processing. Field samples are reduced for laboratory testing purposes. Some of their standards are presented in Table 1.

<table>
<thead>
<tr>
<th>Nominal Maximum Size of Square Opening in millimeters (in)</th>
<th>Minimum Weight of Test Sample in kilograms (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.5 (⅜)</td>
<td>1 (2.2)</td>
</tr>
<tr>
<td>12.5 (⅜)</td>
<td>2 (4.4)</td>
</tr>
<tr>
<td>19.0 (¾)</td>
<td>5 (11)</td>
</tr>
<tr>
<td>25.0 (1)</td>
<td>10 (22)</td>
</tr>
<tr>
<td>37.5 (1½)</td>
<td>15 (33)</td>
</tr>
</tbody>
</table>

Fine Aggregates 300 g minimum

<table>
<thead>
<tr>
<th>Nominal Maximum Size of Square Openings in inches</th>
<th>Minimum Weight of Test Sample in grams</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 4 (4.75)</td>
<td>500</td>
</tr>
<tr>
<td>⅜ (9.5)</td>
<td>1,000</td>
</tr>
<tr>
<td>½ (12.5)</td>
<td>2,000</td>
</tr>
<tr>
<td>¾ (19.0)</td>
<td>2,500</td>
</tr>
<tr>
<td>1 (25.0)</td>
<td>3,500</td>
</tr>
<tr>
<td>1½ (37.5)</td>
<td>5,000</td>
</tr>
</tbody>
</table>

There are several variations on the definition of aggregate Nominal Maximum Size. MDOT uses the following definition because some Michigan aggregate materials have very few sieves specified with gradation requirements. The Nominal Maximum Size is defined as the sieve with the next smaller square opening size than the smallest one which is specified to allow 100 percent of the aggregate to pass after the sieves have been shaken.

For sieve analysis, the Department has modified the AASHTO T-27 test and developed Michigan Test Method (MTM) 109. Based on experience, the minimum laboratory test sample weighs after drying are presented in Table 2.

<table>
<thead>
<tr>
<th>Nominal Maximum Size of Square Openings in millimeters (in)</th>
<th>Minimum Weight of Test Sample in grams</th>
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<td>3,500</td>
</tr>
<tr>
<td>1½ (37.5)</td>
<td>5,000</td>
</tr>
</tbody>
</table>

Generally, the contract documents note whether MDOT or ASTM/AASHTO specifications will be used. If no designation is made, following ASTM and AASHTO minimum sample sizes will meet MDOT requirements.

MECHANICAL DEVICES

A mechanical sample splitter can reduce Coarse, Dense-Graded and Open-Graded field samples. The Gilson Model SP-1 Sample Splitter is illustrated in Figure 1. Other sizes of mechanical splitters are commercially available.

These types of splitters do an excellent job of reducing field samples to a representative laboratory test sample. It is very important to set them on a level surface, such as a concrete
floor or pad. If set on an uneven surface, the splitter will split the material unevenly.

Open the splitter’s top and look down inside. There will be a set of aluminum bars that are ½ inch wide. Inside smaller splitters, the bars will be ⅛ inch or ¼ inch. These bars pivot around a rod through the lower ends of the bars. The top ends of the bars are not fastened to the splitter. This allows the bars to be flipped from one side of the splitter to the other to form chutes for the various sizes of aggregate to pass through.

According to ASTM and AASHTO standards, “the minimum width of the individual chutes shall be approximately 50 percent larger than the largest particles in the sample to be split.” If the largest particle size is 1 inch, multiply 1 inch by 1.5 to determine the settings. To set the splitter in Figure 1 to 1½ inch, flip three bars to one side and the next three bars to the next side. With 48 bars, this works out to 8 chutes on each side, see Figure 2.

If the largest expected particle size is 1½ inches multiply by 1.5. The answer is 2¼ inches. Flipping four fingers to one side creates a chute width of 2 inches which is too narrow. If five bars were flipped, the opening would meet the specification. However, since the splitter pictured only has 48 bars, making openings of five bars each would result in one chute on the end only three bars wide. This would result in more material being diverted to one side of the splitter. AASHTO T-248/ASTM C-702 test methods state this is not acceptable. In addition, the minimum number of chutes permissible is eight (4 in each direction). Therefore, the splitter pictured cannot be used for aggregates with particles larger than one inch.

After setting the bars in the splitter, check to see that the splitter pans are under the splitter and together. Pour the whole field sample into the splitter, spreading it evenly from edge to edge as shown in Figure 3. This helps the material to flow smoothly through the chutes when the gates are opened.

In actual lab testing, materials may not flow smoothly through the chutes. Dense-graded aggregates contain clay, silt, small stone particles and moisture that bind together. When the gates are opened, the material either sets in the gates or drops to the chutes below and does not pass through to the pans below. When this happens, use a rubber mallet (hammer) to tap the wing nuts on the ends of the splitter causing its bars to vibrate. This will usually break up the bound aggregate permitting it to fall through the chutes into the pans below.

After all the material has passed through the chutes into the pans below, take one pan from under the splitter and dump it back into the original sampling container. Place the pan back under the mechanical splitter. Take the opposite pan of aggregate out from under the
splitter and dump half of the pan diagonally back into the top of the splitter as shown in Figure 4. Turn the pan so the end which was closest to you is now the furthest away and pour in the rest of the aggregate in to splitter. This will help to spread the material evenly.

![Figure 4: Dumping Material Into Splitter](image)

Repeat the splitting of the field sample while altering the side from which the material will be dumped back into the splitter. Continue splitting the aggregate until it is the proper laboratory sample size. Do not throw away any of the sample. The remainder may be needed for other tests or to start over in case the first split sample does not work out or spills on the floor.

**QUARTERING**

Quartering works with any type of material, aggregate or asphalt. All that’s needed is a nonporous smooth surface of sufficient size to accommodate the whole sample, a straight edge, a scoop, a trowel, a square point shovel, a dust pan, and a brush or broom, depending upon the technique used.

Start by dumping the entire field sample on the smooth surface. Blend the material and form into a cone as shown in Step 1.

![Step 1](image)

Use the trowel to flatten the cone to a uniform thickness by pushing straight down on the pile of material as shown in Step 2.

![Step 2](image)

The flattened cone should look like Step 3.

![Step 3](image)

Cut the flattened cone into quarters. Save the opposite quarters as illustrated in Step 4. Remove the opposite quarters using a scoop to remove the bulk of the material. Clean up the fine particles with the brush or broom and dust pan. Place the removed aggregate back into the original sampling container.

![Step 4](image)

Using the trowel, pile the material back into a cone as illustrated in Step 5.

![Step 5](image)

Flatten the cone again as shown in Step 6.
Step 6

Step 7 shows the second cone flattened. The diameter of the flattened cone should be 4 to 8 times the thickness.

Step 7

Quarter the material and save the opposite quarters from those saved in Step 4, as illustrated in Step 8.

Step 8

Repeat the coning and quartering process until the proper sample size has been obtained.

An alternative to quartering on a hard flat surface begins by pouring the entire field sample into the center of a non-porous tarp. Mix the material by rolling the blanket as shown in Step 1A.

Step 1A

Form the material into a cone as shown in Step 2A.

Step 2A

Flatten the cone either with a square point shovel or trowel into a pile of uniform thickness. This is shown in Step 3A.

Step 3A

Divide the flattened cone into quarters as shown in Step 4A.

Step 4A

Remove the opposite quarters and place them back into the sampling container. Use a broom or brush to clean up and remove any fine material that was not picked up by the scoop or shovel. This is shown in Step 5A.

Step 5A

Repeat the coning and quartering process until the proper test sample size has been reached.

MINIATURE (MINI) STOCKPILE SAMPLING

The miniature (mini) stockpile sampling is used for damp fine aggregates only. There
are special mechanical sample splitters made specifically for splitting dry fine aggregates.

The following two methods of sample reduction both start out by dumping the entire bag of fine aggregate on a flat, clean non-porous surface. ASTM and AASHTO both recommend folding the pile over three times ending up with a pile shaped like a cone, see Step 1B and 1C. Be careful not to segregate the fine aggregate. When obtaining the reduced sample, AASHTO and ASTM standards recommend using a small sample thief, small straightedge scoop or spoon to sample the cone or flattened cone. Take a scoop of material from a minimum of five random locations from the miniature stockpile or flattened cone.

**Method 1**

Step 1B: Form the fine aggregate into a cone.

Step 2B: Using a small sample thief or spoon take a minimum of five sample increments from random locations around the miniature stockpile as illustrated.

**Method 2**

Step 1C: Form the fine aggregate into a cone.

Step 2C: Use a trowel to flatten the pile from the apex (top) pushing straight down.

Step 3C: Using a small scoop or table spoon take at least five random sample increments from the flattened pile.

**DRYING THE SAMPLE**

Once the proper sample size has been split, the material must be dried to a constant weight. This may be done on a gas or electric stove, or by using a hot plate or in a conventional or microwave oven.

First obtain an initial weight. Place the sample on or in the heat source. If a conventional oven is used, set the temperature to 220°F. After 15 to 16 hours the sample should be completely dry.

If any of the other apparatuses are used, the aggregate sample must be stirred to
prevent overheating. A simple method to determine if the material is dry involves placing a slip of paper on top of the hot aggregate. If the paper lies flat, the material is dry. If the paper curls, it still contains moisture and is not dry. Once the piece of paper does not curl, remove the sample from the heat source and allow it to cool before weighing. However, the paper curling does not work with recycled crushed concrete. Dry recycled crushed concrete using the procedure described in the next paragraph. In addition, recycled crushed concrete is likely to contain small amounts of HMA material which may melt during the drying.

If the piece of paper is not used, heat the material until it appears dry. Cool the sample until the heat will not damage the scales. Then weigh it and record the mass. Place the material back on or in the heating device. If an oven is used, then wait 20 to 30 minutes. If a hot plate or burner is used, then allow no more than 10 minutes. *Even a very low heat setting using a hot plate or burner can quickly overheat the aggregate.* Remove the material from the heat source. Let it cool and reweigh the material. If the two weighs are within 0.10 percent of each other, the material is considered to have reached constant weight. If the weight difference is greater than 0.10 percent, continue the drying process until two successive weighs are within 0.10 percent.
CHAPTER 4 – AGGREGATE MATERIALS AND SPECIFICATIONS

This chapter contains the entire “Section 902. Aggregates” from the Department’s “2003 Standard Specifications for Construction”. Section 902 provides a list of the ASTM, AASHTO standards and Michigan Test Methods plus a basic understanding of what types of materials are considered aggregates along with some of their applications. (The ASTM, AASHTO and MTM’s are not reproduced in this manual but are readily available from the organizations that publish them and can be located at many of the public libraries.) The technician should have a current copy of the “2003 Standard Specifications for Construction” and a current copy of the latest Michigan Test Methods in their laboratory as reference material prior to starting any test.

902.01 General Requirements.
Approval of aggregates at the producing plant does not constitute a waiver of the Department’s right to inspect and test at the point of actual use. Furnish equipment or the means necessary to allow safe access to the material for sampling from haul units or stockpiles.

Aggregate must be transported and placed without material loss or contamination when it is loaded and measured. Foundry sand which has been used for metal castings is not permitted on Department projects in any form.

902.02 Testing. Testing will be by the methods specified throughout this section and by the following general methods:

Wire-Cloth and Sieves ................. ASTM E 11
Materials Finer than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing ......................... ASTM C 117
Specific Gravity and Absorption of Coarse Aggregate ..................... ASTM C 127
Specific Gravity and Absorption of Fine Aggregate ..................... ASTM C 128
Sieve Analysis of Fine and Coarse Aggregates .................. ASTM C 136
Sampling and Testing Fly Ash ....... ASTM C 311
Sand Equivalent of Fine Aggregate ................................ ASTM D 2419
Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate ............... ASTM D 4791
Organic Impurities in Fine Aggregate ................................... AASHTO T 21
Sieve Analysis of Mineral Filler .................................... AASHTO T 37
Mortar Strength ..................... AASHTO T 71
Particle Size Analysis .......... AASHTO T 88
Water Asphalt Preferential Test ..... MTM 101
L.A. Abrasion Resistance of Aggregate ................................ MTM 102
Insoluble Residue in Carbonate Aggregate .................................... MTM 103
Sampling Aggregates ................. MTM 107
Loss By Washing ..................... MTM 108
Sieve Analysis of Aggregate ........ MTM 109
Deleterious and Objectionable Particles ................................. MTM 110
Aggregate Wear Index ............. MTM 112
Selection and Preparation of Course Aggregate Samples for Freeze-Thaw Testing............................................ MTM 113

Making Concrete Specimens for Freeze-Thaw Testing on Concrete Coarse Aggregate........................... MTM 114

Freeze-Thaw Testing of Coarse Aggregate....................................... MTM 115

Crushed Particles in Aggregates .... MTM 117

Angularity Index of Fine Aggregate....................................... MTM 118

Dry Unit Weight (LM) of Coarse Aggregate....................................... MTM 123

A. **Terminology.** The following terminology is used in the testing and acceptance of aggregates:

1. **Natural Aggregates.** Originating geologically from stone quarries, gravel, sand or igneous/metamorphic rock deposits.

2. **Slag Aggregates.** By-products formed in the production of iron, copper, and steel.
   a. Iron Blast-Furnace Slag is a synthetic nonmetallic by-product produced simultaneously with pig iron in a blast furnace. The slag consists principally of a fused mixture of oxides of silica, alumina, calcium, and magnesia.
   b. Reverberatory-Furnace Slag is a nonmetallic by-product resulting from refining copper ore.
   c. Steel-Furnace Slag is a synthetic by-product of basic oxygen, electric, or open hearth steel furnaces and consists principally of a fused mixture of oxides of calcium, silica, iron, alumina, and magnesia.

3. **Crushed Concrete Aggregate.** Produce by crushing Portland cement concrete.

4. **Salvaged Aggregate.** Any dense-graded aggregate saved or manufactured from Department project sources. The material may consist of natural aggregate, blast furnace slag, crushed concrete, or reclaimed asphalt pavement with a maximum two inch particle size and no visible organic or foreign matter, including steel reinforcement.

5. **Manufactured Fine Aggregate.** Produced by totally crushing rock, gravel, iron blast-furnace slag, reverberatory-furnace slag, steel-furnace slag, or Portland cement concrete.

6. **Natural Sand 2NS and 2MS.** Fine granular material resulting from the natural disintegration of rock. The material must be clean, hard, durable, uncoated particles of sand, free from clay lumps and soft or flaky material. These aggregates are used in concrete mixtures, mortar mixtures, and intrusion grout for pre-placed aggregate concrete.

7. **Stone Sand 2SS.** Manufactured from stone meeting all the physical requirements of Coarse Aggregate 6A. Stone sand is permitted only in concrete base course or in structural concrete not exposed to vehicular traffic.

8. **Soft Particles.** Nondurable particles that are structurally weak or experience environmental deterioration in service; includes shale, siltstone, friable sandstone, ochre, coal, and clay-ironstone.

9. **Crushed Particles.** A particle which has one or more fractured faces. The
number of fractured faces is determined by its use.

10. **Base Fineness Modulus.** The average fineness modulus typical of the source for a specific fine aggregate.

11. **Cobblestone (Cobbles).** Rock fragments, usually rounded or semi-rounded, with an average dimension between 3 and 10 inches.

**902.03 Coarse Aggregates for Portland Cement Concrete.** Use Michigan Class 4AA, 6AAA, 6AA, 6A, 17A, and 26A coarse aggregate produced from natural aggregate, iron blast furnace slag, or reverberatory furnace slag sources. Michigan Class 6A, 17A and 26A may be produced by crushing Portland cement concrete, but only for uses stipulated by this specification. The bulk dry specific gravity must be within the limits established by freeze-thaw testing. Aggregates must conform to the grading requirements in Table 902-1, the physical requirements in Table 902-2, and the following:

A. **Slag Coarse Aggregate.** Iron blast furnace slag or reverberatory furnace slag conforming to the grading specified for the concrete mixture will have a dry (loose measure) unit weight of not less than 70 pounds per cubic foot as determined by MTM 123.

B. **Crushed Concrete Coarse Aggregate.** Use only crushed concrete coarse aggregate originating from concrete sources owned by the Department as part of the contracted project. Crushed concrete coarse aggregate may be used in concrete mixtures for curb and gutter, valley gutter, sidewalk, concrete barriers, driveways, temporary pavement, interchange ramps with commercial ADT below 250, and concrete shoulders. Crushed concrete coarse aggregate may not be used in mainline pavements or ramps with commercial ADT equal to or greater than 250, concrete base course, bridges, box or slab culverts, head walls, retaining walls, pre-stressed concrete, or other heavily reinforced concrete.

Process crushed concrete coarse aggregate in a manner that avoids contamination with any non-concrete materials including joint sealants, HMA patching, and base layer aggregate or soil. Contamination particles retained on the one inch sieve are limited to 3.0 percent maximum by particle count of the total aggregate particles. The aggregate stockpile will be rejected totally when there is any evidence of contamination from non-Department sources, such as building brick, wood, or plaster. Pieces of steel reinforcement are allowable in the stockpile provided they pass the maximum grading sieve size without hand manipulation. The fine aggregate portion of the gradation must not exceed a liquid limit of 25.0 percent or a plasticity index of 4.0.

Crushed concrete coarse aggregate will be tested for freeze-thaw durability for each project. This testing requires a minimum of three months after samples of the produced aggregate are received in the laboratory.

Use equipment and methods to crush concrete that will maintain uniformity in aggregate properties: specific gravity ±0.05 and absorption ±0.40, with no apparent segregation. This requirement includes separating crushed concrete aggregate according to its original coarse aggregate type, except for the following situations:

1. Different aggregate types may exist in the same stockpile, if the quantities by weight of each aggregate type retained on the No. 4 sieve do not differ by more than ±10 percent from the average quantity obtained from at least three representative samples.

2. When aggregate is produced from concrete pavement with only one
aggregate type that has been repaired with concrete patches with a different aggregate type.

902.04 Coarse Aggregates for HMA Mixtures. Use natural aggregate, iron blast furnace slag, reverberatory furnace slag, steel furnace slag, or crushed concrete meeting the grading and physical requirements in the contract documents.

902.05 Coarse Aggregates for Chip Seals. Use chip seal 25A coarse aggregate that meets both the grading and physical requirements in Tables 902-1 and 902-2 and the following: have a minimum AWI of 260, a maximum moisture content of 4 percent at the time of placement and meet any special requirements stated in Section 508. There is no AWI requirement for shoulder chip seal aggregates.

902.06 Dense-Graded Aggregates for Base Course, Surface Course, Shoulders, Approaches and Patching. Use Michigan Class 21AA, 21A, 22A, and 23A dense-graded aggregates that consist of natural aggregate, iron blast furnace slag, reverberatory furnace slag, or crushed concrete, in combination with fine aggregate as necessary to meet the gradation requirements in Table 902-1, the physical requirements in Table 902-2, and the following:

A. Dense-graded aggregate produced by crushing Portland cement concrete must not contain building rubble as evidenced by the presence of more than 5.0 percent by particle count, building brick, wood, plaster, or similar materials. Sporadic pieces of steel reinforcement may be present provided they pass the maximum grading sieve size without hand manipulation.

B. Class 21AA, 21A and 22A dense-graded aggregate produced from crushing Portland cement concrete may not be used to construct either an aggregate base or aggregate separation layer when either of the following conditions apply:

1. When there is a geotextile liner or membrane present with permeability requirements.

2. In a pavement structure with an underdrain, unless there is a filter material between the crushed concrete and the underdrain. This filter material will be either a minimum of 12 inches of granular material or a geotextile liner or blocking membrane that will be a barrier to leachate.

C. Class 23A dense-graded aggregate may be produced from steel furnace slag, but only for use as an unbound aggregate surface course or as unbound aggregate shoulder.

902.07 Open-Graded Aggregates for Earthwork, Open-Graded Drainage Courses and Underdrains. Use Michigan Class 2G, 3G, 4G, 34G and 34R open-graded aggregates obtained from natural aggregate, iron blast furnace slag, or reverberatory furnace slag. These aggregates must conform to the grading requirements in Table 902-1, and the physical requirements in Table 902-2.
Table 902-1 Grading Requirements for Coarse Aggregates, Dense-Graded Aggregates, and Open-Graded Aggregates

<table>
<thead>
<tr>
<th>Material Type</th>
<th>Class</th>
<th>Item of Work by Section Number (Sequential) (a)</th>
<th>Sieve Analysis (MTM 109)</th>
<th>Loss by Washing (MTM 108)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>2.5 in</td>
<td>2 in</td>
</tr>
<tr>
<td>Coarse Aggregates</td>
<td>4 AA (c)</td>
<td>602</td>
<td>100</td>
<td>90-100</td>
</tr>
<tr>
<td></td>
<td>6 AAA (c)</td>
<td>602</td>
<td>100</td>
<td>90-100</td>
</tr>
<tr>
<td></td>
<td>6 AA (c)</td>
<td>601, 602, 706, 708, 806</td>
<td>100</td>
<td>95-100</td>
</tr>
<tr>
<td></td>
<td>6 A</td>
<td>205, 401, 402, 601, 602, 603, 706, 806</td>
<td>100</td>
<td>95-100</td>
</tr>
<tr>
<td></td>
<td>17 A</td>
<td>706, 712</td>
<td>100</td>
<td>90-100</td>
</tr>
<tr>
<td></td>
<td>25 A</td>
<td>706</td>
<td>100</td>
<td>90-100</td>
</tr>
<tr>
<td></td>
<td>26 A</td>
<td>706, 712</td>
<td>100</td>
<td>90-100</td>
</tr>
<tr>
<td>Dense-Graded Aggregates</td>
<td>21 AA</td>
<td>302,304, 305</td>
<td>100</td>
<td>85-100</td>
</tr>
<tr>
<td></td>
<td>21 A</td>
<td>302, 305</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>22 A</td>
<td>302, 305, 306, 307</td>
<td>100</td>
<td>90-100</td>
</tr>
<tr>
<td></td>
<td>23 A</td>
<td>306, 307</td>
<td>100</td>
<td>60-85</td>
</tr>
<tr>
<td>Open-Graded Aggregates</td>
<td>2 G</td>
<td>303(b)</td>
<td>100</td>
<td>85-100</td>
</tr>
<tr>
<td></td>
<td>3 G</td>
<td>303</td>
<td>100</td>
<td>85-100</td>
</tr>
<tr>
<td></td>
<td>4 G (i)</td>
<td>303</td>
<td>100</td>
<td>60-80</td>
</tr>
<tr>
<td></td>
<td>34 R</td>
<td>404</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>34 G</td>
<td>404</td>
<td>100</td>
<td>95-100</td>
</tr>
</tbody>
</table>

a. Designated Item of Work (Section):
   - 205 Roadway Earthwork
   - 302 Aggregate Base Courses
   - 304 Rubblizing Existing PCC Pavements - Filler Aggregate
   - 305 HMA Base Crushing and Shaping
   - 306 Aggregate Surface Course
   - 307 Aggregate Shoulders and Approaches
   - 401 Culverts
   - 402 Storm Sewers
   - 404 Underdrains - Trench Backfill
   - 502 Temporary Patching with HMA Mixture
   - 508 Chip Seals 303 Open-Graded Drainage Courses
   - 601 PCC Pavement Mixtures
   - 602 Concrete Pavement Construction
   - 603 Concrete Pavement Repair
   - 706 Structural Concrete Construction
   - 708 Pre-stressed Concrete Beams
   - 712 Bridge Rehabilitation - Concrete
   - 806 Bicycle Paths

b. Based on dry weights.

c. Class 6AAA will be used exclusively for all mainline and ramp concrete pavement when the directional commercial ADT is greater than or equal to 5000 vehicles per day.

d. Loss by Washing will not exceed 2.0 percent for material produced entirely by crushing rock, boulders, cobbles, slag or concrete.

e. When used for aggregate base courses, surface courses, shoulders and approaches and the material is produced entirely by crushing rock, boulders, cobbles, slag or concrete, the maximum limit for Loss by Washing must not exceed 10 percent.

f. The limits for Loss by Washing of dense-graded aggregates are significant to the nearest whole percent.

g. For aggregates produced from sources located in Berrien County, the Loss by Washing shall not exceed 8 percent and the sum of Loss by Washing and shale particles must not exceed 10 percent.
h. For use with stabilized aggregate base.
i. Acceptance gradation at production site only.
<table>
<thead>
<tr>
<th>Material</th>
<th>Series/Class</th>
<th>Gravel, Stone, and Crushed Concrete</th>
<th>Slag (a)</th>
<th>All Aggregates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Crushed Material, % min (MTM 117)</td>
<td>Loss, % max, Los Angeles Abrasion (MTM 102)</td>
<td>Soft Particles, % max (MTM 110)</td>
</tr>
<tr>
<td>Coarse Aggregates</td>
<td>4 AA (b)</td>
<td>40</td>
<td>2.0 (c)</td>
<td>0.020</td>
</tr>
<tr>
<td></td>
<td>6 AAA</td>
<td>40</td>
<td>2.0 (c)</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>6 AA (g)</td>
<td>40</td>
<td>2.0 (c)</td>
<td>7.0</td>
</tr>
<tr>
<td></td>
<td>6 A (g)</td>
<td>40</td>
<td>3.0 (e)</td>
<td>7.0</td>
</tr>
<tr>
<td></td>
<td>17 A (g)</td>
<td>40</td>
<td>3.5 (e)</td>
<td>8.0</td>
</tr>
<tr>
<td></td>
<td>25 A</td>
<td>95</td>
<td>45</td>
<td>8.0 (i)</td>
</tr>
<tr>
<td></td>
<td>26 A (g)</td>
<td>40</td>
<td>2.0 (c)</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>29 A</td>
<td>95</td>
<td>45</td>
<td>8.0 (i)</td>
</tr>
<tr>
<td>Dense-Graded Aggregates (j)</td>
<td>21 AA</td>
<td>95</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td></td>
<td>21 A</td>
<td>25</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td></td>
<td>22 A</td>
<td>25</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td></td>
<td>23 A</td>
<td>25</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Open-Graded Aggregates</td>
<td>2 G</td>
<td>90</td>
<td>45 (k)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 G</td>
<td>95</td>
<td>45 (k)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 G</td>
<td>95</td>
<td>45 (k)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>34 R</td>
<td>20 max</td>
<td>45 (k)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>34 G</td>
<td>100</td>
<td>45 (k)</td>
<td></td>
</tr>
</tbody>
</table>

a. Iron blast furnace and reverberatory furnace slag must contain no free (unhydrated) lime.
b. 2.50 percent maximum 24 hour soak absorption based on oven dry 6 series aggregate.
c. 1.0 percent maximum for particles retained on the 1 inch sieve.
d. If the bulk dry specific gravity is more than 0.04 less than the bulk dry specific gravity of the most recently tested freeze-thaw sample, the aggregate will be considered to have changed characteristics and be required to have a new freeze-thaw test conducted prior to use on Department projects.
e. Clay-ironstone particles must not exceed 1.0 percent for 6AAA, 6AA and 26A, and 2.0 percent for 6A and 17A. Clay-ironstone particles are also included in the percentage of soft particles for these aggregates.
f. Maximum freeze-thaw dilation is 0.067 when the directional commercial ADT is less than 5000 vehicles per day.
g. Except for pre-stressed beams, the sum of soft and chert particles may be up to 3.0 percent higher than the values determined from the sample tested for freeze-thaw durability. However, under no circumstances will the deleterious particle percentages exceed the specification limits in Table 902-2. In addition, a source may be restricted to a minimum percent crushed not to exceed 15 percent less than the percent crushed in the freeze-thaw sample. When the freeze-thaw dilation is between 0.040 and 0.067 percent per 100 cycles, more restrictive limits will be applied.
h. Maximum dilation of 0.010 for pre-stressed concrete beams.
i. Friable sandstone is included in the soft particle determination for chip seal aggregates.
j. Quarried carbonate (limestone or dolomite) aggregate may not contain over 10 percent insoluble residue finer than No. 200 sieve when tested in accordance with MTM 103.
k. If a blend of different aggregate sources, the abrasion value applies to each source.
l. ASTM D 4791 Section 8.4 will be followed. The test will be performed on the material retained down to and including the 1 inch sieve.
m. ASTM D 4791 Section 8.4 will be followed. The test will be performed on the material retained down to and including the No. 4 sieve.
902.08 Granular Materials for Fill and Subbase. Use granular materials for fill, trench backfill, and subbase that consists of sand, gravel, crushed stone, iron blast furnace slag, reverberatory furnace slag or a blend of aggregates conforming to the grading requirements of Table 902-3 and this subsection.

When Class II material is specified, Class I material may be substituted. When Class III material is specified, Class I, Class II, Class IIA, Class IIIA material may be substituted.

Material with cementitious properties or with permeability characteristics that do not meet design parameters may not be used for fill or subbase.

When used for trench backfill, no aggregate particles larger than two inches may be placed within 12 inches of the pipe.

Granular material produced by crushing Portland cement concrete is an acceptable material for swamp backfill, embankment (except the top three feet below subgrade) and as trench backfill for nonmetallic culvert and sewer pipes without associated underdrains. All other uses are unacceptable.

Granular material produced from steel furnace slag may be acceptable below the top three feet of the embankment and fill when permitted by the contract documents.

902.09 Fine Aggregates for Portland Cement Concrete and Mortar. The aggregate must be free from organic impurities to the extent that when subjected to the test for organic impurities, AASHTO T 21, it does not produce a color darker than Plate 3 (light brown). Fine aggregate failing this requirement may be approved for use provided the discoloration is due principally to the presence of small quantities of coal, lignite, or similar discrete particles; or the relative 7-day strength of the concrete under test is found to be at least 95 percent per AASHTO T 71.

The aggregate must be uniformly graded from coarse to fine and meet the grading requirements and fineness modulus variation requirements, specified in Table 902-4. The specified gradation represents the extreme limits which determine suitability for use from all sources of supply. The gradation from any one source must be reasonably uniform and not subject to the extreme percentages of gradation specified in Table 902-4.

Fine aggregate produced by crushing Portland cement concrete is not permitted.

902.10 Fine Aggregates for HMA Mixtures. Use fine aggregate for HMA mixtures consisting of clean, hard, durable, uncoated particles, free from clay lumps, organic materials, soft or flaky materials, and other foreign matter. These aggregates must be natural sand, manufactured fine aggregate, or a uniformly graded blend meeting the grading and physical requirements specified in the contract documents.

902.11 Fine Aggregates for HMA Surface Treatments.

A. Slurry Seal. Use 2FA fine aggregate consisting of crushed material from a quarried stone, natural gravel, slag source or a blend meeting the grading requirements of Table 902-4. Sands with Angularity Index less than 2.0 may not exceed 50 percent of the fine aggregate blend. This fine aggregate must have a maximum L.A. Abrasion value of 45 percent (MTM 102).

B. Micro-Surfacing. Use 2FA and 3FA fine aggregates, consisting of crushed material from quarried stone, natural gravel, slag source, or a blend meeting the grading requirements of Table 902-4. Microsurfacing aggregate must have a minimum AWI of 260 (MTM 111), a minimum sand
equivalent (ASTM D 2419) of 60 percent, and a minimum Angularity Index (MTM 118) of 4.0 for natural gravel, quarried stone or slag. These fine aggregates must have a maximum L.A. Abrasion value of 45 percent (MTM 102).

902.12 Mineral Filler for Bituminous Mixtures. Mineral filler, 3MF, must be limestone dust, dolomite dust, fly ash, collected by an electrostatic precipitation method, slag or hydrated lime. The free carbon in the fly ash may not exceed 12 percent by weight as measured by the loss on ignition test in accordance with ASTM C 311. Sources for fly ash must be selected from the Qualified Products List. Fly ash from a new source must show satisfactory performance on the basis of both laboratory mix stability tests and actual construction field experience.

Mineral filler shall be dry and have 100 percent passing the No. 30 and 75 to 100 percent passing the No. 200 sieve.

The fraction passing the No. 200 sieve must have 15-60 percent finer than 10 micron diameter. The sub-sieve particle size distribution shall be determined according to AASHTO T 88, using Tucker dispersing agent.

Mineral filler must be free of objectionable characteristics as measured by MTM 101.
### Table 902-3 Grading Requirements for Granular Materials

<table>
<thead>
<tr>
<th>Material</th>
<th>6 in</th>
<th>3 in</th>
<th>2 in</th>
<th>1 in</th>
<th>1/2 in</th>
<th>3/8 in</th>
<th>No. 4</th>
<th>No. 30</th>
<th>No. 100</th>
<th>Loss by Washing % Passing No. 200 (a)(b)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100</td>
<td></td>
<td></td>
<td>45-85</td>
<td>20-85</td>
<td>5-30</td>
<td>0-30</td>
<td>0-7</td>
<td>0-5</td>
<td></td>
</tr>
<tr>
<td>Class I</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class II (c)</td>
<td>100</td>
<td>60-100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0-30</td>
<td>0-7</td>
<td>0-5</td>
<td></td>
</tr>
<tr>
<td>Class IIA (c)</td>
<td>100</td>
<td>60-100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0-35</td>
<td>0-10</td>
<td>0-5</td>
<td></td>
</tr>
<tr>
<td>Class III</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0-15</td>
<td></td>
</tr>
<tr>
<td>Class IIIA</td>
<td>100</td>
<td>95-100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0-30</td>
<td>0-15</td>
<td>0-15</td>
<td></td>
</tr>
</tbody>
</table>

- a. Test results based on dry weights.
- b. Use test method MTM 108 for Loss by Washing.
- c. Except for use in granular blankets and underdrain backfill, Class IIA granular material may be substituted for Class II granular material for projects located in the following counties: Arenac, Bay, Genesee, Gladwin, Huron, Lapeer, Macomb, Midland, Monroe, Oakland, Saginaw, Sanilac, Shiawassee, St. Clair, Tuscola, and Wayne counties.
- d. Grading requirements are 0-20 for the No. 100 sieve and 0-5 for loss by washing when material is used as backfill for underdrains.

### Table 902-4 Grading Requirements for Fine Aggregates

<table>
<thead>
<tr>
<th>Material</th>
<th>3/8 in</th>
<th>No. 4</th>
<th>No. 8</th>
<th>No. 16</th>
<th>No. 30</th>
<th>No. 50</th>
<th>No. 100</th>
<th>Loss by Washing % Passing No. 200 (a)(b)</th>
<th>Fineness Modulus Variation (c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2NS</td>
<td>100</td>
<td>95-100</td>
<td>65-95</td>
<td>35-75</td>
<td>20-55</td>
<td>10-30</td>
<td>0-10</td>
<td>0-3.0 ±0.20 (d)</td>
<td>±0.20 (d)</td>
</tr>
<tr>
<td>2SS (e)</td>
<td>100</td>
<td>95-100</td>
<td>65-95</td>
<td>35-75</td>
<td>20-55</td>
<td>10-30</td>
<td>0-10</td>
<td>0-4.0 ±0.20 (d)</td>
<td>±0.20 (d)</td>
</tr>
<tr>
<td>2MS</td>
<td>100</td>
<td>95-100</td>
<td>65-95</td>
<td>35-75</td>
<td>20-55</td>
<td>10-30</td>
<td>0-10</td>
<td>0-3.0 ±0.20 (d)</td>
<td>±0.20 (d)</td>
</tr>
<tr>
<td>2FA (f)</td>
<td>100</td>
<td>90-100</td>
<td>65-90</td>
<td>45-70</td>
<td>30-50</td>
<td>18-30</td>
<td>10-21</td>
<td>5-15 (g)</td>
<td></td>
</tr>
<tr>
<td>3FA (f)</td>
<td>100</td>
<td>70-90</td>
<td>45-70</td>
<td>28-50</td>
<td>19-34</td>
<td>12-25</td>
<td>7-18</td>
<td>5-15 (g)</td>
<td></td>
</tr>
</tbody>
</table>

- a. Test results based on dry weights.
- b. Use test method MTM 108 for Loss by Washing.
- c. Aggregate having a fineness modulus differing from the base fineness modulus of the source by the amount exceeding the maximum variation specified in the table, will be rejected. Use ASTM C 136.
- d. The base fineness modulus will be supplied by the aggregate producer at the start of each construction season and be within the range of 2.50-3.35. The base FM, including the permissible variation, will be within the 2.50-3.35 range.
- e. Not for any application subject to vehicular traffic.
- f. Gradation represents the final blended product.
- g. The limits for loss by Washing of Fine Aggregates, 2FA and 3FA are significant to the nearest whole percent.
Section 902 does not include all the material specifications used by the Department. **For a complete listing of material specifications be sure to examine the job plans and contract documents, and the appropriate sections in the Department’s “Standard Specifications for Construction”**.

Tables 902-1, 902-3 and 902-4 each contain information needed to perform two tests. One is the sieve analysis and the other is the percent loss by washing. Or, if the aggregate is used in asphalt mixes, the P-200.

Table 902-2 contained information regarding *picks*. It shows a minimum/maximum specification requirement for crushed material. The table also shows what the maximum specification amount of deleterious material (bad material) is allowed in the aggregates.

Table 902-2 also contains information regarding the Los Angeles Abrasion Test and the Freeze Thaw Dilation Test. These tests are briefly described in the Chapter titled “Other Testing Procedures.”

Also included in the following pages are the two most common AASHTO coarse aggregate sizes and the criteria for aggregates used in Superpave™ (Superior Performing Asphalt Pavement) mixtures. These are found in the Department’s Special Provision’s for “Superpave™ Bituminous Mixtures”. The tables that relate to aggregate properties have been reproduced in this section. Tables that provide mix design and volumetric properties have not been reproduced. However the Superpave™ Special Provision consists of ten tables.

### AASHTO M-43 AND ASTM D-448 SIZE OF AGGREGATES FOR ROAD AND BRIDGE CONSTRUCTION

<table>
<thead>
<tr>
<th>Size Number</th>
<th>Sieve Size</th>
<th>SIEVE ANALYSIS (ASTM C136) TOTAL PERCENT PASSING</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>37.5 mm</td>
</tr>
<tr>
<td>56</td>
<td>25.0 mm to 9.5 mm</td>
<td>100</td>
</tr>
<tr>
<td>57</td>
<td>25.0 mm to 4.75</td>
<td>100</td>
</tr>
</tbody>
</table>
### Superpave™ Tables

#### Table 1: Crush Minimum Criteria

<table>
<thead>
<tr>
<th>Estimated Traffic (million ESAL)</th>
<th>Mix Type</th>
<th>Top &amp; Leveling Courses</th>
<th>Base Course</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.3</td>
<td>E03</td>
<td>55/</td>
<td></td>
</tr>
<tr>
<td>&lt;1.0</td>
<td>E1</td>
<td>65/</td>
<td></td>
</tr>
<tr>
<td>&lt;3.0</td>
<td>E3</td>
<td>75/</td>
<td>50/</td>
</tr>
<tr>
<td>&lt;10</td>
<td>E10</td>
<td>85/80</td>
<td>60/</td>
</tr>
<tr>
<td>&lt;30</td>
<td>E30</td>
<td>95/90</td>
<td>80/75</td>
</tr>
<tr>
<td>&lt;100</td>
<td>E50</td>
<td>100/100</td>
<td>95/90</td>
</tr>
</tbody>
</table>

Note: "85/80" denotes that 85 percent of the coarse aggregate has one fractured face and 80 percent has two fractured faces.

#### Table 2: Fine Aggregate Angularity Minimum Criteria

<table>
<thead>
<tr>
<th>Estimated Traffic (million ESAL)</th>
<th>Mix Type</th>
<th>Top &amp; Leveling Courses</th>
<th>Base Course</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.3</td>
<td>E03</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>&lt;1.0</td>
<td>E1</td>
<td>40</td>
<td>-</td>
</tr>
<tr>
<td>&lt;3.0</td>
<td>E3</td>
<td>40(1)</td>
<td>40(1)</td>
</tr>
<tr>
<td>&lt;10</td>
<td>E10</td>
<td>45</td>
<td>40</td>
</tr>
<tr>
<td>&lt;30</td>
<td>E30</td>
<td>45</td>
<td>40</td>
</tr>
<tr>
<td>&lt;100</td>
<td>E50</td>
<td>45</td>
<td>45</td>
</tr>
</tbody>
</table>

(1) For an E3 mixture type that enters the restricted zone as defined in Table 10, the minimum criteria shall be 43.

#### Table 3: Sand Equivalent Minimum Criteria

<table>
<thead>
<tr>
<th>Estimated Traffic (million ESAL)</th>
<th>Mix Type</th>
<th>Top &amp; Leveling Courses</th>
<th>Base Course</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.3</td>
<td>E03</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>&lt;1.0</td>
<td>E1</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>&lt;3.0</td>
<td>E3</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>&lt;10</td>
<td>E10</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>&lt;30</td>
<td>E30</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>&lt;100</td>
<td>E50</td>
<td>50</td>
<td>50</td>
</tr>
</tbody>
</table>
Table 4: L.A. Abrasion Maximum Criteria

<table>
<thead>
<tr>
<th>Estimated Traffic (million ESAL)</th>
<th>Mix Type</th>
<th>Top &amp; Leveling Courses</th>
<th>Base Course</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.3</td>
<td>E03</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>&lt;1.0</td>
<td>E1</td>
<td>40</td>
<td>45</td>
</tr>
<tr>
<td>&lt;3.0</td>
<td>E3</td>
<td>35</td>
<td>40</td>
</tr>
<tr>
<td>&lt;10</td>
<td>E10</td>
<td>35</td>
<td>40</td>
</tr>
<tr>
<td>&lt;30</td>
<td>E30</td>
<td>35</td>
<td>35</td>
</tr>
<tr>
<td>&lt;100</td>
<td>E50</td>
<td>35</td>
<td>35</td>
</tr>
</tbody>
</table>

Table 5: Soft Particles Maximum Criteria

<table>
<thead>
<tr>
<th>Estimated Traffic (million ESAL)</th>
<th>Mix Type</th>
<th>Top &amp; Leveling Courses</th>
<th>Base Course</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.3</td>
<td>E03</td>
<td>10.0</td>
<td>10.0</td>
</tr>
<tr>
<td>&lt;1.0</td>
<td>E1</td>
<td>10.0</td>
<td>10.0</td>
</tr>
<tr>
<td>&lt;3.0</td>
<td>E3</td>
<td>5.0</td>
<td>5.0</td>
</tr>
<tr>
<td>&lt;10</td>
<td>E10</td>
<td>5.0</td>
<td>5.0</td>
</tr>
<tr>
<td>&lt;30</td>
<td>E30</td>
<td>3.0</td>
<td>4.5</td>
</tr>
<tr>
<td>&lt;100</td>
<td>E50</td>
<td>3.0</td>
<td>4.5</td>
</tr>
</tbody>
</table>

Note: "Soft Particles Maximum" is the sum of the shale, siltstone, ochre, coal, clay-ironstone, and particles which are structurally weak or are found to be non-durable in service.

Table 6: Flat and Elongated Particles Maximum Criteria

<table>
<thead>
<tr>
<th>Estimated Traffic (million ESAL)</th>
<th>Mix Type</th>
<th>Top &amp; Leveling Courses</th>
<th>Base Course</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.3</td>
<td>E03</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>&lt;1.0</td>
<td>E1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>&lt;3.0</td>
<td>E3</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>&lt;10</td>
<td>E10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>&lt;30</td>
<td>E30</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>&lt;100</td>
<td>E50</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>

Note: Maximum 10 percent by weight with a 1 to 5 aspect ratio.
Tables 7 Superpave™ Mix Design Criteria, Table 8 VFA Minimum and Maximum Criteria and Table 9 Superpave™ Gyratory Compactor (SGC) Compaction Criteria have not been reproduced in this book.

### Table 10: Aggregate Gradation Requirements

<table>
<thead>
<tr>
<th>Standard Sieve</th>
<th>Percent Passing Criteria (control points)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mixture Number</td>
</tr>
<tr>
<td>1½ in</td>
<td></td>
</tr>
<tr>
<td>1 in</td>
<td></td>
</tr>
<tr>
<td>3/4 in</td>
<td>100</td>
</tr>
<tr>
<td>½ in</td>
<td>100</td>
</tr>
<tr>
<td>3/8 in</td>
<td>90 -100</td>
</tr>
<tr>
<td>No. 4</td>
<td>90 max</td>
</tr>
<tr>
<td>No. 8</td>
<td>32 -67</td>
</tr>
<tr>
<td>No. 16</td>
<td></td>
</tr>
<tr>
<td>No. 30</td>
<td></td>
</tr>
<tr>
<td>No. 50</td>
<td></td>
</tr>
<tr>
<td>No. 100</td>
<td></td>
</tr>
<tr>
<td>No. 200</td>
<td>2.0 -10.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sieve</th>
<th>Restricted Zone (see note)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 4</td>
<td>39.5</td>
<td></td>
</tr>
<tr>
<td>No. 8</td>
<td>47.2 39.1 34.6 26.8-30.8</td>
<td></td>
</tr>
<tr>
<td>No. 16</td>
<td>31.6 -37.6 25.6 -31.6 22.3 -28.3 18.1 -24.1</td>
<td></td>
</tr>
<tr>
<td>No. 30</td>
<td>23.5 -27.5 19.1 -23.1 16.7 -20.7 13.6 -17.6</td>
<td></td>
</tr>
<tr>
<td>No. 50</td>
<td>18.7 15.5 13.7 11.4</td>
<td></td>
</tr>
</tbody>
</table>

Note: The final gradation blend must pass between the control points established. The following conditions must be satisfied in order for the final gradation blend to enter the restricted zone:

1. Mixture types E03, E1, E10, E30 and E50 may enter the restricted zone provided the final gradation blend enters from above the maximum density line.

2. Mixture type E3 may enter the restricted zone provided the final gradation blend enters from above the maximum density line and the fine aggregate angularity of the final blend is a minimum of 43.

3. If these criteria are satisfied, acceptance criteria and associated incentive/disincentive or pay adjustment tied to this gradation restricted zone requirement which may be included in other contract documents do not apply. Otherwise, final gradation blend has to be outside of the area bounded by the limits set for the restricted zone.
CHAPTER 5 – THE MECHANICAL ANALYSIS

It is important to learn the correct procedures necessary to perform a sieve analysis, loss by wash, and various particle identifications. Filling out the related test forms completely and accurately is very important. The test results will be used by many people to make important decisions such as the acceptance or rejection of material, determining product use and even settle court disputes. Errors can be very costly to the product producers and purchasers.

ROUNDING PROCEDURES

Government agencies and private industry require the reporting of numerical data in some form such as whole numbers, tenths or hundredths. When performing mathematical calculations, it becomes necessary to round numbers. The American Society for Testing and Materials (ASTM) Standard E-29 assures consistent rounding of numbers.

ASTM Standard E-29 states the following when using the Rounding Method:

1. When the figure next beyond the last place to be retained is less than 5, retain unchanged the figure in the last place retained. (Example: Round to the nearest tenth 3.74 = 3.7).

2. When the figure next beyond the last place to be retained is greater than 5, increase by 1 the figure in the last place retained. (Example: Round to the nearest tenth 7.79 = 7.8).

3. When the figure next beyond the last place to be retained is 5 and there are no figures beyond this 5, or only zeros, increase by 1 the figure to be retained if it is odd, (Example: Round to the nearest tenth 6.75 = 6.8) leave the figure unchanged if it is even, (Example: Round to the nearest tenth 9.45 = 9.4). Increase by 1 the figure in the last place retained, if there are figures beyond this 5 (Example: Round to the nearest tenth 9.450001 = 9.5).

A typical Mechanical Analysis Report form is illustrated in Figure 1 at the top of page 36. This report can be used with most aggregate specifications.

EXAMPLE PRODUCTION PROBLEM

Adam's Asphalt Company has a proposal for road construction. The Job Number is 49307A, Control Number DST 5400, Federal Number STP 0893 (312) and Federal Item Number JH3621. They have contracted with Statewide, an aggregate producer, to produce the following material: 1000 tons 6A, 20,000 tons 22A, 10,000 tons of 4E10, and 1700 tons of 2NS.

The two contractors have agreed along with the state agencies involved to test the material as follows:

1. 6A - Two tests: One at approximately 500 tons and the other at approximately 1000 tons in the concrete producer’s material yard.

2. 2NS - Three tests taken randomly at approximately 600 ton intervals in the concrete producer’s yard.

3. 22A - Twenty tests will be conducted by the producer and contractor at approximately 1000 ton intervals as the material is placed in the road bed. Random numbers will be used to determine when to collect the sample and carry out the testing. Informational test may be run by the contractor at any time but will not be considered as a payment item. The state agency will take samples from the grade.
4. The Hot Mix Asphalt 4E10 shall meet all the mixture specifications.

The state agency will split a sample of aggregate with the producer’s aggregate technicians to conduct an independent assurance test during production. This will be an unannounced check.

**COARSE AGGREGATE**

Begin by filling in the known contractual data at the top of the Mechanical Analysis Report form as shown in Figure 2. The *Date* in the upper right corner is the date the sample was taken. The *Date* in the lower right corner is for when the test was completed.

Fill in the specifications for *Material Type* - Coarse Aggregate, *Spec.* - 6A. From Table 902-1 and Table 902-2 obtain the specification limits for gradation and deleterious particle determinations as illustrated in Figure 2, page 37.

When working with the Tables, it is important to look for the small letters in parenthesis ( ). Table 902-1 indicates the small letters a, b and d must be read. Table 902-2 indicates the small letters d, e, and g must be read.

Following the *Item of Work by Section Number* in Table 902-1 is the letter (a). Reading across the Coarse Aggregates 6A line are the numbers 205, 401, 402, 601, 602, 603, 706, and 806. Looking down at the bottom of Table 902-1, Note a, states 6A can be used in the following:
205 Roadway Earthwork
401 Culverts
402 Storm Sewers
601 PCC Pavement Mixtures
602 Concrete Pavement Construction
603 Concrete Pavement Repair
706 Structural Concrete Construction
806 Bicycle Paths

The letter (b) after Sieve Analysis and Loss by Washing states “Based on dry weights.”

Note (d) states “Loss by Washing will not exceed 2.0 percent for material produced entirely by crushing rock, boulders, cobbles, slag, or concrete.” This means that washed natural or glacial aggregates will be permitted a maximum of 1.0 percent Loss by Washing. Those operations that produce aggregate entirely by crushing will be allowed to increase the Loss by Washing to 2.0 percent.

Table 902-2 has a (d) in parenthesis. It states “If the bulk dry specific gravity is more than 0.04 less than the bulk dry specific gravity of the most recently tested freeze-thaw sample, the aggregate will be considered to have changed characteristics and be required to have a new freeze-thaw test conducted prior to use on Department projects.” Note (e) states “Clay-Ironstone particles must not exceed 1.0 percent for 6AAA, 6AA and 26A, and 2.0 percent for 6A and 17A. Clay-Ironstone particles are also included in the percentage of soft particles for these aggregates.” Note (g) states “Except for pre-stressed beams, the sum of the soft and chert particles may be up to 3.0 percent higher than the values determined from the sample tested for freeze-thaw durability. However, under no circumstances will the deleterious particle percentages exceed specification limits in Table 902-2. In addition, a source may be restricted to a minimum percent
crushed not to exceed 15 percent less than the percent crushed in the freeze-thaw sample. When the freeze-thaw dilation is between 0.040 and 0.067 percent per 100 cycles, more restrictive limits will be applied.”

Table 902-2 has requirements for the Los Angeles Abrasion Test and the Freeze-Thaw Dilation Test. These tests are not done as part of the Mechanical Analysis. However, they are briefly described in the Chapter titled Other Tests. Table 902-2 has no requirement for crushed material for 6A as indicated by the blank space in the column under Crushed Material, % min. Michigan Test Method 110 (reproduced in the Appendix) indicates which sieves the deleterious material (soft and chert) must be picked. It is recommended to draw a heavy line under the ⅜ inch data entry line. This serves as a memory device to add the ⅜ inch sieve to the nest of sieves during the sieve analysis. It is not a requirement for the gradation analysis. However, the material retained on the ⅜ inch sieve and the larger sieves are saved in a separate pile to be examined (also known as "picked") for deleterious material.

A representative sample from the field must be reduced in size as described in the Chapter 3 Sample Sizes and Sample Reduction. Using 6A as an example; 100 percent of the material must pass the 1.5 inch sieve. The first sieve that may retain aggregate is the 1 inch sieve. Looking at the chart used by the Michigan Department of Transportation in Chapter 3, Laboratory Sample Size; the sample shall weigh a minimum of 3500 grams after splitting.

Do not assume the sample is totally dry. Therefore, the sample must be dried after it has been split (reduced to testing weight) to a constant weight. Drying of the sample is described in the last paragraph of Chapter 3.

Weigh the sample after it has been dried and cooled. This weight becomes the Initial Weight of Sample recorded on the Mechanical Analysis Report form. The Initial Weight of Sample for the 6A example in Figure 2 is 3563 grams.

**LOSS BY WASHING**

The Loss by Washing (LBW) removes the clay, and silt sized particles from the sample.

The following equipment is necessary to wash aggregate:

1) A pan that’s large enough to hold the aggregate while allowing its agitation without water or aggregate loss.
2) 3-inch spatula or a large spoon.
3) No. 200 sieve.
4) A No. 4, No. 8 or No. 16 sieve to act as a guard sieve and protect the No. 200 sieve from large aggregate particles falling onto the No. 200 sieve and causing damage.

Before starting the wash procedure, examine the pan and sieves to be sure they are not damaged or plugged up.

Pour clear water through the No. 200 sieve before starting the washing process.

Add enough water to cover the material in the pan approximately 2 to 3 inches. Using a spatula or spoon vigorously stir the aggregate and water. Be sure to stir all of the material in the corners and across the bottom of the pan. Pour (decant) the water through the protective sieve and the No. 200 sieve as shown in Figure 3.
Keep the bottom corner of the pan over the guard sieve and No. 200 sieve so all the water being poured off (decanted) passes through these sieves. Take care not to spill any of the large material on the floor. Repeat the washing process as many times as necessary until the water is clear. The wash water is considered clear if after agitation the suspended sediment settles to the pan’s bottom in less than ten seconds. Do not pour the fine and coarse aggregate into the guard and No. 200 sieves and then rinse the material.

Do not let the No. 200 sieve overflow when decanting (pouring) the wash water. In the event that the No. 200 sieve becomes plugged, tap on the side of the sieve. This will usually start the water flowing. If tapping does not restore flow, rinse the No. 200 sieve with clear water while tapping until flow is restored.

After decanting the last clear wash water, use clear water to rinse the material retained on the No. 200 sieve. This will assure that all of the clay, silt and fine crushed aggregate that will pass through the wash sieve has done so.

Carefully rinse all the material to one side of the Number 200 sieve as shown in Figure 4.

Figure 4: Rinse To Side Of Sieve

Turn the sieve upside down over the pan and rinse all the material back into the pan as shown in Figure 5.

Figure 5: Rinse Into Pan

To eliminate excessive water, carefully pour the water through the No. 200 sieve one last time. Be sure to rinse any material from the last decantation back into the sample.

If the aggregate is being washed after an asphalt extraction process, a few drops of dish-washing detergent will be added to the sample to be washed. The dish-washing detergent is sometimes called a wetting or dispersing agent.

Mechanical washing equipment exists for washing samples. Care must be taken to ensure accurate test results which are comparable to the hand washing techniques. Mechanical washing techniques may cause sample degradation and increase the Loss by Wash.

After washing a sample, dry to a constant weight. Figure 2 shows the Weight after Washing to be 3537 grams.

To calculate the Loss by Washing, subtract the Weight after Washing (3537 grams) from the Initial Weight of Sample (3563 grams). This equals a Loss by Washing (Clay and Silt)
of 26 grams. Write this after the Loss by Washing (Clay and Silt) and also in the Retained Fractional Weight column on the LBW line as shown on Figure 2.

Calculate the Loss by Washing (Clay and Silt) as follows:

$$\left( \frac{\text{Loss By Washing (Clay and Silt)} 26g}{\text{Initial Weight of Sample} 3563g} \right) \times 100 = 0.7\%$$

This equals 0.7 percent. The specifications control how the calculated amount will be reported. For 6A it is 0.7 percent. This figure is also written in the Retained Fractional Percent column on the LBW line as shown in Figure 2.

**MECHANICAL WASHERS**

The Department’s Michigan Test Method (MTM) 108 states concerns about use of Mechanical Washing Equipment (illustrated in Figure 6.)

“The use of a mechanical washer to perform the washing operation is not precluded, provided the results are consistent with those obtained using manual operations.”

NOTE: If the Loss by Wash results using a mechanical washer is either just within specification or on the low side or out of specification on the high side, then a hand wash should be conducted on the other half of the saved final sample split.

ASTM C 117 does not adequately consider the fact that some aggregates are degraded by the action of the mechanical washer. Place the test specimen in the tilted container, start the wash water, and rotate the container. After a predetermined time, turn off the motor and wash water. The mechanical washing operation is complete if the suspended sediment settles to the bottom in approximately ten seconds or less. Continue washing if the water is still cloudy. If no improvement in the water clarity is observed after additional wash time, stop the wash process. Excessive wash time may result in increased Loss by Wash values. All wash water discharged from the tilted container must pass through the No. 200 sieve.

Upon completion of the washing, the rotating container is tilted downward to discharge the test specimen into a pan. The container is rinsed with water to remove any retained material. The rinse water must be collected in the pan. It is then decanted from the pan through the No. 200 sieve.

**SIEVING**

Construct a nest or stack of sieves by stacking the sieves from the largest size opening on the top to the smallest size sieve opening on the bottom. These are placed on a pan as shown in Figure 7.
<table>
<thead>
<tr>
<th>Opening Sieve</th>
<th>8 inch Round</th>
<th>10 inch Round</th>
<th>12 inch Round</th>
<th>14 by 14 inch</th>
<th>16 by 24 inch</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 inch (50mm)</td>
<td>3562g</td>
<td>5716g</td>
<td>8376g</td>
<td>15,312g</td>
<td>26,970g</td>
</tr>
<tr>
<td>1½ inch (37.5mm)</td>
<td>2672g</td>
<td>4287g</td>
<td>6282g</td>
<td>11,484g</td>
<td>20,227g</td>
</tr>
<tr>
<td>1 inch (25.0mm)</td>
<td>1781g</td>
<td>2858g</td>
<td>4188g</td>
<td>7656g</td>
<td>13,485g</td>
</tr>
<tr>
<td>¾ inch (19.0mm)</td>
<td>1353g</td>
<td>2172g</td>
<td>3183g</td>
<td>5818g</td>
<td>10,248g</td>
</tr>
<tr>
<td>½ inch (12.5mm)</td>
<td>890g</td>
<td>1429g</td>
<td>2094g</td>
<td>3828g</td>
<td>6742g</td>
</tr>
<tr>
<td>⅜ inch (9.5mm)</td>
<td>676g</td>
<td>1086g</td>
<td>1591g</td>
<td>2909g</td>
<td>5124g</td>
</tr>
<tr>
<td>No. 4 (4.75mm)</td>
<td>338g</td>
<td>543g</td>
<td>795g</td>
<td>1454g</td>
<td>2562g</td>
</tr>
<tr>
<td>No. 8. to No. 100 (2.36mm to 150µm)</td>
<td>200g</td>
<td>320g</td>
<td>469g</td>
<td>857g</td>
<td>1510g</td>
</tr>
</tbody>
</table>

Figure 8: Maximum Weight Retained on Sieve after Shaking

The 6A example will need as a minimum the following sieves: 1½ inch, 1 inch, ½ inch, ⅜ inch, No. 4 sieves and the pan. Because it is possible to overload the sieves, extra sieves may be added to the stack of sieves such as the ¾ inch sieve. This will prevent any one sieve from retaining excessive material during the shaking process.

Figure 8, above, is a table of the Maximum Weight Retained on Sieve after Shaking (Per ASTM C-136 in grams) which is provided to prevent overloading the sieves.

After assembling the stack of sieves, pour the aggregate specimen onto the top of the sieve stack. Shake the sieves by hand or with a mechanical shaker. Continue agitating the sieves until no more than 1 percent of the material retained on each sieve passes after one minute of additional shaking. If using a mechanical shaker, the shaker must not be allowed to run more than ten minutes. Longer shaking periods may result in aggregate breakdown as stipulated in ASTM C-136 Paragraph 6.3 Note 2.

An easy way to decide if the sieves have been shaken long enough is to set the sieves, one at a time, inside a large bowl as shown in Figure 9. Shake the sieve over the bowl to visually see how much material is passing through the sieve while shaking.

Figure 9: Sieve in Bowl

After sufficient shaking, record the weight of the aggregate retained on each sieve and in the pan on the Mechanical Analysis Report.
Depending on the accuracy required by the specification, weigh the aggregate to either
the nearest whole gram or tenth of a gram, see Figure 10. Generally concrete aggregates are
weighed to the whole gram. Whereas, asphalt aggregates are weighed to the nearest tenth of
a gram.

Notice in Figure 10 that a zero has been placed in the Retained Fractional Weight
column on the 1½ inch sieve line. If these boxes are left blank with no entry or a dash (-) is
recorded, a good lawyer can raise doubt about the completeness of the rest of the test.

Total the Retained Fractional Weight column. This should equal the Initial Weight of Sample. During the weighing process, a small amount of material may be misplaced, or due to rounding of numbers, the column may not add to the Initial Weight of Sample.

Because of past practices spanning many years, the Department allows an adjustment to
the Retained Fractional Weight Total, and the largest numerical weight in the Retained
Fractional Weight column. The adjustment will result in the column’s total equaling the
Initial Weight of Sample. This adjustment may be a plus or minus number.

The maximum adjustment allowed is 0.3 of 1 percent as stated in ASTM C 136
Paragraph 8.7. If the difference between the initial dry weight and the total retained
fractional weight is greater than 0.3 percent, recheck the individual sieve weights and the
total weight. If no mathematical error can be found, the sample cannot be used for
acceptance purposes. A new split must be obtained if this test was for acceptance.

The example 6A test sample’s Initial Weight of Sample multiplied by 0.003 equals 10.689 grams. The maximum permissible adjustment would be 10 grams. If the 10.689 grams were rounded to 11 grams the adjustment would be “more than” the 0.3 of 1 percent permitted.

NOTE: The only way to adjust this column is to draw a line through the figure to
be corrected and to write in the correct figure. It is not acceptable to erase, blot out figures or
to use another means to change the numbers.
Complete the Retained Fractional Percent column, shown in Figure 10, next. Report the calculations in this column to the nearest tenth. Divide each weight in the Retained Fractional Weight column by the Initial Weight of Sample. This answer is then multiplied by 100 to obtain a percent.

The calculations for the Retained Fractional Percent column in Figure 11 are as follows:

\[
\frac{1\frac{1}{2}\text{ inch sieve}}{0 \div 3563} \times 100 = 0.0
\]

This is rounded to 0.0

\[
\frac{1\text{ inch}}{98 \div 3563} \times 100 = 2.75049
\]

This is rounded to 2.8

\[
\frac{\frac{3}{4}\text{ inch sieve}}{706 \div 3563} \times 100 = 19.81476
\]

This is rounded to 19.8

\[
\frac{\frac{1}{2}\text{ inch sieve}}{1436 \div 3563} \times 100 = 40.30311
\]

This is rounded to 40.3

\[
\frac{\frac{3}{8}\text{ inch sieve}}{1050 \div 3563} \times 100 = 29.46954
\]

This is rounded to 29.5

\[
\frac{\text{No. 4 sieve}}{204 \div 3563} \times 100 = 5.72551
\]

This is rounded to 5.7

\[
\frac{\text{Pan}}{38 \div 3563} \times 100 = 1.0665
\]

This is rounded to 1.1

After completing the mathematical calculations, total the Retained Fractional Percent column. This total should equal 100.0.

When rounding the numbers, the column may add to 99.9 or 100.1. The difference can be adjusted in the column by changing the
total to 100.0. Add or subtract the plus or minus adjustment to the largest number in the column, see Figure 11.

If the numbers add to 100.2, 100.3, 100.4 or more, or 99.8, 99.7, 99.6 or less, go back and check the column addition. If this doesn’t reveal the error, check the division. If this doesn’t locate the error, add the Retained Fractional Weight column again. An adjustment of more than ±0.1 is uncommon.

Complete the Percent Cumulative Retained column next, as shown in Figure 12. The numbers in the column are computed with cumulative addition from the top to the bottom of the column.

Start by moving the 0.0 from the Retained Fractional Percent column to the Percent Cumulative Retained column on the 1½ inch sieve. Add the 2.8 in the Retained Fractional Percent column to the 0.0 on the Percent Cumulative Retained column on the 1 inch line. This equals 2.8. Next add the 19.8 on the ¾ inch line to the 2.8 in the Percent Cumulative Retained column. This equals 22.6. The rest of the calculations are as follows:

\[
\begin{align*}
22.6 + 40.4 &= 63.0 \\
63.0 + 29.5 &= 92.5 \\
92.5 + 5.7 &= 98.2
\end{align*}
\]

Figure 11
The last column to be calculated is the Percent Cumulative Passing shown in Figure 13. The calculations are performed by rounding the Percent Cumulative Retained to a whole number. Then subtract the whole number from 100. The Percent Cumulative Passing is recorded as whole numbers except when the aggregate is used in asphalt mixtures.

The calculations for Figure 13 are as follows:

1½ inch sieve:
- 0.0 Rounds to 0
- 100 - 0 = 100

1 inch sieve:
- 2.8 Rounds to 3
- 100 - 3 = 97

½ inch sieve:
- 63.0 Rounds to 63
- 100 - 63 = 37

No. 4 sieve:
- 98.2 Rounds to 98
- 100 - 98 = 2

Next, compare the numbers in the Percent Cumulative Passing column to the specifications. In the event that a number in the Percent Cumulative Passing column does not meet the specifications, draw a circle around the number out of specification. This quickly calls attention to the problem area.

DELETERIOUS PICKS

To complete the Mechanical Analysis Report for 6A aggregate, you must do a deleterious pick.
Basically a deleterious pick involves sorting through the material retained on a specific set of sieves. For the 6A example, the aggregate to be sorted is the material retained on the 1½ inch, 1 inch, ¾ inch, ½ inch and ⅜ inch sieves. This test separates the good aggregate from the bad (deleterious) aggregate. The deleterious aggregates are: friable sandstone, siltstone, shale, ochre, coal, clay-ironstone, structurally weak, material found to be nondurable in service and chert. The deleterious particles are separated into three groups: clay ironstone, other soft and chert.

After completing the deleterious pick according to MTM 110, weigh and record the deleterious material picked. Figure 14 indicates that 43 grams of Clay-Ironstone were picked from the sample. The next line (1) Soft Particles Including: Clay-Ironstone has 79 grams of deleterious material picked. The (2) Chert picked from the sample was 212 grams.

Add the (1) Soft Particles Including: Clay-Ironstone and (2) Chert together. Record the total of these items on the line Sum of (1) + (2). This total should equal 291 grams.

Next, calculate the pick weight. This is the sum total of the weights recorded in the Retained Fractional Weight column of the 1½ inch, 1 inch, ¾ inch ½ inch, and the ⅜ inch sieves. This weight is 3295 grams as shown in Figure 14. It is a good practice to write and label this figure in the remarks space on the mechanical analysis form.

To calculate the percentage of deleterious particles, divide the weight of the deleterious material picked from the sample by the pick weight. Multiply the answer by 100 and record the answer to the nearest tenth.
The calculations for the 6A in Figure 15 are as follows:

### Clay-Ironstone:

\[
\left( \frac{43}{3295} \right) \times 100 = 1.305007
\]

This is rounded to 1.3 percent.

### (1) Soft Particles including: Clay-Ironstone:

\[
\left( \frac{79}{3295} \right) \times 100 = 2.397572
\]

This is rounded to 2.4 percent.

### (2) Chert:

\[
\left( \frac{212}{3295} \right) \times 100 = 6.433990
\]

This is rounded to 6.4 percent.

### Sum of (1) + (2):

\[
\left( \frac{291}{3295} \right) \times 100 = 8.831563
\]

This is rounded to 8.8 percent.

The percentage of deleterious particles is now compared to the specifications. Note the specifications for the deleterious material are the maximum amounts allowable. The percent of deleterious in the example are all less than the allowable maximum. If the deleterious calculations were to exceed the specifications, the item out of specification would be circled to show the material does not meet specifications. One circle indicates the entire test does not meet specifications.
To complete the test, place an “X” in the appropriate box to indicate if the material Meets or Fails, sign the form and clearly print your name. Enter the date the test was completed. See Figure 15 for the completed test.

THE AGGREGATE INSPECTION DAILY REPORT

The Aggregate Inspection Daily Report form, Figure 16, page 49, is used as a summary of the daily testing activities. The technician must submit it daily. The form is filled out from the information on the Mechanical Analysis Report. The Aggregate Inspection Daily Report is to be filled out completely and accurately.

In addition to the information found at the top of the Mechanical Analysis Report, the following information is also required on the form:

1) The name of the project engineer.
2) The name of the prime contractor for the project.
3) The pit/quarry name (Pit and quarries are named after many things such as people, companies, cities, towns, roads geographic locations or landmarks.).
4) Where the material is produced.
5) The MDOT Aggregate Source Inventory (ASI) pit number. The pit numbers always start with two numbers that indicate the county or state where the pit/quarry is located. (Our example is number 54, which is Mecosta County.) The next numbers are the registration number of the pit or quarry. Having these numbers will
enable the user of the information to go to the “Aggregate Source Inventory” published and available from the Department’s publications unit. This book contains aggregate sources, selected test results and driving directions to get to the pit/quarries.

All results required by the specifications are to be reported on the form. The specifications for the material being tested are to be written in the boxes under the Specification Requirements. Also, if specifications are indicated for Crushed Material, Clay Ironstone, Soft Particles Including Clay Ironstone or Chert, place these above the boxes that will contain the test data. When the test data is recorded, transfer the Cumulative Percent Passing and the percents of crushed and deleterious material as appropriate from the Mechanical Analysis Report (do not transfer weights.)

For aggregates, which require a determination of deleterious particles (commonly known as a “pick”), an entry must be made under each item designated by the specifications. For example, if there is a specification limit of chert content for the aggregate being tested and no chert is found in the test sample, the figure 0.0 must be recorded. If such a space on the form is left blank, or if a dash (-) is recorded, it is inferred that no check for that item was made. General information is to be given as shown on the sample report. Carry the test numbers independently for each project, and continue the number sequence to the end of the project. Give the source from which the aggregate was sampled and if the shipment is by rail, include the car initials and number of each car. Do not record a Test Number for materials visually inspected. Report the quantities represented as accurately as possible, breaking them down into sub-totals as shown in Figure 16.

Be sure to make a note on the form if a Special Provision, Supplemental Specification or Modification to the material exists in the contract documents.

The Aggregate Inspection Daily Report is to be completed each day production is in progress for a project. Note processing changes in the Remarks such as changing wire cloth sizes that will affect test results or plants not producing for a day due to rain.

The Mechanical Analysis Reports are retained by the technician at the field inspection quarters and are to be available for review by supervisory personnel. When independent assurance samples are submitted to the Region or Construction and Technology Division, a copy of the technician’s Mechanical Analysis Report must accompany the sample.

The Aggregate Inspection Daily Report is to be made out in quadruplicate and mailed at the close of each day. The original is to be mailed to Construction and Technology (C & T) Division, one copy is to be mailed to each of the following: the Region office and the Project Engineer with one copy retained by the technician. Depending on the particular Region, the copy for the Region may be directed to the Transportation Service Center.

Unless other instructions are given, separate Aggregate Inspection Daily Reports are to be prepared for each project or purchase order. If concrete aggregates (coarse and/or fine), open graded and dense graded aggregates are shipped to the same project from the same source, separate Aggregate Inspection Daily Reports are required for each type of aggregate.

The copy of the Aggregate Inspection Daily Report on aggregates supplied to fulfill Maintenance purchase orders, which would normally be sent to the Project Engineer, should be mailed to the Region Maintenance Engineer receiving the aggregate shipment.
All aggregate rejected by the technician must be reported and its disposition noted even if the quantity is small. Circle the specific result or results which failed to meet the specification requirements. In cases where the aggregates are rejected on visual inspection, the reason for the rejection is to be stated on the report. All rejections shall be reported on a separate Aggregate Inspection Daily Report.
DENSE-GRADED AGGREGATES

Dense-graded aggregates are a uniformly graded blend of Coarse, Intermediate, Fine Aggregates, and materials finer than the No. 200 sieve such as clay, silt and fine crushed stone. When produced, these aggregates may achieve high density and stability. They are generally used as base courses, shoulder gravel, on county gravel roads, and as driveway gravel. HMA mixtures are similar to dense-graded aggregates.

One difficulty associated with the production of dense-graded aggregates in Michigan is most natural gravel pits contain too much fine aggregate in the minus No. 4 size range. This means the recoverable reserves are reduced if the production set up favors the coarse gradation of the dense-graded specification. During processing this will either create the necessity of extracting sand during processing or the blending of stone to compensate. When taken from a pit or quarry, the opposite may be true and sand may have to be added to meet specifications.

Occasionally it becomes necessary to blend clay and silt with the aggregates to increase the Loss by Washing. If this is the case, take a small sample of the clay and silt before blending and do a Loss by Wash. Material that appears to be all clay and silt may contain a considerable amount of fine aggregate (sand). This fine aggregate may increase the amount passing the fine sieves such as the No. 8 sieve creating more problems.

Figure 17 illustrates a Mechanical Analysis Report form with the contractual data and the specifications filled in to perform a test on 22A Dense-Graded Material. Tables 902-1 and 902-2 were used to obtain the specifications.

<table>
<thead>
<tr>
<th>Sieve</th>
<th>Retained Fractional Weight</th>
<th>Percent</th>
<th>Retained</th>
<th>Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 1/2&quot;</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2&quot;</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 1/2&quot;</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1&quot;</td>
<td></td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3/4&quot;</td>
<td></td>
<td>90-100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/2&quot;</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3/8&quot;</td>
<td></td>
<td>65-85</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/4&quot;</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NO. 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NO. 6</td>
<td></td>
<td>30-50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NO. 16</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NO. 30</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NO. 60</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NO. 100</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fine</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LBIV</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

MECHANICAL ANALYSIS REPORT

Figure 17
Again, Table 902-1 indicates to read the footnotes (a) and (b). This aggregate also has the following footnotes (e), (f) and (g) located in the Loss by Washing column. It states: “(e) When used for aggregate base courses, surface courses, shoulders and approaches and the material is produced entirely by crushing rock, boulders, cobbles, slag, or concrete, the maximum limit for Loss by Washing will be increased to 10 percent. (f) The limits for Loss by Washing of dense-graded aggregates are significant to the nearest whole percent. (g) For aggregates produced from sources located in Berrien County, the Loss by Washing will not exceed 8 percent and the sum of Loss by Washing and shale particles will not exceed 10 percent.”

Table 902-2 has the letter (j) in parentheses. Footnote (j) states, “Quarried carbonate (limestone or dolomite) aggregate will not contain over 10 percent insoluble residue finer than the No. 200 (0.075 mm) sieve when tested in accordance with MTM 103”.

Note the crush pick is a minimum percent. The answer obtained to meet specifications must be greater than 25 percent for the 22A. The calculation for the crushed aggregate is as follows:

\[
\left( \frac{260}{684} \right) \times 100 = 38\%
\]

Figure 18, illustrates a completed Mechanical Analysis Report form for the 22A. The splitting, washing, drying, weighing, and Loss by Washing procedures are the same as was done for the 6A.
# AGGREGATE INSPECTION DAILY REPORT

**Figure 19** illustrates the Aggregate Inspection Daily Report.

<table>
<thead>
<tr>
<th>TEST NO.</th>
<th>SPECIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>22A, GRADE</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CUMULATIVE PERCENT PASSING</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LOSS BY WASHING</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SIEVE OPENINGS - INCHES OR SIEVE NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-1/2&quot;</td>
</tr>
<tr>
<td>100</td>
</tr>
</tbody>
</table>

**MATERIAL (Specifications)**: 22A

**SPECIAL PROVISIONS/SUPPLEMENTALS/MODIFICATIONS**

**THIS MATERIAL** ☑ DOES ☐ DOES NOT MEET SPECIFICATION

**AGGREGATE INSPECTOR (Signature)**: DANIELC. ROCK

**DATE**: 09/10/0X

---

**PROJECT ENGINEER**: A. R. WRIGHT  
**JOB NO.**: 45007A  
**REPORT NO.**: 2  
**DATE TESTED**: 09/10/0X  
**PIT NAME**: ROOKY ROAD  
**PIT NO.**: 54-101  
**PRODUCER STATE WIDE**:  
**CONTRACTOR GENERAL CONTRACTING**:  
**CONTROL SECTION**: DST5400
FINE AGGREGATE

Fine aggregate (sand) is composed of material finer than the No. 4 sieve and coarser than the No. 200 sieve. The necessary contractual information and test specifications for testing 2NS from Table 902-4 have been entered in Figure 20.

The additional footnotes for this product are (b), (c) and (d). Footnote (b) states, “Use test method MTM 108 for Loss by Washing.” Footnote (c) is, “Aggregate having a fineness modulus differing from the base fineness modulus of the source by the amount exceeding the maximum variation specified in the table, will be rejected.” Footnote (d) states, “The base fineness modulus will be supplied by the aggregate producer at the start of each construction season and be within the range of 2.50 - 3.35. The base fineness modulus (FM) including the permissible variation, will be within the 2.50 - 3.35 range.”

Figure 21, illustrates a completed Mechanical Analysis Report form for 2NS. The Loss by Washing, sieve analysis, and mathematical calculations are the same as the other materials.

Calculate the fineness modulus by adding the figures in the Percent Cumulative Retained column from the ⅜ inch sieve down to and including the No. 100 sieve. Divide this figure by 100 and report to the second decimal place.

The calculation for the fineness modulus in Figure 21 is:

\[
\frac{0.0 + 1.3 + 19.5 + 43.7 + 63.1 + 81.0 + 95.4}{100} = 3.04
\]
To establish a base fineness modulus, run ten mechanical analysis tests. Add the calculated fineness modulus from each test together and then take an average. This average may be determined at the beginning of the year, or, in some instances, before beginning a specific project.

The base FM for the 2NS must be within the range of 2.50 to 3.35 for the aggregate to be accepted. After establishing the base FM, a tolerance is applied, such as the ±0.20 for the 2NS. This reduces the production range and increases the aggregate’s uniformity. Note: Neither the 2FA nor 3FA require the calculation of the fineness modulus.

The fineness modulus measures the material’s grain size. The 2.50 suggests a fine material whereas the 3.35 suggests a coarser material. In Michigan, the concrete industry uses this figure, whereas, the asphalt industry does not use this figure.

When a fineness modulus is required as part of the testing procedure, be sure to add all of the sieves from the ⅜ inch sieve down to and including the No. 100 sieve to the stack of sieves used for sieving. For example, the 2MS aggregate does not require the No. 16 and the No. 30 sieves to do a sieve analysis, but they are required to calculate the fineness modulus.

The right column of the Mechanical Analysis Report form has a line called the Organic Plate Number. This line in Figure 21 indicates a number four colorimetric test result. This was determined by comparing the results of soaking sand in a 3 percent solution of sodium hydroxide for 24 hours then comparing the color of the solution to a glass or plastic color reference chart.

The chart colors are numbered from one to five. The number’s one, two or three are within acceptable limits. Test results four and
If the sand is to be used in Portland Cement Concrete and it is tentatively rejected, further testing on the fine aggregate must be done. This involves making Portland Cement Concrete cubes and testing them for strength.

Figure 22 illustrates the completed Aggregate Inspection Daily Report for the tentatively rejected pending further testing.

If five indicate the aggregate shall be rejected. Figure 22 shows the completed Aggregate Inspection Daily Report for the 2NS aggregate, indicating it is tentatively rejected pending further testing.
HOT MIX ASPHALT

The form used for testing of HMA is shown in Figure 23, page 58. This form is similar to those used by the asphalt industry. Begin by filling in the known contractual information at the top of the form.

The specifications for aggregates used in Superpave™ HMA mixtures are found in Special Provision 501F published by the Department. This Special Provision consists of ten tables from which those that are applicable to aggregates have been reproduced in Chapter 4.

The technician must understand the designations used for the various mixtures. An example is the designation 4E10. Each part of the designation has a meaning to the technicians who work with Hot Mix Asphalt.

The number four indicates the gradation requirements the mixture must meet. This is found in Table 10, page 34, Chapter 4. Notice that all the sieves are used to determine the gradation, but not all sieves have gradation requirements.

The next part of the designation is the letter $E$. The $E$ indicates the number of Equivalent Single Axle Load’s (ESAL’s) projected over a 20-year period. For design purposes, an ESAL carries a load of 18,000 pounds and has four tires.

The last figure in the example is the number “10”. This indicates that the HMA mixture is expected to withstand ten million equivalent single axle loads (ESAL’s) over a 20-year period. The mix type designations in the Tables on pages 32 to 34 in Chapter 4 range from a mix type E03 which indicates 300,000 ESAL’s to an E50 which indicates 50,000,000 ESAL’s over a 20-year period.

The aggregates for Hot Mix Asphalt are processed and stockpiled in fractional sizes such as 1/2 to 5/16 inch and 5/16 inch minus.

The technician will perform gradations on these stockpiles for information to use in blending for a specific asphalt mix design.

Once a mix design has been completed and approved for use, a Job Mix Formula will be prepared for the field application of the design. The gradations will then be stated as target values.

The asphalt plants have several cold feed bins that supply proportionally the materials into the asphalt plant. This is how the plant operators maintain a uniform blend of the aggregates. At a location after the last cold-feed bin has emptied onto the belt but before the combined aggregate is fed into the plant, a sample is taken to determine if the blended aggregates meet the gradation requirements of the mixture.

After the mixture is made, samples of the Hot Mix Asphalt are taken. The asphalt is removed either by a chemical extraction process or ignition furnace, which burns the asphalt from the mix. The gradations are then checked for Quality Control/Quality Assurance purposes. At this point, a tolerance is applied to the total percent passing of some of or all of the sieve’s specifications listed on the Job Mix Formula. For example, the No. 8 sieve may have a tolerance of ±5.00 percent and the material passing the No. 200 sieve may have a tolerance of ±1.70 percent depending upon contract requirements. The aggregate would then have an upper and lower specification limit.

If the target for the Cumulative Fraction Passing Percent the No. 8 sieve was 35.86 then the upper and lower limit using the ±5.00 percent would become as follows:

$$35.86 - 5.00 = 30.86$$ lower limit
$$35.86 + 5.00 = 40.86$$ upper limit

From this point on, all the aggregate in the mixture would have to fall within the new established range.
NOTE: In Figure 24 all weights are to the tenth (0.0). The calculations in the Fraction Retained Percent and the Cumulative Fraction Passing Percent columns are to the nearest tenth (0.0). This is typical for Local agency contracts. The calculations for the Fraction Retained, Percent and the Cumulative Fraction Passing columns for MDOT Quality Control/Quality Assurance projects are carried out to hundredths (0.00). The answer as to how far to carry out the calculations is found in the Special Provisions of project contracts.
The sample is dried to a constant weight, the weight recorded, washed, re-dried, weighed again and recorded to determine the Loss by Wash the same as the 6A, 22A and 2NS examples. The material is dumped into a stack of sieves and shaken using the same rules as applied to the 6A, 22A and 2NS. A significant difference is the addition of the No. 200 sieve to the stack of sieves when shaking. A small amount of material will pass through the sieve when shaking and be retained in the pan. This is called Wt. Passing No. 200 (75 µm) By Shaking, Row K in Figure 24. This weight is added to the Wt. Loss By Washing, Row J in Figure 24 to
obtain the *Total Passing No. 200*, Row L. See Figure 24 left hand side of form.

Calculate the Fraction Retained Percent column exactly as was done for the 22A, 6A and 2NS. The Cumulative Fraction Passing Percents are calculated as follows:

<table>
<thead>
<tr>
<th>Size (mm)</th>
<th>Percentage Passed</th>
</tr>
</thead>
<tbody>
<tr>
<td>19.0</td>
<td>100.0</td>
</tr>
<tr>
<td>12.5</td>
<td>93.9</td>
</tr>
<tr>
<td>9.5</td>
<td>82.1</td>
</tr>
<tr>
<td>4.75</td>
<td>57.0</td>
</tr>
<tr>
<td>2.36</td>
<td>36.0</td>
</tr>
<tr>
<td>1.18</td>
<td>15.4</td>
</tr>
<tr>
<td>600</td>
<td>6.4</td>
</tr>
<tr>
<td>300</td>
<td>52.6</td>
</tr>
<tr>
<td>150</td>
<td>5.2</td>
</tr>
<tr>
<td>75</td>
<td>0</td>
</tr>
</tbody>
</table>

The material for all crush and deleterious picks is saved from the material retained on the No. 4 (4.75 mm) sieves and above. Table 1 Crush Minimum Criteria in Chapter 4 shows that for E10 Hot Mix Asphalt the crush particle percents for *Top and Leveling Courses* shall be 85/80 and for *Base Course* it shall be 60/-. The ‘85/80’ denotes that 85 percent of the coarse aggregate has one fractured face and 80 percent has two fractured faces. If the Hot Mix Asphalt were used as a BASE Course the 60/- denotes that 60 percent of the coarse aggregate has one fractured face and no requirement for two fractured faces.

Table 5 Soft Particles Maximum Criteria in Chapter 4 shows that for the E10 Hot Mixture Asphalt the Soft Particles Maximum for *Top and Leveling Courses* and *Base Course* is 5.0 percent. The pick for the Soft Particles Maximum is the sum of the shale, siltstone, friable sandstone, ochre, coal, clay-ironstone, and particles which are structurally weak or found to be non-durable in service. This table lists four specific items that will be picked from the material retained on the No. 4 (4.75 mm) sieve and larger sieves.

The calculations to determine the crushed and soft particles on the weight of the aggregate retained on the No. 4 (4.75 mm) and larger sieves are as follows:

Pick weight in grams: 

\[
\left(0.0 + 141.8 + 274.1 + 584.0 = 999.9\right)
\]

Percent Crushed material: (One Fractured Face)

\[
\left(\frac{912.9}{999.9}\right) \times 100 = 91.3
\]

Percent Crushed material: (Two Fractured Face)

\[
\left(\frac{874.4}{999.9}\right) \times 100 = 87.4
\]

Percent Soft Particles:

\[
\left(\frac{28.2}{999.9}\right) \times 100 = 2.8
\]
Picking crushed and deleterious particles is done by visual inspection. The specification requirements may require a crush pick, a deleterious pick or picking both crush and deleterious.

When picking the crushed or deleterious material, be sure to examine each piece. You may have to pick up some particles and roll them to observe all sides in order for you to accurately identify the particle.

Before starting the pick, examine the specifications so you know what to pick and determine which sieves need to be included in the mechanical analysis. All asphalt aggregates use the material retained on all sieves down to and including the No. 4 sieve for picking crushed and deleterious particles. Generally aggregates used in Portland cement concrete and dense graded aggregates used for base courses, surface courses, shoulders and approaches are picked from all sieves retaining aggregate down to and including the \( \frac{3}{8} \) inch sieve.

**CRUSHED PARTICLES**

A crushed particle is a particle having at least one fractured face. Some specifications may require the aggregate have two or more fractured faces.

A fractured face may be defined as an aggregate having a surface broken by a mechanical device constituting an area equal to or greater than 50 percent of the projected face as viewed perpendicular to the fractured face. Natural aggregate, to be accepted as crushed must have fractures similar to those produced by mechanical devices.

All sandstone particles are considered as crushed particles. Crag, which looks like small stones cemented together naturally, will be considered crushed as long as the largest rock fragment is less than 50 percent of the total aggregate particle. These particles are considered crushed due to the angular nature of the sand grains or adhering concrete matrix.

To pick crushed material, inspect and separate the aggregate into piles. Separate the crushed from the uncrushed aggregate and place in separate piles using the criteria of one or more fractured faces, or two or more fractured faces according to the specifications.

**DELETERIOUS AND OBJECTIONABLE PARTICLES**

Deleterious means having a harmful effect. When deleterious particles are exposed to weathering, such as freezing and thawing, they weaken the product in which they are used.

Objectionable particles and particles found to be nondurable in service include aggregate particles which have harmful affects on the product in which they are used and are not covered by the list of deleterious particles. An example would be silty limestone which retains internal moisture through the HMA plant and prevents bonding of the asphalt. In addition, things such as large balls of clay or wood particles would also be classified as objectionable.

Read the specifications and Special Provisions before picking the deleterious and objectionable particles. At the present time, all types of deleterious particles are picked for Portland cement concrete. Be sure to check the Special Provisions for deleterious picks for Hot Mix Asphalt.

Before picking deleterious particles, rinse the material with clear water. This will remove any undesirable coatings on the
aggregate and help in the visual inspection. It is hard to determine an aggregate’s type or texture when it’s covered with a thin film of clay or silt. Picking deleterious particles is performed while the particles are wet. It is handy to have a water bottle or cup of water near to moisten particles that may become air dry.

Another handy tool is the rat tail file. It is used to check the hardness of the particles.

A hammer, steel block, safety ring and safety glasses will be required to break deleterious particles in question. Sometimes, looking at the exterior may not provide enough information as to the material’s identity. If it is necessary to break a particle, put on the safety glasses then place the rock on the steel block and place the safety ring around the rock. Give the rock a quick sharp blow. Examine the fresh fractured face.

**DELETERIOUS PARTICLES**

Many years ago, a gentleman named Friedrich Mohs developed a scale to determine the mineral hardness. He designated number one as the softest mineral and number ten as the hardest mineral. His ten reference minerals are:

1. Talc
2. Gypsum
3. Calcite
4. Fluorite
5. Apatite
6. Orthoclase
7. Quartz
8. Topaz
9. Corundum
10. Diamond

As a comparison, dolomite has a hardness of 3½ to 4, Pyrite (fool’s gold) a hardness of 6 to 6½, basalt (diabase) and chert 7. A copper penny has a value of 2½, a pocket knife 5 to 5½, window glass has 5½ to 6, and the rat tail file has a hardness of 6 to 6½.

Chert - Chert occurs in many aggregate sources and in a variety of colors. It also can vary in appearance from a dull to a vitreous (glassy) luster and in porosity from porous to dense. All chert is very hard with the exception of chalky chert.

The size of chert’s porosity makes it undesirable in Portland concrete cement. Chert has very small microscopic holes which hold water. When the water freezes it expands and physically expands the chert particle. This expansion is not elastic and leaves slightly large pores available to hold more water during the next freeze cycle. Repeated cycles will eventually create enough strain to break the rock particle and surrounding Portland cement concrete.

You may see chert particles in the following forms:

1. White, light gray to tan. These particles are generally light colored, porous, dull and, in general, have a low specific gravity. Chalky chert fits into this classification.

2. Mottled chert can be any combination of white, gray, black, tan or brown. There is no pattern to the color variation. One way to easily remember is to think of a herd of Holstein cows. No two have the exact same color markings. The porosity within these particles can vary greatly.

3. Vitreous (Glassy) Lustrous chert is generally a gray to black color. The particles look like broken glass and generally have a higher specific gravity and are darker in color. These also produce very sharp edges.

Physical characteristics to look for:

1. Chert will generally break with a conchoidal fracture (concave or dish shape).
2. A file may be used to mark the surface. Firmly pressing the file and drawing a solid line may indicate the aggregate is chert. Some other aggregates will be harder than the file, such as quartz, basalt and hard clay-ironstone centers.

3. Chert will scratch glass.

4. The surface will feel smooth if scratched with a fingernail.

5. If in doubt, break the particle.

If part of an aggregate particle is chert, then the whole aggregate is considered to be chert. This is often referred to as a nodule of chert. More information can be found in MTM 110.

The following aggregates are all considered soft materials. When picking, they are kept separate from the chert.

**Friable Sandstone** - Friable sandstone is distinguishable because individual sand grains **may be easily abraded** by rubbing the particle between the thumb and finger. This is because the individual sand grains are loosely cemented together. The grains in good, or non-friable, sandstones will not rub off.

**Siltstone** - These soft and very porous cemented silt particles range in color from white to a yellow-brown or tan in color. They have a powdery feel when dry and a slippery feel when wet. When dry, they quickly absorb water. They are softer than the file.

**Shale** - Shale particles vary from dark gray to black. They are generally soft, laminated in layers, and have an earthy texture. Some physical characteristics which aid in the identification are:

1. When damp, most shale will mark greenish-black to black on a canvas bag.

2. If rubbed with the end of a file, shale feels smooth. The mark on the surface will have a waxy appearance like writing with wax, crayon or grease pencil. You will not feel grains.

3. When scratched with a file, the groove left by the file will be a brownish black color.

4. When wet, shale generally has a dull appearance, compared to the other aggregates.

**Coal** - A natural dark-brown to black color, coal’s surface appearance ranges from dull to shiny. Coal can be from moderately soft to brittle and may have a laminated structure. If rubbed with the end of a file, the scratch will also have a waxy appearance.

**Structurally Weak** - These particles have a mixture of light and dark minerals. They can be either white and black or pink and black. They may be readily broken apart by the fingers of one hand.

**Ochre** - Ochre particles have an earthy texture, are extremely soft, porous, and vary from yellowish to brown and red in color. They leave a very distinct color streaks when rubbed on paper or hands.

**Clay-Ironstone** - Clay-ironstone has a separate specification limit. Make sure to check Table 902-2 for the limit applied to the class of aggregate being tested. Clay-ironstone is a siderite concretion derived from various shale formations. These particles are softer than the file, porous and can range from a yellowish-brown to dark brown, almost black in color. They are present in aggregates in the following four forms.

**Shells** - This is the relatively thin exterior cover that encases the center of the siderite formation. They generally have a smooth exterior and rough interior.
Thicker particles often display a laminated structure.

Centers - These particles form the irregularly shaped central portion of some siderite concretions. Some have hard exterior surfaces, while others have a thin, very soft, clay type surface covering a hard, dense center. If the center is impure or a stone center, the fragment may be as hard as a file. These particles are generally buff to brown on the surface with a dark gray to black interior. The surface will scratch brown while the interior will scratch white. In addition, the interior of a stone center will not have crystal grains.

Fossiliferous - These particles contain traces of fossil shells. Some particles are composed almost entirely of shell fragments.

Massive - These particles are generally structureless or may be very finely laminated.

WARNING: Some sandstone will contain iron. It will leave a brown color when rubbed on a cloth or hands, but it also leaves sand grains. This is sandstone.
ORGANIC IMPURITIES TEST (The Colorimetric Test)

This simple preliminary test determines the possible presence of organic compounds in Portland cement concrete sand. The test is done at the beginning of production and at regular intervals. The frequency of testing is at the discretion of the technician. However, if the producer opens a new or shifts to another area of the pit, the technician should run an organic test immediately.

For testing, the following laboratory equipment and supplies are needed:

- One graduated colorless glass bottle (prescription bottle) approximately 12 or 16 ounces (350 or 470 milliliters). According to ASTM C-40, the maximum outside thickness of the bottle shall be of oval design not less than 1½ inches (40 mm) and no greater than 2½ inches (60 mm) thick, measured along the line of sight.
- Dry sodium hydroxide pellets.
- A standard color glass reference chart.
- Distilled water.

The Department’s procedure states how to make a 3 percent solution of sodium hydroxide. The procedure is:

1. Completely dissolve 9 grams of sodium hydroxide pellets in a small amount of water.
2. Add enough water to make 300 cc of the solution.
3. Shake well.

Next, fill the 12 to 16 ounce clear glass bottle to the 4½ ounce line with the fine aggregate sample. Use the fine aggregate that is going to be mixed into the Portland concrete cement. Do not wash the fine aggregate for the test. The sand may be damp or air dried. Drying at high temperatures will “burn” or alter the organic particles in the fine sand and invalidate the test.

After adding sand to the bottle, add the 3 percent sodium hydroxide solution until the volume of sand and solution equals seven ounces after shaking. Seal the bottle, shake well, and let stand undisturbed for 24 hours.

After 24 hours, the liquid portion is compared against a light background to a glass color chart. If the color is less than three, the color nearest the color of the liquid is recorded as the “Organic Plate Number.”

The color plate, or standard glass reference, has five separate colors, from a light yellow to a dark brown. Light yellow is designated number one; dark brown is designated number five. A passing test that matches the colors one, two or three is accepted. Any test that is darker than color three is tentatively rejected pending further testing. A sample of the tentatively rejected sand will then be sent to the laboratory for further strength testing. If it passes the strength test, it will be approved for use.

ANGULARITY INDEX

The angularity index was developed to measure the interlocking ability of fine aggregates (sand). Fine aggregates are the major controlling factor in the amount of rutting and shoving seen in hot mix asphalt roads. Rutting is caused by vehicle wheel loads traveling over the same path on the road surfaces. Shoving is caused by vehicles stopping in the same location.

To illustrate the point, look at Figure 1. If you stack a pile of marbles, what happens
when you apply a downward force? It 
doesn’t take much pressure before the 
marbles start rolling.

![Figure 1: Marbles](image1)

If the pile was made up of irregular 
shapes, would the same pressure produce the 
same results? Look at Figure 2. Obviously, 
the particles will hold together under the same 
pressure.

![Figure 2: Irregular Shapes](image2)

The angularity index test must be 
performed in a vibration free area, not near an 
operating plant or when heavy equipment or 
trucks are operating nearby. This will cause 
false readings.

The test uses the fine aggregate that 
passes through the No. 8 sieve and is retained 
on the No. 30 sieve. The sample of fine 
aggregate is washed through the No. 30 sieve 
until clear. Sieve, wash and dry enough 
material to yield at least 750 grams of fine 
aggregate.

The test requires a glass or plastic 
graduated cylinder that has a capacity of 250 
ml, readable to the nearest 2 ml. The inside 
diameter will be 3.7 mm. The test also 
requires the use of distilled water and a 
funnel. The funnel is illustrated in Figure 3.

![Figure 3: Funnel](image3)

Fill three graduated cylinders to the 100 
ml mark with distilled water. Weigh three 
200 gram samples of the fine aggregate. 
Then, insert the funnel into the top of the 
graded cylinder to approximately 1 inch 
above the water. At a steady rate, pour the 
sand into the funnel while picking the funnel 
upward at the same time to keep it 
approximately 1 inch above the water at all 
times while pouring. The procedure should 
take less than ten seconds. This test is 
repeated three times.

Figure 4 at the top of the next page is a 
form that will help calculate the angularity 
index.

To complete the form:

1. Record the weight of the three fine 
aggregate samples at 200 g. each in 
*Weight of Sample*. 

---

66
2. The **Total Volume** is the measurement to the top of the water with the fine aggregate added.

3. The **Sample Volume** measurement is the height of the fine aggregate in the cylinder.

4. The **Volume Solids** is height of the water with the sand added less the 100 ml of water (Number (2) - 100).

5. This equals the **Sample Volume** (3) minus the **Volume Solids** (4).

6. The **Angularity Void Ratio** equals the **Volume Voids** (5) divided by the **Volume Solids** (4). This is reported to the hundredth 0.00.

Next, add the angularity void ratios and write this figure where it says **Total**. Divide the figure by three to obtain the **Average Void Ratio** (e,avg.). The “Angularity Index” is calculated by subtracting 0.6 from the e,avg. Then multiply the answer by 10. The resulting answer is reported to the tenth (0.0).

Each mixture of asphalt has its own criteria for the angularity index. Be sure to check all specifications for the type of asphalt being produced.

The calculated indexes start with the lowest acceptable number of 2.0 and increase. The larger the number, the more angular the sand. It may be possible to blend a low angularity sand with one of a higher angularity to meet the specific mixture’s production requirements.

**AGGREGATE WEAR INDEX**

Some types of aggregate particles polish (wear smooth) when exposed to high traffic volumes. This polishing can be measured in the field by using a friction trailer. The tow vehicle travels at 40 mile per hour. A signal is sent to the friction trailer to initiate a test. A spray bar shoots a jet of water onto the pavement ahead of one of the trailer’s tires. The tire then is locked and the resulting drag is measured. This value can then be computed into a coefficient of friction. Low coefficients of friction increase the stopping distance and makes it easier to skid. This is magnified when the pavement is wet.

Limestones are softer and tend to polish more rapidly, while granite is hard and resists polishing. Sandstone is polish-resistant because individual grains break off before they will polish leaving a sandpaper-like surface. Other rock types have polishing resistance between these extreme examples. The polishing resistance of each type of aggregate particle is determined to provide an Aggregate Wear Index (AWI). The AWI is a direct measure of the frictional resistance to a rubber tire sliding on a wet concrete slab with

<table>
<thead>
<tr>
<th>(1) Weight of Sample, g W</th>
<th>(2) Total Volume, ml Vt</th>
<th>(3) Sample Volume, ml Va</th>
<th>(4) Volume Solids, Vs =Vt - 100</th>
<th>(5) Volume Voids, Vv =Va - Vs</th>
<th>(6) Angularity Void Ratio E = Vv/Vs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AVG. V. RATIO e,avg. (Total/3)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Angularity Index 10* (e, avg. -0.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Figure 4: Angularity Computation Table*
the coarse aggregate exposed after it has been polished by four million passes of a test-tire in a special wear track, Figure 5.

An initial friction value is obtained using a Static Friction Tester Figure 6.

Each slab is tested every 500,000 wheel passes using the Static Friction Tester until 4 million wheel passes have been completed. Each friction value is plotted on a chart Figure 7. The AWI is calculated using the least-square best fit friction value for each sample at 4.0 million wheel passes.

Figure 6: Static Friction Tester

Figure 7: Typical Wear Track Polishing Curves

The AWI for natural gravel and blends of aggregates is calculated by petrographic composition using MTM 112, Figure 8.
These samples are submitted with bituminous mix designs. The Procedures Manual for Mix Design Processing outlines how these samples are submitted for testing.

**FREEZE-THAW TESTING**

Concrete pavement is observed to deteriorate due to freezing and thawing of water in some coarse aggregates. Freezing and thawing are the common terms used to describe the change in water from a liquid to a solid, and from a solid to a liquid.

Since aggregate particles are solid over the temperature range under consideration in this manual, it is the water absorbed into the aggregate particles which freezes and thaws, causing damage to the particle and surrounding concrete. If there is no water, there is no freezing and thawing. When water freezes, it expands by approximately 10 percent. The ability of aggregate particles to resist this freeze-thaw cyclic degradation is related to its porosity, permeability, absorption and pore structure. If there is adequate free space within the pore structure of the aggregate, the expansion is accommodated with no damage.

One way to predict the durability of aggregate under freeze-thaw conditions is to artificially accelerate the process in a controlled environment. This operation is completed using a freeze-thaw test apparatus shown in Figure 9.

Coarse aggregate samples are obtained and prepared for freeze-thaw testing in accordance with MTM 113. Generally, sources are sampled once every five years by the Department’s C & T Division or by regional aggregate technicians.

The procedure for making concrete beams to be tested in the freeze-thaw apparatus is described in MTM 114. The molds used to make the beams are illustrated in Figure 10.

Once the beams are cured, they are placed in the freeze-thaw chamber shown in Figure 11 and subjected to freeze-thaw cycles that alternately lowers and raises the temperature between zero and 40 degrees Fahrenheit.
Each cycle is three hours long. The test is completed after 300 cycles. The procedure for testing these concrete beams to evaluate their durability in rapid freezing and thawing, specifically for the evaluation of the coarse aggregate used in the concrete is described in MTM 115. The durability of the aggregate is measured as a length change or dilation (expansion) of the beam. The beam expansion is measured to the nearest thousandth of an inch using a length change comparator, Figure 12.

Freeze-thaw results are given as a percent dilation per 100 freeze-thaw cycles. Any concrete aggregate used by MDOT must have a freeze-thaw dilation less than or equal to 0.067 percent.

**SHRP TEST**

The Strategic Highway Research Program (Abbreviated SHRP, pronounced Sharp) was established by Congress during 1987 as a $150 million research program to improve the performance and durability of roads. Another purpose was to make the roads safer for the motorist and the highway workers. Over 130 products were developed as a result of this project including specifications, tests, and equipment.

In addition to the usual sieve analysis, Los Angeles Abrasion Test and the aggregate wear index used in Michigan, the experts generally agreed that the following properties should be measured:

- Coarse aggregate angularity
- Fine aggregate angularity
- Flat and elongated particles
- Clay content

A consensus on how to perform the tests has been attained. However, the interpretations of the test results have not been uniform among the states.

The first test is the Coarse Aggregate Angularity. This is simply picking the crushed from the uncrushed material retained on the No. 4 and larger sieves. Some of the picks require the aggregates to be sorted into piles of one face fractured, two faces fractured and an unfractured pile. The “weight” (mass) of the crushed material is divided by the “total weight” of the sorted aggregate.

The terminology is important when determining what constitutes a fractured face. The Department defines a fractured face as a broken surface constituting an area equal to at least 50 percent of the projected area of the particle as viewed perpendicular to the fractured face. The Federal Highway Administration Publication FHWA SA-95-003 has defined a fractured face as any
fractured surface that occupies more than 25 percent of the area of the outline of the aggregate particle visible in that orientation. This is a significant difference in the surface area of the fractured face.

**FINE AGGREGATE ANGULARITY**

The Fine Aggregate Angularity Test has been written as AASHTO TP 33 and ASTM C 1252 “Standard Tests Methods for Uncompacted Void Content of Fine Aggregate (as Influenced by Particle Shape, Surface Texture, and Grading).” The test measures the fine aggregate’s void content which is an indication of the particle angularity, roundness and surface texture.

All of the material is dry weight. Methods A and B are washed over the No. 100 sieve. The Bulk Dry Specific Gravity of the fine aggregate must be known. Test method A is recommended for Department Superpave™ projects.

The equipment needed to perform the test is shown in Figure 13.

The test procedure is simple. Place a finger over the small opening of the funnel from the bottom. Pour the fine aggregate into the Mason jar. Remove the finger and allow the fine aggregate to flow freely into the Nominal 100 ml Cylindrical Measure. When the cylinder is full and the stream of aggregate has stopped flowing, use a straight blade spatula to strike off the top of the cylindrical measure in one single pass. After striking off the excess fine aggregate, the cylindrical measure may be tapped lightly on the side. Remove the cylindrical measure with the contents and weigh to the nearest one tenth of a gram. Repeat the procedure twice and report the answer to the nearest tenth of a percent (0.1 percent).

![Figure 13: Fine Aggregate Angularity Test Apparatus](image)

**ASTM and AASHTO options for the Fine Aggregate Angularity Test**

<table>
<thead>
<tr>
<th>Individual Size Fractions</th>
<th>Test Method A</th>
<th>Test Method B</th>
<th>Test Method C</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.75 mm (No. 4)</td>
<td>190 g ± 1 g</td>
<td>190 g ± 1 g</td>
<td>190 g ± 1 g</td>
</tr>
<tr>
<td>2.36 mm (No. 8) to 1.18 mm (No. 16)</td>
<td>44 g</td>
<td>190 g ± 1 g</td>
<td></td>
</tr>
<tr>
<td>1.18 mm (No. 16) to 600 µm (No. 30)</td>
<td>57 g</td>
<td>190 g ± 1 g</td>
<td></td>
</tr>
<tr>
<td>600 µm (No. 30) to 300 µm (No. 50)</td>
<td>72 g</td>
<td>190 g ± 1 g</td>
<td></td>
</tr>
<tr>
<td>300 µm (No. 50) to 150 µm (No. 100)</td>
<td>17 g</td>
<td>Do not mix. Run three tests. Use all material passing the 4.74 mm sieve.</td>
<td></td>
</tr>
<tr>
<td>190 g ± 0.2 g Combined Total</td>
<td>Do not mix. Run three tests. Use all material passing the 4.74 mm sieve.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The formula for calculating the fine aggregate angularity is:

\[
U = \left( V - \frac{W}{G_{sb}} \right) \times 100\%
\]

Where:
- \( U \) = Aggregate Angularity
- \( V \) = Volume of cylindrical measure
- \( W \) = Mass (weight) of the fine aggregate
- \( G_{sb} \) = Dry aggregate bulk specific gravity

The larger the calculated number, the more angular the fine aggregate. See Table 2, page 32, for test requirements for Superpave™ asphalt mixtures.

**FLAT PARTICLES, ELONGATED PARTICLES, OR FLAT AND ELONGATED PARTICLES**

Test number three determines if the aggregate particles are flat and elongated (thin and elongated). This is ASTM D 4791 “Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Course Aggregate.” The material retained on the pick sieves is evaluated one particle at a time in an apparatus that compares the length of the particle to its thickness.

Aggregate particles with greater than a one to five ratio (length to thickness) are considered to be unacceptable for use in bituminous mixtures. See Table 6, page 33, for the maximum criteria. Aggregates used in concrete have a three to one aspect ratio. See Table 902-2, page 27, for aspect ratio and the maximum percent allowed by specification. These particles are considered undesirable in asphalt mixtures for two reasons. The first reason is they have a tendency to fracture during the paving operation and under traffic. The second reason is they make it more difficult to compact the asphalt and create large air voids. They are undesirable in the concrete mixtures because they create large air voids which generate weak areas in the concrete and make it more difficult to achieve a smooth finish.

Before starting the test, review the Contract Documents for Special Provisions, review the Standard Specifications and the appropriate ASTM and AASHTO publications to determine the size of sample and sieves to be picked.

One type of the Proportional Caliper Devices is shown in Figure 14. To use the device, take an aggregate particle and place it first with the longest dimension between the fixed post (A) and the swinging arm. Without moving the arm, remove the aggregate particle and turn it to its thinnest or flat side. Attempt to insert it without moving the swinging arm into the gap between post (B) and the swinging arm. If it fits between the swinging arm and post (B) the particle is considered flat and elongated. Repeat this process with each aggregate particle in the sample.

![Proportional Caliper Device](image)

**SAND EQUIVALENT TEST**

The fourth test is AASHTO T 176 or ASTM D 2419 “Plastic Fines in Graded Aggregates and Soils by use of the Sand Equivalent Test.” The test separates the clay like or plastic fines and dust from the fine aggregate (sand). A comparative reading is taken between the suspended clay and the settled sand in the measuring cylinder to
determine a ratio of the aggregate’s clay to sand content.

The procedure for the test is to pour 85 ml of the fine aggregate into a graduated cylinder. Add to this a mixture of distilled, demineralized or clear tap water and a flocculating agent (a mixture of calcium chloride, glycerin and formaldehyde). A rubber stopper is placed in the top of the graduated cylinder and then the graduated cylinder is shaken either with a mechanical shaker or by hand. An irrigation tube with a siphon tube attached to a container of the flocculating agent is then carefully prodded to the bottom of the graduated cylinder. Turn on the solution and agitate the fine aggregate as the irrigation tube is pulled upward filling the graduated cylinder to a prescribed level. Let it stand undisturbed for twenty minutes of settling. The heights of the sand and clay are measured in the cylinder.

The Sand Equivalent is calculated as follows:

\[
\text{Sand Equivalent} = \left( \frac{\text{Height of sand reading}}{\text{Height of clay reading}} \right) \times 100
\]

Cleaner fine aggregate will have a higher sand equivalent value. The minimum criterion of the sand equivalent is set according to traffic conditions.

**Figure 15: Sand Equivalent Test**

RESISTANCE TO DEGRADATION OF SMALL-SIZE COARSE AGGREGATE BY ABRASION AND IMPACT IN THE LOS ANGELES MACHINE

You will find the exact test procedures for operating the Los Angles machine in ASTM C-131 and AASHTO T-96. The Michigan Department of Transportation has altered the ASTM and AASHTO standard by issuing Michigan Test Method 102. This was done to provide additional standard gradations of aggregate, which more nearly conform to the coarse fraction of dense-graded aggregates and some coarse aggregates for bituminous mixtures used by the Michigan Department of Transportation.

To perform the test, prepare a sample that conforms closely to the aggregate’s size range specifications. Wash the sample unless it is essentially free of any adherent coatings and dust. The aggregate is dried and sieved into individual fractions.

Check the existing charts for the specifications on material re-blending prior to loading the sample into the machine. An example of method “B” is:

<table>
<thead>
<tr>
<th>Aggregate Sieve Sizes</th>
<th>Passing</th>
<th>Retained on</th>
<th>Weight in grams</th>
</tr>
</thead>
<tbody>
<tr>
<td>¼ in.</td>
<td>½ in.</td>
<td>2500 g ± 10</td>
<td></td>
</tr>
<tr>
<td>½ in.</td>
<td>⅜ in.</td>
<td>2500 g ± 10</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>5000 g ± 10</td>
<td></td>
</tr>
</tbody>
</table>

Load this properly prepared sample material into the machine.

The test method states to place a “charge” (steel spheres or steel ball bearings) into the machine. The test procedure states the steel spheres shall be approximately 1 27/32 in. in diameter and weigh from 309 to 445 grams each. Ball bearings that are 1 13/16 in. or 1 7/8 in. weigh between 400 to 440 grams each and meet this criteria. Test method “B” has a table that indicates 11 spheres are needed to perform the test.
Place and lock the cover on the machine. Turn on the machine which rotates 500 complete revolutions at the rate of 30 to 33 per minute. The machine has a counter and many have an automatic shut-off built in.

After turning the machine off, remove all of the aggregate and sieve it again. Sieve it over a No. 12 sieve. Weigh any material retained on the No. 12 and larger sieves. Subtract the amount retained on the sieves from the amount originally placed into the machine. Divide this figure by the weight of the material originally placed into the machine. The answer is recorded as a whole percent.

For the maximum criteria for the Los Angeles Abrasion see Table 902-2 and Table 4 for Superpave™ mixtures in Chapter 4.

A picture of the machine is shown in Figure 16.

![Figure 16: Los Angeles Machine](image)

**MOISTURE CONTENT**

Moisture becomes a very important variable in the technician’s work. Some company policies may require measuring moisture amounts at least once a day and some will require it several times a day. The amount of moisture must be known to properly batch a load of Portland cement concrete. The water cement ratio is one controlling factor determining strength. Moisture amounts enable proper calibration of the amount of asphalt being added to an asphalt mix. When the moisture increases, the computer operating the asphalt plant feeds the plant according to the pre-determined asphalt moisture content. When asphalt is added to dry aggregates it will develop a much better bond. The inverse relationship is also true. Knowing the moisture content helps produce consistent mixtures.

Moisture is also an important factor when determining the “optimum moisture content.” This is the moisture content in a soil at which a specific amount of compaction will produce maximum dry density. Another reason to calculate moisture content is for payment purposes. A reduction in payment may occur for excessive moisture.

All moisture determinations are based upon the dry weight of the aggregate. The formula for calculating moisture is:

$$ \text{Moisture} = \left( \frac{\text{Wet Weight} - \text{Dry Weight}}{\text{Dry Weight}} \right) \times 100 \%$$

Two common examples of methods for calculating moisture percentages are illustrated. The first method includes the weight of the pan.

1) Weight of empty pan 1,447.8 g
2) Weight of wet sample and pan 4,080.2 g
3) Weight of dry sample and pan 3,946.1 g
Loss of weight after drying (2-3) 134.1 g
Weight of dry sample (3-1) 2,498.3 g

$$ \left( \frac{4,080.2 - 3,946.1}{3,946.1 - 1,447.8} \right) = \left( \frac{134.1}{2,498.3} \right) \times 100 \% = 5.4\%$$

Example 2: The second method has a pan tared to a set of scales just to weigh in. This way, the material is weighed wet and dried. Subtract the dry weight from the wet weight to determine the amount of moisture. Divide the moisture amount by the dry weight and multiply the answer by 100 to determine the moisture.
<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Wet weight</td>
<td>2,634.2 g</td>
</tr>
<tr>
<td>(2) Less dry weight</td>
<td>2,498.3 g</td>
</tr>
<tr>
<td>Amount of moisture. (1-2)</td>
<td>1,34.1 g</td>
</tr>
</tbody>
</table>

The calculation looks the same:

$$\left( \frac{134.1}{2,498.3} \right) \times 100 = 5.4\%$$

The amount of moisture is generally reported to the tenth. This way it can be easily calibrated to the asphalt and concrete plant controls.
REFERENCES


2. American Society for Testing and Materials, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959. Telephone: 610.832.9585 Website: www.astm.org


4. Michigan Department of Transportation’s Website: http://www.mdot.state.mi.us/contractors/