Michigan Department of Transportation

PROCEDURES FOR AGGREGATE INSPECTION

2025
Construction Field Services Division
Aggregate Quality Unit

Updated: March 2025

MDOT

Michigan Department of Transportation

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Engineering Manual Preamble

This manual provides guidance to administrative, engineering, and technical staff. Engineering practice requires that professionals use a combination of technical skills and judgment in decision making. Engineering judgment is necessary to allow decisions to account for unique site-specific conditions and considerations to provide high quality products, within budget, and to protect the public health, safety, and welfare. This manual provides the general guidelines for aggregate control operations for the Michigan Department of Transportation (MDOT). However, it is understood that adaptation, adjustments, and deviations are sometimes necessary. Innovation is a key foundational element to advance the state of engineering practice and develop more effective and efficient engineering solutions and materials. As such, it is essential that our engineering manuals provide a vehicle to promote, pilot, or implement technologies or practices that provide efficiencies and quality products, while maintaining the safety, health, and welfare of the public. It is expected when making significant or impactful deviations from the technical information contained in these guidance materials, that reasonable consultations with experts, technical committees, and/or policy setting bodies occur prior to actions within the timeframes allowed. It is also expected that these consultations will eliminate any potential conflicts of interest, perceived or otherwise. MDOT Leadership is committed to a culture of innovation to optimize engineering solutions.

The National Society of Professional Engineers Code of Ethics for Engineering is founded on six fundamental canons. Those canons are provided below.

Engineers, in the fulfillment of their professional duties, shall:

1. Hold paramount the safety, health, and welfare of the public.
2. Perform Services only in areas of their competence.
3. Issue public statement only in an objective and truthful manner.
4. Act for each employer or client as faithful agents or trustees.
5. Avoid deceptive acts.
6. Conduct themselves honorably, reasonably, ethically, and lawfully to enhance the honor, reputation, and usefulness of the profession.

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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). Adherence to the procedures contained herein will ensure that tests performed by numerous individuals on the same stockpile of aggregate material will be in close agreement. This, in turn, will promote uniformity and alignment for the large number of testing laboratories providing aggregate testing services to MDOT construction projects.

The professionals providing aggregate inspection are typically MDOT employees or consultants under contract with MDOT, and they act as the authorized representative of MDOT during aggregate evaluations. It is the duty of all staff performing aggregate tests and inspection to study and understand 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 testing and inspection duties. Personnel performing aggregate sampling and testing for State or Federally funded projects are to be certified aggregate technicians and must pass a Michigan Certified Aggregate Technician (MCAT) training course at the level appropriate for the acceptance work being performed. Some aggregate application examples with required minimum MCAT certification levels are listed below:

- *Granular Fill (Level 1)*
- *Sand Subbase (Level 1)*
- *Aggregate Base (Level 1)*
- *Advanced Aggregate Physical Properties Tests (Level 2)*
- *Optimized Aggregate Gradation Control (Level 1)*
- *Aggregate Sampling (Sampling-Only Certification)*

The American Association of State Highway and Transportation Officials (AASHTO), the American Society for Testing and Materials (ASTM), and MDOT publish many aggregate related standards. Other federal, state, and local governmental agencies, and individual companies also develop their own standards. These agencies may adopt major published standards, or parts of published standards, modify them and rename them as a local test method. The Michigan Test Methods (MTM's) can either be stand alone or can include modifications to other common test methods. Therefore, it is important to know which testing standards are being used for a project or evaluation.

Some federal and state agencies have adopted quality initiative programs such as Quality Control - Quality Assurance (QC/QA), Total Quality Management (TQM), or ISO-9000:2000 (International Organization for Standardization) programs. To be successful these quality initiatives require active leadership and participation in the quality process by all members of the organization. A commitment to training is typically a major component of these programs. MDOT laboratories and industry laboratories performing quality control and quality assurance testing are required to meet certain training and material tracking requirements. Quality control is more than a product shipped or a service provided. Quality control and continuous improvement are a mindset necessary for success in the aggregate supply and construction industries and must be applied to customer relations, product production, laboratory evaluations, test procedures, and product documentation from source to point of use.

MDOT and aggregate suppliers each test aggregates during a construction project. In general, the MDOT 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.

One of the greatest challenges an aggregate professional may face is creating good communication**.** The technician and/or engineer responsible for the laboratory and testing must know and understand how to use the applicable quality control and testing standards. Individuals might interpret the written procedures differently when it comes to performing a specific procedure. Arguments can develop about a standard's correct interpretation and whether a procedure is being carried out correctly. The Standards agencies revise and update the standards and specifications over time to address these issues. Be prepared to adapt to new technologies and requirements.

The MDOT has its own unique way of contracting construction work for the highway system. Figure 1 shows the names for key types of construction documents used in construction contracts, and their order of precedence within MDOT construction contracts, with the top listing taking precedence over those below.

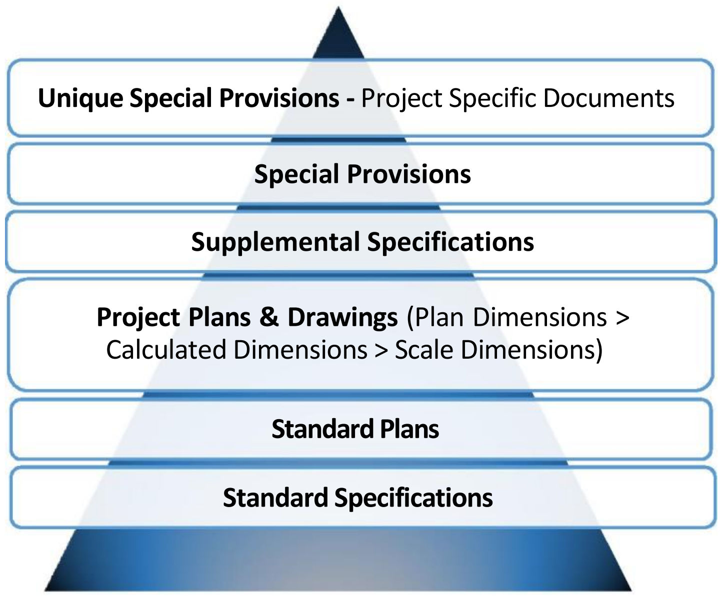


Figure 1. Order of precedence for contract documents in construction projects.

Closely examine the MDOT construction contract proposal for aggregate related special provisions and be aware of MDOT's published supplemental specifications related to aggregates. Special Provisions generally deal with how to perform special procedures and may also alter standard aggregate material specifications or introduce new unique special aggregate materials on a project specific basis. Supplemental Specifications are typically modifications or additions to the MDOT Standard Specifications for Construction.

It is recommended that before aggregate production starts for a new source, or before aggregate delivery for a construction project, schedule a meeting to discuss expectations for aggregate materials, such as sampling procedures and locations, and the required intervals/frequencies for test procedures. Work through the first procedures together and be sure to reach an agreement on how inspection(s) will be done.

DEFINITIONS

Aggregate – A produced product having a specified range of physical and gradation properties created by manipulation of source material through a processing operation. Engineered aggregate materials used by MDOT typically come from natural mixed sand and gravel deposits, natural quarried bedrock, industrial byproduct slag from steel mills or copper refineries, excavated natural rock from mining operations, or recycled crushed concrete.

AASHTO Accredited Lab – A laboratory that has a current Certificate of Accreditation from the AASHTO Accreditation Program (AAP) for the required aggregate testing procedures and equipment. The scope of the laboratory accreditation will include evaluation for Aggregate Testing as described for the directory of accredited laboratories on the AASHTO *re:source* website (formerly known as AMRL).

Acceptance Tests – Tests conducted on produced material for acceptance or rejection. These tests may be conducted any time or on samples obtained at any point in the supply chain for an aggregate including where the aggregate is incorporated into the finished work. These tests include MDOT's official construction project level Quality Assurance (QA) testing.

Aggregate Source Inventory (ASI) Number – Any natural geologic source, slag furnace source, recycled aggregate source, or redistribution point seeking to stockpile and provide aggregate materials for MDOT projects must first establish an official ASI number. The Department uses the ASI number to track the material from its creation location to its point of use in a project.

Capital Preventative Maintenance (CPM) Aggregates – Aggregates used for MDOT's pavement surface treatments program including chip seals, slurry seals, and micro-surfacing, that have detailed gradation and physical properties requirements.

Coarse Aggregates – These aggregates are used primarily for concrete mixtures and typically have particle sizes smaller than 3 inches (75 mm) in diameter and contain negligible amounts of material smaller than the No. 4 sieve (4.75 mm) or sand-sized material. The highest quality coarse aggregates are used in Portland cement concrete and Hot Mix Asphalt (HMA) pavements and have detailed physical properties requirements.

Construction Field Services (CFS) – The Michigan Department of Transportation's Construction Field Services Division is the central office team that contains MDOT's Aggregate Quality Unit. The CFS Aggregate Quality Unit focuses on the prequalification program for aggregate suppliers, statewide aggregate supply issues, the tracking of source physical properties, and geologic testing and research.

Controlling Region – The name of the MDOT Region where the aggregate source or redistribution point is located. Controlling Region staff are focused on evaluation of aggregates for construction projects and they visit aggregate source sites frequently for sampling of products.

Crushed Concrete Recycling Yard – A mobile or stationary crusher site location that recycles existing concrete into aggregate products and is responsible for the quality control of the final product(s).

Crushed Portland Cement Concrete Aggregates – Aggregates obtained by crushing salvaged Portland Cement Concrete (PCC). Aggregate products meeting MDOT requirements for coarse, dense-graded, and open-graded aggregates can be manufactured from salvaged PCC.

Crushed Stone – Aggregates that are derived from the mechanical crushing and sorting of quarried or excavated rock and characterized by particles with sharp edges and fractured faces.

Dense-Graded Aggregates – These aggregates are used primarily as aggregate base support for pavements and shoulder gravel and are typically composed of rock fragments smaller than $1^1/_2$ inches (37.5 mm) in diameter, with a wide range of particle sizes (uniformly graded) down to smaller than the No. 200 sieve (0.075 mm) or silt and clay sized material. When properly produced, these aggregates can achieve high density, stiffness, and stability.

Fine Aggregates – These aggregates are composed of rock fragments smaller than the No. 4 sieve (4.75 mm) and with only small amounts allowed that are smaller than the No. 200 sieve (0.075 mm). Fine Aggregate is generally used as mortar sand, concrete sand for PCC, and filler sand for HMA mixtures.

Granular Materials – These aggregates consist of primarily sand sized material and allow higher amounts of silt and clay, or particles smaller than the No. 200 sieve (0.075 mm). Granular material is used primarily as non-cohesive embankment and fill material.

Independent Assurance Tests (IAT) – Tests conducted to evaluate a technician's sampling and testing procedures and the condition of their testing equipment. The official IAT sample is typically 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 Test will be completed and compared to the results of the comparison test. These samples may be submitted to the Construction Field Services Aggregate Lab for further processing if the inspector deems the test equipment to be deficient.

Information Tests – This is a general laboratory classification for tests performed that are not a part of a construction project testing database being used as a basis for acceptance or rejection of aggregate materials. This test type is commonly used for preliminary screening of aggregate sources for fundamental physical properties and for evaluation of in-place aggregate base, subbase, and fill materials for possible reuse. When managing a stockpile or aggregate placement for a construction project, if a technician feels that an aggregate material source has changed substantially, or suspects an aggregate's quality in general, the technician may perform supplemental Information-Only Tests to guide the aggregate evaluation process.

Intermediate Aggregate – These aggregates are typically smaller than the $^1/_2$ -inch sieve and larger than the No. 4 sieve. This aggregate category is typically used in production of optimized aggregate blends for use in HMA and PCC mixtures.

Michigan Certified Aggregate Technician (MCAT) – Qualified aggregate technicians are to possess a current certification with the appropriate level for the material series/class that is being tested (Sampling-Only certification is available, Level One certification required for Dense-Graded, Fine, and Open-Graded Aggregates, Level Two certification required for advanced physical properties characterizations for aggregates).

Natural Gravel – These aggregates are found naturally in sand and gravel pits situated in glacial river spillways, glacial outwash, and glacial till deposits, and are derived from many types of rock fragments that may be rounded, naturally crushed, or a combination of both. These deposits may be found either above or below the water table and are present above bedrock formations. Gravel aggregates consist predominantly of particles larger than sand, the No. 4 sieve (4.75 mm), but smaller than cobbles, or 3 inches (76 mm) in diameter.

Natural Sand – Naturally broken down, aged, deposited and sorted rock fragments or detrital particles derived from the chemical and/or physical disintegration of rocks as part of the natural weathering process and consisting predominantly of particles smaller than gravel, the No. 4 sieve (4.75 mm) and larger than silt and clay, or the No. 200 sieve (0.075 mm).

Open-Graded Aggregates – Open-graded aggregates are typically used as drainable base material immediately below Portland cement concrete or HMA pavements, or as peastone in trench-drain or under-drain systems. Open-graded aggregates are typically gap-graded to create larger void space for higher permeability, and contain only small amounts of material finer than the No. 200 sieve (0.075 mm). Recycled crushed concrete and crushed slag can be used as open-graded aggregate for some applications.

On-Site and Pre-Existing Material – Some jobs/projects call for re-use of existing material that had been incorporated into a previous job or use of natural deposits that are within the right-of-way. Prior job acceptance of material does not waive the ability or need for current acceptance testing when the existing material must meet a new specification. Much can happen to the material in the intervening time, including but not limited to compaction degradation and erosion of fines (silt and clay) into or out of the material.

Optimized Aggregate Blend – A processed and optimized mixture of coarse intermediate and fine aggregate sources blended at specific ratios to obtain a densely packed optimized gradation with reduced void space between aggregates. Optimized aggregate blends are described in section 902.03 in the *Standard Specifications for Construction* or may be custom, called out in a special provision within a contract.

Quality Assurance (QA) Tests – These are tests run by the owner (MDOT in this case) or owner's representative to verify materials meet the specification requirements for a construction project. The required minimum QA test frequency is dependent upon the type of aggregate product being evaluated and the performance history of the aggregate source.

Quality Control (QC) Tests – These are tests run by a material supplier for their own information and used to control the quality of material being produced, including testing contracted by the supplier to a qualified testing lab. The frequency of testing is dependent upon the uniformity of the production operation and is stated in the supplier's approved quality control plan.

Quarried Carbonate – This aggregate type typically consists of mined limestone, dolomite sedimentary, or meta-sedimentary rocks that are common around the lower penninsula of Michigan.

Redistribution Point – A location that stores aggregate material for redistribution, such as a shipping dock or yard that is not the original geologic/geographic source ASI site for an aggregate product. When acceptance testing is run on aggregate material that is placed in a redistribution point, the ASI number used on the test results will correspond to the origin source for the material.

Slag Aggregates – Aggregates produced as a byproduct of the refining operations that turn iron and copper ore into refined metals. The raw slag product includes Steel Furnace Slag, Blast Furnace Slag, and Reverberatory Slag. The raw slag can be crushed, washed, and sorted into various sizes for aggregate products.

Source (Origin) – The geographic location where the aggregate is produced by the excavation, sorting, and crushing processes. This is considered the geologic or initial place of origin for the material and is the map location the ASI number is assigned to. Natural aggregates always have the source ASI connected to where they were geologically deposited.

Stamp Sand – A fine aggregate that is the result of a stamp-mill crushing operation. This aggregate is typically composed of hard, durable particles, uniformly graded in size, and consists predominantly of particles smaller than the No. 4 sieve (4.75 mm). Some mining stamp sand parent material can be chemically reactive and can generate undesirable leachates.

Stone Sand – A fine aggregate produced from the quarried rock crushing process, which is uniformly graded and consists predominantly of particles smaller than the No. 4 sieve (4.75 mm). Stone sands consist of sharp crushed particles and can be more chemically reactive and softer than natural sands. This is because sharp rock crusher fines have not experienced natural aging and weathering like naturally broken-down sands, which tend to have harder and more rounded particles.

Supplier – An aggregate producer or dock or yard having ownership of the material.

Using Region – The MDOT Region where the construction project using an aggregate is located.

Warning Band – The upper and lower mechanical analysis specification limits specific to the MDOT aggregate series/class being tested.

HEALTH AND SAFETY

It is the technician’s responsibility to make sure their personal protective equipment meets current Michigan and Federal Occupational Health and Safety Administration standards. Prior to entering a construction zone, processing area, pit, or quarry, make sure you have all the necessary personal protective equipment. This equipment may include but is not limited to steel-toed work boots, reflective vest or clothing, hard hat, safety glasses, hearing, and dust protection.
When entering a construction zone, processing area, pit, or quarry, check in with the person in charge of the operation. Do not 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. Most quarries or pit operations require specific safety training on a yearly basis for both employees and visitors that must be completed prior to being allowed on-site.

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

Experts generally agree that sound levels below 80 decibels (dB) are considered 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 workday can cause permanent hearing loss over time.

Repetitive activities or awkward postures can cause cumulative damage 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. Field samples of aggregate can exceed 50 pounds in weight and many sample bags may need to be transferred from the ground to the bed of a truck, please plan accordingly. Maintain the necessary level of fitness to perform aggregate sampling and testing tasks.

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 when working.

CHAPTER 2 – SAMPLING PROCEDURES AND EQUIPMENT

Sampling for acceptance by MDOT can be done anywhere along the supply chain, from the production site (quarry site, sand and gravel source, etc.) to where it is incorporated in the finished product. The justification for this is found in the MDOT Standard Specifications for Construction under Division 1, General Provisions, Section 105.05 Approval of Materials Incorporated into the Work. 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. No matter how much planning is put into acquiring a sample, the effort is wasted if the sample does not truly represent the approximate average condition of the material stockpile. Discard any non-representative samples. Managing segregation of aggregates is key to success in aggregate operations. If you sample on the grade in obvious coarse or fine segregated areas the test results will likely not be representative of the stockpile created by a producer.

MDOT requires that aggregate supply stockpiles be tested at specified intervals during use, such as "1 test for every 10,000 tons" of aggregate material used from a stockpile. Different testing rates are required for different products depending generally on how critical the application is. For example, high performance concrete aggregates are tested more frequently than general soil fill aggregate materials.

MDOT allows less frequent testing for well-established (registered and prequalified) aggregate sources and suppliers. The minimum acceptance testing sampling frequencies for suppliers or sources is described more in the next chapter under the MDOT Aggregate Supplier Program discussion regarding prequalified and non-prequalified aggregate sources (see figure 32). In addition, contract special provisions may be present in construction contracts that can change materials, testing requirements, and the required minimum sample frequency during use of an aggregate stockpile.

FIELD SAMPLE SIZE

Care must be taken to make sure enough aggregate is obtained during a sampling visit to adequately perform all the required tests being done for an aggregate evaluation. MTM 107 - Sampling Aggregates, provides guidelines for minimum aggregate field sample sizes as summarized below.

- **Fine aggregates and Granular Material Class IIIA** for independent assurance or acceptance test - approximately 25 lbs. (11 kg) which equates to roughly one half of a standard canvas sample bag.

- **Coarse, Dense-Graded, Open-Graded aggregates and Granular Materials** (except Class IIIA) for independent assurance or acceptance test - approximately 50 lbs. (25 kg) which equates to one full standard canvas sample bag.

- Aggregates for **L.A. Abrasion** test and **Micro-Deval** (as produced) - approximately 120 lbs. (50 kg) which equates to two full standard canvas sample bags.

- Aggregates for **Concrete Mix Design** - approximately 60 lbs. (25 kg) which equates to one full standard canvas sample bag.

- ***For both abrasion and mix design** - approximately 120 lbs. (50 kg) which equates to two full standard canvas sample bags.

ASTM and AASHTO standards also have guidelines for the minimum field sample sizes for laboratory testing based on the nominal maximum 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 contracts may have different requirements. Eliminate the need for a revisit to a site, and delay to your aggregate evaluation by making sure you have obtained enough material during your initial visit.

SAMPLING FREQUENCY FOR SPECIALTY TESTING AT CFS LABORATORIES

The following summarizes the MDOT minimum required testing frequency for some key aggregate physical property tests that are required for source approval for use on state and federally funded construction projects.

Los Angeles (LA) Abrasion (AASHTO T 96 and Michigan Test Method 102) – Sources furnishing dense-graded, open-graded, and coarse aggregates must have an initial passing LA Abrasion test as part of qualification checks, and then must continue to have passing LA Abrasion tests recorded at intervals of five years or less. More frequent testing is required for the following applications.

- *Bituminous mixtures - if the current LA Abrasion value for a source is greater than 35 percent loss, verify passing LA Abrasion tests at 1-year intervals for that source.*

- *Crushed concrete sources - verify passing LA Abrasion tests at 1-year intervals, or when the aggregate QA technician considers a new representative test necessary due to a change in source concrete.*

Insoluble Residue (MTM 103) – Quarried carbonate limestone and dolomite sources furnishing aggregates for dense-graded aggregate and bituminous mixtures must have a minimum one insoluble residue test conducted every five years by MDOT CFS or an approved testing laboratory, or whenever there is a change in the deposit.

Wear Track - Aggregate Wear Index (MTM 111) – Quarried carbonate, igneous/metamorphic sources, and slag sources furnishing aggregates for HMA mixtures, CPM aggregates or high-friction special provision materials must have a minimum of one AWI wear track polishing test conducted approximately every five years. New tests are warranted if major changes in deposit occur.

Freeze-Thaw Durability Testing – Sources furnishing coarse aggregate for Portland cement concrete must be evaluated for freeze-thaw durability once every five years. The test procedure is described in MTM's 113, 114, and 115. New tests are warranted and should be requested if there are major changes in the deposit or production method. If the relative density oven-dried (bulk dry specific gravity) of the sample being evaluated for a concrete mixture is more than 0.04 units less than the bulk specific gravity reported within the most recent official freeze-thaw sample, or if change in another physical property such as the deleterious content is significant, the aggregate will be considered to have changed characteristics. The source may then be required to have a new freeze-thaw test conducted prior to continued use on Department projects. The aggregate producer may also request additional freeze-thaw testing if their current freeze-thaw test result on record is border-line relative to potential high-quality applications, but only if there is an indication that the characteristics have improved sufficiently to warrant a new test. Specific Gravity testing of sources is to be performed approximately yearly in the intervening years to confirm results are within 0.04 units of the material tested for official freeze-thaw durability evaluations by the State.

SAMPLING TOOLS

Some common field sampling tools are:

Figure 2: Canvas bags, plastic or steel pails capable of holding approximately sixty pounds

Figure 3: Square point shovels (round point shovels are not allowed)

Figure 4: Square nosed scoops

Figure 5: A sample thief made from $1^1/_2$ to 2 inch diameter by approximately 30 inches long thin wall electrical conduit to sample fine aggregates (sand) only

Figure 6: 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

Become familiar with MTM 107, which 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 geotextile separator is used be careful not to tear or punch a hole in it.

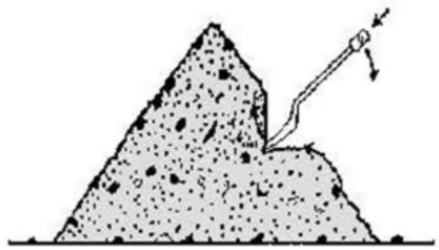


Figure 7: Shovel Taking Sample

As illustrated in Figure 7, 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 8 illustrates a typical random sample pattern over 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 7 prior to obtaining your sample increment.

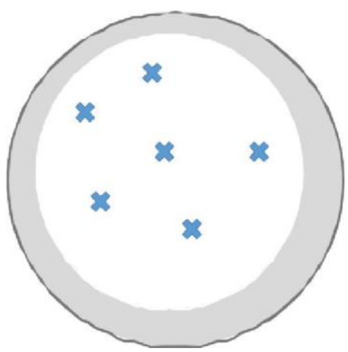


Figure 8: Top View Sample Pattern for a “Mini” Stockpile after Back Blading

The three areas back-bladed in Figure 9 are arranged from 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 9 shows six randomly selected sample increment locations. 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.

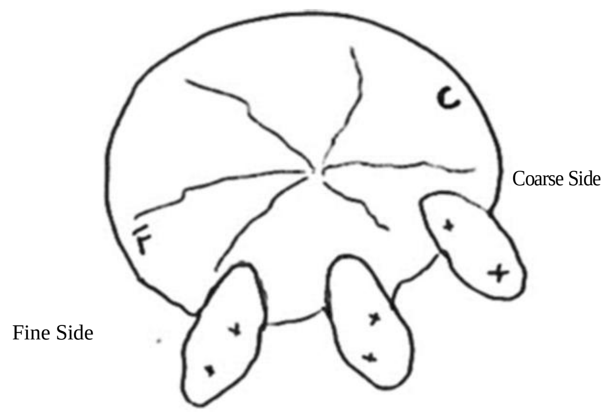


Figure 9: Top View Back Blading Sampling Method

A “sample thief” tube may be used for sampling 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, taking care to remove any material stuck to the outside of the tube before emptying into your sample bag. Continue this process at random locations until you obtain the proper field sample size. A sample thief about to be inserted into a stockpile is illustrated in Figure 10.

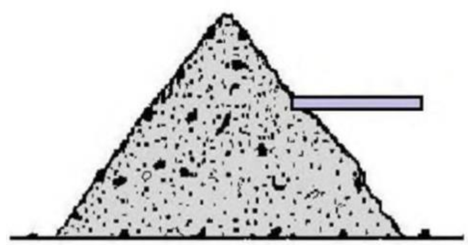


Figure 10: Thief Taking Sample

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 particles 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, then turn the auger until it reaches sufficient depth to obtain a sample increment. Empty the auger into a sample container. Repeat the procedure in random locations to obtain a representative field sample.

If the dumps have been prepared for the next layer, use the sample pattern for bottom dump earthmovers and there is no need to remove material before auguring into the surface of the stockpile. With truck-built stockpiles, the layers of material are two to four feet deep. Bottom dump earthmovers 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 each and every time they are handled**. Managing segregation is a key to success in aggregate operations.

Conveyors carrying material to the stockpiles vibrate causing the fine material to separate and settle to the bottom, as illustrated in Figure 11. Also, the distance between the rollers and the length of the conveyor system affects aggregate separation or segregation.

Figure 11: 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 when blending the crushed oversize stone back with the fine material. Usually, the operator deposits the over-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 be placed in stockpiles, bins, trucks, or bottom dump earthmovers without any correction, segregation can become a major problem. The material's gradation will not be consistent. The stockpile may segregate like that shown in Figure 12 with the fine material falling towards the conveyor and the coarse material falling away from the conveyor.

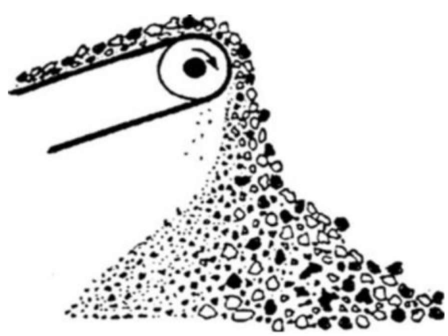


Figure 12: Conveyor Dumping on Ground without a Baffle Feature

Placing baffles and other mechanical devices in the ends of conveyors can help control segregation problems. A typical mechanical device is illustrated in Figure 13.

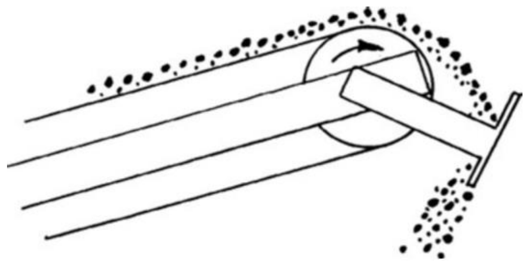


Figure 13: Conveyor with Baffle

Before taking the sample, view the operation to observe how the material flows 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 can be loaded and may fail testing, causing problems. This is illustrated in Figure 14.

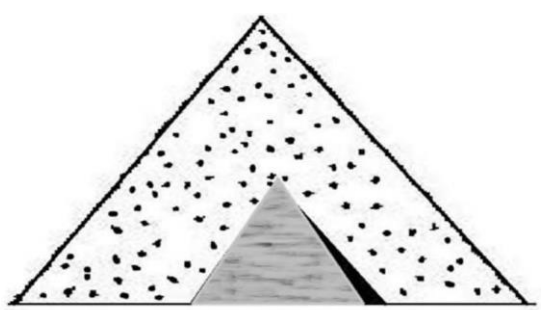


Figure 14: "Contaminated" Core of any Stacker Built Stockpile

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 removed and washed again.

OTHER SOURCES OF CONTAMINATION

When using earthmovers or dump trucks for stockpiling aggregate, the equipment's tires can carry undesirable material from the pit or quarry floor up on the stockpile causing contamination, especially after 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.

When aggregate piles are manipulated while frozen, the finer particles can freeze to the larger particles, rendering standard stockpile management practices unsatisfactory. They cannot be mixed adequately and "breaking" into a pile by removing frozen outer material can significantly change the gradation of material.

Contamination of crushed concrete is anything that is not crushed concrete, examples are brick, shingles, HMA coated particles, and household construction debris.

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 3 approximately equal increments be sampled from the stopped conveyor belt to obtain a representative sample. To do this, you will need 2 templates formed to the conveyor curvature as illustrated in Figure 15.

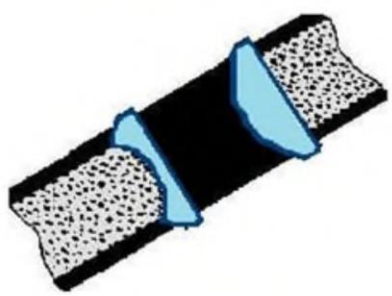


Figure 15: Conveyor with Inserted Templates for Sampling

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 remaining 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 16.

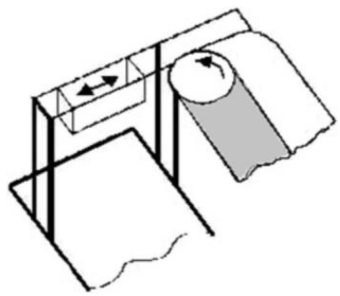


Figure 16: Mechanical Sampling Device

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 3 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 17. 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.

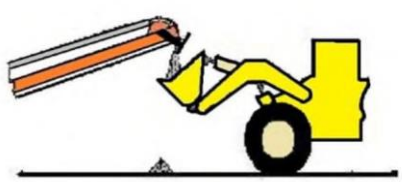


Figure 17: Conveyor Dumping into Loader

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 18. If not, a belt sample must be taken.

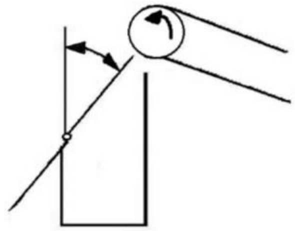


Figure 18: Sampling Device

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 6 sites and distribute them according to the stockpile's volumetric proportions. Figure 19 represents a typical cone shaped stockpile.

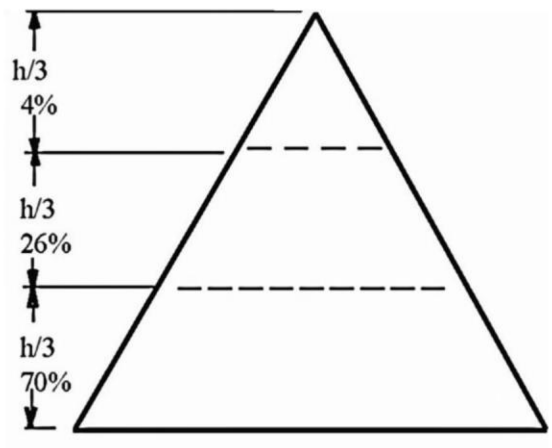


Figure 19: Cone Stockpile Proportion

If 10 sample increments are collected to form the composite field sample, 7 would be from the bottom third of the stockpile and 3 from the middle third of the stockpile. Since the top third only contains four 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 6 sites are sufficient, the distribution would be 4 from the bottom third, 2 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 20.

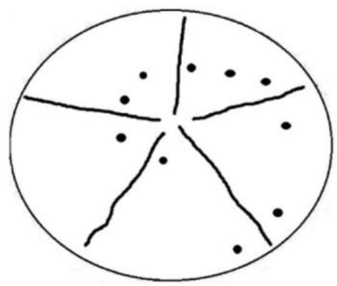


Figure 20: Top View of Cone Stockpile

If the stockpile has a shipping face, the sample pattern may be similar to Figure 21.

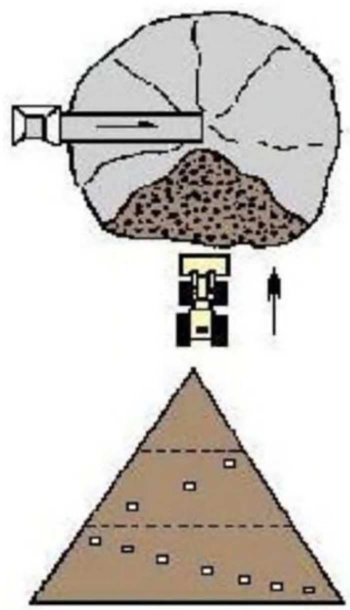


Figure 21: Sampling from Cone Shaped Stockpile with Loading Face

Notice that the material being loaded in figure 21 is loaded at right angles to the aggregate's deposition flow. If segregated, loading in this manner will help prevent all the coarse or fine material from being loaded first.

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, as shown in Figure 22.

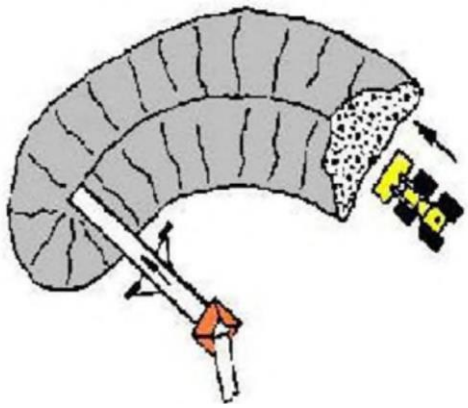


Figure 22: Loader Removing Material from End of Stockpile

There are 4 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 23.

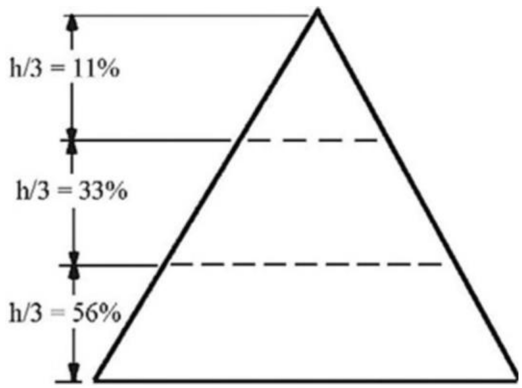


Figure 23: Radial Stacker Stockpile Proportions

The technician may want to obtain the sample sites from a radial stockpile as illustrated in Figure 24.

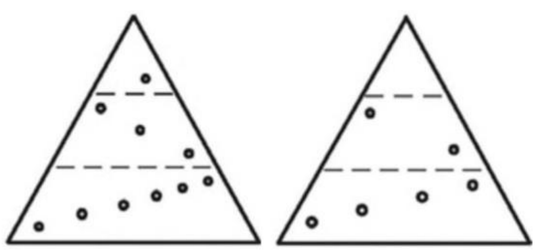


Figure 24: Typical Sample Patterns – The left shows distribution of sampling sites through the stockpile if 10 sample points are taken from a radial stacker stockpile. The right shows distribution of sampling sites through the stockpile if 6 sample points are taken.

The second method can be used prior to shipping. 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 25. Repeat this procedure at least 3 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.

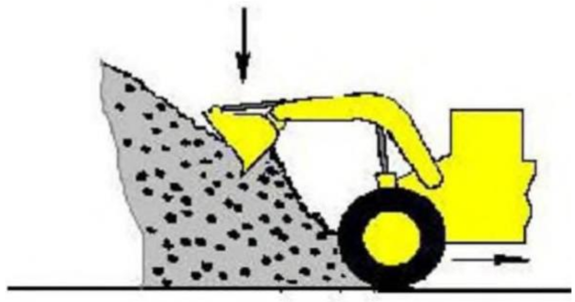


Figure 25: Front End Loader Backing Away

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 3 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 flattened 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 backbladed to create a large flattened 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 26.

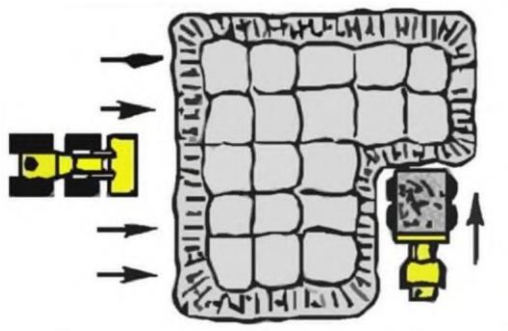


Figure 26: Truck Built Stockpile

Obtain aggregate sample 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 27. Use a sufficient number of sample sites to obtain a representative sample.

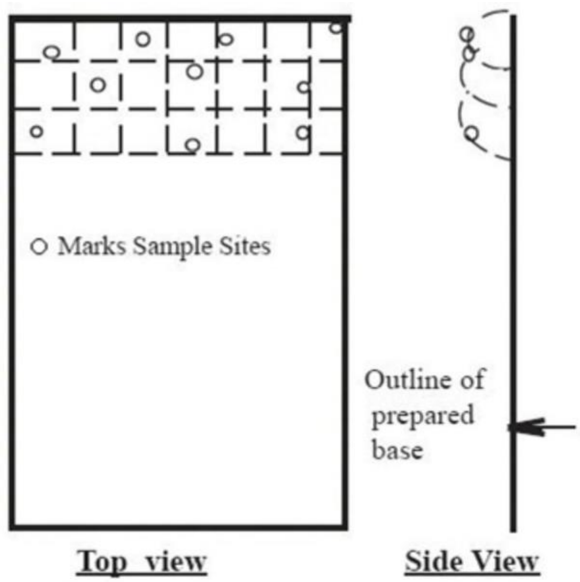


Figure 27: Truck Dump, Front End Loader, or Dumpster Stockpile

Another way to sample a truck-built stockpile is to obtain the sample increments from the flattened top of the previous layer. The technician may take a sample diagonally across the top of the pile as shown in Figure 28 or use a random number process to obtain sample locations.

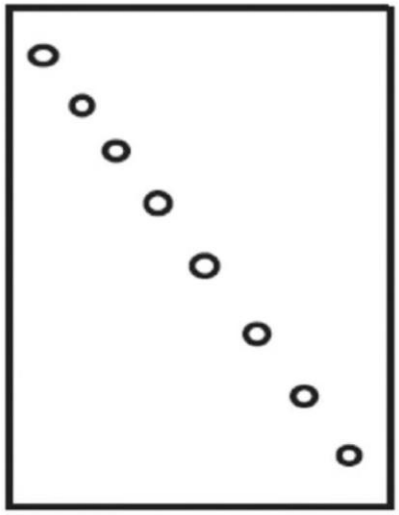
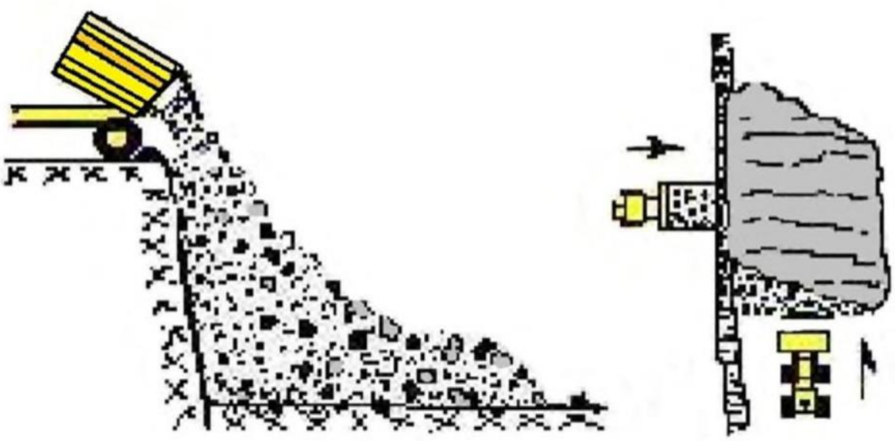


Figure 28: Diagonal Sample Pattern - Top View

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 reduce segregation.

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 tend to roll down the outside, accumulating at the base of the stockpile, as shown in Figure 29. The best solution for sampling aggregate stockpiles in this manner is to construct a "mini" stockpile.



Side View Top View

Figure 29: Aggregate Dumped Over Wall

BOTTOM DUMP OR EARTHMOVER BUILT STOCKPILES

Bottom dump earthmovers 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 during dumping will reduce the aggregate's segregation and increase the likelihood a uniform product will be shipped.

A typical sampling pattern consisting of 10 locations diagonally across the stockpile is shown in Figure 30. 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.

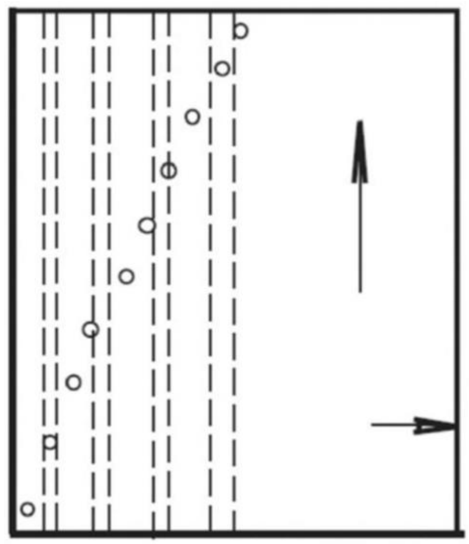


Figure 30: Top View of Pan Dump Stockpile

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 1,000 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 31. If the 1,000 foot section ends in an odd size increment of less than 500 feet, add that partial section to the previous full section. If the odd sized 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.

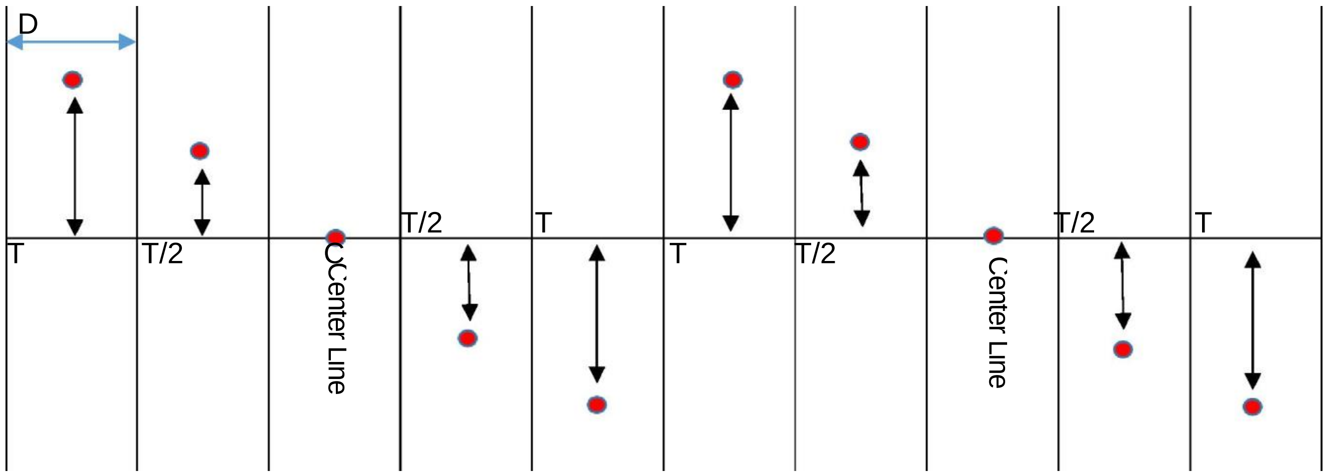


Figure 31: On Grade Sample Points

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

T = Distance from centerline to furthest sampling point offset.

For example, in a two-lane placement where each lane is 12 feet:

- *The first sample increment T is approximately 10 feet left of centerline.*
- *The second sample increment T/2 is approximately 5 feet left of centerline.*
- *The third sample increment is on centerline.*
- *The fourth sample increment is approximately 5 feet right of centerline.*
- *The fifth sample increment is approximately 10 feet right of centerline.*
- *The sixth through tenth increments repeat the measurements from edge of pavement from the first through fifth increments.*

*Distances to the sampling points may be approximated 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 layer being sampled as this can mix the two materials. Also, avoid cutting a hole into the geotextile fabric that separates the layers of aggregate.

*Michigan Test Method 119 for Sampling Open-Graded Drainage Course (OGDC) Compacted in Place is to be used to verify the grading and physical properties of open-graded aggregate.

Figure 31 applies to this type of sampling as well, although the value of T changes dependent on the amount of material placed before sampling.

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. 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.

CHAPTER 3- MDOT AGGREGATE SUPPLIER PROGRAM

INTRODUCTION

The MDOT Aggregate Supplier Program allows eligible registered aggregate suppliers the opportunity to provide material to MDOT projects. MDOT uses what is referred to as prequalified and non-prequalified status for aggregate sources. MDOT encourages all aggregate providers to become registered prequalified providers. Materials from non-prequalified sources are tested at what is called the Standard Sample Frequency. The sample frequency is the target maximum allowable value for the material weight or volume interval used between QA tests for gradation, crushed particle content, and in some cases deleterious particle content values from a stockpile of aggregate as it is used. Materials from prequalified aggregate suppliers do not have to be tested as frequently, and can be QA tested at the Prequalified Sample Frequency. Prequalified sources have more flexible failing-test resolution requirements. Figure 32 summarizes the target Prequalified and Standard average QA testing frequencies for common aggregate types provided by aggregate producers in Michigan.

MDOT Standard Specifications Material Type	Basis of Acceptance	Prequalified Sample Frequency	Standard Sample Frequency	Sample Size*	Maximum Visual Inspection Quantity**
Coarse Aggregate	Test	1 per 10,000 tons	1 per 2,000 tons	50lb	500 tons
Dense-Graded Aggregate	Test	1 per 15,000 tons	1 per 5,000 tons	50lb	1,500 tons
Open-Graded Aggregate	Test	1 per 15,000 tons	1 per 5,000 tons	50lb	1,500 tons
Granular Material Class I	Test	1 per 15,000 tons	1 per 5,000 tons	50lb	1,500 tons
Granular Material Class II (Subbase), Class IIA, Class IIAA	Test	1 per 15,000 cyds	1 per 5,000 cyds	50lb	1,500 cyds
Class II (for Bridge Abutments)	Test	1 per substructure	1 per substructure	50lb	100 cyds
Granular Material Class III	Test	1 per 30,000 cyds	1 per 10,000 cyds	50lb	3,000 cyds

Granular Material Class IIIA	Test	1 per 15,000 cyds	1 per 5,000 cyds	25lb	1,500 cyds
Fine Aggregate	Test	1 per 10,000 tons	1 per 2,000 tons	25lb	500 tons
CPM Aggregate	Test	1 per project	1 per 2,000 tons	50lb	50 tons

Figure 32: MDOT Required QA Aggregate Material Testing Frequencies

Notes: *A standard size canvas sample bag will hold approximately 50lbs full and 25lbs half full.
**Visual Inspection does not waive physical testing requirements. These small quantities should not be used to avoid or delay QA testing, but these maximum amounts are allowed for visually inspecting materials where a project deems gradation as suitable or non-critical. This suitable or non-critical determination must be recorded with the visual inspection for acceptance.

REQUIREMENTS FOR ALL MDOT AGGREGATE SUPPLIERS

All aggregate sources seeking to have their aggregate products used and paid for within state or federally funded MDOT projects are to meet the following minimum requirements.

1. **Establish an ASI number for the site**. The ASI number is to accompany all aggregate shipments and testing reports for a site's products. There are three primary types of ASI numbers and number formats currently used by MDOT for aggregate suppliers as follows:

   - Geologic Source Sites – These include natural sand and gravel pits and rock quarries, along with industrial furnace locations where slag byproduct is created and processed into aggregate products. These sites use ASI number code CN-XXXXID. The first two digits of the ASI number for slag and natural sources correspond to the Michigan County Number (CN) code for the source location. The four digits (XXXX) are a site-specific tracking number that is assigned sequentially within the county number Region as new sites come into the system. The four number code is followed by a two-letter source type identification (ID) code used to classify the source material consisting of one of the following:

     - **SG**: Sand and Gravel Quarry
     - **CA**: Carbonate Quarry
     - **IG**: Igneous Quarry
     - **MM**: Metamorphic Quarry
     - **IM**: mixed Igneous/Metamorphic Quarry
     - **BF**: Blast Furnace Slag
     - **SF**: Steel Furnace Slag
     - **RF**: Reverberatory Furnace Slag

   - Shipping Docks – Shipping docks that receive freighter loads of aggregates from various sources and maintain/control stockpiles of aggregates are assigned unique ASI tracking numbers (CN-DK-XXXX) that start with the two-letter county number (CN) and then the code DK, for Dock, followed by a four-digit numerical designation that is sequential across the entire State as new docks become registered into the system. An example format is 70-DK-0002 for the D&M Dock port facility in Grand Haven, Ottawa County, Michigan.

- Inland Aggregate Storage Yards - Concrete recycling (crusher) yards and inland aggregate redistribution yards are assigned unique ASI tracking numbers (CN-YD-XXXX) that start with the two-letter county number (CN) and then the code YD, for Yard, followed by a four-digit numerical designation that is sequential across the entire State for yards. An example format is 50-YD-0105 for the aggregate storage yard at the Cadillac Asphalt Plant in Shelby Township, Macomb County, Michigan.

ASI numbers are assigned by MDOT materials control software staff and the CFS Aggregate Quality Unit. Apply for a new source ASI number or make changes to the general information regarding your current site ASI number, by filling out and submitting MDOT FORM 3594 - MDOT AGGREGATE SOURCE IDENTIFICATION REQUEST. Follow the instructions on the form accurately before sending them to the e-mail listed on the form. If you do not supply all of the requested information, your ASI number assignment may be delayed. When making changes to information for an existing ASI number check the UPDATE box in the upper-right portion of the form and include the existing and/or historic site ASI/pit number in the lower portion of the form.

2. Sampling and testing procedures used at the facility for MDOT products will be in accordance with Michigan Test Methods, ASTM, and AASHTO standards as referenced in the MDOT contract documents.

3. Scales used to produce delivery tickets for aggregates on MDOT projects need to have current certification available upon request per Michigan Standard Specification for Construction section 104.01.

4. Must have a minimum of one documented passing MCAT test within 6 months of proposed use on any project, per material class/series. This test data showing conformance is to be provided by the contractor/supplier to the controlling Region and Aggregate Quality Unit, prior to the start of supplying state or federally funded projects to document passing material.

5. Producer assumes responsibility for being current on the required physical properties/characteristics testing for their products (Freeze-Thaw, LA Abrasion, Wear Track AWI, etc.), including the requesting of sampling of materials by MDOT staff or resampling before their current valid physical properties test expiration dates.

   - *It is recommended to notify the Region or Aggregate Quality Unit and request additional testing:*

     - *At least 4 months in advance of expiration for Freeze-Thaw testing*
     - *At least 1 month in advance of expiration for LA Abrasion testing*
     - *At least 6 months in advance of expiration for Aggregate Wear Track Testing*

Note*: Freeze-Thaw, LA Abrasion, and Wear Track testing aggregate samples should be requested to be collected and tested at the same time, although they may not necessarily be done on the same classifications.

6. Suppliers of fine aggregates will establish and maintain reporting of the base fineness modulus (ASTM C33, Section 6.4, including Note 7) as required in the Standard Specifications for Construction. The base fineness modulus is to be comprised of the average of the ten most recent QC gradation tests. Submit this data to the controlling Region and Aggregate Quality Unit as part of the initial request for use or for prequalification of new fine aggregate products.

7. Suppliers of fine aggregates that are to be used in concrete mixtures for long service life roads and bridges must demonstrate resistance to alkali-silica reaction (ASR) using ASTM C1293, which is a 1 year long accelerated aging test (expansion to be less than 0.040 percent after 1 year). As an alternate to ASTM C1293, the shorter duration but more aggressive ASTM C1260 procedure can be used to evaluate a sand source for ASR resistance (expansion to be less than 0.010 percent after 14 days). Coordinate ASR testing with a local well-established consultant testing lab that is certified and experienced in ASR screening procedures for concrete and mortar sands. Provide the current passing ASR test data to concrete mixture designers planning to use the fine aggregate in concrete. Perform ASR testing for concrete fine aggregates at maximum 2 year intervals.

PROJECT ENGINEER RESPONSIBILITIES

Project Engineers must coordinate with the Region/Transportation Service Center's Material's Supervisor to verify passing quality assurance tests and provide adequate supporting data in the construction project files. Verify adequate QA documentation is included in the construction project files in the form of actual QA test results and/or suitable QA summary report correspondence by email or phone log. The project engineer must ensure that an adequate number of QA tests are completed for the various aggregates series/classes used and based on the testing interval guidelines herein and the contract documents.

NON-PREQUALIFIED AGGREGATE SUPPLIERS

All aggregate material provided by non-prequalified aggregate suppliers for MDOT or federally funded projects will be tested, by MDOT, for project specific acceptance. Non-prequalified materials are to be tested at intervals equal to or less than the standard testing frequencies shown in Figure 32.

FAILING MATERIAL RESOLUTION (NON-PREQUALIFIED SOURCES)

If a quality assurance sample taken from the source or point of use does not meet specification, the controlling Region will follow the standard procedures for disposition of materials based on laboratory tests results described in section 1.08 and 1.09 in the MDOT Materials Quality Assurance Procedures (MQAP) Manual and immediately notify the key supplier and construction personnel of the approval status for the material. Resampling is allowed for non-prequalified aggregate sources when MQAP procedures are followed. If any second quality assurance sample (not including resamples) does not meet specifications, then it will be communicated, by the controlling Region, to the Region construction/project engineer, contractor, supplier, and the Aggregate Quality Unit (CFS) that the material is "not for further use" on the respective project. Future use of the source will be evaluated on a case-by-case basis. Where pay adjustments are required in a contract for an aggregate product having failing tests, additional testing or special procedures may be required to determine payment adjustments outside of acceptance or resampling.

PREQUALIFIED AGGREGATE SUPPLIERS

"Prequalification" in the MDOT Aggregate Supplier Program is a partnership between MDOT and aggregate suppliers. Prequalified suppliers provide MDOT proof of quality laboratory capabilities and quality control programs, and current certified testing personnel that can produce accurate QC test results. In return, prequalified aggregate suppliers have a reduction in the required acceptance testing frequency during construction, and a more flexible failing material resolution protocol from MDOT should a QA test result be outside of specification limits. Once the supplier's overall operation becomes prequalified, each individual aggregate product (MDOT series/class) also has its own specific gradation and physical properties requirements that must be proven to become a prequalified product under that prequalified supplier.

PROCESS OF APPLICATION

Aggregate suppliers seeking to obtain prequalified supplier status must complete the following:

1. Submit a letter request to the CFS Aggregate Quality Unit (carbon copy the controlling Region) stating the intent to be become a prequalified aggregate supplier for MDOT construction projects. Include the following information in the request letter:

    - Company Name
    - Source (Pit) Name(s)
    - Aggregate Source Inventory (ASI) number(s)
    - Primary Contact, including phone number and e-mail address
    - Secondary Contact (if applicable), including phone number and e-mail address
    - Credentials for the Qualified Aggregate QC Testing Laboratory that will be performing the QC testing for the supplier including the required QMS Manual and AASHTO proficiency testing results
    - List of the anticipated MDOT aggregate types (series/class) to be produced
    - List of the MCAT personnel that will be responsible for acquiring and testing the QC samples (at least one is required to be considered for prequalification)

2. Submit the site Quality Control Plan (QCP) for aggregate products to the controlling Region and the CFS Aggregate Quality Unit. The QCP will be reviewed by MDOT aggregate program staff for approval by the CFS Aggregate Quality Unit. Use MDOT Form 2641 (Quality Control Lab/Source Inspection Checklist) as a guide for developing the QCP. The QCP must document the following information:

    a. Production sampling frequency and location, including:

        1. *Where, when, and how samples are obtained*
        2. *The approximate amount of material covered by each test*

    b. How major events including, but not limited to, plant start up, screen failures/changes, and breakdowns that may affect aggregate production quality are managed and recorded.

    c. How the supplier is establishing and identifying control of the required gradation from testing results (production charts, warning bands, spreadsheets, etc.).

    d. An established action plan (for suppliers who produce their own aggregates), to be used when material is testing outside the warning band or specification limits. The action plan must include the following:

- *List of corrective actions and operational procedures to be followed to bring the material back within the warning band or specification limits.*
- *State when and where sampling and testing the new production will occur.*
- *When the material is outside the specification limits, halt or divert production from adding to the existing stockpile until test results indicate the material is within specification limits.*
- *Describe the method that will be used to distinguish the failing material stockpile from the specification material.*

e. An established corrective action plan for docks, stockpile yards, or redistribution points when a failing result occurs. The action plan must include the following:

- *Remove the failing aggregate from the stockpile until specification material is located.*
- *Increase the testing frequency for the aggregate remaining in the stockpile.*
- *Describe the method that will be used to distinguish and label the failing material from the specification material.*

f. The specified load-out (shipping) QC sampling and testing frequency.

g. Use of a detailed document retention policy, particularly, but not limited to, quality control tests and MDOT or federally funded material shipment quantities (weekly summaries are acceptable). All documents must be retained for a minimum of 5 years.

h. Tracking of dates the QCP has been updated, with appropriate revision numbers.

The Supplier will be notified by the Aggregate Quality Unit once the application process has been approved by both the Aggregate Quality Unit and controlling Region.

SUPPLIER DOCUMENTATION AND QUALITY CONTROL

Prequalified aggregate suppliers must remain current on all the following points of documentation to maintain prequalified status:

1. Adhere to all points of accountability in the agreed upon QCP.

2. Formally notify the controlling Region's Materials Supervisor and Aggregate Quality Unit by e-mail on or before the first aggregate shipment for each calendar year.

3. Accompany each aggregate shipment delivered to a project or concrete plant with a delivery ticket meeting the requirements described in the Standard Specifications for Construction and appropriate for the aggregate type, use, and method of payment being used (see sections 109.01, 302.03, 303.03, 306.03, 307.03, 1001.03). The ticket must show clearly the supplier's

dock or yard ASI number and the aggregate material original source ASI number. When the pay item for the aggregate is loose measure (LM) using pre-approved hauler vehicles with known volumes, include the load volume in each delivery on the ticket for each vehicle and track the daily volumes delivered. If approved by the Engineer, a single daily ticket for LM and cubic yard type pay items may be suitable for some aggregate materials. For aggregates, each delivery ticket requires a signed quality statement for the aggregate specification properties. Print or stamp, and sign the following statement on each aggregate delivery ticket:

"I attest that the aggregate as delivered from this source meets specification requirements for listed Michigan series and class for quantity stated." Date Signature _

This statement must be signed (hand, electronic, or otherwise) and dated by an accountable authorized company representative. The statement on each delivery ticket is to be provided by the supplier, as verifiable by the results of their internal quality control testing for the material. This QC statement does not signify acceptance by MDOT. Lack of delivery tickets will result in rejection of the aggregate.

For project uses that do not require delivery tickets for acceptance, the prequalified supplier may submit a daily project shipping summary to the project engineer and Aggregate Quality Unit, provided it includes all the relevant information from above.

4. Tracking of aggregate tonnages provided to state and federally funded construction projects and MDOT suppliers, from the source to the jobs, concrete plants, and redistribution points such as docks and yards is required. The producer agrees to provide formal submitted weekly summaries of shipped weights provided. This is necessary for processing contract payments for aggregates and maintaining adequate QA testing frequencies. Use an appropriate format that describes the shipment dates and amounts and locations including shipments to MDOT registered redistribution yards and docks, concrete plants making mixtures for MDOT projects, and MDOT job numbers for deliveries to active construction projects. Deliver by e-mail the weekly summaries data to both the controlling Region and Aggregate Quality Unit by close of business on Monday of the week following shipment. A standardized weekly summary format blank spreadsheet is available from the MDOT Aggregate Quality Unit upon request and is recommended for use. Alternatively, a supplier may work with MDOT for an approved method for direct input of daily and/or weekly summary data into the MDOT materials control software (AASHTOWare Project Construction and Materials - APCM) using an automated E-ticket based system or other approved data entry mechanism.

   When the supplier does not anticipate any aggregate shipments to MDOT or federal aid projects for at least one full business week, they may indicate “Until further notice, no state work” on the last weekly summary. Once this report is transmitted, the supplier will not be required to continue sending the weekly summaries until shipping resumes, at which point the supplier will contact the controlling Region and Aggregate Quality Unit on or before time of shipment. Additionally, at the close of the construction season, the supplier may indicate “Last shipment for the season” on the weekly summary report. Once this report is transmitted, the supplier will not be required to continue sending the weekly summaries until the start of the next construction season.

5. Maintain an MCAT certified technician (employed or contracted) to conduct all sampling and testing of aggregate material for MDOT or federally funded projects.

MDOT QUALITY ASSURANCE TESTING (PREQUALIFIED SUPPLIER)

A prequalified supplier can have prequalified and non-prequalified products on their site. Sometimes an individual prequalified product will drift out of specification, lose prequalified status, and then require corrective action and testing at the standard frequencies until the problem is resolved for that specific product. Each aggregate series/class is evaluated separately for prequalification within a prequalified quarry or pit. MDOT maintains a list of prequalified aggregate suppliers and their prequalified products (Prequalified Aggregate Supplier List) that is updated intermittently as new entries and changes occur. All prequalified aggregate materials provided by aggregate suppliers for state or federally funded projects will be tested, by MDOT, for quality assurance. Prequalified materials are to be tested at intervals approximately equal to the prequalified testing frequencies shown in Figure 32. Although the Aggregate Quality Unit prescreens aggregates for physical properties prior to allowing them into the listing, project and region staff are responsible for ensuring aggregates meet specification requirements for project uses.

FAILING MATERIAL RESOLUTION (PREQUALIFIED SUPPLIER)

When QA samples taken from the shipping face or point of use do not meet specifications, the controlling Region will immediately notify the supplier and inform the supplier of the planned QA resample time and location. In addition, the supplier's quality control tests for the stockpile are to be made available and reviewed by MDOT.

1. Aggregate Resample at Source or Distribution Point – If the failing QA sample was taken from the stockpile's shipping face at the aggregate's source, or a redistribution point, two resamples will be obtained from the same stockpile's shipping face using the mini-stockpile sampling method. Both resamples must meet specification requirements. If the average of the original failing QA test and the two QA resamples meets specifications, then the material will be approved for use and no further action is required. If the average of the failing QA sample and two QA resamples does not meet specifications, the QA test round fails. The failing material produced will be removed from the stockpile and continued out of specification production will be diverted elsewhere. The supplier and the controlling Region are then to develop a plan of corrective action. If the corrective action plans fail to resolve material quality issues, it will then be communicated by the controlling Region, to the Region construction/project engineer, contractor, and Aggregate Quality Unit that the material is "not for further use" for that stockpile.

2. Aggregate Resample at Point of Use – If the failing QA sample was taken from the point of use, attempt to obtain two resamples from the same use area and placement where the failing QA sample was obtained. If the average of the original failing QA test and the two QA resamples meets specifications, then the material will be approved for use and no further action is required. If the average of the failing QA sample and two QA resamples does not meet specifications, the QA test round fails. The engineer may require that the failing material placed be removed from the grade depending on the contract language and use or may determine that penalties apply and/or the material can remain in place. The contractor, supplier, and the controlling Region will then identify and isolate out of specification material and develop a plan of corrective action. If the corrective action plan fails to resolve material quality issues, it will then be communicated, by the controlling Region, to the Region construction/project engineer, contractor, and Aggregate Quality Unit that the material is "not for further use".

   Once an aggregate product is determined "not for further use" that product loses its prequalification status. A supplier can re-apply for prequalification for that product, as described later in this section, and by showing the key passing QC test strip charts and/or results for at least the last 10 QC tests for the corrected product.

MDOT DOCUMENTATION AND QUALITY ASSURANCE

Controlling Regions will maintain the following documentation and quality assurance procedures:

- *Retain a copy of each supplier's weekly summaries for a minimum of 5 years and quantify, in a documented fashion, the quantities supplied to all MDOT and federally funded projects.*
- *Retain a copy of each quality assurance test for a minimum of 5 years.*
- *Retain a copy of any correspondence regarding approvals of and amendments to QCP's (including pit changes or yard additions), on-site visit or inspection reports, or other major local source events that affect MDOT aggregate supply.*

Aggregate Quality Unit will maintain the following documentation and communicate the following:

- *Retain a copy of each supplier's weekly summaries for a minimum of 5 years and quantify, in a documented fashion, the reported quantities supplied to state and federally funded projects.*
- *Retain a copy of any correspondence regarding approvals of and amendments to QCP's (including pit changes or yard additions), on-site visit or inspection reports, or other major local source events that affect MDOT aggregate supply.*
- *Retain a copy of any correspondence regarding acceptance into or removal from the prequalified supplier program for specific suppliers and products, and distribution to affected controlling Regions and suppliers.*

QUALIFIED QC LABORATORY (PREQUALIFIED AGGREGATE SUPPLIERS)

All quality control testing done by prequalified aggregate suppliers must be done by a qualified QC laboratory and by qualified certified QC technicians in accordance with the Michigan Quality Assurance Procedures (MQAP) Manual section 4.03.03. To improve uniformity and accuracy in prequalified QC labs across the State, MDOT requires all prequalified QC labs to participate in the annual "aggregate gradation and gravity" proficiency sample evaluation program coordinated through AASHTO *re:source* (Compilation of Statistics (aashtoresource.org)).

MDOT requires aggregate QC laboratories to follow the guidelines in AASHTO R-18; Standard Recommended Practice for Establishing and Implementing a Quality Management System for Construction Materials Testing Laboratories. The QC laboratory's Quality Management System (QMS) documentation and other data as required in the MQAP Manual section 4.03.03 will be reviewed for approval by MDOT CFS Aggregate Quality Unit. MDOT CFS Aggregate Quality Unit will use Form 2641 Quality Control Lab/Source Inspection Checklist as the basis for these reviews.

Some large prequalified aggregate supply companies control multiple pits, quarries, and yards using just one or a few QC laboratories, with multiple pit locations controlled by one QC laboratory. Some operations may control multiple pits/quarries using a mobile laboratory and staff rather than a stationary lab at a facility. Mobile labs and stationary labs are considered the same in terms of required documentation. However, mobile labs must detail how they re-establish calibrations or standardizations for equipment that has been moved. Owners of mobile crusher yards can have changing ASI numbers as the equipment moves from site to site, project to project, with the material being controlled by one QC lab nearby the entire time. For these larger operations, the QC plan for each umbrella type laboratory must clearly define which of their ASI sites are operating under that QMS and if/how they support mobile crusher yard operations. If a new mobile recycled crushed concrete yard is established at a new job site, the QC plan for the new crusher yard site must clearly identify which of the prequalified supplier's approved QC labs are controlling the product quality for the new yard. Using this umbrella QC lab type system for large suppliers should enable simplified submittals for new/relocated mobile crusher sites without needing a major revision for the supplier's entire operation QMS Manual and QC plans.

PROJECT AND PRODUCT SPECIFIC PREQUALIFICATION

Once an aggregate producer operation becomes prequalified, each individual aggregate product from that source must pass its own specific initial gradation and physical properties requirements tests to become prequalified and shown as a prequalified product on the preapproved aggregate suppliers and products list published by MDOT. Prequalification of a specific product can also be granted within a single job and limited to the duration of the construction project. Project specific prequalification could be used for mobile on-site crusher recycling yard operations within a project or for local temporary barrow pits near active construction projects. Project specific prequalification can also be used for unique special provision aggregate products that are only required for one project. These project-specific qualified products will not be listed on the online Prequalified Suppliers listing and documentation will be held at the project level. Prequalification of individual products is generally handled the same way for either case. In addition to passing physical properties tests and the typical requirements for acceptance as an MDOT aggregate series or class, the following must be met, and detailed in the Quality Control Plan, before project or product specific prequalification is granted:

- Three (3) consecutive 1,000-ton test production piles with passing QC and QA data
- Site evaluation to determine reasonable accommodation of the following:
    - Material control including stockpile access and product labeling
    - Sampling/Testing, both QC and QA
    - Safety
- Plan for excess material (if to be used on other MDOT federally funded projects)
- If supplier and prime split responsibility, detail responsibility for the following:
    - Load out QC testing plan
    - Weekly summaries reporting
    - Primary contact for QC Plan revisions

An exception to the above criteria is applied to pre-qualified mobile concrete crusher machine operations. If a producer's crushing operation has been granted prequalified status and has been performing suitably, when the system is relocated the MDOT QA technicians may rely on the supplier's similar QC data for the new production pile and visual inspection of the new material to allow continued use and tracking at the pre-qualified QA test frequency. This is provided the same crusher system is used and the supporting QC documentation verifying material meets specification once the plant is operational at the new location. The three additional production piles noted above would not be necessary for a relocation.

Acceptance as a prequalified aggregate supplier or product will be based on the above criteria and is evaluated on an individual basis. Project and product specific prequalification must be approved by CFS Aggregate Quality Unit and the controlling Region.

WAIVER PROCESS (USING OR CONTROLLING REGION WAIVERS)

The MDOT standard aggregate sampling and testing requirements for both prequalified and non-prequalified suppliers may be modified or waived, in some cases, for high-quality well-established materials or other special circumstances. Waivers are typically initiated at the request of the controlling Region and considering unique local situations. Waivers can cover a wide range of aggregate topics but are typically justified requests for reduced quality assurance test frequencies.

PROCEDURE FOR WAIVER REQUEST

Controlling or using Regions will submit a formal letter of request to the Aggregate Quality Unit containing the following:

- Supplier name and ASI pit number(s)
- Material class
- Requirement to be waived (testing frequency, etc.)
- Justification for waiver (excellent product, passing tests, etc.)
- Definition of a new/revised requirement (new proposed testing frequency, etc.)
- Duration of waiver (note the approximate start and end dates)
- Region terms and conditions (what conditions would terminate or end this waiver)

Once approved, a letter stating the new terms of the requirement will be delivered to the controlling Region, the supplier, and in all pertinent project files (in the instance the waiver amends project specific requirements such as testing frequency).

JUSTIFICATION FOR REDUCED TESTING FREQUENCY WAIVERS

The primary justification for allowing reduced aggregate testing requirements as part of a waiver request is passing QA testing results. Products from non-prequalified suppliers meeting the following passing test rates may qualify for a further reduction in minimum QA testing frequency:

- 90 percent passing quality assurance test proficiency over either 24 months or 50,000 tons
- 100 percent passing quality assurance test proficiency over either 12 months or 25,000 tons

Products from prequalified suppliers meeting the following passing test rates may qualify for a further reduction in minimum testing frequency:

- 90 percent passing assurance test proficiency over either 12 months or 50,000 tons

Each source and material is evaluated on a case-by-case basis and the same waiver for one location or use may not be appropriate to apply to another.

DISTRIBUTION AND CONTACT INFORMATION

Submit all documentation to the Aggregate Quality Unit and the controlling Region materials contact as required:

Michigan Department of Transportation
Construction Field Services Division
Aggregate Quality-PASP
8885 Ricks Road
P.O. Box 30049
Lansing, MI 48909
Fax: 517-636-5363
MDOT-PASS@Michigan.gov

- Weekly summary reports must be submitted to the Aggregate Quality Unit via e-mail at MDOT-PASS@Michigan.gov and the appropriate MDOT Region contact.
- Questions or concerns can be directed to the CFS Aggregate Quality Unit at MDOT-AggregateQuality@Michigan.gov.

CHAPTER 4 – LABORATORY SAMPLE SIZES AND SAMPLE REDUCTION

LABORATORY SAMPLE SIZE

ASTM and AASHTO have established standards for the minimum sample sizes for laboratory processing. Field samples are reduced or split for laboratory testing purposes. Some of the standards are presented in Figure 33.

Nominal Maximum Size of Square Opening in millimeters (in)	Minimum Weight of Test Sample in kilograms (lb)
9.5 (3/8)	1 (2.2)
12.5 (1/2)	2 (4.4)
19.0 (3/4)	5 (11)
25.0 (1)	10 (22)
37.5 (1 ½)	15 (33)
Fine Aggregates	**300g minimum**

Figure 33: AASHTO and ASTM Minimum Laboratory Test Sample Sizes

There are several variations in the definition of aggregate nominal maximum size. MDOT uses the following definition because some Michigan classifications 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. 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 for coarse aggregate and MDOT minimum for fine aggregate will meet both guidelines.

For sieve analysis, the Department has modified the AASHTO T-27 test and developed Michigan Test Method 109. Based on experience, the minimum laboratory test sample weights after drying are presented in Figure 34.

Nominal Maximum Size in Inches (mm)	Minimum Weight of Test Sample in grams
No. 4 (4.75)	500
3/8 (9.5)	1,000
½ (12.5)	2,000
¾ (19.0)	2,500
1 (25.0)	3,500
1 ½ (37.5)	5,000
Fine Aggregate	**500 to 700 g**

MECHANICAL DEVICES

A mechanical sample splitter can reduce coarse, dense-graded, and open-graded field samples. A typical sample splitter is shown in Figure 35. Other sizes of mechanical splitters are commercially available.

Figure 35: Sample Splitter

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 chute and look down inside. There will be a set of aluminum bars that are $^1/_2$ inch wide. Inside smaller splitters, the bars will be $^1/_8$ inch or $^1/_4$ 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 C702 and AASHTO T248 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 36 to $1^1/_2$ 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 36. ASTM C702 requires that the mechanical splitter must have an even number of equal width chute openings, but not less than 8 for coarse aggregate, or 12 for fine aggregate.

If the largest expected particle size is $1^1/_2$ inches multiply by 1.5. The answer is $2^1/_4$ 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 T248/ASTM C702 test methods state this is not acceptable. In addition, the minimum number of chutes permissible is eight (four bars flipped in each direction this splitter only has six chutes). Therefore, the splitter pictured cannot be used for aggregates with particles larger than one inch.

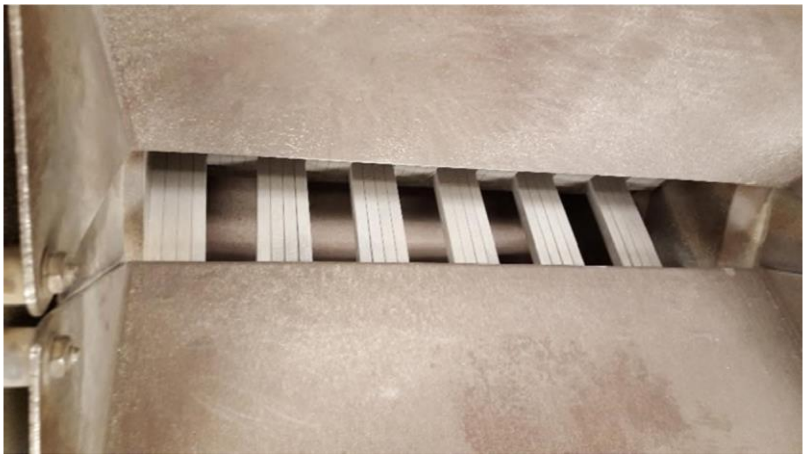


Figure 36: View Inside Splitter

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 37. This helps the material to flow smoothly through the chutes when the gates are opened.

Figure 37: Splitter Filled – Top View

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. If aggregate material is field damp condition when splitting, reduce the speed at which you allow aggregate to flow from the "hopper" into the separation bars and use a rubber mallet to tap the wing nuts while the material is flowing. This will usually eliminate material sitting on the bars.

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 38. Turn the pan so the end which was closest to you is now the furthest away and pour in the rest of the aggregate into a splitter. This will help to spread the material evenly.

Figure 38: Dumping Material into Splitter

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.

A splitter can only be used for material amounts that can completely fit in the “hopper,” for aggregates that require field sampling amounts above this amount, quartering on a tarp is recommended.

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. The material needs to be completely blended, this is accomplished by inserting the trowel into where the base of the material meets the flat surface and flipping it upside down back into the pile. Continue flipping the material in this manner while rotating around the pile in a clockwise manner until the entire pile has been turned three times. With the last turn around the material, form a cone or stockpile shaped “pile” as shown in Step 1.

Step 1 - Coning

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. Not side to side, and no "spreading" of material.

Step 2 - Flattening

When flattened the diameter should be 4 to 8 times the thickness and be similar to Step 3.

Step 3 – Flattened

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 – Quartered

Using the trowel, pile the material back into a cone again as illustrated in Step 1. Flatten the cone again as shown in Steps 2 and 3.

Quarter the material again and save the opposite quarters from those saved in Step 4. Placing the removed aggregate back into the original sample container.

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 tarp as shown in Step 1A.

Step 1A - Mixing

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

Step 2A – Coning

Flatten the cone either with a square point shovel or trowel into a pile of uniform thickness. You may then use the shovel blade to quarter the material as shown. You may also use a dowel bar slid under the tarp and lifted up.

Step 3A – Quartering

Divide the flattened cone into quarters as shown in Step 3A.

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 4A.

Step 4A – Quartered

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 nonporous surface. ASTM C702 and AASHTO T248 both recommend folding the pile over three times ending up with a pile shaped like a cone, see Steps 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

Form the fine aggregate into a cone.

Step 1 - Coning

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

Step 2 - Reduction

Method 2

Form the fine aggregate into a cone.

Step 1a - Coning

Use a trowel to flatten the pile from the apex (top) pushing straight down. Take care to not "spread" the material from side to side, using pressure from above only.

Step 2a - Flattening

Using a small scoop or tablespoon take at least five random sample increments from the flattened pile.

Step 3a - Reducing

DRYING THE SAMPLE TO CONSTANT WEIGHT

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. ASTM C117 for Loss by Washing allows for use of a conventional oven, and MTM 108 for Loss by Washing modifies this to include other methods of heating/drying that are more applicable to field labs.

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

If any of the other apparatus 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 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, wait 20 to 30 minutes. If a hot plate or burner is used, 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.

For aggregate material that is weighed to the whole gram, such as material gradations from the 902-1 chart in the Standard Specifications for Construction, use the following procedure to measure constant weight.

- *If the two weights 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.*

For aggregate material that is weighed to the tenth of a gram, such as material gradations from the HMA Production Manual use the following procedure to measure constant weight.

- *According to the **HMA Production Manual** constant weight is achieved when two successive weights have changed less than 0.3g in 15 mins.*

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 to settle claim disputes. Errors can be costly to the product producers and purchasers. A typical Mechanical Analysis Report form is MDOT Form 1901. This report can be used with most aggregate specifications.

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 E29 assures consistent rounding of numbers.

ASTM Standard E29 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 to 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.

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 **Stay Strong Aggregate**, an aggregate producer, to produce the following material: 1,000 tons 6A, 20,000 tons 22A, 10,000 tons of 4EMH HMA, and 1,700 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 1,000 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 1,000 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 tests 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 4EMH must 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. 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* from Table 902-1 and Table 902-2 obtain the specification limits for gradation and deleterious particle determinations.

When working with the Tables, it is important to look for the small letters in parenthesis ( ). These are footnotes and can radically change what you are testing for and against.

For instance, the Loss by Washing specification has the footnote (b). 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 Chapter 7, *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, percent minimum* Michigan Test Method 110 specifies which sieves the deleterious material (soft and chert) must be picked. It is recommended to draw a heavy line under the $^3/_8$ inch data entry line. This serves as a memory device to add the $^3/_8$ 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 $^3/_8$-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 Chapter 4, 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 4, *Figure 35: MDOT Minimum Laboratory Sample Size;* the sample must weigh a minimum of 3,500 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 4.

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.

LOSS BY WASHING

ASTM C117 Standard Test Method for Materials Finer than 75 um (No.200) Sieve in Mineral Aggregates by Washing and MTM 108 Michigan Test Method for Materials Finer than No. 200 Sieve in Mineral Aggregates 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:

- A pan that is large enough to hold the aggregate while allowing its agitation without water or aggregate loss

- 3-inch spatula or a large spoon
- No. 200 sieve
- 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 39.

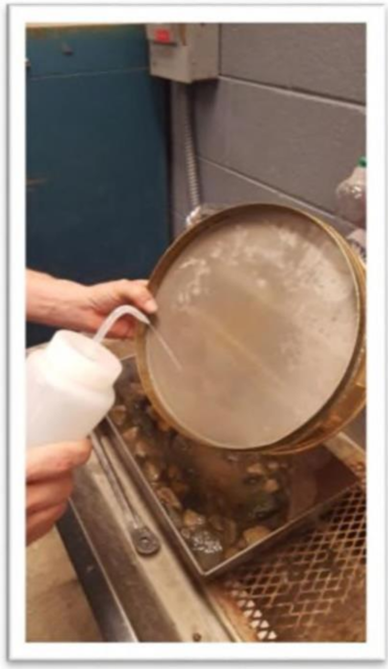
Figure 39: Pour Rinse Water into Stacked Sieves

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. If the No. 200 sieve becomes plugged, tap on the side of the sieve near the crimping band. This will usually get the water to start 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 No. 200 sieve as shown in Figure 40.



Figures 40: Rinse material to side of the sieve and back into the pan

Turn the sieve upside down over the pan and rinse all the material back into the pan as shown in Figure 41. Do this for both the protector sieve and the No. 200.

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 Washing.

After washing a sample, dry to a ***constant weight*** using the procedure applicable to the material tested as described in Chapter 4.

To calculate the *Loss by Washing*, subtract the *Weight after Washing* from the *Initial Weight of Sample*. This equals a *Loss by Washing (clay and silt)*. Write this after the *Loss by Washing (clay and silt)* and also in the *Retained Fractional Weight* column on the *LBW* line.

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

(Weight of material lost by washing / Initial weight of sample) x 100

The specifications control how the calculated amount will be reported. For example, 6A, is to the tenth of a percent (0.0 percent). For dense-graded and granular materials this is recorded to a whole number (0 percent). This figure is also written in the *Retained Fractional Percent* column on the *LBW* line.

MECHANICAL WASHERS

The Department's Michigan Test Method 108 states concerns about use of Mechanical Washing Equipment (illustrated in Figure 41).

It is important to remember that for acceptance purposes if you are using a mechanical washer, retain the final companion split from your reduction until the test results are calculated. If the results are either outside specification or just inside, run the companion split as a hand wash for verification purposes and keep both MA records, labeled clearly as to which is the mechanical wash and which is the hand wash.

"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 Washing 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 C117 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 washing 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.

Figure 41: Mechanical Washer

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 below.

Figure 42: Sieve Nest

Opening Sieve	Diameter of Sieve				
	8 inch Round	**10 inch Round**	**12 inch Round**	**14 by 14 inch**	**16 by 24 inch**
2 inch (50mm)	3,562g	5,716g	8,376g	15,312g	26,970g
1 $^{1}/_{2}$ inch (37.5mm)	2,672g	4,287g	6,282g	11,484g	20,227g
1 inch (25.0mm)	1,781g	2,858g	4,188g	7,656g	13,485g
$^{3}/_{4}$ inch (19.0mm)	1,353g	2,172g	3,183g	5,818g	10,248g
$^{1}/_{2}$ inch (12.5mm)	890g	1,429g	2,094g	3,828g	6,742g
$^{3}/_{8}$ inch (9.5mm)	676g	1,086g	1,591g	2,909g	5,124g
No.4 (4.75mm)	338g	543g	795g	1,454g	2,562g
No 8. to No. 100 (2.36mm to 150µm)	200g	320g	469g	857g	1,510g

Figure *43*: Maximum Allowable Weight Retained for selected sieves without Overloading.

A 6A example will need as a minimum the following sieves: 1$^{1}/_{2}$ inch, 1 inch, $^{1}/_{2}$ inch, $^{3}/_{8}$ 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 $^{3}/_{4}$ inch sieve. This will prevent any one sieve from retaining excessive material during the shaking process.

Figure 43, above, defines the Maximum Allowable Weight Retained on Sieve after Shaking (per ASTM C136 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 for more than ten minutes. Longer shaking periods may result in aggregate break down as stipulated in ASTM C136 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 44. Shake the sieve over the bowl to visually see how much material is passing through the sieve while shaking.

Figure 44: Sieve in bowl for 1 min of hand shaking

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. Generally concrete aggregates are weighed to the whole gram. Whereas asphalt aggregates are weighed to the nearest tenth of a gram.

Note that when sieving material, if you include a sieve that retains no material, you must record that as a zero. If these boxes are left blank with no entry or a dash (-) is recorded, a good lawyer can raise doubts 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***.

Due to 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 and is called the ***maximum allowable adjustment***.

The ***maximum adjustment allowed*** is 0.3 of 1 percent as stated in ASTM C136 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.

For example, a 6A test sample's **Initial Weight of Sample** *of 3,563g multiplied by 0.003 equals 10.689 grams. The maximum permissible adjustment would have to 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 any other means to change numbers.

Complete the ***Retained Fractional Percent*** column 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.

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, remember in some instances this may be the pan.

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. The numbers in the column are computed with cumulative addition from the top to the bottom of the column.

The last column to be calculated is the ***Percent Cumulative Passing***. 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 or an IAT is being done.

Next, compare the numbers in the ***Percent Cumulative Passing*** column to the specifications. If 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 coarse aggregate, you must do a deleterious pick. This process is described in more detail in Chapter 6 and in MTM 110.

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 $1^1/_2$ inch, 1 inch, $^3/_4$ inch, $^1/_2$ inch and $^3/_8$ 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. The categories picked for coarse aggregate are ***Soft**, **Clay-ironstone**,* and ***Chert***. Add the ***Soft*** and ***Clay-ironstone*** to get the sum for ***(1) Soft Particles including Clay-ironstone***. Sum **(*1) Soft Particles including Clay-ironstone*** and ***(2) Chert*** together. Record the total of these items on the line **Sum of (1) + (2).**

Next, calculate the pick weight. This is the sum total of the weights recorded in the ***Retained Fractional Weight*** column of the sieves included in the sieve stack. To know which sieves are totaled, refer to MTM 110, and mark that sieve and above on your mechanical analysis. It is a good practice to total and label this figure in the remarks space on the mechanical analysis form as well.

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 proper significant digit.

Deleterious%= Deleterious picked/ pick weight x 100

The percentage of deleterious particles is now compared to the 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.

Crush percent is calculated as below:

Crush % = crushed weight/ total pick weight x 100

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 sieve 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.

The mechanical analysis calculations are identical to how they are described in coarse aggregate above. What changes is how the results are recorded, some are whole numbers, and some are to the tenth. ***Always check the specifications to ensure you are recording the results to the proper significant digits.***

FINE AGGREGATE

Fine aggregate (sand) is composed of material finer than the No. 4 sieve and coarser than the No. 200 sieve.

The additional footnotes for these products 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.”

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 $^3/_8$ inch sieve down to and including the No. 100 sieve. Divide this figure by 100 and report to the second decimal place.

To establish a **base fineness modulus (FM)**, run ten mechanical analysis tests (ASTM C33). 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. Unlike the asphalt industry, the concrete industry uses FM as a parameter for mix development.

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.

When a fineness modulus is required as part of the testing procedure, be sure to add all of the sieves from the $^{3}/_{8}$ 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.

ORGANIC PLATE NUMBER

The right column of the Mechanical Analysis Report form has a line called the ***Organic Plate Number***. This line indicates a 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 numbers one, two, or three are within acceptable limits. Test results four and five indicate the aggregate must be "tentatively rejected pending further testing." This is described in more detail in Chapter 7.

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.

RUBBLE CHECK FOR CRUSHED CONCRETE AGGREGATE

In addition to gradation testing for crushed concrete, you must do a rubble check. This ensures that the material does not include material detrimental to its use. Rubble in crushed concrete includes the following particles: building brick, wood, plaster, or any particle with HMA coating. This pick would be on the same size fraction and sieves specified for deleterious particles in MTM 110, but is calculated by particle count as below:

Rubble %= (# of particles considered rubble)/(# of particles picked for rubble) x 100

MDOT Standard Specifications for Construction 902.05 specifies a maximum of 5.0 percent building rubble or HMA by particle count for dense-graded aggregates for base course, surface course, shoulders, approaches, and patching.

MDOT Standard Specifications for Construction 902.06 specifies a maximum of 5.0 percent building rubble or HMA by particle count for 4G open-graded drainage course.

THE AGGREGATE INSPECTION DAILY REPORT

The Aggregate Inspection Report Forms 1900/1901, or equivalent AASHTOWare data input formats, are used as a summary of the daily aggregate testing activities for a project. The following information is to be tracked for each workday.

1. The name of the project engineer in charge.
2. The name of the prime contractor for the project.
3. The MDOT Aggregate Source Inventory (ASI) number for each aggregate material used.
4. The pit/quarry name (pit and quarries are named after many things such as people, companies, cities, towns, roads, geographic locations, or landmarks) for each aggregate material used.
5. Where each aggregate material was stored and/or sampled.
6. Quantities approved for payment.

All results required by the specifications are to be reported on the form. 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.

For aggregates that 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 in the forms. 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.

Aggregate Inspection Reports are required for each type of aggregate used. The Mechanical Analysis Reports are to be retained and available for review by key personnel. The Aggregate Inspection Reports must be sent to the construction project files for retention. Unless other instructions are given, separate Aggregate Inspection Reports are to be prepared for each project or purchase order.

Do not record a test number for materials visually inspected and accepted. Note all quantities accepted by visual inspection on the daily work report.

If requested by MDOT maintenance operations teams as part of an aggregate purchase, the Aggregate Inspection Reports for aggregates supplied to fulfill maintenance purchase orders should be sent to the Region maintenance engineer managing the aggregate use.

All aggregate rejected by the technician must be reported and its disposition noted even if the quantity is small. Circle or highlight the specific result or results that 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 in the Daily Work Report. Assist the project engineer with the failing material resolution process when needed for non-passing aggregate QA tests.

HOT MIX ASPHALT (HMA)

The form used for testing of HMA is dependent on the material tested. Make sure to check the MDOT forms repository for the most current form needed. The aggregate sieve analysis on these forms is all calculated in the same way. Begin by filling in the known contractual information at the top of the form.

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

The number four indicates the gradation requirements the mixture must meet, with 2 being the coarsest standard mixture and 5 being the finest standard mixture aggregate size gradation. **Note that all the sieves are used during HMA aggregate testing to determine the gradation through mechanical analysis,** but not all sieves have gradation requirements.

The next part of the designation is the letter code *EML,* which specifies the required asphalt binder type and aggregate physical properties. The code *EML* also shows the range of Equivalent Single Axle Load's (ESAL's) projected over a 20-year period, in the medium to low (ML) category and in the range of 300,000 to 3,000,000 ESAL's for the example. For design purposes, an ESAL is a single passing of a standard reference truck axle load of 18,000 pounds and having a typical dual-tire configuration. Pavement thickness design models estimate the amount of service-life fatigue damage caused by each ESAL for a pavement cross section design to get an estimate of expected service life for a design.

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 determining the required aggregate blending ratios 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: 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) for local agency contracts. The calculations for the *Fraction Retained, Percent* and the ***Cumulative Fraction Passing, Percent*** 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 material is dumped into a stack of sieves and shaken using the same rules as discussed earlier. 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 sometimes called **Wt. Passing No. 200 (75 µm) by Shaking** but may have a different designation dependent on the worksheet you use. This weight is added to the **Wt. Loss by Washing** to obtain the **Total Passing No. 200.**

Calculate the **Fraction Retained Percent** by dividing the **Weight Retained, g** by the **WT of Dry Aggregate** and multiplying by 100.

Calculate the **Cumulative Fraction Passing, percent** by taking the **Fraction Retained Percent** and for the first entry subtracting it from 100. For the second and remainder of entries, take the value from the sieve above in the **Cumulative Fraction Passing, percen**t column and subtract **Fraction Retained Percent.**

The material for all crush and deleterious picks is saved from the material retained on the No. 4 (4.75 mm) sieves and above. In the specification tables for HMA, the crush requirement is listed as 00/00. The first '00' denotes the percent of the coarse aggregate that is required to have one fractured face and the second '00' denotes the percent of the coarse aggregate that is required to have two fractured faces.

Soft particles maximum criteria for HMA 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. It will be picked from the material retained on the No. 4 (4.75 mm) sieve and larger sieves.

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

Percent Crushed material: (One Fractured Face)

Percent Crushed, One Fractured Face = (One face crush picked +Two Face crush) / pick weight x 100

Percent Crushed material: (Two Fractured Faces)

Percent Crushed, Two Fractured Faces = Two Face crush/ pick weight x 100

Percent Soft Particles

Percent Soft = Soft pick/ pick weight x 100

CHAPTER 6- PICKING CRUSHED AND DELETERIOUS MATERIAL

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 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. 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 $^{3}/_{8}$ 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 if 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. Calculations are shown on Page 62.

DELETERIOUS AND OBJECTIONABLE PARTICLES

Deleterious means having a known harmful effect. When deleterious particles are exposed to weathering, such as freezing and thawing or wetting and drying cycles, they breakdown relatively quickly and can weaken the product in which they are used. MDOT has a well-defined list of known “deleterious particles” that are relatively easy to identify.

Objectionable particles also include particles found to be nondurable in service through observation and research that are hard to detect using typical geologic pick techniques. These somewhat unusual cases are not included on the typical list of deleterious particles. An example would be silty limestone that retains internal moisture through the HMA plant and prevents bonding of the asphalt.

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 HMA.

Before picking deleterious particles, rinse the material with clear water. This will remove any undesirable coatings on the aggregate and help with 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 evaluate the hardness of 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 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, typical dolomite has a hardness of $3^1/_2$ to 4, Pyrite (fool's gold) has typical hardness of 6 to $6^1/_2$, basalt (diabase) and chert average about 7. A copper penny has a value of $2^1/_2$, a pocketknife 5 to $5^1/_2$, window glass has $5^1/_2$ to 6, and the rat-tail file has a hardness of 6 to $6^1/_2$.

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. Chert in Michigan is typically very hard except for some chalky chert variants.

The chert's porosity makes it undesirable in Portland concrete cement. Chert has very small, microscopic holes that hold water. When the water freezes it expands and physically expands the chert particle. This expansion is not elastic and leaves slightly larger 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:

- *Chert will generally break with a conchoidal fracture (concave or dish shape).*
- *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.*
- *Chert will scratch glass.*
- *The surface will feel smooth if scratched with a fingernail.*
- *If in doubt, break the particle.*

If part of an aggregate particle is chert, then the whole aggregate is counted as 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.

<u>Friable Sandstone</u> – 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.

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

<u>Shale</u> – 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:

- *When damp, most shale will mark greenish-black to black on a canvas bag.*
- *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.*
- *When scratched with a file, the groove left by the file will be a brownish-black*

color.

- *When wet, shale generally has a dull appearance, compared to other aggregates.*

Coal – A natural dark-brown to black color, coal's surface appearance ranges from dull to shiny. Coal can range 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 the relevant specification 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 structure-less 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.

CHAPTER 7 – OTHER TESTING PROCEDURES

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 site 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 approximately 12 or 16 ounces (350 or 470 milliliters). According to ASTM C40, the maximum outside thickness of the bottle shall be of oval design not less than $1^1/_2$ inches (40 mm) and no greater than $2^1/_2$ 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 $4^1/_2$ 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." If the color is darker than three but not as dark as five, it is four.

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.** You will not mark pass or fail on the Mechanical Analysis, instead you will add the bold comment above to the remarks section. 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 may be approved for use.

ANGULARITY INDEX TEST (MTM 118)

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 road surfaces. Shoving is caused by vehicles stopping in the same location.

To illustrate the point, look at Figure 45. 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.

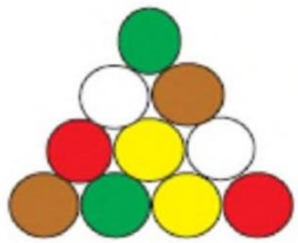


Figure 45: Marble Stacked showing poor interlocking

If the pile was made up of irregular shapes, would the same pressure produce the same results? Look at Figure 46. Obviously, the particles will hold together under the same pressure.

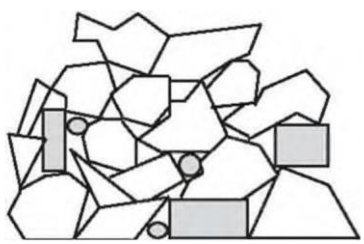


Figure 46: Irregular Shapes showing good interlocking

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 47.

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 graduated cylinder to approximately 1 inch above the water. At a steady rate, always pour the sand into the funnel while picking the funnel upward at the same time to keep it approximately 1 inch above the water. The procedure should take less than ten seconds. This test is repeated three times.

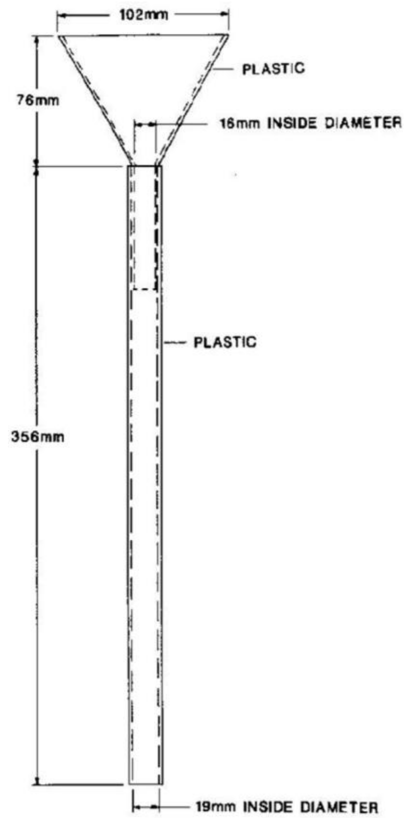


Figure 47: Angularity Index Testing Funnel

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

Figure 48: Angularity Index Testing Computation Table

To complete the form:

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

1. *The Total Volume is the measurement to the top of the water with the fine aggregate added.*
2. *The Sample Volume measurement is the height of the fine aggregate in the cylinder.*
3. *The Volume Solids is the height of the water with the sand added less the 100 ml of water (Number (2) - 100).*
4. *This equals the Sample Volume (3) minus the Volume Solids (4).*
5. *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 on the “Total” line. 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 ten

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.

UNCOMPACTED VOID CONTENT OF FINE AGGRGATE

The Fine Aggregate Angularity Test has been written as AASHTO T 304 "Standard Method of Test for Uncompacted Void Content of Fine Aggregate". 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.

Test procedure: Place a finger over the small opening at the bottom of the funnel. 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).

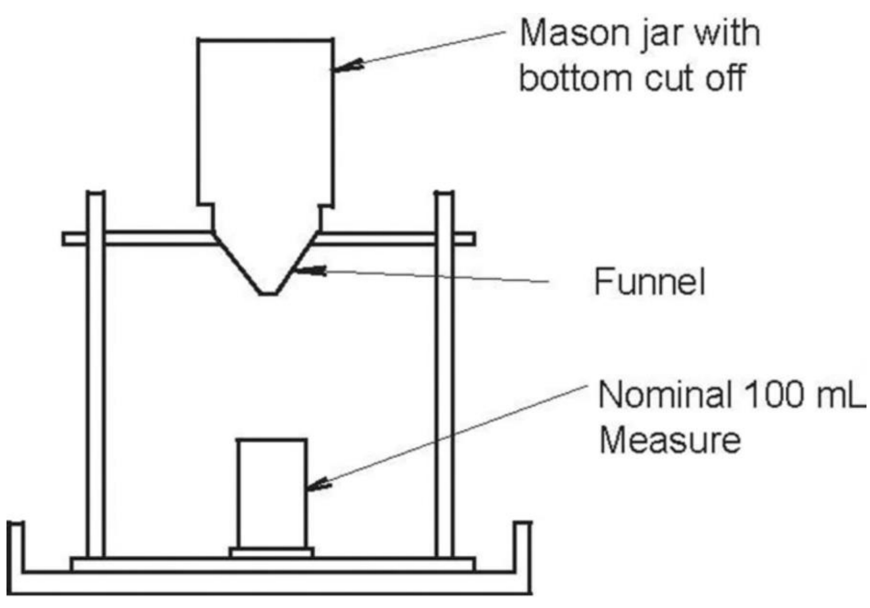


Figure 49: Uncompacted Voids Test Apparatus

Figure 50: ASTM and AASHTO options for the Uncompacted Void Test

Individual Size Fractions	Test Method A	Test Method B	Test Method C
4.75 mm (No. 4)			190 g ± 1 g
2.36 mm (No. 8) to 1.18 mm (No. 16)	44 g ± 0.2 g	190 g ± 1 g	
1.18 mm (No. 16) to 600 µm (No. 30)	57 g ± 0.2 g	190 g ± 1 g	
600 µm (No. 30) to 300 µm (No. 50)	72 g ± 0.2 g	190 g ± 1 g	
300 µm (No. 50) to 150 µm (No. 100)	17 g ± 0.2 g		
	190 g Total (approximate)	Do not mix. Run three tests.	Use all material passing the 4.74 mm sieve.

The formula for calculating is:

$$U= ((V-(F-G)/V) * 100$$

U = Uncompacted voids in the material, percent
V = Volume of cylindrical measure
F = Mass (weight) of the fine aggregate [Weight of cylindrical measure with fine aggregate contents - weight of cylindrical measure]
G = Dry aggregate bulk specific gravity

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

AGGREGATE WEAR INDEX TESTING (MTM 111 AND MTM 112)

Some types of exposed surface aggregate in pavements will polish (wear smooth) when subjected to high traffic volumes. The Aggregate Wear Index (AWI) test procedure is a specialized procedure designed to identify polish-susceptible aggregates. The AWI value for a rock source is defined as; the peak measured lateral friction force developed when a spinning standard ASTM rubber tire with equivalent velocity of 40 mph is dropped from a standard height onto a stationary wetted exposed aggregate special concrete test slab after it has been polished by four million passes of the standard ASTM test-tire on MDOT's special wear track assembly shown in Figure 51.

Limestones are softer rocks, and some limestone aggregates can polish into a very smooth glassy condition during the test procedure, while granite is a hard rock and resists polishing. Sandstone is polish-resistant because individual sand grains break off before they polish smooth, leaving a rough higher friction, sandpaper-like surface. Other rock types have polishing resistance between these extreme examples. Low coefficients of friction on pavements increase the stopping distance required and make it easier to skid/lose traction. Friction is generally reduced when the pavement is wet with fluids, which act as lubricants between the tire and the pavement texture.

Pavement friction is measured in the field using a mobile friction test trailer. The tow vehicles typically travel at about 40 mph while performing skid tests. A signal is sent to the automated friction trailer to initiate a test.A spray bar shoots a jet of water onto the pavement ahead of the trailer's test tire. The test tire then is locked-up, and the resulting lateral friction force development is measured. The peak lateral resistance force value can then be combined with vertical force estimates to estimate the effective coefficient of friction. In the laboratory we measure the AWI friction force index using a Static Friction Tester apparatus like that shown in Figure 52.

Figure 51: Wear Track with Specimen in Place

There are two methods used to calculate AWI. The first, direct method is Michigan Test Method 111, "Determining an Aggregate Wear Index by Wear Track Polishing Tests", which is used on quarried rock sources and slag. An initial friction value and friction values at 500,000 tire pass intervals, up to 4,000,000 wheel passes, are obtained using the Static Friction Tester. This device is designed to be like the field friction test trailer rig and drops a spinning tire on the textured test pad when its equivalent velocity is 40 mph and then measures the maximum dynamic lateral force developed by the tire as it hits the texture pad during tire impact.

The typical polishing resistances for the major geologic rock types in Michigan have been determined in past research using this direct method. For mixed sand and gravel aggregate sources, a simplified numerical weighted average AWI representative of the primary rock types at the gravel pit site as determined by geologic petrographic composition "pick" technique is used to approximate the AWI for a mixed sand and gravel source. The AWI for natural mixed gravel and blends of different aggregates is calculated using MTM 112, from a select pick sample similar to that shown in Figure 53.

CPM aggregates and surface-course bituminous mixtures for Department projects must use aggregates that have an AWI friction index number that meets specifications. AWI numbers for various sources range from about 150 to 400 lb-force. Current minimum AWI for CPM and HMA surface-course aggregates are typically 220 and 260 lb-force for low and high traffic, respectively (ADT = 4,000 vpd threshold). The HMA Production Manual provides additional information on how aggregate samples are to be submitted for AWI and HMA mixture testing.

Samples for the wear track are to be evaluated on approximately five year intervals by the Department's Construction Field Services Division personnel or regional aggregate technicians. The material sampled is a class of aggregate that has the bulk of the material passing the $^{3}/_{8}$ inch and retained on the No. 4 sieves. This sample is delivered to the Department's Construction Field Services Aggregate laboratory located in the Lansing. The material is re-screened to separate the No. 3 sized particles which are then cast into test slabs.

Figure 52: Static Friction Tester

Figure 53: Petrographic Examination

FREEZE-THAW TESTING

Some aggregates are sensitive to the effects of freezing and thawing and can crack or break into pieces after many cycles of freezing and thawing. If susceptible aggregates are present in concrete mixtures, premature distress can develop in the materials.

It is the water absorbed into the aggregate particles that freezes and thaws, potentially causing damage to the particle and surrounding concrete. If there is no water, there is no freezing and thawing. When water freezes, it expands approximately 9 percent by volume. The ability of aggregate particles to resist this freeze-thaw cyclic degradation is related to its porosity, permeability, absorption, and pore structure. If the rock is dense and the pore structure of the aggregate is good, the expansion is accommodated or confined with little damage to the rock and surrounding concrete paste.

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, a specialized computer controlled environmental freezer chamber. Proposed concrete aggregate sources are to be evaluated for freeze-thaw physical characteristics at approximately five-year intervals by the Department's Construction Field Services Division.

Coarse aggregate samples are obtained by Region or CFS aggregate staff and prepared for freeze-thaw testing in accordance with MTM 113. This Michigan method requires strategic use of the following ASTM procedures:

- C29 Test Method for Unit Weight and Voids in Aggregate
- C127 Test Method for Specific Gravity and Absorption of Coarse Aggregate
- C131 Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
- D75 Methods for Sampling Aggregates

The procedure for making concrete beams to be tested in the freeze-thaw apparatus is described in MTM 114. 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.

Once the test beams are cured, they are placed in the freeze-thaw chamber and subjected to freeze-thaw cycles with temperatures varying between zero and 40 °F. Each cycle is three hours long. The test is completed after 300 cycles. The durability index for the aggregate is measured as a length change or dilation (expansion) of the beam that develops because of exposure. The beam expansion is measured to the nearest thousandth of an inch using a length change comparator.

Freeze-thaw results are reported as a percent dilation per 100 freeze-thaw cycles. MDOT generally has three threshold limit values for standard concrete aggregates as follows:

- precast concrete bridge beams = freeze-thaw dilation less than or equal to 0.010 percent
- high performance concrete mixtures = less than 0.040 percent
- miscellaneous concrete uses and low volume roads = less than 0.067 percent

The approval of aggregate sources based on freeze-thaw testing was formalized in a 1992 MDOT policy document as follows:

1. <u>New Source or Source with Expired Freeze-Thaw Results</u>

The source will be approved if the dilation on the first passing freeze-thaw test does not exceed 0.050 percent per 100 cycles. If the dilation exceeds 0.050 percent but does not exceed 0.067 percent, a second freeze-thaw sample will be taken from different production from the first sample. The source will be approved if the second freeze-thaw does not exceed 0.067 percent per 100 cycles. The effective date is the date on the certified letter notifying the producer.

If the first or second freeze-thaw samples, taken from a new source or a source with expired freeze-thaw results, have a dilation test result exceeding the 0.067 percent specification limit, the source will not be approved. Freeze-thaw results on a source will expire five years after notification to the producer of the most recent freeze-thaw test results.

2. <u>Currently Approved Source</u>

A. Meets Specification

- *When a subsequent freeze-thaw test results in a dilation less than or equal to the MDOT' s basic specification or specific use requirement, the freeze-thaw result will be effective as of the date on the certified letter notifying the producer.*

B. Does Not Meet Specification

- *When a subsequent freeze-thaw test results in a dilation greater than MDOT's basic specification requirement, or specification limit for specific use, the effective date of the new result will be the date of the receipt of the letter sent by certified mail to the producer.*

1. <u>Disapproval of a Source</u>

For those sources where there has been no change in the aggregate characteristics, when a freeze-thaw test results in a dilation greater than 0.120 percent per 100 cycles, or the average of the current sample and previous regular freeze-thaw sample is greater than 0.080 percent, the source will be disapproved. All shipments to MDOT projects must stop within 24 hours of receipt of the certified letter notifying the producer. Stocks of aggregate at a contractor's plant may be authorized by the engineer for use until satisfactory material can be obtained, but under no condition will this authorization exceed 14 calendar days.

2. <u>Extension of Previous Test Result</u>

For freeze-thaw test results failing to meet the basic specification requirement but not covered by B.1. above, the producer must, within 14 calendar days from date of receipt of the certified letter of notification, make arrangements with MDOT's Materials Section, for submitting a new freeze-thaw sample. The retest sample will be obtained and submitted to the Aggregate Quality Lab within 30 days of receipt of the certified letter. If a new freeze-thaw test sample is not received within this 30 calendar day period because the producer was unable to supply aggregate for MDOT to sample, material will no longer be accepted for use on Department projects *unless an extension is granted by MDOT.*

Upon receipt of a freeze-thaw retest sample, MDOT will extend the results of the previous acceptable freeze-thaw test until the retest is complete, provided the aggregate can be produced to acceptable quality as determined on a case-by-case basis as stated in the chart to follow. New orders will be allowed to be bid during this retest period, contingent on these conditions and the following retest requirements.

3. <u>Retest Fails</u>

Should the freeze-thaw retests verify the previous failing result, material from the source will not be acceptable for use on those Department projects bid between the notification of the first test's results by certified mail and the notification of the retests' results (the contractor will have to locate an alternate source at no additional cost to the Department). In addition, material from the source will be reviewed as to its suitability to continue supplying current projects, with the Materials Section making a recommendation to the affected MDOT Regions. The contractor will be notified by the Region if material is deemed unsuitable.

Figure 54: GUIDELINES FOR THE APPROVAL OF SOURCES BASED ON FREEZE-THAW TEST RESULTS

<table>
<tr><th>CASE #</th><th>TEST A</th><th>TEST B</th><th>ACTION</th><th>RETEST C</th><th>ACTION</th></tr>
<tr><td>1.</td><td>Pass</td><td>Pass</td><td>Approve</td><td>N/A</td><td>N/A</td></tr>
<tr><td rowspan="3">2.</td><td rowspan="3">Pass</td><td rowspan="3">Fail - Changed characteristics</td><td rowspan="3">Continue approval under Test A with restrictions and retest. If dilation >0.120 or average >0.080, continue under Test A with severe restrictions and retest</td><td>Pass - Characteristics same as A</td><td>Approve - For material similar to A</td></tr>
<tr><td>Pass - Characteristics same as B</td><td>*Average B & C - If average passes, approve with restrictions. If average fails, approve on basis of A with severe restrictions and retest</td></tr>
<tr><td>Fail</td><td>Reject</td></tr>
<tr><td rowspan="6">3.</td><td rowspan="6">Pass</td><td rowspan="6">Fail - Not changed characteristics</td><td rowspan="3">Average A & B - If average passes, continue approval on A with restrictions and retest</td><td>Pass</td><td>*Average B & C - If average passes, approve</td></tr>
<tr><td>Pass</td><td>*Average B & C - If average fails, continue on basis of C with restrictions</td></tr>
<tr><td>Fail</td><td>Reject</td></tr>
<tr><td rowspan="3">Average A & B - If average fails and is <=0.080, continue approval on basis of A with severe restrictions and retest</td><td>Pass</td><td>*Average B & C - If average passes, continue on basis of C with restrictions</td></tr>
<tr><td>Pass</td><td>*Average B & C - If average fails, continue on basis of C with severe restrictions and retest</td></tr>
<tr><td>Fail</td><td>Reject</td></tr>
<tr><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td>Average A & B - If average >0.080</td><td>None</td><td>Reject</td></tr>
<tr><td>Dilation of Test B >0.120</td><td>None</td><td>Reject</td></tr>
</table>

COMMENTS:

Changed Characteristics – A considerable change in deleterious content, specific gravity, absorption, crushed content, known changes in deposit, or processing procedures, etc. as determined by Aggregate Quality. Only a change in negative mode (increase in deleterious or absorption, decrease in specific gravity or crushed content, etc.) are considered as changed characteristics.

Restrictions - Restrict the deleterious content and/or specific gravity to the more restrictive of Sample A, B, or C with tolerances as noted in footnote g in Table 902-2 in the MDOT Standard Specifications for Construction.

Severe Restrictions - As above except with no tolerances. To be permitted for current contracts only.

Reject - All shipments to MDOT projects stop within 24 hours of notification. Contractor stocks may be used until satisfactory material can be obtained, not to exceed 14 calendar days (Aggregate producer is responsible for notifying contractors).

Pass/Fail - Results meeting or failing to meet the dilation requirements of the basic specification, or the specification limits for a specific use.

*If Test A has a dilation greater than or equal to 0.040 and Test B has a dilation which exceeds A and differs from A by greater than 50 percent, two resamples, C1 and C2 will be obtained. Sample B will not be averaged. Test results of C1 and C2 will be used to determine acceptance or rejection. Samples C1 and C2 must be from material which has been produced since Sample B. In addition, C2 must be from material which has been produced since C1.

BULK DRY SPECIFIC GRAVITY & ABSORPTION

According to 902-2 footnote (d), the bulk dry specific gravity of sources tested for freeze-thaw durability must stay within .04 (less) of the most current freeze-thaw bulk dry specific gravity to use the current freeze-thaw result. There are many different test methods for calculating bulk dry specific gravity, MDOT uses *ASTM C127 Test Method for Specific Gravity and Absorption of Coarse Aggregate.*

Specific gravity and absorption are to be verification tested at approximately 1-yr intervals for sources that have a current freeze-thaw result, with samples collected by the Region staff during normal acceptance testing. If a source’s yearly bulk dry specific gravity falls outside the allowance specified for the freeze-thaw data, that source can no longer supply coarse aggregate for any MDOT project that has a freeze-thaw requirement until a new freeze-thaw evaluation has been completed due to the apparent changed physical properties. This includes any material that is shipped to or is stored at pre-cast or concrete plants.

MDOT will conduct random bulk dry specific gravity tests directly at concrete and pre-cast plants for verification. If the results are outside specified allowances the material represented by the sample will not be allowed to be used, and the Region will collect a production sample directly from the source for bulk dry specific gravity testing. If the results confirm that the bulk dry specific gravity at the source is outside specified allowances, the source can no longer supply coarse aggregate for concrete for any MDOT project subject to a freeze-thaw requirement until a new freeze-thaw evaluation has been completed. This includes any material that is shipped to or is stored at pre-cast or concrete plants.

Repeated instances of being outside specified allowances on the bulk dry specific gravity for either material sampled at the source or material shipped to concrete plants will result in re-evaluation of the source’s suitability for concrete use.

SHRP TEST

The Strategic Highway Research Program (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 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.

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-95003 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.

FLAT PARTICLES, ELONGATED PARTICLES, OR FLAT AND ELONGATED PARTICLES

This is ASTM D4791 “Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse 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. This ASTM has been clarified in MTM 130 to allow material used for the Mechanical Analysis to be used for determination.

Aggregate particles with greater than a one to five ratio (length to thickness) are considered to be unacceptable for use in bituminous mixtures. Aggregates used in concrete have a three to one aspect ratio. See the 902 tables in the Standard Specification for Construction 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 tend 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 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 55. 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.

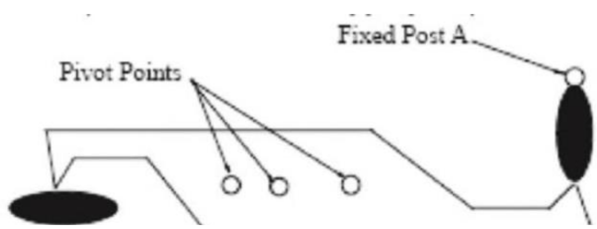


Figure 55: Proportional Caliper Device

SAND EQUIVALENT TEST

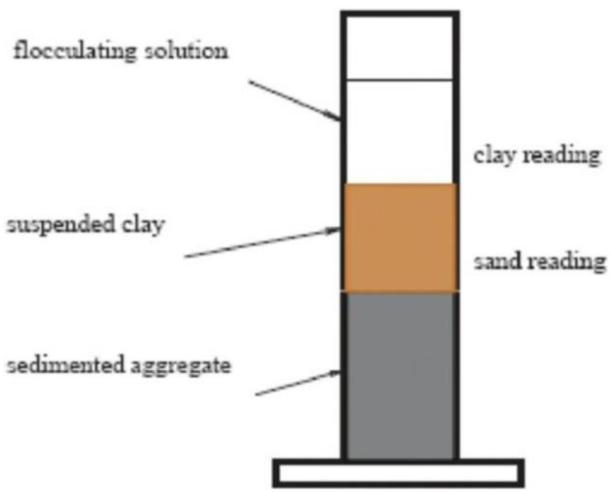
This test is AASHTO T176 or ASTM D2419 “Plastic Fines in Graded Aggregates and Soils by use of the Sand Equivalent Test.” The test separates the clay like or plastic fines and dust from the fine aggregate (sand). A comparative reading is taken between the suspended clay and the settled sand in the measuring cylinder to determine the 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:

Sand Equivalent = Height of sand reading / Height of clay reading x 100

Figure 56: Sand Equivalent Test



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

Testing and guidance on this method is available from the Soils Unit at CFS.

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 C131 and AASHTO T96. The Michigan Department of Transportation has altered the ASTM and AASHTO standard by issuing Michigan Test Method 131. 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" gradation is:

Passing	Retained On	Weight in Grams
$^{3}/_{4}$ in.	$^{1}/_{2}$ in.	2500 g ± 10
$^{1}/_{2}$ in.	$^{3}/_{8}$ in.	2500 g ± 10
	Total	**5000 g ± 10**

Figure 57: LA Abrasion Gradation B - Aggregate Sieve Sizes

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 refer to the specifications for the material being tested

Figure 58: Los Angeles Machine

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:

Moisture % = (Wet Weight- Dry Weight) / Dry Weight * 100

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

1. American Association of State Highway and Transportation Officials, 444 North Capital Street NW, Suite 225, Washington D.C. 20001.

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

3. Michigan Test Methods, available from Michigan Department of Transportation, Financial Operations Division, Cashiers Office, P.O. Box 30050, Lansing, MI 48909.

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

5. HMA Production Manual: http://www.michigan.gov/documents/mdot_HMA_ProductionManual_79005_7.pdf

6. Michigan Department of Transportation's Standard Specifications for Construction

If you require assistance accessing this information or require it in an alternative format, contact the Michigan Department of Transportation's (MDOT) Americans with Disabilities Act (ADA) coordinator at Michigan.gov/MDOT-ADA.