SOILS TECHNICIAN
CERTIFICATION WORKBOOK

ARIZONA TECHNICAL TESTING INSTITUTE

Revised MAY 2025

FORWARD:

The Arizona Technical Testing Institute (ATTI) is a nonprofit organization formed to promote the highest standard in highway construction materials sampling and testing through certification of technicians. ATTI certifications emphasize a hands-on approach, that is, applicants must satisfactorily demonstrate test methods as well as pass a written exam to receive certification. The organization is represented by members from the Arizona Department of Transportation (ADOT), highway contractors, materials suppliers, materials testing laboratories, Arizona Rock Products Association (ARPA), Federal Highway Administration (FHWA), and Arizona General Contractors (AGC). ATTI certifications satisfy ADOT and federal requirements which specify that technicians performing materials sampling and testing on ADOT projects are properly qualified.

ATTI provides the following certifications:

ATTI FIELD TECHNICIAN – field sampling and testing of soils, aggregates, asphalt, and asphaltic concrete,

ATTI LABORATORY SOILS/AGGREGATE TECHNICIAN – laboratory sampling and testing of soils and aggregate,

ATTI ASPHALT TECHNICIAN – laboratory sampling and testing of asphaltic concrete.

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PROCEDURES

INTRODUCTION:

- The ATTI Field Technician Certification program evaluates the competency of applicants performing sampling and testing of soils, aggregates, bituminous materials, and hot mix in the field.

- Certification is based on satisfactory demonstration of all specified sampling and testing methods, as well as passing a written examination. Applicants are advised to receive training or have experience performing the test methods and calculations before attempting to obtain certification.

- This workbook provides information regarding the requirements for ATTI Field Technician certification, administration of the certification process, and topics covered during the certification, administration of the certification process, and topics covered during the certification examinations.

- Brief coverage is given to safety issues, plan and profile, representative samples, record keeping, and properties of soils, aggregates, and asphaltic hot mix. Most importantly, the workbook contains copies of the applicable testing methods which a certified ATTI Field Technician must be able to perform.

PERFORMANCE EXAMINATION:

- As Stated earlier, the emphasis of this certification program is technician demonstration of proficiency in performing all test methods which have been specified above.

- Technicians may not use any notes or books while taking the performance exam. The examiner will maintain possession of all examination paperwork.

- Instead of performing both Method A and Alternate Method D one point proctor tests, the examiner may ask the technician to verbally recite the differences between the two tests.

- The examiner will use standardized checklists to verify proper procedure by the technician. During the performance examination, the examiner will indicate a technician's compliance with each identified item on the individual test method checklist with a "Yes" or "No" in the space provided. If any significant deficiencies are observed during the exam, the examiner must indicate "No" for that item. Any "No" will constitute failure of that test method. All checklist items must be performed correctly or the test method is considered failed.

- Once completed, the examiner will inform the technician if the test method was passed or failed. If failed, the examiner will indicate the step or steps that were not performed properly. The failed test method may be demonstrated a second time at the discretion of the examiners. The retest should be performed after all other tests have been completed, the technician has studied the failed test method, and the examiner is available. If a test method is failed a second time, the applicant must schedule a retest within 1 year at a cost of $50.00.

- If the technician requests to start over a test method once they have begun, the examiner will allow the technician to restart the test method and disregard findings of the incomplete test. The technician will be allowed to restart a test method one time only.

- If the technician has successfully attained an ATII Asphalt, Soils I Aggregate, or Field Technician Certification within the last 12 months you may receive credit for some of the test methods performed included in that certification.

- ***It is recommended that technicians perform all test methods during an examination period. Any test methods not performed will be considered failed.***

WRITTEN EXAMINATION:

- The written examination has a 3-hour time limit to complete. The questions and calculations are derived directly from the previously mentioned test methods and from information presented in the first few chapters of this manual. Eighty (80) percent of the written examination questions must be answered correctly and all calculations performed correctly to achieve a passing score.

- Notes and books may not be used while taking the written examination. The examiner will maintain possession of all examination paperwork.

RETEST:

- If a technician fails to successfully demonstrate a test method as prescribed, the technician may be allowed to demonstrate the failed test method a second time during the same examination period at the discretion of the examiners. The retest should be performed after all other tests have been completed, the technician has studied the failed test method, and the examiner is available. Failed test methods must be re-demonstrated within twelve months of the original examination date. All retesting is at the discretion of the examiners.

- A technician failing the written or calculations examination is required to retake the entire written or calculations examination within twelve months of the original test date.

- If a technician fails the performance and /or written examinations a second time, a fee will be charged for additional testing that must be performed within twelve months of the original examination date. If the failed items are not successfully passed the third try, the technician will be required to register and retake the entire certification examination.

CERTIFICATION:

- To receive certification, the technician must successfully demonstrate all test methods as well as correctly answer at least 80 percent of the written exam questions and correctly perform all calculations. Certification is granted for a period of five years. Successful completion of the entire examination program is required for re-certification.

CANCELATION / NO SHOW POLICY:

- The cancellation policy is detailed in the ATTI Administration Manual which is available on the ATTI website at www.attiaz.org.

APPEALS:

- ATTI certification examinations, policies, procedures, requirements, and materials are developed through a cooperative effort of the ATTI technical advisory board and industry experts. The ATTI Board of Directors approves and provides oversight of the certification program. If a technician feels that the certification exams have not been correctly administered or if the technician desires to appeal their exam scores, they may do so.

- Appeals should be made in the following sequence:
  1. Senior Examiner
  2. Executive Director
  3. Technical Advisory Board
  4. ATTI Board of Directors

- If there is not consensual resolution at any level, the technician may escalate their appeal to the next level. The decision of the Board of directors is final.

- Technicians are encouraged to provide feedback to ATTI on any portion of the examinations, manual content, exam administration, or requirements of the ATTI certification process. The comments received will be discussed by the technical advisory board and, if merited, revisions to the program will be initiated.

SAFETY:

- Some of the test methods in this manual may involve hazardous materials operations, and/or equipment. This manual does not claim to address all relevant safety issues which may be encountered or which may be associated with its use or with the performance of test procedures introduced here.

- It is the responsibility of the technician to determine, establish, and follow appropriate health and safety practices. The technician must also determine the applicability of any regulatory limitations of test equipment and chemicals.

OSHA:

- OSHA has established safety requirements for individuals working in various environments. In the field and laboratory these requirements include such measures as wearing hard hats, eye protection, and protective footwear as well as the need to observe certain precautions when operating machinery and other equipment.

- There are also regulations pertaining to the handling and storage of chemicals, nuclear devices, and other hazardous materials. This short discussion on safety is not meant to preclude or to include OSHA requirements. It is up to the individual technician to be acquainted with OSHA regulations that apply to their particular job assignment.

PLAN & PROFILE

The plan and profile of a specific segment of a roadway are typically printed on a single sheet of the project plans with the plan view at the top of the sheet and the corresponding profile view at the bottom of the sheet. Plan and profiles are drawn such that profile stationing is directly below the plan stationing. See Figure 1.

The plan shows an aerial view of the roadway, as if the observer is looking directly down on the roadway. Roadway details such as horizontal alignment, roadway width, right-of-way, and structure locations are illustrated on the plan sheet relative to the roadway centerline. The profile shows a longitudinal cross-section view of the roadway elevation, taken through the centerline of the roadway. The profile illustrates details such as vertical alignment of the centerline, existing ground line elevation, culvert elevation, and structure elevations.

PLAN DETAILS

The ***centerline***, denoted, ℄ is the surveyed center of the roadway. It may be an existing centerline or a newly established centerline. If both are illustrated, they should be clearly identified.

Station numbers are established along the centerline. Each station represents 100 feet; therefore, a distance of 700 feet is equivalent to 7 stations. Most projects will begin at station 0+00 and increase in stationing to the end of the project. For example, the location of a culvert is given as Station 21+76.8 which is equal to 2,176.8 feet from the beginning of the project. When a new centerline is established, and it is desired that the new stationing matches the old, it is often necessary to add a correction equation.

Sampling of roadway materials is conducted randomly; consequently, very few samples are taken on the centerline. Specific sample locations are identified by station and **centerline offset** to the left of centerline or to the right of centerline. As an individual is facing in the direction of increasing stationing, the individual's left defines "left of centerline" and the individuals right defines "right of centerline."

PROFILE DETAILS

Elevations of various roadway centerline details are illustrated on the profile sheet. The elevations represent vertical distance above or below sea level.

The existing ground elevation along the **centerline** and the design finished roadway **centerline** are illustrated by lines drawn at the appropriate elevations.

The top elevation and depth of a sample is often drawn on the profile sheet.

TYPICAL SECTIONS

Typical sections illustrate the components and dimensional requirements of each pavement structure used on the project. The typical pavement sections are cross-sections taken transversely across the roadway. See Figure 2.

Pavement structural sections provide details on the material type and depth of each layer of the pavement structure. The pavement structure includes all pavement materials placed above the subgrade, including aggregate subbase, aggregate base, asphaltic concrete, Portland cement concrete, and asphaltic concrete friction course.

REPRESENTATIVE SAMPLES

As should be apparent, acceptance or rejection of materials is highly dependent on the representativeness of a small sample that is tested to determine the quality of a large quantity of material. If the sample is not truly representative of the larger quantity, acceptable material might be rejected or unacceptable material might be accepted. Unbiased samples must be obtained in a way that the true nature of the material is represented. For example, aggregate stockpiles should not be sampled at the surface where coarser slough material is present. Similarly, all material from an asphaltic concrete plate sample should be obtained with single strokes of the sampling device through the middle of the plate, excluding material that sloughs onto the plate after initial sampling.

RANDOM SAMPLING

A random sample is any sample which has an equal chance as any other sample of being selected from a population. In other words, there is an equal chance for all locations and all fractions of materials to be sampled.

Samples should not be obtained on a predetermined basis or based on the quality of the material in a certain area. If sampling is not performed on a random basis, the quality of the sample can be artificially modified and the sample will no longer be representative of the larger quantity.

When a sample is not representative, it is said to be biased. Examples of biased sampling that should not be used include sampling a roadway at a given interval such as 1500 feet; sampling asphaltic concrete production at a given frequency, such as every 500 tons; or taking samples at a given time, such as every hour on the hour.

Random sampling is usually accomplished with the use of random number generators or tables of random numbers. Most calculators and computers contain a random number generator that merely requires the operator to hit a button. The automated random number generators use programmed tables of random numbers similar to the table shown in figure 3. Random number tables are simply random arrangements of numbers of any table length.

.72	.51	.98	.45	.01	.55	.25	.24	.73	.43
.99	.13	.69	.59	.88	.35	.07	.66	.82	.78
.68	.40	.08	.83	.11	.48	.56	.19	.46	.31
.03	.96	.49	.10	.74	.38	.22	.87	.33	.57
.70	.28	.04	.63	.27	.15	.60	.44	.03	.37
.16	.53	.85	.09	.39	.91	.47	.30	.77	.42

Figure 3. Table of random Numbers

ASTM D3665 - "Standard Practice for Random Sampling of Construction Materials" is a reference used by the industry for determining random locations or timing at which samples of construction materials are to be taken. The ASTM method uses a table of random numbers and details the procedures for determining random times for belt sampling, random lengths for windrow sampling, random sampling of in-place paved materials, and random truck load number sampling.

To obtain a group of random numbers, select a starting number in a random number table, never repeating the same starting number, and proceed from the starting number reading left to right, top to bottom, bottom to top, right to left or diagonally. Each number will then correspond to a sampling frequency.

Example 1:

Four samples are required for a 12 feet wide pavement with a lot size determined to be 4000 linear feet. The lot begins at station 100+00. Use the random number table in Figure 3 to determine the sample locations.

Step 1, from the given information:
Lot begins at station 100+00
Lot ends at station 140+00
Length of lot = 4,000 feet

Step 2, determine the sample location:

Using the random number table, obtain two sets of 4 random numbers each.

Set 1 will be used to determine stationing (X) of the samples by multiplying the random numbers by 4,000 feet.

Set 2 will be used to determine the sampling distance from the right edge of pavement (Y) by multiplying the random numbers by 12 feet.

Step 2a, random numbers chosen from table:

Set 1:	.13	.69	.59	.88
Set 2:	.73	.82	.46	.33

Step 2b, sample coordinate locations determined:

Sample #1:
X= .13 X 4000 = 520 feet
Y= .73 X 12 = 8.8 feet

Sample #2:
X= .69 X 4000 = 2760 feet
Y= .82 X 12 = 9.8 feet

Sample #3:
X= .59 X 4000 = 2360 feet
Y= .46 X 12 = 5.5 feet

Sample #4:
X= .88 X 4000 = 3520 feet
Y= .33 X 12 = 4.0 feet

Step 2c, samples located by stationing and offset:

Sample #1:
Station 100+00 + 520 feet = Station 105+20 @ 8.8 feet from right edge of pavement

Sample #2:
Station 100+00 + 2760 feet = Station 127+60 @ 9.8 feet from right edge of pavement

Sample #3:
Station 100+00 + 2360 feet = Station 123+60 @ 5.5 feet from right edge of pavement

Sample #4:
Station 100+00 + 3520 feet = Station 135+20 @ 4.0 feet from right edge of pavement

[illegible]

When obtaining samples from a large area (or lot), divide the area into sublots if necessary and obtain samples from each sublot using stratified random sampling. Stratified random sampling assures that samples are taken from throughout the entire lot and are not concentrated in one area of the lot. See Figure 4.

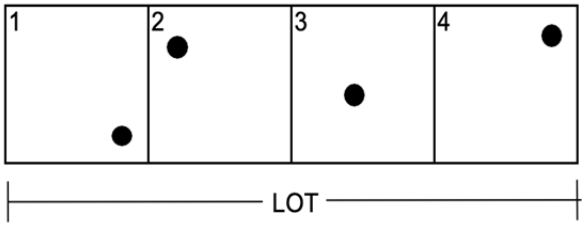


Figure 4. Sublots for stratified sampling.

SAMPLING AND TESTING RECORDS

All data collected during the sampling and testing processes should be documented electronically or retained on paper. This documentation provides:

- Records pertaining to individual samples.
- A process to trace samples and test results.
- Control of samples as they are processed and tested.
- Who did the sampling and testing.
- What testing was done.
- Permanent record of test data and test results.

Sample tickets used for sample identification, work instruction cards directing which tests to perform, logs of samples and tests performed, test data worksheets, and test result reporting forms are all routinely used records which a technician must have familiarity.

Test methods provided in AASHTO Standard Specifications, Part I/tests and in the ADOT Materials Testing Manual define which data to collect, calculations to perform, and what information to report. They also have guidelines for determining if test results are reasonable.

SAMPLE TICKETS

Sample tickets need to be attached to or accompany all samples. A sample ticket is the document which identifies an individual sample. Sample tickets will usually contain information such as:

- Project number or code.
- Name of the person who obtained sample.
- Type of material.
- Date and time the sample was obtained.
- Purpose of the sample. • Where the sample was taken
- Sample number.
- Type of testing to be performed.

TEST RESULTS

Field sampling and testing must always be done according to test methods. Precise and reliable sampling and testing directly impacts the acceptance and payment of a product. If sampling and testing are not performed correctly, a substandard product could be accepted at full compensation or an acceptable product could be rejected. Test methods used most frequently are contained in the ADOT Materials Testing Manual and the AASHTO Standard Specifications,

Part II, Tests. These methods describe how large a sample should be, step-by step procedures, what data is to be collected, what calculations are to be performed, and what test results are reported.

The reliability of testing is often checked with the use of split samples which are tested by two different technicians. If individual test results or the comparison of split samples do not seem reasonable, an investigation should be conducted to establish why. Usually, the discrepancy will be due to procedural or equipment deficiencies, errors in calculations, incorrect transposition of data, or the use of procedural shortcuts. Poor equipment calibration or equipment malfunction and improper handling of samples can also cause unreliable test results. Retesting should be performed only after the discrepancies have been corrected.

All test reports should clearly identify the individual who performed the test and the date the test was completed. Test reports should also include the signature of the individual taking responsibility for the validity of the testing. All revisions made to a test report must identify the person making the changes and the date the changes were made. Example copies of test report forms are included in some of the test methods presented in this workbook.

MATERIALS PROPERTIES

Specific strength, durability, water dispersion and other similar properties of soils, aggregates, and asphaltic concrete are the basic properties a highway construction material is designed to satisfy. The soils and aggregate properties of interest to the field-testing technician are briefly discussed below. Compaction testing and sampling of mixtures for laboratory testing are the items of asphaltic concrete construction that are of primary interest to the field technician involved with sampling and testing.

ENGINEERING PROPERTIES OF SOILS

Selected characteristics of soils directly influence the design, construction, and performance of highway features. The properties of soils on a construction project determine the slope of a cut, the load bearing capacity of a subgrade and the sheer strength of embankments. Soils as well as aggregate base courses must have enough strength to support the applied loads of traffic, embankments, and structures under all climatic conditions. Two tests commonly used to determine the strength properties of a subgrade or embankment are the gradation and plasticity index test. These properties directly influence the soil support value of the subgrade under the pavement structure. The plasticity index is an indication of the cohesiveness, bonding, and moisture susceptibility of a soil.

For the purposes of this course, the engineering properties of three major soil types will be considered. Engineering properties for our use will refer to the properties of these soil types as they relate to highway design and construction.

These three main soil types consist of:

Granular soils-Sands and gravels

Fine-grained soils- silts and clays

Organic soils - organic clays and organic peat.

Granular soils, when free draining is not susceptible to frost and will settle quickly under a load. These characteristics make granular soils a good choice for use in foundations, embankments, and as wall backfill material. The drawback to the use of granular soils is that due to their high permeability it can be difficult to dewater them.

Cohesive soils are fine-grained soils. They sometimes possess low shear strength and are compressible and plastic. Wetting of these soils results in a further reduction of shear strength and also in expansion. The expansion will be followed by shrinkage as the material dries. Shear strength is also lost when a cohesive soil is disturbed. These soils can be subject to landslides. Cohesive soils are usually considered a poor choice for construction materials.

Organic refers to decayed animal and vegetable materials. Therefore, an organic soil is any soil containing enough organic material to influence the properties and characteristics of the soil. In general, organic soils are not used in highway construction. All soils, which contain an organic component, should be reviewed carefully and with suspicion when used in highway construction. The presence of organic material in the soils results in an increase in compressibility and a reduction of load bearing capacity. Organic materials can also contain toxic gases, which are released when the soil is disturbed.

ENGINEERING PROPERTIES OF AGGREGATES

Particle size and shape, gradation, and cleanliness are three important properties of aggregates that are considered in highway construction. These three properties directly influence the capability of an aggregate mixture to compact, drain water, and adhere to binders.

Aggregate particles are sieved through screens to obtain portions of the same **particle size**. Percentages of the different sizes are then combined to create engineered base, bedding, backfill, and mineral aggregate composites. Particle shape also influences the compactibility and surface to surface contact of aggregates. Angular and irregular particles interlock and resist displacement much better than rounded particles.

Particle shape also influences the compactibility and surface to surface contact of aggregates. Angular and irregular particles interlock and resist displacement much better than rounded particles. Particle shapes of interest include irregular, angular, flaky, elongated and rounded. Elongated particles have a long dimension which is 1.8 times the average dimension and flaky particles are those whose shortest dimension is less than 0.6 times the average dimension. Each of these shapes is determined by test methods contained later in this manual.

Gradation defines the distribution of a variety of aggregate particle sizes and is often referred to as aggregate grading. The intended use for the aggregate will determine the percentage of each particle size to be used in the gradation or size distribution. Plant screening and crushing processes are used to control gradation. Sieve analyses (AASHTO T27)) are performed on an aggregate mixture to determine the true percentage of each size in the mixture.

ENGINEERING PROPERTIES OF ASPHALTIC CONCRETE

Field sampling of asphaltic concrete mixes is performed to check the produced mix properties for compliance with mix design requirements. Asphaltic concrete mixture performance is affected by the mineral aggregate properties and liquid asphalt cement properties. Consequently, it is important that representative samples are taken. The common method for sampling asphaltic concrete mats is to place a 1’ x 4’ metal plate in front of the paver. As the paver travels across the plate, material is placed on the plate. When obtaining the asphaltic concrete sample from the surface of the plate, all slough material from the sides of the cut of the surface should not be collected.

Asphalt cements function as a binder, or glue, which hold the aggregate particles together and provide protection against the effects of water. Liquid asphalt cement samples are taken to check viscoelastic, temperature sensitivity and aging properties.

COMPACTION

Asphaltic concrete, soils and aggregate bases, backfills and beddings are typically compacted to a specified percentage of maximum density in the field by use of rollers or mechanical compactors. Maximum compaction is desirable to reduce settling and deformation, and increase load bearing capacity. The density of a layer of in-place soils/aggregate material is checked by the sand cone density test (AASHTO T191), nuclear density gauge (AASHTO T310), or one-point proctor test (AASHTO T271). Asphaltic concrete compaction is checked with the nuclear density gauge (AASHTO T355) or lab testing of cores (AASHTO T67) taken from the compacted roadway. The in-place density of soils/aggregates is then compared to the maximum dry density determined in the lab by proctor testing to determine the degree of compaction. Similarly, the in-place density of a layer of compacted asphaltic concrete is compared to the maximum density determined by laboratory testing.

TEST METHODS

SAMPLING/ REDUCING / & SIEVING PROCEDURES

Field construction materials sampling is a critical process in ensuring the quality, safety, and longevity of construction projects. Field sampling involves collecting representative samples of various construction materials, in this, case soil and aggregates directly from the construction site, plant, or transport for analysis in the lab. Sieving is an essential part of this analysis, particularly for assessing the grain size distribution of fine and coarse aggregates and soils. This type of testing helps ensure that the materials used in construction meet quality standards and required specifications.

All sampling, reducing and sieving procedures that will be covered during ATTI:

- **AASHTO R90:** *SAMPLING AGGREGATE PRODUCTS*
- **AASHTO R76:** *REDUCING SAMPLES OF AGGREGATE TO TESTING SIZE*
- **AASHTO T27:** *SIEVE ANALYSIS OF FINE AND COARSE AGGREGATE*
- **AASHTO T11:** *MATERIALS FINER THAN #200 SIEVE IN MINERAL AGGREGATES BY WASHING*

Learning objectives for these sections are:

- ***How to obtain a representative sample of aggregate materials through various methods.***
- ***How to reduce samples, once collected, to their appropriate testing sizes.***
- ***Learn the sieving process and how to calculate and report the resulting percent passing.***

PLEASE REFER TO THE PROCEDURE FOR MORE DETAIL. NOT ALL SECTIONS WILL BE COVERED BY ATTI. THE SECTION NUMBER WILL BE PROVIDED FOR REFERENCE.

AASHTO R90:

SAMPLING AGGREGATE PRODUCTS

DEFINITIONS:

Nominal maximum size - *is the smallest sieve size through which the majority of the sample passes (up to 10% can be retained).*

Windrow - *is a long ridge of loose construction material.*

Stockpile - *is a collection of materials in piles that are segregated by type & size and intended for specific uses on a construction site.*

Increment - *is a portion of material that is collected by a sampling device in a single operation.*

SEC:

SCOPE:

1.1.

This practice covers the procedures for obtaining representative samples of coarse, fine, or combinations of both to determine compliance with all relevant specifications.

EQUIPMENT:

4.0.

- **SHOVELS OR SCOOPS**
- **BROOMS, BRUSHES, AND SCRAPING TOOLS**
- **MECHANICAL SAMPLING SYSTEMS-** Normally, a permanently attached device that allows a sample container to pass perpendicularly through the entire stream or diverts the material into the container.
- **BELT TEMPLATE-** a device that is the shape and width of the aggregate belt.
- **SAMPLING CONTAINERS**

PROCEDURE:

- Make sure to **clean and dry** all **equipment and containers** before sampling. 5.1.1
- Field **samples** should meet or exceed **TABLE 1** found in the procedure. 5.2.
- **Sample size is based upon the tests that are required**. Rule of thumb, generally the sample should be enough that if you split it twice you should end up with the approximate testing size amount. 5.2.N1

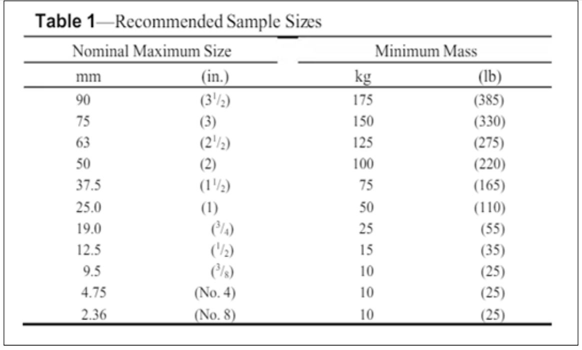


Table 1—Recommended Sample Sizes

Nominal Maximum Size		Minimum Mass	
mm	(in.)	kg	(lb)
90	(3½)	175	(385)
75	(3)	150	(330)
63	(2½)	125	(275)
50	(2)	100	(220)
37.5	(1½)	75	(165)
25.0	(1)	50	(110)
19.0	(¾)	25	(55)
12.5	(½)	15	(35)
9.5	(⅜)	10	(25)
4.75	(No. 4)	10	(25)
2.36	(No. 8)	10	(25)

Record the sampling time or location or both. If being used for quality control or acceptance use a random sampling procedure to obtain the time and location.

SAMPLING FROM CONVEYOR BELT USING A TEMPLATE:

***By taking regular samples from the conveyor belt, technicians can obtain their representative samples at the production facility. This allows for corrective actions to be taken before potentially substandard aggregate is used or transported to the job site.** (The method of sampling a technician employs are generally project and/or agency specific.)*

1 Have the **belt stopped.** 5.3.1

2 Set the **sampling template** on the **belt** in a way that avoids adjacent material from falling into the space inside the template. 5.3.2

3 **Remove** the material from **INSIDE** the **template; including** any **material adhering** to the belt utilizing scoops and brushes. 5.3.3

When sampling aggregate from the conveyor belt avoid sampling from the beginning or the end of the aggregate run to avoid segregation of material.

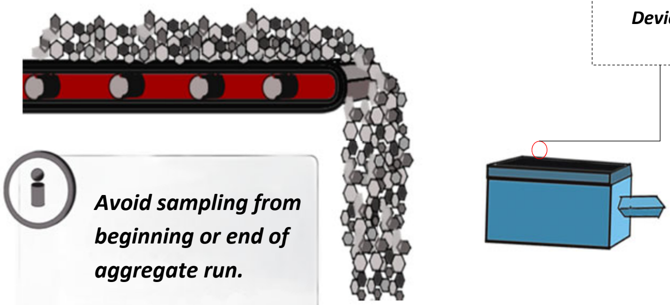
4 If that increment is not enough **repeat the process** obtaining equal increments each time. **Combine** the increments to form a **single sample**. 5.3.4

Be careful when sampling in the rain it can make removing the finer material more difficult.

Clean all material (including fines) off belt.

SAMPLING FROM CONVEYOR BELT DISCHARGE:

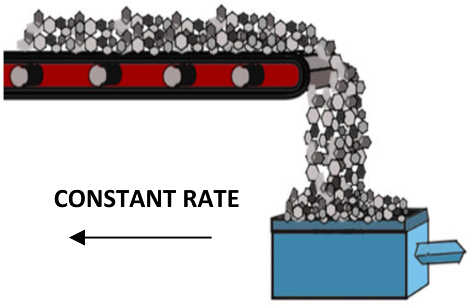
Similar to sampling from the conveyor belt with a template, this form of sampling can be utilized and may be easier to accomplish in certain instances. By taking regular samples from the conveyor belt, in general, technicians can obtain their representative samples at the production facility. This allows for corrective actions to be taken before potentially substandard aggregate is used or transported to the job site. *(The method of sampling a technician employs are generally project and/or agency specific.)*



Sampling Device

Avoid sampling from beginning or end of aggregate run.

1 The **sampling device** (manual or automatic) must be passed through the **full stream** of material as it runs off conveyor belt. 5.4.



When emptying the sampling device include all material that may adhere to the device.

2 Pass the **sampling device** through the full stream of material **once in each direction**. Sampling must be done at a **constant speed** and **perpendicular** to the flow of the material **without overflowing**. **5.4.1**

3 **Empty** the sampling device into an appropriate **sampling container**. *Considered 1 increment.* **5.4.1**

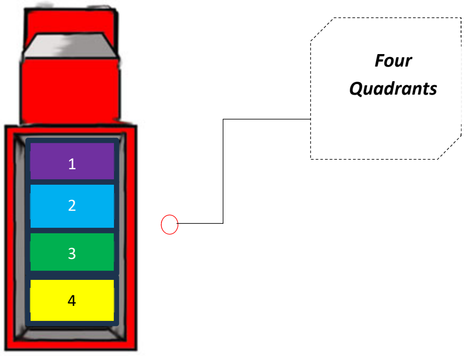
4 If that increment is **not enough** repeat the process obtaining equal increments each time. **Combine the increments** to form a **single sample**. **5.4.2**

SAMPLING FROM TRANSPORT UNITS:

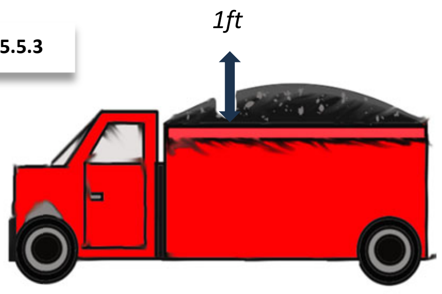
Sampling from transport units ensures that samples taken are representative of the entire batch being delivered to the job site. This ensures that the material actually delivered conforms to the required specifications. (*The method of sampling a technician employs are generally project and/or agency specific.)*

1 **Visually divide** the transport unit into **four** quadrants. **5.5.1**

2 Pick **one quadrant** and identify a **random sampling location** within. **5.5.2**



3 **Remove** approximately **1 ft** of material from sampling area. **Obtain an increment** from the exposed surface and **repeat procedure** in each of the remaining quadrants. **Combine** increments into one sample. **5.5.3**



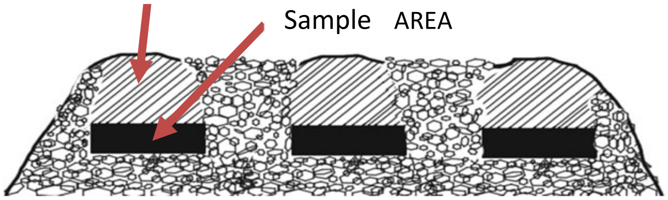
SAMPLING FROM ROADWAY – BERM OR WINDROW:

Sampling aggregate and soils from a windrow (a long pile or ridge of material) or berm (a raised strip or mound of material) is an essential procedure in obtaining a representative sample for later testing at the job site itself. (The method of sampling a technician employs are generally project and/or agency specific.)

WINDROW

BERM

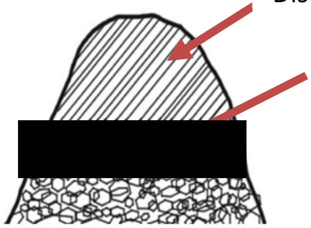
Make sure NOT to take the sample or any increment from the beginning or end of the windrow or berm.



1 **Remove** the **top 1/3** of the windrow or berm **before** taking increment. **5.6.1**

2 Obtain a minimum of **3 approximately equal increments** from **random** locations along the window or berm. **5.6.3**

3 **Fully** insert the **shovel** into the location (exclude underlying material), roll back and lift the shovel slowly so as not to lose any material. **Combine** the increments to form a **single sample**. **5.6.3.1**

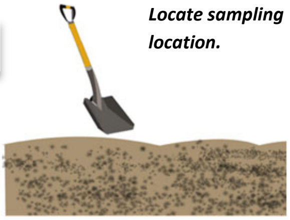


SIDE VIEW

SAMPLING FROM ROADWAY- INPLACE:

***Sampling aggregate and soils from the roadway in place is a commonly quick but least sophisticated way to obtain representative samples for analysis.** (The method of sampling a technician employs are generally project and/or agency specific.)*

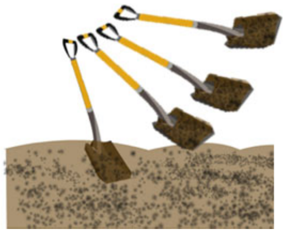
1 Obtain representative sample **after spreading** and **before compacting**. **5.7.1.**



Locate sampling location.

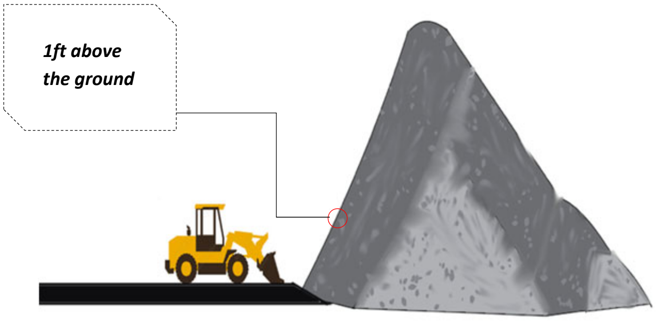
Fully insert the shovel to the full depth of the material. Excluding underlying material.

Roll back the material avoid material rolling off. Repeat as necessary.



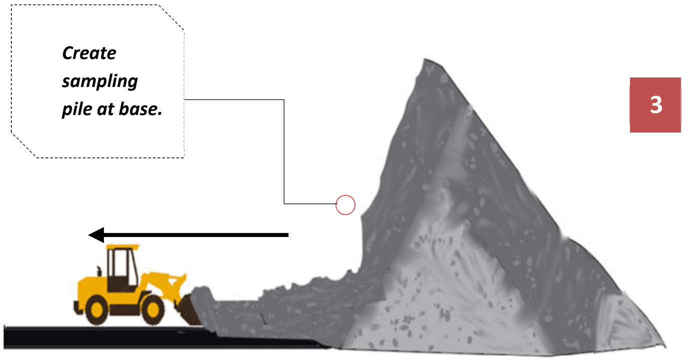
SAMPLING FROM STOCKPILE – FRONT LOADER PAD:

***Stockpiled materials often experience segregation, where fine particles settle at the bottom and larger particles accumulate at the top and the sides. Using a front loader to sample and mix material from different layers of the stockpile helps ensure that the sample taken is representative of the entire stockpile, rather than just the surface or just one section.** (The method of sampling a technician employs are generally project and/or agency specific.)*

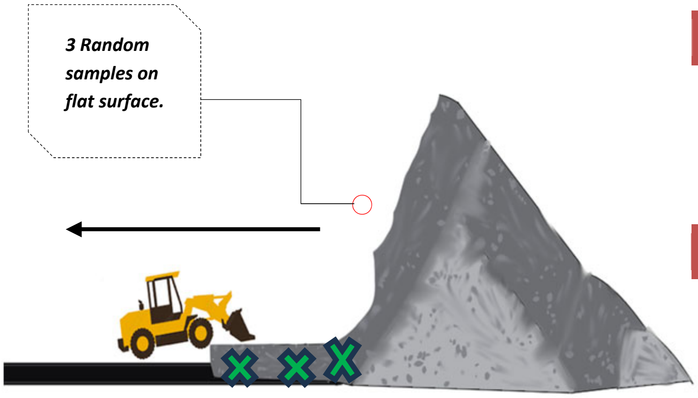


1 The **front loader** must enter the stockpile with the bucket at least **1ft above** the ground. 5.8.1.1

2 Discard the **1st bucket** full. 5.8.1.2



3 Have the front loader **re-enter** the stockpile securing another **bucket full**. Keep taking buckets full until desired amount is obtained. Create a small **sampling pile at the base** of the stockpile by gently rolling the material out of the bucket. **Repeat as necessary**. 5.8.1.3



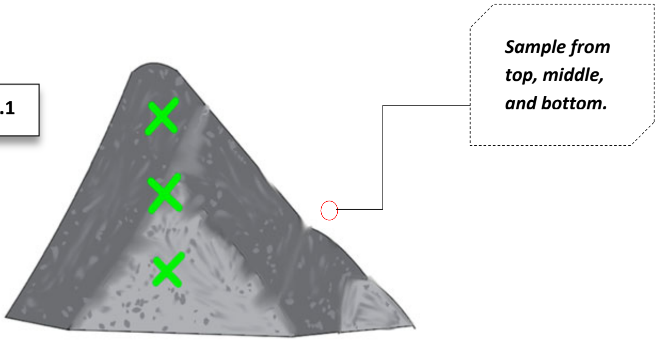
4 Have the loader create a **flat surface** by back dragging the pile. Obtain **increments** from at least **3 randomly** selected locations on the flat surface at least **1 ft** from the edges. 5.8.1.6

5 **Fully insert the shovel** into the location and lift shovel slowly so as not to lose any material. **Combine** each increment to form a **single sample.** 5.8.1.7

SAMPLING FROM STOCKPILE – HORIZONTAL SURFACE ON FACE:

Sampling from the face of the stockpile utilizing the following procedure helps mitigate some of the material segregation issues had while obtaining a representative sample from a material stockpile. (The method of sampling a technician employs are generally project and/or agency specific.)

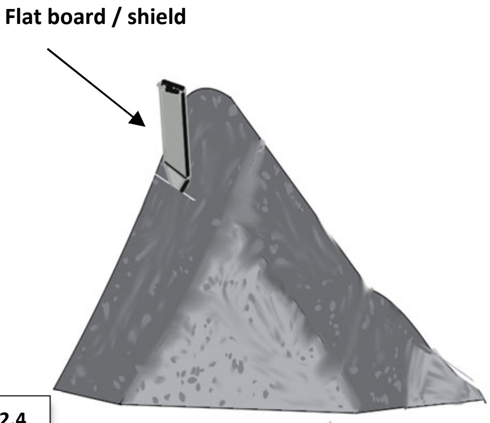
1 Create **horizontal surfaces** with vertical faces in the **top, middle, and bottom third** of the stockpiles with a shovel or loader. 5.8.2.1

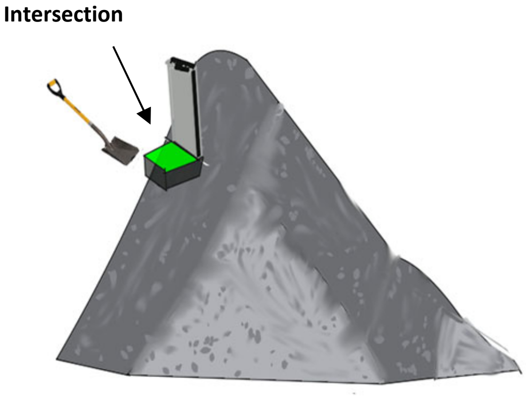


2 Insert a flat board against the **vertical face** behind sampling location to prevent sloughing. Discard slough material to create horizontal surface. **5.8.2.2**

3 Obtain sample from the horizontal surface as close as possible to the **intersection of the horizontal and vertical faces**. **5.8.2.3**

4 Obtain at least **1 increment** of equal size from **each** of the **top, middle, and bottom thirds** of the pile. Combine all increments into a single sample. **5.8.2.4**





IDENTIFICATION & SHIPPING (example)

6.

IDENTIFICATION & SHIPPING:

Date
Time
Sampling Location
Quantity of Material (if applicable)
Material Type
Supplier

- Please refer to approved agency or companies' internal procedures and forms. This EXAMPLE in no way indicates all that may be required.

Please refer to the standard for any material not cover.

SECTIONS NOT COVERED:

SAMPLING FROM STOCKPILE – FINE AGGREGATE (ALTERNATE TUBE METHOD:)

PLEASE REFER TO THE SECTION FOUND IN THE PROCEDURE FOR MORE DETAIL IF INTERESTED. THIS PROCEDURE IS NOT COVERED OR TESTED ON DURING ATTI CERTIFICATION. **5.9.**

AASHTO R76:

REDUCING SAMPLES OF AGGREGATE TO TESTING SIZE

DEFINITIONS:

Coarse Aggregate - *is a granular or irregular material that is typically larger than #4 (4.75mm) screen and is used in concrete.*

Fine Aggregate - *are the particles that pass through a #4 (4.75 mm) sieve and retain on a #200 (0.075mm) sieve.*

Splitting - is the process of dividing a sample of aggregate into fractions that contain particles within specific limits. The resulting particle size distribution is called the gradation.

Saturated Surface Dry - *the condition of the aggregate when all permeable pores of each particle are completely saturated with water and its surface has no free moisture.*

SCOPE:

1.1.

This standard covers the reduction of large samples of aggregate to the right size for testing.

METHOD:

5.

- **The following is quick reference on the method selection for common types of material. There will be a detailed description of each method with the type of equipment used.**

5.1.

FINE AGGREGATE
(DRIER THAN SSD)

=

METHOD A –
MECHANICAL SPLITTER

If the technician wants to utilize METHOD B or METHOD C. The sample can be moistened, and thoroughly mixed.

If the technician desires to utilize METHOD A for Fine Aggregate wetter than SSD. The entire sample can be dried to at least the SSD condition using temperatures that doesn't exceed specs for other potential testing.

5.1.2

FINE AGGREGATE (WETTER THAN SSD)

=

METHOD C – MINATURE STOCKPILE

METHOD B - QUARTERING

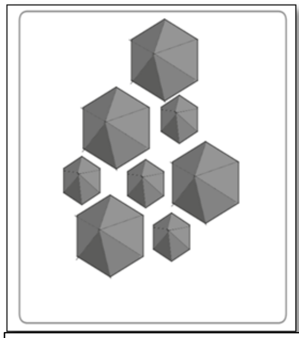
QUARTERING ON CLEAN AND LEVEL SURFACE 10.1.1

QUARTERING ON TARP 10.1.2

QUARTERING SECTORING 10.1.3

GOAL OF REDUCING:

Example of particle distribution of aggregate BEFORE reduction.



If the moist sample is very large a preliminary split can be made using a mechanical splitter with chute opening of 1 ½ inches or more. The sample can't be reduced less than 5000 grams.

GOAL OF REDUCING:

Example of particle distribution of aggregate AFTER reduction.

5.2.

COARSE AGGREGATE

=

METHOD A – MECHANICAL SPLITTER

METHOD B - QUARTERING

QUARTERING ON CLEAN AND LEVEL SURFACE 10.1.1

QUARTERING ON TARP 10.1.2

~~**QUARTERING SECTORING 10.1.3**~~

5.3.

COARSE & FINE AGGREGATE (DRIER THAN SSD)

=

METHOD A – MECHANICAL SPLITTER

METHOD B - QUARTERING

QUARTERING ON CLEAN AND LEVEL SURFACE 10.1.1

QUARTERING ON TARP 10.1.2

~~**QUARTERING SECTORING 10.1.3**~~

Determining saturated surface-dry condition is if the fine aggregate will retain its shape when molded in the hand.

EXAMPLE: Aggregate Base Material

COARSE & FINE AGGREGATE (WETTER THAN SSD)

5.3.

METHOD B - QUARTERING

QUARTERING ON CLEAN AND LEVEL SURFACE

QUARTERING ON TARP 10.1.2

QUARTERI[illegible]ECTORING 10.1.3

If the technician finds it advantageous to utilize METHOD A the entire sample may be dried to where it appears dry or until clumps can be broken up, using temperatures that don't exceed any specs other potential testing.

The dryness of a sample can be tested by squeezing tightly a portion of the material in your hand. If it crumbles easily, you've reached the correct moisture.

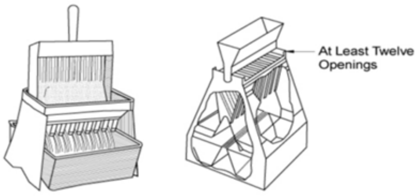
Splitting aggregate down to size is necessary in the process of construction materials testing. It enables technicians to ensure that the material is representative, the aggregate is properly distributed, and is the amount indicated in the test method. The process allows for accurate testing of gradation, moisture content, and other performance characteristics.

METHOD A – MECHANICAL SPLITTER:

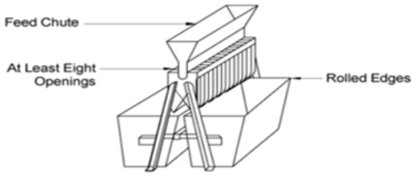
EQUIPMENT:

SAMPLE SPLITTER:

- Sample splitters **MUST** have an **even number** of equal-width chutes. At least **8 chutes** for coarse aggregate, and **12 chutes** for fine aggregate. **7.1.**
- Discharge will be on either side of the splitter with **two receptacles** to catch the material. **7.1.**
- If the material is **coarse or mixed aggregate** then the **minimum width** of the chutes will be approximately **50% larger** than the **largest particle**. **7.1.**



(b) Small Sample Splitters for Fine Aggregate



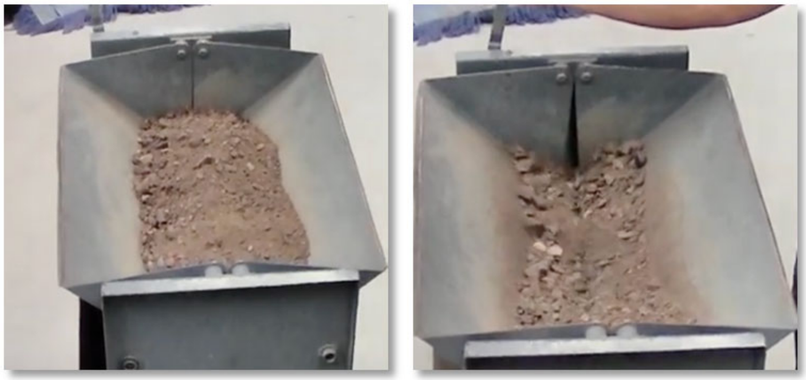
Riffle Sample Splitter
(a) Large Sample Splitter for Coarse Aggregate

- If the material is **dry fine aggregate** that 100% which entirely passes the 3/8" screen the **minimum width** of the individual chutes shall be at least **50% larger** than the largest particle and the **maximum width will be ¾".**

7.1.

The mechanical splitters for coarse aggregate should be used on particles 1 ½" or less.

PROCEDURE:



1 Place the sample in the **hopper or pan** and distribute sample from **edge to edge**. Introduce at a **rate** that allows the material to **flow freely** through the chutes.

8.1.

2 Keep **splitting** until the sample is **reduced** to the size for the specific test desired.

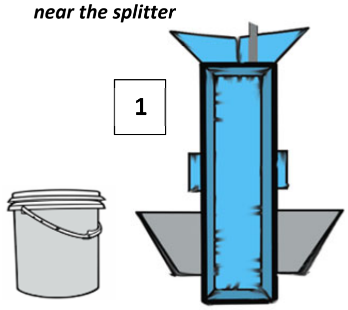
8.2.

3 Place **one portion** of the sample from one of the receptacles back **into the splitter** while placing the **other portion into container**.

8.2.

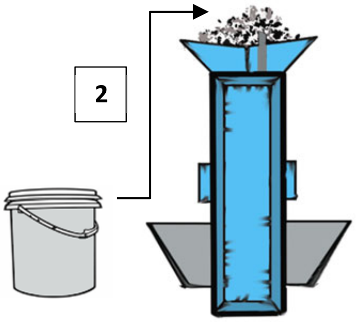
Place your bucket near the splitter

1

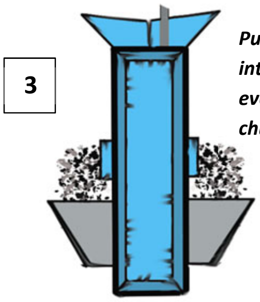


Place the contents of the bucket in the hopper distributing evenly.

2

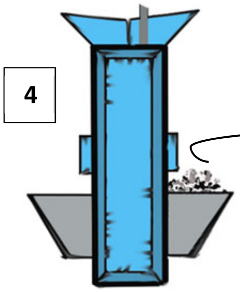


3



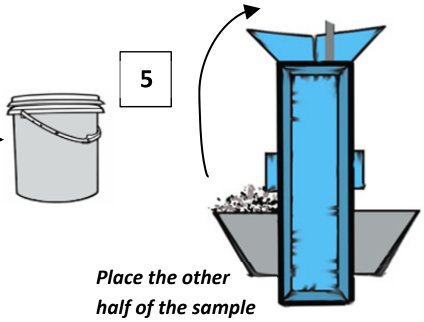
Pull the handle so as to introduce the material evenly through the chutes.

4



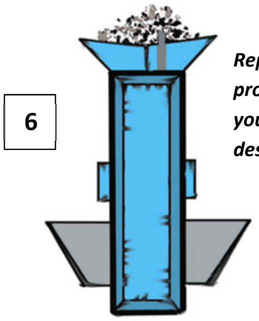
Place half of the sample portion back into the bucket.

5



Place the other half of the sample portion back into the hopper distributed evenly.

6



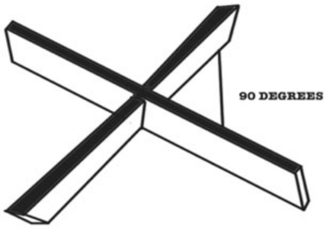
Repeat the procedure until you reach your desired amount.

METHOD B – QUARTERING:

EQUIPMENT:

9.

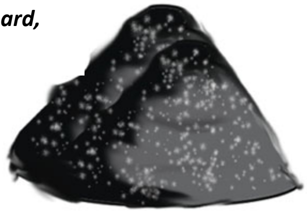
- **STRAIGHT EDGE OR SHOVEL**
- **SPATULAS OR TROWELS**
- **BROOM OR BRUSH**
- **STICK OR PIPE**
- **TEAR RESISTANT RECTANGULAR TARP**
- **QUARTERING TEMPLATE:** In the shape of 90° sides that exceed the diameter of the flattened cone of material. The height of the sides must be sufficient to extend above the thickness of the flattened cone of the sample.



PROCEDURE:

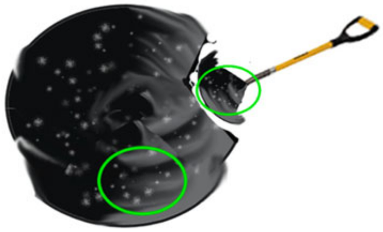
10.1.1 Quartering on a Clean, Hard, Level Surface:

Stockpile on clean, hard, level surface.



1 Place the sample on a **clean, hard, level surface** where there will **NOT** be loss of material or contamination.

10.1.1.1.

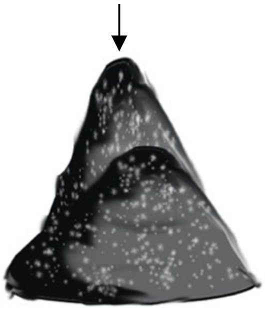


Go around the perimeter turning the sample to mix and form a cone.

2 **Turn the entire** sample over **three times** to mix the sample. On the **last turn** form the material into a **conical pile**.

10.1.1.2

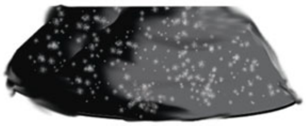
Final cone



3 **Flatten** the conical pile to a **uniform thickness** and the **diameter** should be approximately **four to eight** time the thickness.

10.1.1.3

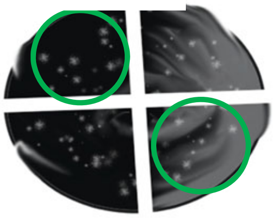
Flatten sample.



4 Divide the flattened mass into approximately **four equal parts**. With:

10.1.1.4

Sample from diagonally opposite quarters.



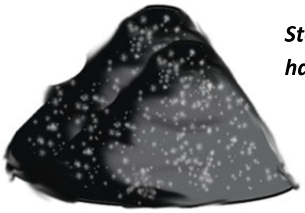
5 Remove the **two diagonally opposite** quarters (*including all the fine material using a brush*). Set aside the unused quarters for later testing. **Repeat** the above steps until **the desired amount** is achieved.

10.1.1.5

10.1.3 Quartering Sectoring:

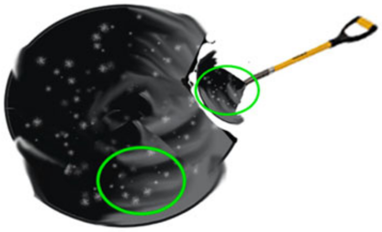
1 Place the sample on a surface. **Refer to 10.1.3.**

10.1.3.1



Stockpile on clean, hard, level surface.

Go around the perimeter turning the sample to mix and form a cone.

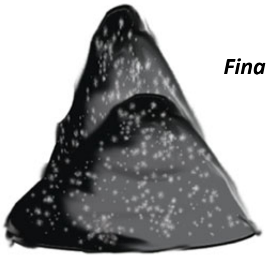


2 Turn the entire sample over **three times** to mix. On the last turn form the material into a conical pile. **Refer to section 10.1.3.**

10.1.3.2

3 Flatten the conical pile. **Refer to 10.1.3.**

10.1.3.3

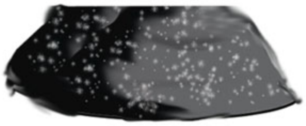


Final cone

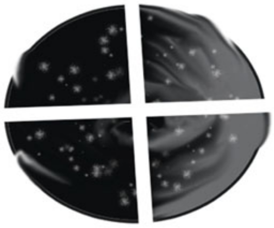
4 **Divide** the flattened mass into approximately **four equal parts**. With:

10.1.3.4

Flatten sample.



Divide into quarters.

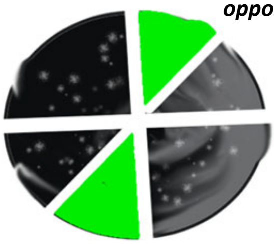


5 Use a **straight edge** to slice through the center of one of the **quarters.** Achieve complete separation.

10.1.3.5

6 Remove approximately equal sectors from diagonally opposite quarters and combine. Repeat procedure until the required amount is obtained.

10.1.3.7



Divide the quarters in half and sample from opposite corners.

METHOD C – MINATURE STOCKPILE SAMPLING:

EQUIPMENT:

- **STRAIGHT EDGE, FLAT BOTTOM SCOOP, SQUARE POINT SHOVEL, OR TROWEL.**
- **A SMALL SAMPLING THIEF, SMALL SCOOP, OR SPOON.**

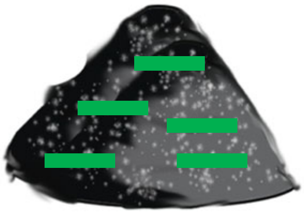
1.1.

PROCEDURE:

1 Place the sample on **a clean, hard, level surface** where there will **NOT** be loss of material or contamination. **12.1.**

2 Turn the entire sample over **three times** to mix. On the last turn form the material into a **conical pile**. **12.2.**

3 **Obtain** a sample for each test by selecting at least **5 increments from random locations**. **12.3**



5 Random increments.

SECTIONS NOT COVERED:

10.1.2 Quartering on a Tarp:

PLEASE REFER TO THE SECTION FOUND IN THE PROCEDURE FOR MORE DETAIL IF INTERESTED. THIS PROCEDURE IS NOT COVERED OR TESTED ON DURING ATTI CERTIFICATION.

10.1.2

AASHTO T27:

SIEVE ANALYSIS OF FINE AND COARSE AGGREGATES

DEFINITIONS:

Nominal Maximum Aggregate Size– The sieve size through which most of the aggregate particles should pass, with a small percentage allowed to be retained on that sieve.

Particle Size Distribution- also known as a gradation, refers to the proportions of different particle sizes present within a sample, typically expressed as a percentage or a curve.

SCOPE:

1.1

This method covers the determination of the particle size distribution of fine and coarse aggregates by sieving.

EQUIPMENT:

5.

- **BALANCE –** is at least readable to 0.1 grams or better.
- **SIEVES –** constructed in a way that will prevent loss of material during sieving. Frames and cloth shall conform to ASTM E11. ***NOTE 1:*** *Recommended that sieves larger than 8 inch in diameter be used for coarse aggregate testing to lessen the chance of overloading.*
- **MECHANICAL SIEVE SHAKER-** a device that creates motion of the sieves that causes the particles to bounce, tumble, or turns presenting different orientations to the sieves surface. Adequacy of sieving is described in section A2.
- **OVEN –** an oven that maintains a uniform temperature of 230 ± 9 °F.
- **THERMOMETER – (for measuring the temperature of the oven)** has a temperature range of 194 °F to 266 °F. and have an accuracy of ± 2.25 °F.

AASHTO T27 describes the procedure for the sieve analysis of fine and coarse aggregates. This test is used to determine the particle size distribution of aggregates which is important for understanding the material's suitability for various construction and pavement applications.

Brief outline:

Preparation of sample: A representative sample of the aggregate is sampled and split (potentially washed in accordance with AASHTO T11).

Sieving: The sample is passed through a series of sieves with different mesh sizes, from large too small.

Weighing: After sieving, the material retained on each sieve is weighed and recorded.

Calculations: The weight of the material retained on each sieve, the percent retained, and the percent passing is then determined and reported.

SAMPLING:

- **Obtain** the aggregate sample according to one of the methods within **AASHTO R90**. **6.1.**
- The **mass of the field sample** is the **minimum mass outlined in AASHTO R90 or 4 times the minimum mass required in the table from Section 6.4 whichever is greater** (except as stated in section 6.6). **6.1.**

Where sieve analysis, including determination of material finer than the #200 screen, is the only testing proposed, the size of the sample may be reduced in the field to avoid shipping excessive amounts of material to the laboratory. **NOTE 4**

- Thoroughly **mix** the sample and **reduce** according to **AASHTO R76** to the appropriate testing size. **6.2.**
- The **sample for testing** shall be the **APPROXIMATE** mass needed **after** it has been **dried and reduced** according to AASHTO R76. **Reducing** to an **EXACT predetermined mass** is **not permitted**. **6.2.**

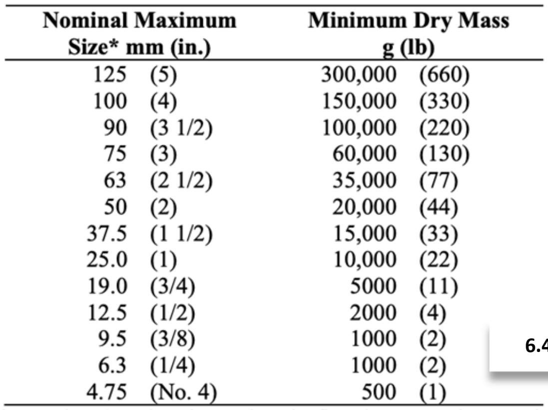
SAMPLING SIZE FINE AGGREGATE

- The **size** of the test sample (after drying) is a minimum of **300 grams**. **6.3.**

If washing was performed (in accordance with AASHTO T 11) before the sieving process. It is acceptable for the sample to be LESS than the minimum mass after washing as long as minimum mass was met prior. The initial sample mass for analysis by AASHTO T27 should be the same as the final sample mass for AASHTO T11. **NOTE 5**

SAMPLING SIZE COARSE AGGREGATE

- The **size** of the test sample (after drying) must conform to the following **table**: **6.4.**
- **Refer to** **NOTE 5** **6.4.**



Nominal Maximum Size* mm (in.)		Minimum Dry Mass g (lb)	
125	(5)	300,000	(660)
100	(4)	150,000	(330)
90	(3 1/2)	100,000	(220)
75	(3)	60,000	(130)
63	(2 1/2)	35,000	(77)
50	(2)	20,000	(44)
37.5	(1 1/2)	15,000	(33)
25.0	(1)	10,000	(22)
19.0	(3/4)	5000	(11)
12.5	(1/2)	2000	(4)
9.5	(3/8)	1000	(2)
6.3	(1/4)	1000	(2)
4.75	(No. 4)	500	(1)

6.4.

SAMPLING SIZE COARSE & FINE AGGREGATE

- For the **mass** of the **test sample of combined coarse & fine aggregate** refer to the table in **SECTION 6.4** in the procedure.

6.5.

- **Refer to** NOTE 5

SAMPLING SIZE LARGE COARSE AGGREGATE

- **For aggregate** with **2inch Nominal Maximum Size (or larger),** instead of combining and mixing material and then reducing to testing size ***(if the appropriate equipment is not available see procedure for detail)***, perform the **sieve analysis** on a number of **approximately equal sample increments** as long as the **total mass tested conforms to the table in Section 6.4**.

6.6.

IF MATERIAL FINER THAN #200 IS TO BE DETERMINED IN THE SAMPLE

TOTAL WASH

½" Nominal maximum aggregate size or LESS

- Use the **same** test sample when testing according to AASHTO T11 & AASHTO T27. **FIRST** perform test method AASHTO **T11 (wash)** up through the final drying step then **sieve** according to **AASHTO T27 (dry sieving)** starting **at Section 7.2 through 7.5**.

6.7.1.

6.7.3

When determining the total amount of material finer than #200 use the procedure according to section 6.7.1

TOTAL WASH OR JUST WASH OF SPLIT FINE

GREATER than ½" Nominal maximum aggregate size

- Use the **same** test sample when testing according to AASHTO T11 & AASHTO T27. **FIRST** perform test method AASHTO **T11 (wash)** up through the final drying step then **sieve** according to **AASHTO T27 (dry sieving)** starting **at Section 7.2 through 7.5**.

OR

6.7.2.

- Separate the test sample, **one to test according to T11 (wash)** (*for fine material)* and **one to test according to T27 (dry sieving)** (*for coarse material)*.

PROCEDURE:

1

Dry the sample to **constant mass** according to **AASHTO T255 (demonstrated is the oven method see T255 for alternative methods).** Place the test sample into an oven at a temperature of **230 ±9°F** and dry to **constant mass.**

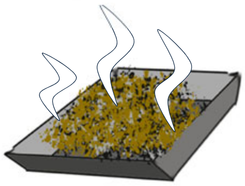
7.1.

CONSTANT MASS (T255):
Sample is dry when further heating causes less than 0.1% additional loss in mass.

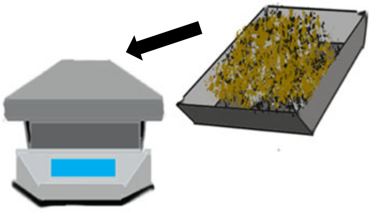
For control purposes, it is generally not necessary to dry coarse aggregate to constant mass for sieving UNLESS:
The nominal max aggregate size is ½" or smaller.
Or
The coarse material contains a good amount of material finer than #4.
Or
The coarse aggregate is highly absorptive.

NOTE 6

CONSTANT MASS



WEIGH & RECORD



2

Weigh & record the **mass** of the sample to be placed in the sieves to **0.1 grams.**

7.1.

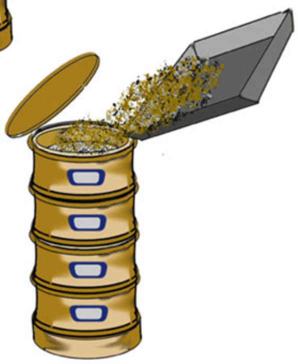
PREPARE SIEVE SET

3

Select a **sieve set** with the correct sizes that will provide the information required **by the specifications or are agency required**. Make sure they are nested in **decreasing size** from **top to bottom**.

7.2.

INTRODUCE SAMPLE



4

Introduce the **sample** into the **top** sieve of the nest. If the sample is **large** enough to cause overloading, **sieve in multiple increments**.

7.2.

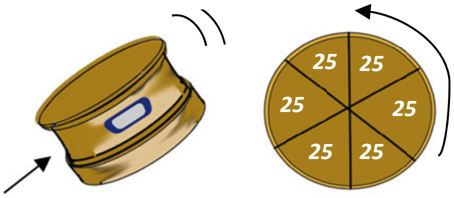
THOROUGHNESS OF SIEVING: **A.2**

Along with a tight-fitting pan and cover, hold the sieve being evaluated at a slightly inclined position.

Hand-shake by striking the side of the sieve sharply with an upward motion with the palm of your free hand continuously for 60 seconds.

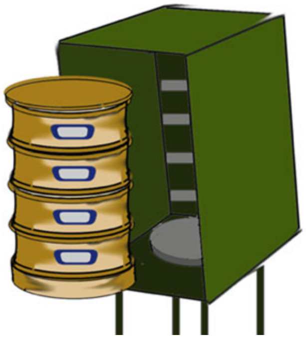
Hand-shake at the rate of about 150 times per minute turning the sieve about 1/6th of a revolution at intervals of about 25 strokes.

150 TIMES PER MINUTE- AT 1/6TH OF REVOLUTION- 25 TIMES EACH



5 **Agitate** the **sieves** by hand or by mechanical shaker for the **adequate** amount of **time established by the sieving time evaluation**. *(See Annex A2).*

7.2.



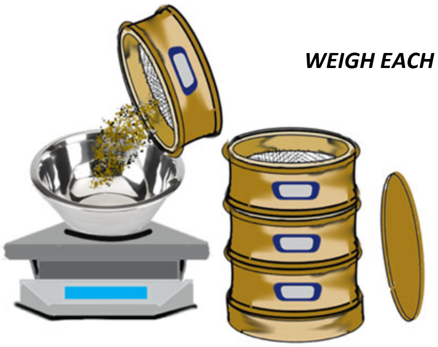
AGITATE SAMPLE

Make sure to limit the amount of material on any given sieve so that all the particles have an opportunity to reach the sieving surface.

7.3.

6 Once agitation is completed **weigh and record the mass** of the material retained on each sieve size to the **nearest 0.1 gram.**

7.5.



WEIGH EACH SIEVE

7 The **total mass** of the material, after sieving, should check closely with the total original dry mass placed in the sieves. If the **two amounts differ** by **more than 0.3% based on the total of original dry sample mass** the **results should not be used for acceptance**.

7.5.

How Aggregates are Cleaned from Screens?

Generally, the industry uses coarser wire brushes to clean the #30 and larger sieves, and soft bristle brushes for smaller sieves.

PREVENT OVERLOADING OF SCREENS BY REFER ING TO THE TABLE IN ANNEX A1 AND/ OR THE FOLLOWING METHODS:

7.3.1.

- Insert an **additional sieve with a size intermediate between the sieve that may be over loaded and the sieve size above it.**
- **Split the sample into two or more portions and sieve each individually.** Combining the weights of each respective sieve when determining mass.
- Use sieves with **larger frame sizes for more sieve area.**
- If material is **retained** on the **3-inch screen** you can **hand rotate each particle to determine the smallest sieve opening** through which the particle will pass. **Do not force particles through.**
- **REFER to the TABLE IN ANNEX A1 in the procedure for maximum allowable mass of material retained on the sieve.**
- If the sample is a Coarse & Fine **mixture the portion finer than #4 screen may be distributed among 2 or more sieve sets.** Combining the weights of each respective sieve when determining mass.
- The **portion passing the #4** screen can be **reduced** in size according to R76. If this is done then the mass of each size increment must be computed using an **equation REFER to SECTION 7.3.1.5**

Ways a technician can run a sieve and calculate the results according to AASHTO T27 & AASHTO T11:

TOTAL WASH-FULL GRADATION

A. *PERCENT RETAINED (CUMULATIVE OR INDIVIDUAL)*
B. *PERCENT PASSING (CUMULATIVE OR INDIVIDUAL)*

JUST FOR REFERENCE. WILL NOT BE TESTED ON DURING ATTI CERTIFICATION.

TOTAL WASH- COARSE FULL GRADATION/ FINE MATERIAL IS REDUCED IN AMOUNT THEN GRADATION IS PERFORMED.

A. *PERCENT RETAINED (CUMULATIVE OR INDIVIDUAL)*
B. *PERCENT PASSING (CUMULATIVE OR INDIVIDUAL)*

JUST FOR REFERENCE. WILL NOT BE TESTED ON DURING ATTI CERTIFICATION.

SPLIT FINE WASH – COARSE FULL GRADATION/ FINE MATERIAL IS REDUCED IN AMOUNT THEN WASHED THEN GRADATION IS PERFORMED.

A. *PERCENT RETAINED (CUMULATIVE)*
B. *PERCENT PASSING (CUMULATIVE)*

CALCULATIONS ASSOCIATED WITH THIS METHOD WILL BE ON ATTI CERTIFICATION TEST. ALL OTHER METHODS ARE SHOWN JUST FOR REFERENCE.

NOT WASHED – NO FINES REQUIRED ***(Will only demonstrate individual method)***

A. *PERCENT RETAINED (CUMULATIVE OR INDIVIDUAL)*
B. *PERCENT PASSING (CUMULATIVE OR INDIVIDUAL)*

JUST FOR REFERENCE. WILL NOT BE TESTED ON DURING ATTI CERTIFICATION.

CALCULATIONS

1 *SUM CHECK* =

$$\frac{(DRY\ MASS\ AFTER\ WASHING - TOTAL\ MASS\ AFTER\ SIEVING)}{(DRY\ MASS\ AFTER\ WASHING)}\ X\ 100$$

2 *PERCENT RETAINED* =

$$\frac{(MASS\ RETAINED\ ON\ SCREEN)}{(TOTAL\ ORIGINAL\ DRY\ MASS)}\ X\ 100$$

3 *PERCENT PASSING* ***= %PASSING OF THE SCREEN ABOVE - % RETAINED ON THE SCREEN***

TOTAL WASH- FULL GRADATION

OVERVIEW

- *Dry the **original test sample to constant mass**.*
- ***Weigh and record** the dry mass of the **original test sample**.*
- ***Wash original test sample** (using Method A or Method B- AASHTO T11) decant over a #200 screen.*
- ***Dry** the **washed original test sample to constant mass**.*
- ***Weigh and record** the **washed sample** after it is dried.*
- ***Sieve** the **washed sample** over the appropriate sieves.*
- ***Determine** (**either the cumulative OR individual**) weight of each sieve size and record.*
- *Perform the **sum check** to make sure that the results can be used for acceptance on both/or either coarse and fine material**.***
- ***Perform the % retained calculation** (either individual or cumulative) on all the retained weights.*
- *Perform the % passing calculation (either the individual or cumulative) on all the retained weights**.***
- ***Report results.***

EXAMPLE SHOWS INDIVIDUAL AND CUMULATIVE METHOD FOR CALCULATION

SUM CHECK $= \dfrac{(DRY\ MASS\ AFTER\ WASHING - TOTAL\ MASS\ AFTER\ SIEVING)}{(DRY\ MASS\ AFTER\ WASHING)}\ X\ 100$

ORIGINAL DRY MASS: *6200.0 grams*

DRY MASS AFTER WASH: *6005.2 grams*

TOTAL MASS AFTER SIEVING: *6001.2 grams*

MINUS #200 WASH OUT: *189.8 grams*

$\dfrac{(6005.2-6001.2)}{(6001.2)}\ X\ 100 = 0.07\ \%$

Less than 0.3% so these results can be used for acceptance.

	INDIVIDUAL MASS RETAINED	CUMULATIVE MASS RETAINED	% Retained Individual Equation	INDIVIDUAL % RETAINED	% Retained Cumulative Equation	CUMULATIVE % RETAINED	% Passing Individual Equation	% PASSING INDIVIDUAL	% Passing Cumulative Equation	% PASSING CUMULATIVE
1”	0	0		0		0		100		100
3/4”	210.1	210.1	$\frac{210.1}{6200.0}$ X 100	3.4	$\frac{210.1}{6200.0}$ X 100	3.4	100 – 3.4	96.6	100 - 3.4	96.6
1/2”	730.0	940.1	$\frac{730.0}{6200.0}$ X 100	11.8	$\frac{940.1}{6200.0}$ X 100	15.2	96.6 – 11.8	84.8	100 – 15.2	84.8
3/8”	609.1	1549.2	$\frac{609.1}{6200.0}$ X 100	9.8	$\frac{1549.2}{6200.0}$ X 100	25.0	84.8 – 9.8	75.0	100 – 25.0	75.0
¼”	302.1	1851.3	$\frac{302.1}{6200.0}$ X 100	4.9	$\frac{1851.3}{6200.0}$ X 100	29.9	75.0 – 4.9	70.1	100 – 29.9	70.1
#4	1100.0	2951.3	$\frac{1100.0}{6200.0}$ X 100	17.7	$\frac{2951.3}{6200.0}$ X 100	47.6	70.1 – 17.7	52.4	100 – 47.6	52.4
#8	815.9	3767.2	$\frac{815.9}{6200.0}$ X 100	13.2	$\frac{3767.2}{6200.0}$ X 100	60.8	52.4 – 13.2	39.2	100 – 60.8	39.2
#10	670.9	4438.1	$\frac{670.9}{6200.0}$ X 100	10.8	$\frac{4438.1}{6200.0}$ X 100	71.6	39.2 – 10.8	28.4	100 – 71.6	28.4
#16	427.9	4866.0	$\frac{427.9}{6200.0}$ X 100	6.9	$\frac{4866.0}{6200.0}$ X 100	78.5	28.4 – 6.9	21.5	100 – 78.5	21.5
#30	370.9	5236.9	$\frac{370.9}{6200.0}$ X 100	6.0	$\frac{5236.9}{6200.0}$ X 100	84.5	21.5 – 6.0	15.5	100 – 84.5	15.5
#40	212.3	5449.2	$\frac{212.3}{6200.0}$ X 100	3.4	$\frac{5449.2}{6200.0}$ X 100	87.9	15.5 – 3.4	12.1	100 – 87.9	12.1
#50	235.0	5684.2	$\frac{235.0}{6200.0}$ X 100	3.8	$\frac{5684.2}{6200.0}$ X 100	91.7	12.1 – 3.8	8.3	100 – 91.6	8.3
#100	190.9	5875.1	$\frac{190.9}{6200.0}$ X 100	3.1	$\frac{5875.1}{6200.0}$ X 100	94.8	8.3 – 3.1	5.2	100 – 94.8	5.2
#200	102.1	5977.2	$\frac{102.1}{6200.0}$ X 100	1.6	$\frac{5977.2}{6200.0}$ X 100	96.4	5.2 – 1.6	3.6	100 – 96.4	3.6
PAN	24.0	Final Cumulative mass: 6001.2								

- For a **TOTAL WASH- FULL GRADATION** all that is needed is to perform a total sum check **AFTER** it has been properly **sieved**. For the sum check use the **Dry Mass After Wash** and **Total Mass After Sieving.**

- The example demonstrates how to **calculate BOTH** the **individual and cumulative methods** when doing a **total wash- full gradation**.

- **Light red** highlights the **individual method** and the **dark red** highlights the **cumulative method**.

- The **individual mass retained** value is the weight of the aggregate retained in each individual sieve. ***(see example)***

- The **cumulative mass retained** value is the weight of the aggregate retained in an individual sieve and the sieves above. ***(see example)***

- To perform the **% RETAINED equation** for **both the individual and cumulative methods** one takes the **amount retained** on the sieve and **divides it by** the **ORIGINAL DRY MASS** and then **multiplies this result by 100**. ***(see example)***

- To perform the **% PASSING equation** for **the individual method** one begins by taking the **first sieve** that has a **% RETAINED value** and **subtracting** this number **from 100.** The **resulting value will be the number that the next % RETAINED is subtracted from. *(see example)***

- To perform the **% PASSING equation** for **the cumulative method subtract each % RETAINED value from 100**. ***(see example)***

- **Report total percent passing to the nearest 1 percent except the #200 sieve % passing is reported to the nearest 0.1 percent.**

	% PASSING INDIVIDUAL OR CUMULATIVE	*REPORTED % PASSING*
	100	*100*
	96.6	*97*
	84.8	*85*
	75.0	*75*
	70.1	*70*
	52.4	*52*
	39.2	*39*
	28.4	*28*
	21.5	*22*
	15.5	*16*
	12.1	*12*
	8.3	*8*
	5.2	*5*
#200 % passing	*3.6*	*3.6*

TOTAL WASH- COARSE FULL GRADATION/ FINE MATERIAL IS REDUCED IN AMOUNT THEN FINE GRADATION IS PERFORMED.

OVERVIEW

- *Dry the **original test sample to constant mass**.*
- ***Weigh and record** the dry mass of the **original test sample**.*
- ***Wash original test sample** (using Method A or Method B- AASHTO T11) decant over a #200 screen.*
- ***Dry** the **washed original test sample to constant mass**.*
- ***Weigh and record** the **washed sample** after it is dried.*
- ***Sieve** the washed sample over the **COARSE size sieves**.*
- ***Weigh and record** the **TOTAL MASS of the FINE material (-#4).***
- ***Determine** (either the **cumulative OR individual**) weight of each **COARSE sieve size and record**.*
- *Perform the **coarse sum check** to make sure that the results can be used for acceptance.*
- ***Perform the % retained calculation** (either individual or cumulative) on all the retained weights of COARSE MATERIAL.*
- *Perform **the % passing calculation** (either the individual or cumulative) on all the retained weights of COARSE MATERIAL.*
- ***Reduce** the **fine material according to AASHTO R76.** Consult **TABLE** in the procedure for sample size.*
- ***Weigh and record** the **MASS of the SPLIT PORTION OF FINE material (-#4).***
- ***Sieve** the new **fine sample portion** over the **FINE size sieves**.*
- ***Determine** (**either the cumulative OR individual**) weight of each **FINE sieve size and record.***
- *Perform the **fine sum check** to make sure that the results can be used for acceptance**.***
- Perform the **adjusted MASS OF EACH SIZE INCREMENT CALCULATION**.
- ***Perform the % retained calculation** (either individual or cumulative) on all the retained weights of FINE MATERIAL.*
- *Perform **the % passing calculation** (either the individual or cumulative) on all the retained weights of FINE MATERIAL.*
- ***Report results.***

EXAMPLE SHOWS INDIVIDUAL METHOD FOR CALCULATION

ORIGINAL DRY MASS: ***5000.0 grams***
DRY MASS AFTER WASH: ***4862.0 grams***
TOTAL MASS AFTER SIEVING: ***4861.3 gram***

MINUS #200 WASH OUT: ***138.0 grams***

SUM CHECK =

$$\frac{(DRY\ MASS\ AFTER\ WASHING - TOTAL\ MASS\ AFTER\ SIEVING)}{(DRY\ MASS\ AFTER\ WASHING)}\ X\ 100$$

COARSE SUM CHECK

$$\frac{(4862.0 - 4861.3)}{(4862.0)}\ X\ 100 = 0.01\%$$

Less than 0.3% so these results can be used for acceptance.

	INDIVIDUAL MASS RETAINED	*% Retained Individual Equation*	*INDIVIDUAL % RETAINED*	*% Passing Individual Equation*	*% PASSING INDIVIDUAL*
1”	*0*		*0*		*100*
3/4”	*210.1*	$\frac{210.1}{5000.0}$ *X 100*	*4.2*	*100 – 4.2*	*95.8*
1/2”	*730.0*	$\frac{730.0}{5000.0}$ *X 100*	*14.6*	*95.8 – 14.6*	*81.2*
3/8”	*609.1*	$\frac{609.1}{5000.0}$ *X 100*	*12.2*	*81.2 – 12.2*	*69.0*
¼”	*302.1*	$\frac{302.1}{5000.0}$ *X 100*	*6.0*	*69.0 – 6.0*	*63.0*
#4	*1100.0*	$\frac{1100.0}{5000.0}$ *X 100*	*22.0*	*63.0 – 22.0*	*41.0*

TOTAL MASS OF COARSE AGGREGATE: ***2951.3 grams***

TOTAL MINUS -#4: ***1910.0 grams***

FINE SPLIT BEFORE SIEVE: ***540.0 grams***
FINE SPLIT AFTER SIEVE: ***539.0 grams***

- For a **TOTAL WASH FINE MATERIAL REDUCED** the coarse sum check must be performed **AFTER** it has been properly **sieved and the total amount of fine - #4 material has been weighed and recorded**. For the coarse sum check use the **Dry Mass After Wash** and **Total Mass After Sieving.**

- The **individual mass retained** value is the weight of the aggregate retained in each individual sieve. ***(see example)***

- To perform the **% RETAINED equation** for **the individual method** one takes the **amount retained** on the sieve and **divides it by** the **ORIGINAL DRY MASS** and then **multiplies this result by 100**. ***(see example)***

- To perform the **% PASSING equation** for **the individual method** one begins by taking the **first sieve** that has a **% RETAINED value** and **subtracting** this number **from 100.** The **resulting value will be the number that the next % RETAINED is subtracted from.** ***(see example)***

- The fine sum check is performed on the fine portion that was reduced, weighed, and sieved from the total amount of fine material. use **Fine Split Before Sieve** and **Fine Split After Sieve for this equation.**

SUM CHECK:

FINE CHECK SUM =

$$\frac{(FINE\ SPLIT\ BEFORE\ SIEVE - FINE\ SPLIT\ AFTER\ SIEVE}{(FINE\ SPLIT\ BEFORE\ SIEVE)}\ X\ 100$$

$$\frac{(540.0\ g - 539.0\ g)}{(540.0\ g)}\ X\ 100 = 0.2\%$$

Less than 0.3% so these results can be used for acceptance.

	INDIVIDUAL MASS RETAINED FROM FINE SPLIT	*MASS OF EACH INCREMENT CALCULATION*	*ADJUSTED INDIVIDUAL MASS RETAINED FROM FINE SPLIT*
#8	*116.9*	$\frac{1910.0}{540.0}$ *X 116.9*	*413.5*
#10	*90.9*	$\frac{1910.0}{540.0}$ *X 90.9*	*321.5*
#16	*77.9*	$\frac{1910.0}{540.0}$ *X 77.9*	*275.5*
#30	*70.3*	$\frac{1910.0}{540.0}$ *X 70.3*	*248.7*
#40	*52.3*	$\frac{1910.0}{540.0}$ *X 52.3*	*185.0*
#50	*65.0*	$\frac{1910.0}{540.0}$ *X 65.0*	*229.9*
#100	*60.6*	$\frac{1910.0}{540.0}$ *X 60.6*	*214.3*
#200	*4.1*	$\frac{1910.0}{540.0}$ *X 4.1*	*14.5*
PAN	*1.0*		

- **Perform the "MASS OF EACH INCREMENT"** calculation to **adjust the amount** of material retained on each sieve to the **total amount for the -#4 material in the sample**. Take the total amount of **fine - #4 material** and divide it by the total amount of the reduced **fine portion before sieve** and then **multiply by** the **individual mass retained** from that **sieve**. ***(see example)***

MASS OF EACH SIZE INCREMENT (FINE MATERIAL) OF THE ORIGINAL SAMPLE CALCULATION:

$$A = \frac{(W1)}{(W2)} X\ B$$

A = the adjusted weight of the size increment retained on each screen *(on total sample basis);*

W1 = total amount of material passing the #4 sieve;

W2 = the reduced amount (according to R76) of passing #4 material that is sieved.

B = the weight of each increment that is retained on the screens used to sieve.

	ADJUSTED INDIVIDUAL MASS RETAINED FROM FINE SPLIT	***% Retained Individual Equation***	*INDIVIDUAL % RETAINED*	***% Passing Individual Equation***	*% PASSING INDIVIDUAL*
#8	*413.5*	$\frac{413.5}{5000.0}$ *X 100*	*8.3*	*41.0 – 8.3*	*32.7*
#10	*321.5*	$\frac{321.5}{5000.0}$ *X 100*	*6.4*	*32.7 – 6.4*	*26.3*
#16	*275.5*	$\frac{275.5}{5000.0}$ *X 100*	*5.5*	*26.3 – 5.5*	*20.8*
#30	*248.7*	$\frac{248.7}{5000.0}$ *X 100*	*5.0*	*20.8 – 5.0*	*15.8*
#40	*185.0*	$\frac{185.0}{5000.0}$ *X 100*	*3.7*	*15.8 – 3.7*	*12.1*
#50	*229.9*	$\frac{229.9}{5000.0}$ *X 100*	*4.6*	*12.1 – 4.6*	*7.5*
#100	*214.3*	$\frac{214.3}{5000.0}$ *X 100*	*4.3*	*7.5 – 4.3*	*3.2*
#200	*14.5*	$\frac{14.5}{5000.0}$ *X 100*	*0.3*	*3.2 – 0.3*	*2.9*

FINAL EXAMPLE OF COMPLETED SIEVE CALCULATED INDIVIDUALLY

ORIGINAL DRY MASS: 5000.0 grams

DRY MASS AFTER WASH: 4862.0 grams

TOTAL MASS AFTER SIEVING: 4861.3 grams

MINUS #200 WASH OUT: 138.0 grams

	INDIVIDUAL MASS RETAINED		INDIVIDUAL % RETAINED		% PASSING INDIVIDUAL	
1”	0		0		100	100
3/4”	210.1	$\frac{210.1}{5000.0}$ X 100	4.2	100 – 4.2	95.8	96
1/2”	730.0	$\frac{730.0}{5000.0}$ X 100	14.6	95.8 – 14.6	81.2	81
3/8”	609.1	$\frac{609.1}{5000.0}$ X 100	12.2	81.2 – 12.2	69.0	69
¼”	302.1	$\frac{302.1}{5000.0}$ X 100	6.0	69.0 – 6.0	63.0	63
#4	1100.0	$\frac{1100.0}{5000.0}$ X 100	22.0	63.0 – 22.0	41.0	41

REPORTED % PASSING

TOTAL MINUS -#4: 1910.0 grams

FINE SPLIT BEFORE SIEVE: 540.0 grams

FINE SPLIT AFTER SIEVE: 539.0 grams

#8	413.5	$\frac{413.5}{5000.0}$ X 100	8.3	41.0 – 8.3	32.7	33
#10	321.5	$\frac{321.5}{5000.0}$ X 100	6.4	32.7 – 6.4	26.3	26
#16	275.5	$\frac{275.5}{5000.0}$ X 100	5.5	26.3 – 5.5	20.8	21
#30	248.7	$\frac{248.7}{5000.0}$ X 100	5.0	20.8 – 5.0	15.8	16
#40	185.0	$\frac{185.0}{5000.0}$ X 100	3.7	15.8 – 3.7	12.1	12
#50	229.9	$\frac{229.9}{5000.0}$ X 100	4.6	12.1 – 4.6	7.5	8
#100	214.3	$\frac{214.3}{5000.0}$ X 100	4.3	7.5 – 4.3	3.2	3
#200	14.5	$\frac{14.5}{5000.0}$ X 100	0.3	3.2 – 0.3	2.9	2.9

REPORTED % PASSING

EXAMPLE SHOWS CUMULATIVE METHOD FOR CALCULATION

	CUMULATIVE MASS RETAINED	% Retained Cumulative Equation	CUMULATIVE % RETAINED	% Passing Cumulative Equation	% PASSING CUMULATIVE
1”	0		0		100
3/4”	210.1	$\frac{210.1}{5000.0}$ X 100	4.2	100 – 4.2	95.8
1/2”	940.1	$\frac{940.1}{5000.0}$ X 100	18.8	100 – 18.8	81.2
3/8”	1549.2	$\frac{1549.2}{5000.0}$ X 100	31.0	100 – 31.0	69.0
¼”	1851.3	$\frac{1851.3}{5000.0}$ X 100	37.0	100 – 37.0	63.0
#4	2951.3	$\frac{2951.3}{5000.0}$ X 100	59.0	100 – 59.0	41.0

- **Perform** the **coarse sum check** and the **fine sum check identical** to the **individual method** shown previously. ***(see example)***
- The **cumulative mass retained** value is the weight of the aggregate retained in an individual sieve and the sieves above. ***(see example)***
- To perform the **% RETAINED equation** for **the cumulative method** one takes the **amount retained** on the sieve and **divides it by** the **ORIGINAL DRY MASS** and then **multiplies this result by 100**. ***(see example)***
- To perform the **% PASSING equation** for **the cumulative method subtract each % RETAINED value from 100**. ***(see example)***

MASS OF EACH INCREMENT CALCULATION

#8	116.9	$\frac{1910.0}{540.0}$ X 116.9 + 2951.3	3364.8
#10	207.8	$\frac{1910.0}{540.0}$ X 207.8 + 2951.3	3686.3
#16	285.7	$\frac{1910.0}{540.0}$ X 285.7 + 2951.3	3961.8
#30	356.0	$\frac{1910.0}{540.0}$ X 356.0 + 2951.3	4210.5
#40	408.3	$\frac{1910.0}{540.0}$ X 408.3 + 2951.3	4395.5
#50	473.3	$\frac{1910.0}{540.0}$ X 473.3 + 2951.3	4625.4
#100	533.9	$\frac{1910.0}{540.0}$ X 533.9 + 2951.3	4839.7
#200	538.0	$\frac{1910.0}{540.0}$ X 538.0 + 2951.3	4854.2
Final Cumulative Mass	539.0		

- **Perform the “MASS OF EACH INCREMENT”** calculation to **adjust the amount** of material retained on each sieve to the **total amount for the -#4 material in the sample**. Take the total amount of **fine - #4 material** and divide it by the total amount of the reduced **fine portion before sieve** and then **multiply by** the **individual mass retained** from that **sieve then add this value to the *TOTAL MASS OF COARSE AGGREGATE retained from the sieving process***. ***(see example)***

			CUMULATIVE % RETAINED		% PASSING CUMULATIVE
#8	3364.8	$\frac{3364.8}{5000.0}$ X 100	67.3	100 – 67.3	32.7
#10	3686.3	$\frac{3686.3}{5000.0}$ X 100	73.7	100 – 73.7	26.3
#16	3961.8	$\frac{3961.8}{5000.0}$ X 100	79.2	100 – 79.2	20.8
#30	4210.5	$\frac{4210.5}{5000.0}$ X 100	84.2	100 – 84.2	15.8
#40	4395.5	$\frac{4395.5}{5000.0}$ X 100	87.9	100 – 87.9	12.1
#50	4625.4	$\frac{4625.4}{5000.0}$ X 100	92.5	100 – 92.5	7.5
#100	4839.7	$\frac{4839.7}{5000.0}$ X 100	96.8	100 – 96.8	3.2
#200	4854.2	$\frac{4854.2}{5000.0}$ X 100	97.1	100 – 97.1	2.9

FINAL EXAMPLE OF COMPLETED SIEVE CALCULATED CUMULATIVELY

ORIGINAL DRY MASS: ***5000.0 grams***

DRY MASS AFTER WASH: ***4862.0 grams***

TOTAL MASS AFTER SIEVING: ***4861.3 grams***

MINUS #200 WASH OUT: ***138.0 grams***

	CUMULATIVE MASS RETAINED		*CUMULATIVE % RETAINED*		*% PASSING CUMULATIVE*	
1”	*0*		*0*		*100*	
3/4”	*210.1*	$\frac{210.1}{5000.0}$ *X 100*	*4.2*	*100 – 4.2*	*95.8*	*96*
1/2”	*940.1*	$\frac{940.1}{5000.0}$ *X 100*	*18.8*	*100 – 18.8*	*81.2*	*81*
3/8”	*1549.2*	$\frac{1549.2}{5000.0}$ *X 100*	*31.0*	*100 – 31.0*	*69.0*	*69*
¼”	*1851.3*	$\frac{1851.3}{5000.0}$ *X 100*	*37.0*	*100 – 37.0*	*63.0*	*63*
#4	*2951.3*	$\frac{2951.3}{5000.0}$ *X 100*	*59.0*	*100 – 59.0*	*41.0*	*41*

REPORTED % PASSING

TOTAL MINUS -#4: ***1910.0 grams***

FINE SPLIT BEFORE SIEVE: ***540.0 grams***

FINE SPLIT AFTER SIEVE: ***539.0 grams***

#8	*3364.8*	$\frac{3364.8}{5000.0}$ *X 100*	*67.3*	*100 – 67.3*	*32.7*	*33*
#10	*3686.3*	$\frac{3686.3}{5000.0}$ *X 100*	*73.7*	*100 – 73.7*	*26.3*	*26*
#16	*3961.8*	$\frac{3961.8}{5000.0}$ *X 100*	*79.2*	*100 – 79.2*	*20.8*	*21*
#30	*4210.5*	$\frac{4210.5}{5000.0}$ *X 100*	*84.2*	*100 – 84.2*	*15.8*	*16*
#40	*4395.5*	$\frac{4395.5}{5000.0}$ *X 100*	*87.9*	*100 – 87.9*	*12.1*	*12*
#50	*4625.4*	$\frac{4625.4}{5000.0}$ *X 100*	*92.5*	*100 – 92.5*	*7.5*	*8*
#100	*4839.7*	$\frac{4839.7}{5000.0}$ *X 100*	*96.8*	*100 – 96.8*	*3.2*	*3*
#200	*4854.2*	$\frac{4854.2}{5000.0}$ *X 100*	*97.1*	*100 – 97.1*	*2.9*	*2.9*

REPORTED % PASSING

- **Report total percent passing to the nearest 1 percent except the #200 sieve % passing is reported to the nearest 0.1 percent.**

SPLIT FINE WASH- COARSE FULL GRADATION/ FINE MATERIAL IS REDUCED IN AMOUNT THEN WASHED THEN GRADATION IS PERFORMED.

OVERVIEW

- *Dry the **original test sample to constant mass**.*
- ***Weigh and record** the dry mass of the **original test sample**.*
- ***Sieve** the sample over the **COARSE size sieves**.*
- ***Weigh and record** the **TOTAL MASS of the FINE material (-#4).***
- ***Determine** the **cumulative** weight of each **COARSE sieve size and record**.*
- *Perform the **coarse sum check** to make sure that the results can be used for acceptance.*
- ***Perform the % retained cumulative calculation** on all the retained weights of COARSE MATERIAL.*
- *Perform **the % passing cumulative calculation** on all the retained weights of COARSE MATERIAL.*
- ***Reduce** the **-#4 fine material according to AASHTO R76.** Consult **TABLE** in the procedure for sample size.*
- ***Weigh and record** the **MASS of the REDUCED PORTION OF FINE material (-#4).***
- ***Wash the reduced portion of fine material** (using Method A or Method B- AASHTO T11) decant over a #200 screen.*
- *Dry the **washed reduced portion of fine material to constant mass**.*
- ***Weigh and record** the **MASS of the DRIED WASHED REDUCED PORTION OF FINE material (-#4).***
- ***Sieve** the new **dried fine sample portion** over the **FINE size sieves**.*
- ***Determine the cumulative** weight of each **FINE sieve size and record.***
- *Perform the **fine sum check** to make sure that the results can be used for acceptance.*
- ***Perform the % retained cumulative calculation** for the - #4 REDUCED PORTION of fine material on all the retained weights and record.*
- ***Perform the % passing cumulative calculation** for the - #4 REDUCED PORTION of fine material on all the retained weights and record.*
- *Next, perform **the TOTAL % passing cumulative calculation** for the **TOTAL FINE PORTION OF TEST SAMPLE and record**.*
- ***Report results.***

CALCULATIONS FOR ATTI CERTIFICATION WILL BE FROM THIS SECTION:

- For a **SPLIT FINE WASH-** ***COARSE FULL GRADATION/ FINE MATERIAL IS REDUCED IN AMOUNT THEN WASHED THEN GRADATION IS PERFORMED*** **the** coarse sum check must be performed **AFTER** it has been properly **sieved and the total amount of fine - #4 material has been weighed and recorded**. For the coarse sum check use the **Original Dry Mass** and **Original Dry Mass After Sieving.**

- The **cumulative mass retained** value is the weight of the aggregate retained in an individual sieve and the sieves above. ***(see example)***

- To perform the **% RETAINED equation** for **the cumulative method** one takes the **amount retained** on the sieve and **divides it by** the **ORIGINAL DRY MASS** and then **multiplies this result by 100**. ***(see example)***

EXAMPLE:

SUM CHECK: **COARSE CHECK SUM =**

$$\frac{(ORIGINAL\ DRY\ MASS - ORIGINAL\ DRY\ MASS\ AFTER\ SIEVING)}{(ORIGINAL\ DRY\ MASS)}\ X\ 100$$

ORIGINAL DRY MASS:
4100.0 grams

ORIGINAL DRY MASS AFTER SIEVING: 4100.0 grams

$$\frac{(4100.0-4100.0)}{(4100.0)}\ X\ 100\ = 0.0\%$$

Less than 0.3% so these results can be used for acceptance.

FINE SPLIT BEFORE WASH: 570.5 grams

FINE SPLIT AFTER WASH: 541.9 grams

FINE SPLIT AFTER SIEVE: 541.1 grams

	CUMULATIVE MASS RETAINED	***% Retained Cumulative Equation***	*CUMULATIVE % RETAINED*	***% Passing Cumulative Equation***	*% PASSING CUMULATIVE*
1"	*0*		*0*		*100*
3/4"	*150.1*	$\frac{150.1}{4100.0}$ *X 100*	*3.7*	*100 – 3.7*	*96.3*
1/2"	*900.1*	$\frac{900.1}{4100.0}$ *X 100*	*22.0*	*100 – 22.0*	*78.0*
3/8"	*1499.3*	$\frac{1499.3}{4100.0}$ *X 100*	*36.6*	*100 – 36.6*	*63.4*
¼"	*1801.5*	$\frac{1801.5}{4100.0}$ *X 100*	*43.9*	*100 – 43.9*	*56.1*
#4	*1901.8*	$\frac{1901.8}{4100.0}$ *X 100*	*46.4*	*100 – 46.4*	*53.6*

PASSING - #4: 2198.2 grams

- To perform the **% PASSING - #4 FINE PORTION equation** for **the cumulative method subtract each % RETAINED value from 100**. ***(see example)***
- The **fine sum check** is performed on the fine **portion that was reduced, weighed, then washed (according to AASHTO T11)** and dried to constant mass. Then sieve according to the procedure calculate using **Fine Split Before Sieve** and **Fine Split After Sieve for this equation.**

#8	*105.9*	$\frac{105.9}{570.5}$ *X 100*	*18.6*	*100 – 18.6*	*81.4*	$\frac{81.4*53.6}{100}$	*43.6*
#10	*211.8*	$\frac{211.8}{570.5}$ *X 100*	*37.1*	*100 – 37.1*	*62.9*	$\frac{62.9*53.6}{100}$	*33.7*
#16	*295.3*	$\frac{295.3}{570.5}$ *X 100*	*51.8*	*100 – 51.8*	*48.2*	$\frac{48.2*53.6}{100}$	*25.8*
#30	*306.1*	$\frac{306.1}{570.5}$ *X 100*	*53.7*	*100 – 53.7*	*46.3*	$\frac{46.3*53.6}{100}$	*24.8*
#40	*412.3*	$\frac{412.3}{570.5}$ *X 100*	*72.3*	*100 – 72.3*	*27.7*	$\frac{27.7*53.6}{100}$	*14.8*
#50	*473.3*	$\frac{473.3}{570.5}$ *X 100*	*83.0*	*100 – 83.0*	*17.0*	$\frac{17.0*53.6}{100}$	*9.1*
#100	*525.4*	$\frac{525.4}{570.5}$ *X 100*	*92.1*	*100 – 92.1*	*8.0*	$\frac{8.0*53.6}{100}$	*4.3*
#200	*539.1*	$\frac{539.1}{570.5}$ *X 100*	*94.5*	*100 – 94.5*	*5.5*	$\frac{5.5*53.6}{100}$	*2.9*
Final Cumulative Mass	*541.1*						

- To solve for **TOTAL % PASSING - #4 FINE MATERIAL take the % PASSING -#4 FINE PORTION** and multiply with the **% PASSING** value from the **#4 screen** (from the coarse sieves) and divide by 100. ***(see example)***

SUM CHECK:

$$\frac{(541.9\ g - 541.1\ g)}{(541.9\ g)}\ X\ 100 = 0.15\%$$

FINE CHECK SUM =

$$\frac{(FINE\ SPLIT\ BEFORE\ SIEVE - FINE\ SPLIT\ AFTER\ SIEVE}{(FINE\ SPLIT\ BEFORE\ SIEVE)}\ X\ 100$$

Less than 0.3% so these results can be used for acceptance.

FINAL EXAMPLE OF COMPLETED SIEVE CALCULATED CUMULATIVELY

ORIGINAL DRY MASS: 4100.0 grams

ORIGINAL DRY MASS AFTER SIEVING: 4100.0

FINE SPLIT BEFORE WASH: 570.5 grams

FINE SPLIT AFTER WASH: 541.9 grams

FINE SPLIT AFTER SIEVE: 541.1 grams

			CUMULATIVE % RETAINED		% PASSING CUMULATIVE	
1”	0		0		100	100
3/4”	150.1	$\frac{150.1}{4100.0}$ X 100	3.7	100 – 3.7	96.3	96
1/2”	900.1	$\frac{900.1}{4100.0}$ X 100	22.0	100 – 22.0	78.0	78
3/8”	1499.3	$\frac{1499.3}{4100.0}$ X 100	36.6	100 – 36.6	63.4	63
¼”	1801.5	$\frac{1801.5}{4100.0}$ X 100	43.9	100 – 43.9	56.1	56
#4	1901.8	$\frac{1901.8}{4100.0}$ X 100	46.4	100 – 46.4	53.6	54

REPORTED % PASSING

#8	105.9	$\frac{105.9}{570.5}$ X 100	18.6	100 – 18.6	81.4	$\frac{81.4 * 53.6}{100}$	43.6	44
#10	211.8	$\frac{211.8}{570.5}$ X 100	37.1	100 – 37.1	62.9	$\frac{62.9 * 53.6}{100}$	33.7	34
#16	295.3	$\frac{295.3}{570.5}$ X 100	51.8	100 – 51.8	48.2	$\frac{48.2 * 53.6}{100}$	25.8	26
#30	306.1	$\frac{306.1}{570.5}$ X 100	53.7	100 – 53.7	46.3	$\frac{46.3 * 53.6}{100}$	24.8	25
#40	412.3	$\frac{412.3}{570.5}$ X 100	72.3	100 – 72.3	27.7	$\frac{27.7 * 53.6}{100}$	14.8	15
#50	473.3	$\frac{473.3}{570.5}$ X 100	83.0	100 – 83.0	17.0	$\frac{17.0 * 53.6}{100}$	9.1	9
#100	525.4	$\frac{525.4}{570.5}$ X 100	92.1	100 – 92.1	8.0	$\frac{8.0 * 53.6}{100}$	4.3	4
#200	539.1	$\frac{539.1}{570.5}$ X 100	94.5	100 – 94.5	5.5	$\frac{5.5 * 53.6}{100}$	2.9	2.9
Final Cumulative Mass	541.1							

- **Report total percent passing to the nearest 1 percent except the #200 sieve % passing is reported to the nearest 0.1 percent.**

REPORTED % PASSING

NOT WASHED – TOTAL GRADATION / NO FINES REQUIRED

OVERVIEW

- *Dry the **original test sample to constant mass**.*
- ***Weigh and record** the dry mass of the **original test sample**.*
- ***Sieve** the sample over the **COARSE size sieves**.*
- ***Weigh and record** the **TOTAL MASS of the FINE material (-#4).***
- ***Determine** the **cumulative** weight of each **COARSE sieve size and record**.*
- *Perform the **coarse sum check** to make sure that the results can be used for acceptance.*
- ***Perform the % retained cumulative calculation** on all the retained weights of COARSE MATERIAL.*
- *Perform **the % passing cumulative calculation** on all the retained weights of COARSE MATERIAL.*
- ***Report results.***

ORIGINAL DRY MASS: 5216.4 grams

ORIGINAL DRY MASS AFTER SIEVING: 5216.4 grams

	INDIVIDUAL MASS RETAINED		*INDIVIDUAL % RETAINED*		*% PASSING INDIVIDUAL*	
1 1/2”	*0*		*0*		*100*	*100*
1”	*317.5*	$\frac{317.5}{5216.4} X 100$	*6.1*	*100 – 6.1*	*93.9*	*94*
3/4”	*2086.5*	$\frac{2086.5}{5216.4} X 100$	*40.0*	*93.9 – 40.0*	*53.9*	*54*
1/2”	*1270.1*	$\frac{1270.1}{5216.4} X 100$	*24.3*	*53.9 – 24.3*	*29.6*	*30*
3/8”	*1043.3*	$\frac{1043.3}{5216.4} X 100$	*20.0*	*29.6 – 20.0*	*9.6*	*10*
¼”	*185.2*	$\frac{185.2}{5216.4} X 100$	*3.6*	*9.6 – 3.6*	*6.0*	*6*
#4	*177.7*	$\frac{177.7}{5216.4} X 100$	*3.4*	*6.0 – 3.4*	*2.6*	*3*
PAN	*136.1*	$\frac{136.1}{5216.4} X 100$	*2.6*			

REPORTED % PASSING

- For a **NOT WASHED-NO FINES REQUIRED** all that is needed is to perform a total sum check **AFTER** it has been properly **sieved**. For the sum check use the **Original Dry Mass** and **Original Dry Mass After Sieving.**

SUM CHECK:

COARSE CHECK SUM =

$$\frac{(ORIGINAL\ DRY\ MASS - ORIGINAL\ DRY\ MASS\ AFTER\ SIEVING)}{(ORIGINAL\ DRY\ MASS)}\ X\ 100$$

$$\frac{(5216.4-5216.4)}{(5216.4)}\ X\ 100\ = 0.0\%$$

Less than 0.3% so these results can be used for acceptance.

- The **individual mass retained** value is the weight of the aggregate retained in each individual sieve. ***(see example)***

- To perform the **% RETAINED equation** for **the individual method** one takes the **amount retained** on the sieve and **divides it by** the **ORIGINAL DRY MASS** and then **multiplies this result by 100**. ***(see example)***

- To perform the **% PASSING equation** for **the individual method** one begins by taking the **first sieve** that has a **% RETAINED value** and **subtracting** this number **from 100.** The **resulting value will be the number that the next % RETAINED is subtracted from. *(see example)***

AASHTO T11:

MATERIALS FINER THAN #200 SIEVE IN MINERAL AGGREGATES

DEFINITIONS:

Decanting - gradually pour liquid, from a container without disturbing the sediment.

Nominal Maximum Aggregate Size– The sieve size through which most of the aggregate particles should pass, with a small percentage allowed to be retained on that sieve.

Passing #200 Material– particles that pass through a sieve with openings of 0.075 mm in diameter, often used in soil and aggregate testing to determine the amount of fine material, like clay and silt.

SCOPE:

1.1

This method is used to determine the amount of material finer than #200 sieve in aggregate by washing. Procedure is generally used in conjunction with AASHTO T27 when necessary.

EQUIPMENT:

5.

- **BALANCE –** is at least readable to 0.1 percent of the sample mass.
- **SIEVES –** frames and cloth that conforms to ASTM E11. A nest of two sieves the lower being #200 and the upper being a sieve with a range of #8 to #16.
- **CONTAINER –** a pan or bowl large enough for sample being covered in water.
- **SPOON OR MIXING UTENSIL**
- **WETTING AGENT –** any dispersing agent. *Example: liquid dishwashing detergent.*
- **OVEN –** an oven that maintains a uniform temperature of 230 ± 9 °F. The heating and drying range of the oven is required to be between 212°F to 248°F within ± 9 °F.
- **MECHANICAL WASHING APPARATUS –** any equipment that aides in the washing process not to be used for more than 10 minutes.

AASHTO T27 analyzes the overall particle size distribution across various sieve sizes, while AASHTO T11 specifically focuses on accounting for the fine material that passes through the No. 200 sieve, providing a more detailed analysis of the fine fraction of the sample. Each procedure works together to provide a complete picture of an aggregate sample's particle size distribution.

Brief outline: **3.**

A sample of aggregate is washed, using either plain water or a wetting agent with water.

The wash water is carefully decanted over a #200 screen. The loss in mass during this process is calculated as the percent by weight of the original sample and is reported as the percentage of material finer than #200 by washing.

SAMPLING:

- **Obtain the aggregate sample** according to **AASHTO R90.** If the same test sample is also tested for sieve analysis *(AASHTO T27)* comply with the applicable requirements of that method. **6.1.**
- Thoroughly **mix** the sample and **reduce** to the appropriate testing size according to **AASHTO R76**. **6.2.**
- If the same test sample is to be **tested** according to ***AASHTO T 27*** then refer to that procedure for the **minimum mass.** Otherwise, the test sample minimum mass (after drying) shall conform with the below **table** according to **Sec 6.2:** **6.2.**

Nominal Maximum Size	Minimum Mass, g
4.75 mm (No. 4) or smaller	300
9.5 mm ($^3/_8$ in.)	1000
19.0 mm ($^3/_4$ in.)	2500
37.5 mm ($1^1/_2$ in.) or larger	5000

DO NOT……. **6.2.**

Reduce the test sample to an exact predetermined mass. If the NOMINAL Maximum size of the aggregate is not in the table proceed to the next larger size to determine minimum sample size.

METHOD A – WASHING WITH PLAIN WATER:

PROCEDURE:

METHOD A will be used unless otherwise specified that the test results will be compared or when directed by the agency where the work is being performed.

7.1

1 **Dry** the sample to **constant mass** according to **AASHTO T255** ***(demonstrated is the oven method see T255 for alternative methods).*** Place the test sample into an oven at a temperature of **230 ±9°F** and dry to **constant mass. Weigh and record** the sample mass to the **nearest 0.1 grams**. **8.1.**

CONSTANT MASS (T255): Sample is dry when further heating causes less than 0.1% additional loss in mass.

REMEMBER

If the specification requires that the amount passing the #200 screen will be determined on a portion of the sample passing a sieve SMALLER than the nominal maximum size of the aggregate, separate the sample on the designated sieve and determine the mass of the material passing the designated sieve to the nearest 0.1 grams. Use this mass as the original dry mass of the test sample. ***(SEE PROCEDURE FOR MORE DETAIL)*** **8.2**

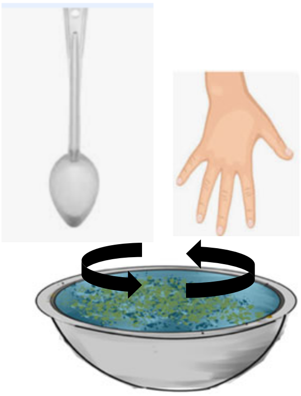
2 **After** drying and weighing, place the sample in a container (if not already in an appropriate container) and **add enough water** to cover it. **Agitate with a large spoon (or similar equipment) or by hand** in a way that achieves complete separation of all particles finer than #200 from the coarser material.

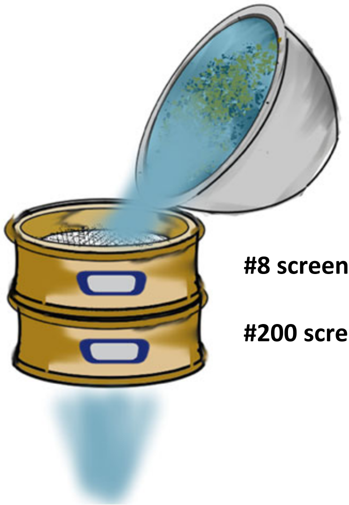
8.3.

OR

3 While the **fine particles** are in **suspension**, immediately **pour** the water over the **nested sieves.** Making sure not to allow too much of the coarse material onto the sieves. ***Coarser sieve on top (see equipment).***

8.3.





DO NOT……. Overflow or overload #200 screen during procedure.

4 **Again, add enough water to cover the sample.** Agitate and decant as before. Repeating the procedure.

8.4.

5 **Repeat** these steps until the **wash water** runs **REASONABLY clear**.

8.4.

6 **Return** all the **material** that is **retained** on the **nest of sieves to the container** by flushing with water making sure to rinse off any spoons, hands (or other tools used) back into the container. ***EXCESS water left in the container is to be evaporated during the drying process***.

8.4./ 8.5

NO water is to be decanted from the container unless through the #200 screen.

8.4./8.5

7 **Dry** the **WASHED** sample to **constant mass** according to **AASHTO** ***T255 (demonstrated is the oven method see T255 for alternative methods).*** Place the test sample into an oven at a temperature of **230 ±9°F** and dry to **constant mass. Weigh and record** the sample mass to the **nearest 0.1 grams**. **8.5**

230 ± 9 ° F

MECHANICAL WASHER

- *Limit the mechanical washing process to a maximum of 10 minutes.* **8.4**

- *When performing the procedure with a mechanical washer the addition of water, agitating, and decanting may be one continuous operation.* **NOTE 4**

- *When performing the procedure with a mechanical washer thoroughly wash out the apparatus into a drying container as well as the material still in the nest of sieves.* **8.5**

METHOD B – WASHING USING A WETTING AGENT:

PROCEDURE:

1 **Prepare** the sample identical to what is outlined **PROCEDURE A.** **9.1.**

2 **After** drying and weighing, place the sample in a container (if not already in an appropriate container) and **add enough water** to cover it. **9.2**

3 Add the **wetting agent to the water**. **9.2**

4 **Agitate the sample with a large spoon (or similar equipment) or by hand** in a way that achieves complete separation of all particles finer than #200 from the coarser material. 9.2

5 While the **fine particles** are in **suspension**, immediately **pour** water over the **nested sieves.** Making sure not to include too much of the coarse material onto the sieves. ***Coarser sieve on top (see equipment).*** 9.2

How Much Wetting Agent Is Enough? **NOTE 6**

The amount should only produce a small amount of suds when the material is agitated. Excessive suds may overflow sieves and carry material with it.

6 **Add additional water WITHOUT wetting agent** to the sample after the water has been decanted and repeat the procedure until the **wash water runs REASONABLY clear**. 9.3

7 **Complete** the procedure identical to **PROCEDURE A.** 9.4

CALCULATIONS:

AMOUNT OF MATERIAL PASSING #200 BY WASHING:

$$A = \frac{(B-C)}{B} X\ 100$$ 10.1

A = percentage of material finer than #200 sieve by washing.

B = original dry mass of sample in grams;

C = dry mass of sample after washing in grams;

REPORT THE PERCENTAGE OF MATERIAL FINER THAN #200 BY WASHING TO NEAREST 0.1% — **EXCEPT IF** 11.1

THE RESULT IS 10% OR MORE THEN REPORT TO THE NEAREST WHOLE PERCENT.

PRACTICE QUESTIONS:

1. When sampling aggregate roadway in place you obtain your sample **after ________** and **before _________** **(**according to AASHTO R90)?
   a. Compacting, spreading
   b. Spreading, icing
   c. Spreading, compacting

2. When reducing according to **METHOD C,** turn the entire sample over **________ times** to mix (according to AASHTO R76)?
   a. 2
   b. 3
   c. 1

3. The sample **size of fine aggregate** (after drying) is a minimum of **______ grams** when (according to AASHTO T27)?
   a. 600
   b. 250
   c. 300

4. **METHOD A is washing** with a wetting agent (according to AASHTO T11)?

   a. TRUE
   b. FALSE

5. What method is used to reduce **fine aggregate (WETTER than SSD)** (according to AASHTO R76)?

   a. METHOD A – Mechanical Splitter
   b. METHOD B – Quartering
   c. METHOD C – Miniature Stockpile
   d. ALL OF THE ABOVE

6. If the **two** amounts differ by **more than_______** based on total of original dry sample mass the results should not be used for acceptance (AASHTO T27)?

   a. 0.2%
   b. 0.3%
   c. 0.4%

7. Repeat the washing procedure until the **wash water runs _________ clear** (AASHTO T11**)?**
   a. Reasonably
   b. Completely
   c. Doesn't Matter

ANSWERS:

1. c
2. b
3. c
4. b
5. d
6. b
7. a

SOILS TESTING

Soil testing in construction is a critical part of the design and planning phase. It helps engineers and technicians understand the composition, structure, and behavior of the soil on a site, which directly influences the choice of foundation and other structural elements. Determining the Liquid Limit, the Plastic Limit, maximum dry density, and optimum moisture are the primary tools (along with sieve analysis) in soils testing to understand the behavior of soil that will be used in construction projects. PH and resistivity are used to determine the possibility of corrosion affecting buried infrastructure and concrete structures.

All soils testing procedures that are covered during the ATTI Certification process.

- **AASHTO T89:** *DETERMINING THE LIQUID LIMIT OF SOILS*
- **AASHTO T90:** *DETERMINING THE PLASTIC LIMIT AND PLASTICITY INDEX OF SOILS*
- **AASHTO T99:** *MOISTURE DENSITY RELATIONS OF SOILS METHODS / ANNEX ROCK CORRECTION*
- **AASHTO T288:** *DETERMINING MINIMUM LABORATORY SOIL RESISTIVITY*
- **AASHTO T289:** *DETERMINING pH OF SOIL FOR USE IN CORROSION TESTING*
- ***AASHTO T265:*** *LABORATORY DETERMINATION OF MOISTURE CONTENT OF SOILS*

Learning objectives for these sections are:

- ***How to perform the liquid and plastic limit and subsequently calculate the Plasticity index.***
- ***How to determine the moisture content in soil used in testing.***
- ***How to determine the max dry density and optimum moisture along with how to graph.***
- ***How to correct max dry density and optimum moisture if the sample contains oversized particles.***
- ***How to perform both Resistivity and PH determinations.***

PLEASE REFER TO THE SECTION FOUND IN THE PROCEDURE FOR MORE DETAIL

AASHTO T89:

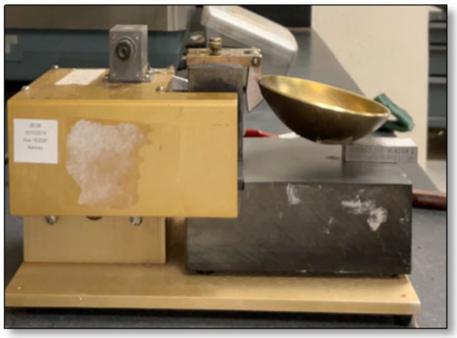
DETERMINING THE LIQUID LIMIT OF SOILS

DEFINITIONS:

Liquid State – the state of a fine-grained soil at which the soil will flow on its own weight.

Plastic State – is the condition at which the soil can be remolded to any shape without cracking.

Uniform Mass of Stiff Consistency - that has a consistent texture and firmness throughout, meaning it is neither too soft nor too hard.



The liquid limit of soil is the moisture content at which the soil transitions from a plastic state to a liquid state. Liquid limit is a key property used in classifying soils. Generally, soils with a high liquid limit are more clayey and tend to be more plastic, while soils with a lower liquid limit are sandy or silty and less plastic. Combined with the plastic limit the results from these tests can assess the behavior of soil in various engineering applications.

SCOPE:

1.1

The liquid limit of a soil is that water content, as determined in accordance with the following procedure, at which the soil passes from a plastic to a liquid state.

EQUIPMENT:

5.

- **DISH-** a porcelain dish (preferably unglazed) or similar around 115mm in diameter.
- **SPATULA –** has a blade around 75 mm to 100 mm in length and around 20 mm in width.
- **LIQUID LIMIT DEVICE –** manual or automatic, constructed of a brass dish and carriage **(refer to the procedure for exact dimensions).**
- **GROOVING TOOL –** curved or flat **(refer to the procedure for critical dimensions)**.
- **GAUGE –** a metal bar that is 10.0 ± 0.2 mm thick and approximately 50 mm long (**can be attached to grooving tool refer to procedure for more detail).**
- **CONTAINERS -** suitable containers made of material that is resistant to corrosion and not subject to change in mass or disintegration on repeated heating & cooling. Must have close fitting lids. One container is needed for each moisture content determination.
- **OVEN –** an oven that maintains a uniform temperature of 230 ± 9 °F. The heating and drying range of the oven is required to be between 212°F to 248°F within ± 9 °F.
- **THERMOMETER (used for monitoring oven) –** with a temperature range of at least 194°F to 266°F with an accuracy of ± 2.25 °F.
- **BALANCE –** sensitive to 0.01 grams with a minimum capacity to at least 100 grams (readable to the nearest 0.1% of the sample mass).

CALIBRATION:

- **Begin** by **inspecting** liquid limit **device** making sure that it's in **good working order**, that the **pin** connecting the cup is **not** worn to the point where there is **side to side play** and the **screws** connecting the hangar arm are **tight**. Check that the **point (worn spot) of contact** between the **cup** and the **base does not exceed 13mm** (***consult the procedure for more detail and additional requirements).***

5.1.

- **Adjust** the **height** of drop of the cup so that the **spot or point** where the **cup** contacts the **base** raises to a **height of 10.0 ± 0.2mm. Do this step once daily before testing starts** (***see illustration).***

5.2.

1 **Lift** the **cup** in order to **locate the contact point**. The definition of this point is the area of the cup that is parallel with the axis of the cup hanger pivot. Generally, this area will have a worn spot.

5.2. (note 5)

2 **Place** a piece of **tape** across the outside bottom of this area. Make sure the edge of the tape facing away from the cup hanger **bisects the spot**. ***(see illustration).***

5.2. (note 5)

3 Turn the crank or start the device until the **cup is raised** to its **maximum height**.

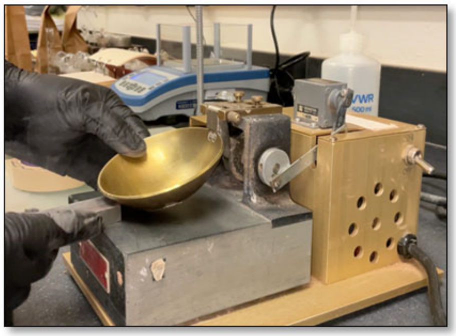
5.2. (note 5)

4 **Slide the gauge** under the cup from the **front** of the device. If the gauge contacts **BOTH** the **tape and cup** during this step your adjustment is **approximately correct**. If **BOTH** are **not** contacted simultaneously make sure to **adjust the drop height** using the adjustment **screws**.

5.2. (note 5)

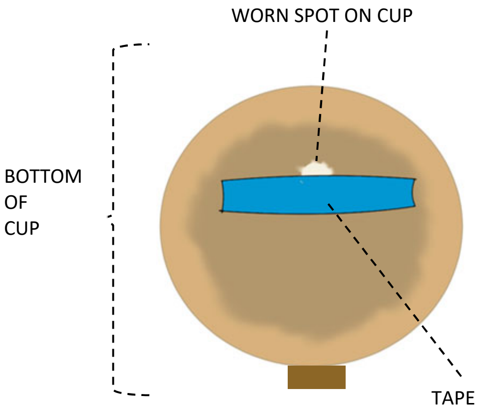
5 **Check** final **height** adjustment by **turning the crank** or starting the device. Making sure that the crank or device turns at **two revolutions per second** and the **gauge is held in position** against the tape and the cup.

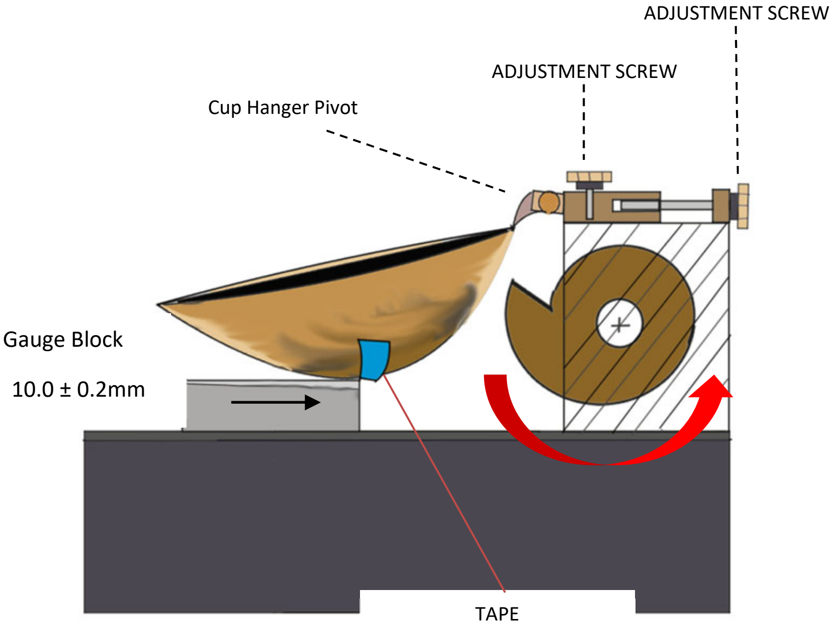
5.2. (note 5)



6 If a **slight ting or ringing sound is heard**, **without** the cup **rising** from the gauge, the adjustment is correct. If nothing is heard or the cup lifts re-adjust the height. **5.2. (note 5)**

ILLUSTRATION OF CALIBRATION PROCESS





METHOD A – MULTI POINT (CURVED GROOVE TOOL):

PROCEDURE:

1 **Obtain** a **100-gram** sample, from a thoroughly mixed portion of material, **passing #40** screen. ***(according to AASHTO R58)*** **4.1.**

2 Place the soil **sample** in the dish and thoroughly **mix with 15mL to 20mL** of **distilled water** by way of **stirring, kneading, and chopping.** **6.1.**

3 If the soil appears too dry, increments of **1 mL to 3 mL of distilled water at a time** can be added. Each addition of water must be mixed thoroughly (the same as above) before adding another increment. **6.1.**

4 If **too much moisture** was added the sample can be **discarded or mixed and kneaded until the closure point is lowered** to the acceptable range.

6.1.

Can Dry Soil Be Added to the Sample?

6.1.

NO. Once testing has begun no additional dry material may be added to soil.

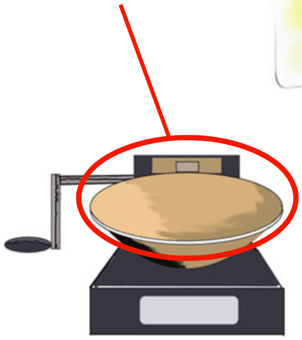
5 Once sample has attained a **uniform mass of stiff consistency**, place an adequate amount into the **recess of the cup** (above the spot where the cup rests on the base) and **spread** with the spatula so its **level**. Spread to a **depth of 10mm** at point of **max thickness**. Use as **few strokes as possible** to **avoid** entrapment of **air bubbles.**

6.1.

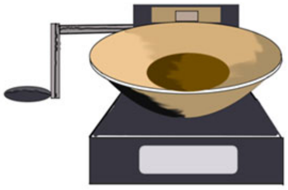
NOTE 6

If the soil being tested is slow to absorb water adding water to quickly will give a false LIQUID LIMIT. Allow sufficient time in between the addition of increments and attempting liquid attainment.

DO NOT USE THE CUP OF THE LL DEVICE TO MIX SOIL AND WATER.



PLACE MATERIAL IN LL CUP



6 **Return** any **excess material** (if any) to remaining sample and **cover** to avoid loss of moisture.

6.1.

AASHTO R58

🟥 ***Sample** size is **at least 300 g** of material that **passes the #40 screen**.*

🟥 ***Dry** sample at no greater than **140** ℉.*

#10 Sieve

#40 Sieve

Pan

🟥 *Place your sample over your **nest of sieves (example shown consists of #10, #40, and pan)**. Separating the sample into **two fractions**. **One portion** is the amount **retained** on the **#10** and the other portion is what passes **(rest of the sample).***

🟥 ***Remove** the material **retained** on the **#10 sieve** and **pulverize** with the mortar and pestle (or other appropriate device) in a way that breaks up the aggregation of material without actually damaging the individual particles.*

🟥 ***Place** the pulverized material **back over the nest of sieves** separating again. After the pulverizing procedure, **discard** any material **retained on the #10**. **Repeat** the above procedure with the **material retained** on **the #40 screen.***

🟥 ***Remove** the material **retained on the #40 sieve** and **pulverize** with the mortar and pestle (or other appropriate device) in a way that breaks up the aggregation of material without actually damaging the individual particles. **Pour** the **pulverized** material back **over the #40 screen**. **If** there is **material retained** on the #40 **repeat the pulverizing process on that material until only a small quantity of soil passes the #40.***

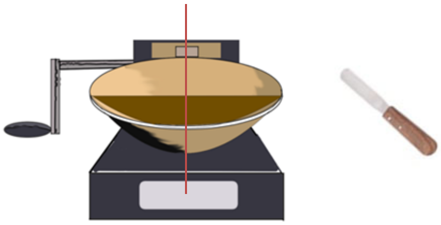
🟥 ***Mix** thoroughly and **obtain** the appropriate amount of soil that applies to the method you will be using.*

Can also do this procedure using the #4 screen then the #10 screen then the #40 screen.

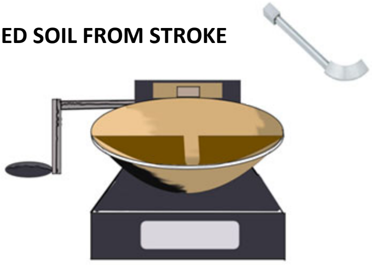
7 **Divide** the soil, in the cup, by a **firm stroke with the grooving tool** through the **center** ***(along the diameter through the centerline of the cam)*** of the material.

6.1.

CENTERLINE OF SPREAD MATERIAL



DIVIDED SOIL FROM STROKE



Tap water may be used for routine testing if comparative tests indicate no differences in results. If there is a referee or a disputed test this procedure will be performed using distilled.

NOTE 6

8 To **avoid tearing and material sliding** on the cup, the technician **can** use **up to 6 strokes** from front to back (or back to front) **each front to back (or back to front) counting as one stroke.** The depth of the groove should increase with each stroke with the last stroke scraping the bottom of the cup.

6.1.

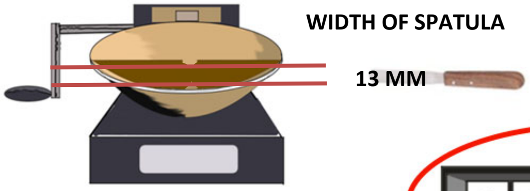
9 **Turn** the crank (or turn on device) so that the cup is **lifted and dropped at a rate of 2 revolutions per second** until the two sides of the groove come into **contact at the bottom** along a distance of approximately **13 mm**. **Record the number of blows required to close the groove (*see step 13 in this manual for the appropriate range of blows).***

6.2.

2 REVOLUTIONS PER SECOND

DO NOT HOLD THE BASE WHILE THE CRANK IS TURNED

WIDTH OF SPATULA



BLOW COUNTER EXAMPLE

10 **Remove** a **slice of soil** approximately the **width** of the **spatula**. **Slice from edge to edge of the soil in the cup**, at right angles to the groove, and from the **portion of the groove that is touching.** Place the portion removed into a **suitable tared container placing the lid on.**

6.3.

If the soil is sliding on the surface of the cup and not flowing?

Add more water, remix, and repeat the procedure. If it continues to slide at a lesser number than 25 shocks then the test is not applicable and note that the liquid limit could not be determined.

11 Determine **moisture content according to AASHTO T265** (**Record** the weight to the **nearest 0.01 grams)**. **6.3.**

12 **Transfer** the **remaining soil** from the cup to the sample in the **mixing dish and cover**. Make sure to **clean** the **grooving tool and the cup** before the next trial begins. **6.4.**

13 Repeat, adding sufficient water to obtain the right condition. The first **test** must be in the **range of 25 to 35 shocks**, the **second** must be in the range of **20 to 30 shocks**, and the **third** must be in the range of **15 to 25 shocks.** The range of the **3 determinations will be at least 10 shocks**. **6.5.**

SECTIONS NOT COVERED:

7. Alternate Procedure Using the Flat Grooving Tool:

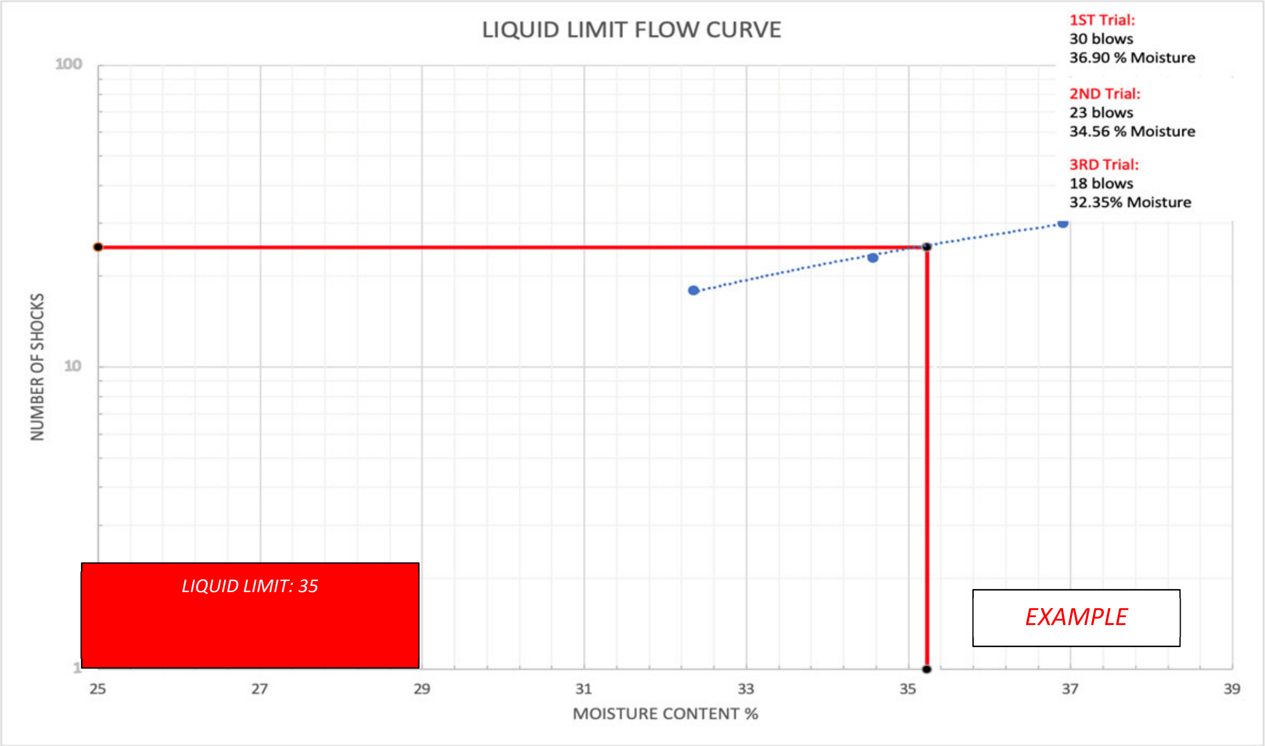
PLEASE REFER TO THE SECTION FOUND IN THE PROCEDURE FOR MORE DETAIL IF INTERESTED. THIS PROCEDURE IS NOT COVERED OR TESTED ON DURING ATTI CERTIFICATION.

7.

FLOW CURVE/ LIQUID LIMIT:

- The **flow curve** shows the relationship between moisture content and a corresponding number of shocks. Needs to be plotted on a semi logarithmic graph with **the moisture content as the x coordinate on a regular arithmetical scale** and **the number of shocks as the y coordinate on a logarithmic scale.**

9.



- The **flow curve is the straight line drawn (as best as can be) between the 3 plotted points.** The liquid limit corresponds to the **intersection of the flow curve with the 25-shock y coordinate**. **Report to the nearest whole number.**

10.

METHOD B – SINGLE POINT (CURVED GROOVE TOOL):

PROCEDURE:

- **The procedure is identical to METHOD A: MULTI POINT (Curved Groove Tool) 6.1 through 6.5. EXCEPT:**

12.1.-12.2.

  - ***Sample size is*** *approximately* ***50g*** *and obtained in the same manner as Method A.*
  - ***Initial*** *amount of* ***water*** *added to the sample is* ***8 mL to 10 mL****.*
  - ***Moisture sample*** *will only be taken for the* ***accepted trial****.*
  - *The* ***accepted*** *number of blows for groove closure is between* ***22 & 28 blows.***
  - *After obtaining a* ***preliminary closure*** *between 22 & 28 blows* ***immediately return the soil*** *in the cup to the mixing bowl.* ***Do Not add water****. Then repeat putting the soil in the cup, spreading, lifting and dropping the cup in the same manner as method A.*
  - *If the* ***second*** *closure is* ***within the acceptable range and is within 2 blows of the first trial*** *then take your* ***moisture content sample*** *the same way as METHOD A.*

CALCULATION:

14.

CALCULATION OF MOISTURE CONTENT

$$\textbf{\textit{Percentage moisture}}\ (W_N) = \left[\frac{mass\ of\ water\ (wet\ sample)}{mass\ of\ oven\ dried\ soil}\right] \text{X } 100$$

LIQUID LIMIT CALCULATION

$$\textbf{\textit{LL}} = W_N\left(\frac{N}{25}\right)^{0.121} \text{X } 100$$

10.

OR

$$\textbf{\textit{LL}} = k\ (W_N)$$

LL = liquid limit corrected for closure at 25 blows;

W_N = water content (moisture content);

N = number of blows causing closure at water content;

k = factor given in Table 1 of the procedure.

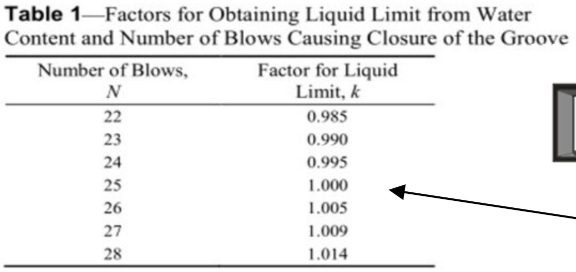


Table 1—Factors for Obtaining Liquid Limit from Water Content and Number of Blows Causing Closure of the Groove

Number of Blows, *N*	Factor for Liquid Limit, *k*
22	0.985
23	0.990
24	0.995
25	1.000
26	1.005
27	1.009
28	1.014

- **Report to the nearest whole number.**

AASHTO T90:

DETERMINING THE PLASTIC LIMIT AND PLASTICITY INDEX OF SOILS

DEFINITIONS:

Liquid State – the state of a fine-grained soil at which the soil will flow on its own weight.

Plastic State – is the condition at which the soil can be remolded to any shape without cracking.

Uniform Mass of Stiff Consistency - that has a consistent texture and firmness throughout, meaning it is neither too soft nor too hard.

The plastic limit (PL) and plasticity index (PI) are crucial soil properties used in construction to understand soil behavior and to classify soils, with the PI being the difference between the liquid limit (LL) and PL, indicating the range of moisture content where soil exhibits plastic behavior. The PI quantifies the soil's ability to deform without cracking or experiencing relative particle displacement.

SCOPE:

1.1

The plastic limit of a soil is the lowest moisture content at which the soil remains plastic. The plasticity index of a soil is the range in moisture content as a percentage of the mass of the oven dried soil that the material is in a plastic state. Plasticity index is calculated as the numerical difference between the liquid limit and the plastic limit of the soil.

EQUIPMENT:

3.

- **DISH-** a porcelain dish (preferably unglazed) or similar around 115 mm in diameter.
- **SPATULA –** has a blade around 75 mm in length and around 20 mm in width.
- **SURFACE FOR ROLLING –** Glass plate or unglazed paper (paper cannot impart foreign matter to the sample).

OPTIONAL *

- ***PLASTIC LIMIT ROLLING DEVICE & PAPER –** a device made of acrylic. (**See figure 1 in procedure).**
- **CONTAINERS -** suitable made of material that is resistant to corrosion and not subject to change in mass or disintegration on repeated heating & cooling. Must have close fitting lids.
- **OVEN –** an oven that maintains a uniform temperature of 230 ± 9 °F. The heating and drying range of the oven is required to be between 212°F to 248°F within ± 9 °F.
- **THERMOMETER (used for monitoring oven) –** with a temperature range of at least 194°F to 266°F with an accuracy of ± 2.25 °F.
- **BALANCE –** sensitive to 0.01 grams with a minimum capacity to at least 100 grams (readable to the nearest 0.1% of the sample mass).

SAMPLE:

If ONLY the plastic limit is to be determined: 5.1.

- Take an amount of soil with a **mass** of approximately **20 grams** from the, thoroughly mixed, portion **of material passing #40 sieve** (***according to AASHTO R58***).
- *Place material in a dish and **thoroughly mix** with **distilled water,** enough that the material becomes plastic and can be easily shaped into a ball.*
- *Remove **10 grams** to use **as the test sample**.*

Do you have to use distilled water for the test?

NO... tap water can be used if the lab has performed comparative tests with tap water and distilled and no differences were found. If a referee is required then use distilled water!

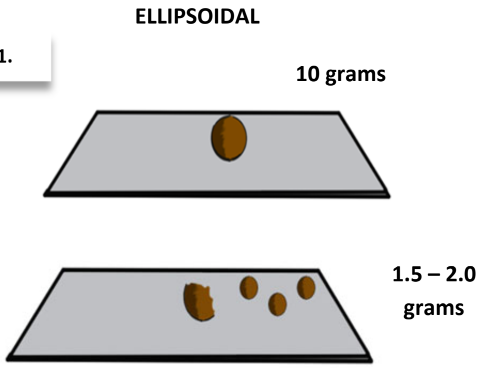
If the plastic limit is to be determined WITH the liquid limit: 5.2.

- Remove **10 grams** of material from the, thoroughly mixed, wet portion of soil that was **prepared for the liquid limit test (AASHTO T89).**
- You can **take the test sample** at any stage of the **mixing processes** long as the soil is plastic enough to be easily shaped into a ball without sticking to the fingers.
- If the material is taken **BEFORE** the completion of the liquid limit test set aside and **allow to season in air until the liquid limit test is complete**.
- Add more water and remix, if the 10-gram **PL test sample**, taken during the liquid limit test, is **too dry to roll to a 3mm thread on the first roll.**

PROCEDURE:

1 **Weigh and record** the moisture content **container to 0.01 grams.** 6.1.

2 Select a **1.5-gram to 2.0-gram portion** from the **10 g mass** of soil that was obtained for the test. (***See section 5.). Form this into an ellipsoidal mass.*** 6.2.



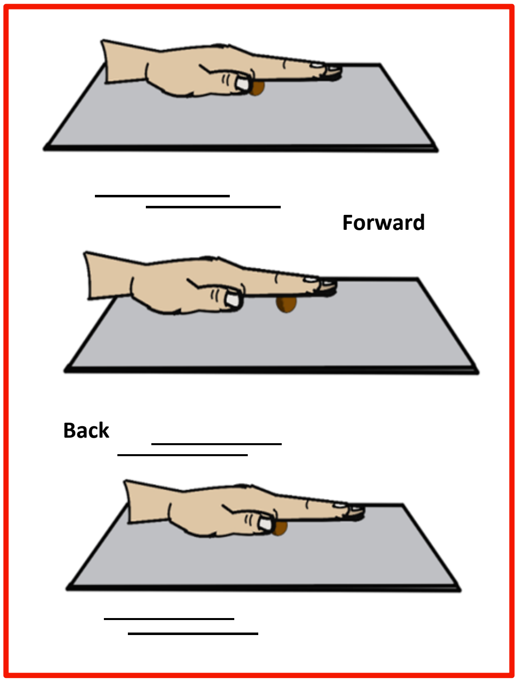
3 **Roll the mass** between the palm (or fingers) and the glass plate (or unglazed paper).

6.3.1.

4 **Roll** the soil mass at a **rate of 80 to 90 strokes per minute**. A stroke being defined as one complete motion of the hand forward and then back to the starting position.

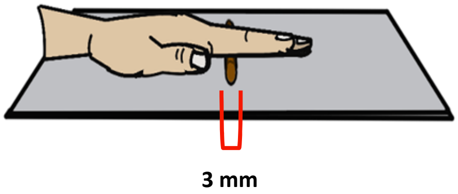
6.3.

1 Stroke



5 Use sufficient pressure to roll the mass into a thread **of uniform diameter throughout its length**. Continue this process until the thread's **diameter** reaches **3 mm**. This process can **NOT** take more than **2 minutes**.

6.3.1.



Fragile soils of low plasticity are best rolled under the outer edge of the palm or at the base of the thumb.

NOTE 5

6 The **thread** must roll to **3 mm** at least **once** to be considered **plastic**.

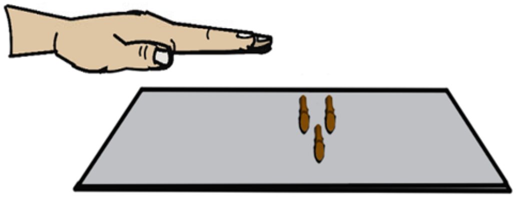
6.4.

7 **Once the thread reaches 3 mm**, squeeze the thread between the thumb and fingers to form it back into a, roughly, **ellipsoidal shape**.

6.4.

8 **Repeat** the procedure until the soil can no longer be rolled into a thread and **begins to crumble**. The crumbling can occur when the thread diameter is greater than 3 mm only when the sample has previously been rolled to 3 mm.

6.4.



The procedure defines crumbling size and shape, pressure used, and how these relate to different types of soil. Please refer to the procedure for more detail.

9 When the end point has been achieved, gather the portions together and **place in the moisture content container** and **immediately cover** with a close-fitting lid to prevent additional loss of moisture. **6.5.**

10 **Repeat** the process until the **entire 10-gram sample is tested**. Place all the crumbled portions into the **SAME** moisture content container. **6.6.**

11 Determine the moisture content of the sample in accordance with **AASHTO T265 and record the results.** (**Record** the weight to the **nearest 0.01 grams**). **6.7.**

Do not attempt to produce failure by purposefully reducing the rate of rolling or the hand pressure, or both. **6.4**

CALCULATION:

- **The plastic limit is the moisture content determined according to AASHTO T265**. This result will be expressed as a percentage of the oven dry mass. The **plastic limit** will be reported to the **nearest whole number**. 7.1.

CALCULATION OF MOISTURE CONTENT (AASHTO T265)

$$W_N = \left[\frac{(W1-W2)}{(W2-Wc)}\right] \text{ X } 100 \quad = \quad \textbf{PLASTIC LIMIT}$$

W_N = Moisture content in percent.
W1 = Mass of the container and sample in grams.
W2 = Mass of the container and oven-dried sample in grams.
Wc = Mass of the container in grams.

- The **plasticity index** of a soil is the **difference** between its **liquid limit and its plastic limit.** 7.2.

LIQUID LIMIT − PLASTIC LIMIT = PLASTICITY INDEX

- When the liquid limit or plastic limit **cannot be determined** report the plasticity index as **NP (non-plastic).** When the **plastic limit is equal to, or greater than the liquid limit** report the plasticity index as **NP**. 7.3.

EXAMPLE:

LIQUID LIMIT

CONTAINER: 60.08 # SHOCKS: 22

$$W_N = \left[\frac{(75.85-72.85)}{(72.85-60.08)}\right] \text{ X } 100$$

ANSWER: 23.49 = 23%

$$LL = 23\left(\frac{22}{25}\right)^{0.121} \text{ X } 100$$

ANSWER: 23.13 = 23%

PLASTIC LIMIT

TARE: 55.69

$$W_N = \left[\frac{(63.21-62.25)}{(62.25-55.69)}\right] \text{ X } 100$$

ANSWER: 14.63 = 15%

23 – 15 = 8

PLASTICITY INDEX = 8

AASHTO T99:

MOISTURE – DENSITY RELATIONS OF SOILS USING A 5.5 LB RAMMER AND A 12 INCH DROP

DEFINITIONS:

Max Dry Density - is the highest dry density that a soil or aggregate can reach.

Optimum Moisture – is the percent of moisture at which the greatest density a soil can be obtained through compaction.

Compaction - is the process of pressing soil particles together to reduce the space between them, which increases the soil's density.

Friable – is easily crumbled.

Maximum Dry Density (MDD) "Max dry density" refers to the highest possible density a type of soil can achieve when compacted at its optimum moisture content or in other words the maximum amount of dry soil mass that can fit within a given volume, indicating the point where further compaction will not increase density.

Optimum Moisture Content (OMC) is the moisture level at which this densest state is achieved.

SCOPE:

1.1.

This procedure describes the methods for determining the relationship between moisture content and density of soils compacted in a mold of a given size with a 5.5 lb. rammer dropped from a height of 12 inches.

EQUIPMENT:

3.

- **MOLD & ASSEMBLY (Mold, Collar, and Base Plate)- *See procedure for precise dimensions and details.***
- **RAMMER:** Either Manual or Mechanical. With a mass of 5.5 +- 0.02 lbs. having a circular face of 2.000 inches. Attached is a suitable guide- sleeve (or if mechanical dropped from a height of) to allow the hammer to drop at a free fall of 12.00 +- 0.06 inches. ***See procedure for precise dimensions and details.***
- **SAMPLE EXTRUDER**
- **BALANCE -** is at least readable to 1 gram or better.
- **OVEN –** an oven that maintains a uniform temperature of 230 ± 9 °F. The heating and drying range of the oven is required to be between 212°F to 248°F within ± 9 °F.
- **THERMOMETER (used for monitoring oven) –** with a temperature range of at least 194°F to 266°F with an accuracy of ± 2.25 °F.
- **STRAIGHT EDGE-** at least 10 inches in length.
- **SIEVES –** ¾" and #4.
- **MIXING TOOLS –** spatulas, spoons, …. etc.
- **CONTAINERS –** Containers capable to handle constant heating and cooling and resistant to corrosion.

METHOD:

- A quick reference to all the alternative methods in **AASHTO T99**: **1.1.**
    - **Method A** – using a 4-inch mold: soil passing #4 screen.
    - **Method B** – using a 6-inch mold: soil passing #4 screen.
    - **Method C** – using a 4-inch mold: soil passing ¾" screen.
    - **Method D** – using a 6-inch mold: soil passing ¾" screen.

- For soil that has **40 % or less retained on #4,** Method **A OR Method B is used.** **1.3**
- Soil that has **30 % or less retained on ¾", Method C OR Method D is used**.
- Generally, follow agency requirements and specifications for material being tested for which method (if none is specified than Method A provisions are to be followed).

- If test sample contains **oversized particles** (**defined by the amount retained on the method's respective screen)** one must **rock correct the max dry density and optimum moisture according to Annex A1**. Some agencies will specify their maximum percentage retained before correcting, if none is specified correct for a sample having more than **5 % by total weight of oversized particles**. **1.4**

- Weights can be recorded in ***lbs.*** **or *grams*.**

METHOD A

SAMPLE:

- **Obtain a representative sample**. **Test sample** must be **7 lbs.,** or more, **AFTER** oversized particles (**material retained on the #4 sieve)** are **removed**. **4.1.**

- **Dry** the sample until it becomes **friable**. Dry in air or by a drying apparatus. The temperature produced and maintained by the apparatus **cannot exceed 140 °F**. **4.2.**

- **Sieve the sample** over a **#4 screen** while thoroughly breaking up the aggregations without reducing the size of the natural size of the individual particles. When the sample has oversized material (particles retained on the #4 screen) refer to **ANNEX A1.** **4.2 / 4.3.**

- **Reduce** the sample to **7lbs or more** in accordance with **AASHTO R76**. **4.4.**

PROCEDURE:

1 **Weigh the mass of the mold and the baseplate** to the nearest 1 **gram (or 0.005lbs). DO NOT** include the collar in the weight. **5.1.**

How to weigh a sample to the nearest 0.005 lbs.:

- Units on the balance must be set to lbs.
- Record out 3 spots after the decimal. **EX: 1.237 lbs.**
- Divide the number by 0.005. **EX:** $\frac{1.237}{0.005}$ **= 247.4**
- Round your result to the nearest whole number. **EX: 247.4 = 247.**
- Multiply the new rounded number by 0.005. **EX: 247 X 0.005 = 1.235 lbs. rounded weight to record.**

2. Thoroughly **mix** the representative sample with enough water to achieve approximately **four to eight percentage points below optimum moisture.**

5.2.

If the material is free draining soils such as uniform sands and gravels where seepage occurs at the bottom of the mold. Take a representative moisture content sample from the mixing bowl.

5.2

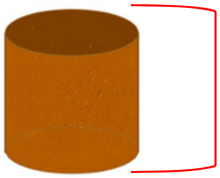
3. Form a specimen by compacting soil in a **4-inch mold in 3 approximately equal** layers.

5.3.

3 Layers

4. The total **compacted depth** of the specimen will be **approximately 5 inches.**

5.3.



5-inches

5. Place the loose soil into the mold and spread into a **uniform layer, distributing evenly. Tamp the loose material down** so that it isn't in such a fluffy state before compaction using the hammer face**.**

5.3.

6. Using the rammer, compact **each layer** with **25** evenly distributed blows from a free fall height of **12-inches**. After the compaction of the first layer and the second layer, **make sure to trim off any material along the mold wall that isn't compacted or extends above compacted surface and redistribute along the surface.**

5.3.

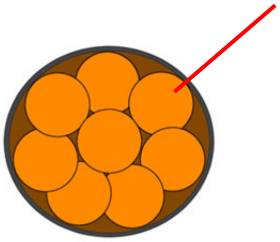
During compaction the mold assembly will rest on:

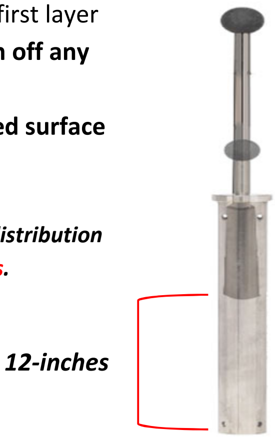
D.U.R.S

5.3.

Dense, uniform, rigid, and stable foundation or base.

Illustration of top view of proctor mold distribution of compaction. Repeat 25 times.





7. After all, **3 layers** are **compacted** completely remove the collar and trim the soil even with the top of the mold using a straightedge.

5.3.1

8. Clean off any material on the mold then determine the **mass** of the **mold, base plate, and sample** to the nearest 1 **gram (or 0.005lbs).**

5.3.1

9 Calculate the **wet density**. **12.1**

- **See AASHTO T19 on how to calculate the volume**. Section 8.
- If you determine your weights in grams make sure to multiply the volume by 453.6 grams / lbs. before performing the wet density calculation ***to obtain your result in*** lb/ft^3 ***units***. (***If in lbs. just divide by the volume as is).***

WET DENSITY CALCULATION:

$$Pt = \frac{(A-B)}{(V)}$$

Pt = wet density of compacted soil in lb/ft^3
A = Mass of the mold, base plate, and wet soil;
B = Mass of the mold, base plate;
V = Volume of the mold.

EXAMPLE: **volume of mold (AASHTO 19) = 0.0333** ft^3

Example weights of the (mold, and base plate) and the (mold, base plate, and wet soil) are in grams:

A = 2100 grams
B = 100 grams

Take 0.0333 ft^3 **X 453.6** $\frac{grams}{lbs}$ **= 15.10488**

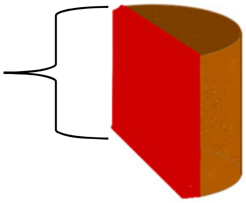
Use this factor in your wet density calculation for **V**. If all your weights were determined in *lbs*., then keep your volume as 0.0333 ft^3.

$$\frac{(2100\ grams - 100\ grams)}{(15.10488)} = 132.4\ lb/ft^3$$

MOISTURE CONTENT

10 **Detach the** base plate and remove the material using an extruder or if using a split mold unscrew the wing nut so the mold can open and release the **sample**. **5.4**

RED AREA IS WHERE YOU ARE TO TAKE MOISTURE CONTENT SAMPLE FROM.



11 Obtain a representative sample by slicing **vertically** through the center of the molded material and **remove the face of the cut** or from the center of the pile. ***(If it falls apart during the process)*** **5.4**

12 Determine the **moisture content** according to **AASHTO T265. 5.4**

CALCULATION OF MOISTURE CONTENT AASHTO T265:

$$W = \left[\frac{(W1-W2)}{(W2-Wc)}\right] \times 100$$

W = Moisture content in percent.
W1 = Mass of the container and sample in grams.
W2 = Mass of the container and oven-dried sample in grams.
Wc = Mass of the container in grams.

13 **Thoroughly break up** the remaining portion of the compacted specimen until it can **pass through a #4 screen *(judged by eye)*** and **add** this to the **remaining portion being tested in the bowl. 5.5**

14 **Then add water to the sample**, enough to increase the moisture **content 1% to 2%.** **Repeat** the compaction procedure and calculate the wet density for **each increment of water added**. Continue until the series of trials indicate a **decrease or no change** in the wet density **THEN** compact and calculate an additional sample after so that there is a **minimum of 2 trials over optimum moisture**.

5.5

15 It is only necessary to **compact 1 additional sample over optimum moisture** for **non-cohesive, drainable soils**.

5.5

If the soil is fragile in nature and the grain size will be reduced significantly by repeated compaction then a separate and new sample will be used in each compaction test.

5.5.2

What can you do If the soil is a heavy clay material?

A separate and new sample will be used in each compaction test. The sample will be mixed with the amount of water that causes the materials moisture content to vary by approximately 2%. These samples will be placed in a covered container and allowed to stand for not less than 12 hours before testing.

NOTE 8

DRY DENSITY CALCULATION

DRY DENSITY CALCULATION:

Pd = $[\frac{Pt}{(W+100)}]$ X 100

W = Moisture content in percent of specimen.
Pt = Wet density of compacted soil in lb/ft^3;
Pd = Dry density of compacted soil in lb/ft^3;

EXAMPLE:

Example is taken from examples at the end of the procedure. This example is from “Completed Proctor Form” first sample.

W = 7.1%

Pt = 132.4 lb/ft^3

Dry Density

$\frac{(132.4\ lb/ft^3)}{(7.1\ \%+100)}$ **X 100 =** $\mathbf{123.6\ lb/ft^3}$

METHOD B

SAMPLE:

- **Obtain a representative sample**. **Test sample** must be **16lbs.,** or more, **AFTER** oversized particles (**material retained on the #4 sieve)** are **removed**. 6.

- **Otherwise, obtaining the test sample and prepping the sample is identical to METHOD A**

PROCEDURE:

- Procedure is **IDENTICAL** to **what is illustrated above EXCEPT**: 7.
  - *Compact the sample in a **6-inch mold**.*
  - *Using **56** uniformly distributed **blows** from the hammer.*

STILL….
The sample is compacted in 3 approximately equal layers.

The total size after compaction is 5 inches.

Rammer will free drop from a 12-inch height.

METHOD C

SAMPLE:

- **Obtain a representative sample**. **Test sample** must be **11 lbs.,** or more, **AFTER** oversized particles (**material retained on the ¾" sieve)** are **removed**. 8.1

- **Dry** the sample until it becomes **friable**. Dry in air or by a drying apparatus. The temperature produced and maintained by the apparatus **cannot exceed 140 F**. 8.2

- **Sieve the sample** over a **¾" screen** while thoroughly breaking up the aggregations without reducing the size of the natural size of the individual particles. When the sample has oversized material (particles retained on the ¾" screen) **refer to ANNEX A1.** 8.2 / 8.3

- **Reduce** the sample to **11lbs or more** in accordance with **AASHTO R76**. 8.4

PROCEDURE:

- Procedure is **IDENTICAL** (**material is compacted in a 4" mold)** to **what is illustrated EXCEPT**:

- *If holes are developed on the surface as coarse aggregate is removed while trimming then **fill those holes in and patch with smaller sized material.*** **9.3.1**

- *When **breaking up** the remainder of the material, after taking the moisture content sample, the technician will break it up until it **passes through a ¾" screen and 90 % will pass the #4 screen** (as judged by eye) and add it back to the remaining portion of the sample being tested.* **9.5**

STILL….
The sample is compacted in 3 approximately equal layers.

The total size after compaction is 5 inches.

Rammer will free drop from a 12-inch height.

METHOD D

SAMPLE:

- **Obtain a representative sample**. **Test sample** must be **25 lbs.,** or more, **AFTER** oversized particles (**material retained on the ¾" sieve)** are **removed**. **10.1**
- **Otherwise, obtaining the test sample and prepping the sample is identical to METHOD C.**

PROCEDURE:

- Procedure is **IDENTICAL** to **what is illustrated EXCEPT**:
  - *If holes are developed on the surface as coarse aggregate is removed during trimming, then **fill those holes in and patch with smaller sized material.*** **11.1**
  - *When breaking up the remainder of the material, after taking the moisture content sample, the technician will break it up until it **passes through a ¾" screen and 90 % will pass the #4 screen** (as judged by eye) and add it back to the remaining portion of the sample being tested.* **11.1**
  - *Compact the sample in a **6-inch mold**.* **11.1**
  - *Using **56** uniformly distributed **blows** from the hammer.* **11.1**

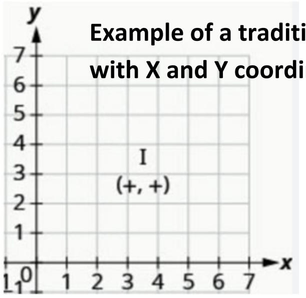
STILL….
The sample is compacted in 3 approximately equal layers.

The total size after compaction is 5 inches.

Rammer will free drop from a 12-inch height.

MOISTURE / DENSITY RELATIONSHIP

- The results of both the wet density and the dry density are **generally in pounds per cubic foot** of the compacted samples ***(can be in kilograms per cubic meter in Arizona generally pounds per cubic foot is used).*** The dry densities, when plotted will be the y coordinates and the moistures will be the x coordinates. 13.1

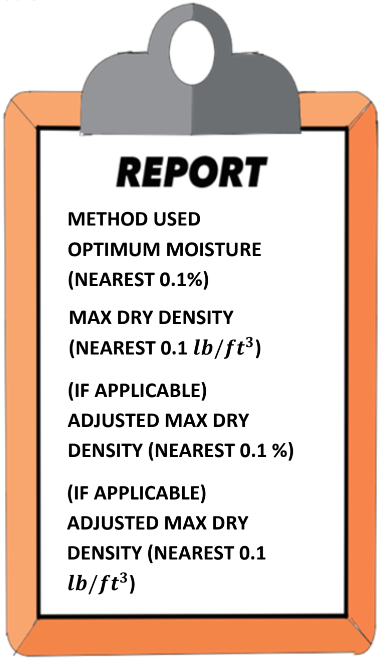


Example of a traditional graph with X and Y coordinates

- **OPTIMUM MOISTURE:** *When the densities and corresponding moisture content for the soil have been determined and plotted (see section 13.1) when the plotted points are connected using a smooth line, a curve is produced. The moisture content corresponding to the peak of the curve will be termed the "optimum moisture content" of the soil under the above compaction.* 13.2

- **MAXIMUM DRY DENSITY**: *The oven dry density in pounds per cubic foot of the soil at optimum moisture content shall be termed "maximum dry density" under the above compaction.* 13.3

14.



REPORT

METHOD USED

OPTIMUM MOISTURE (NEAREST 0.1%)

MAX DRY DENSITY (NEAREST 0.1 lb/ft^3)

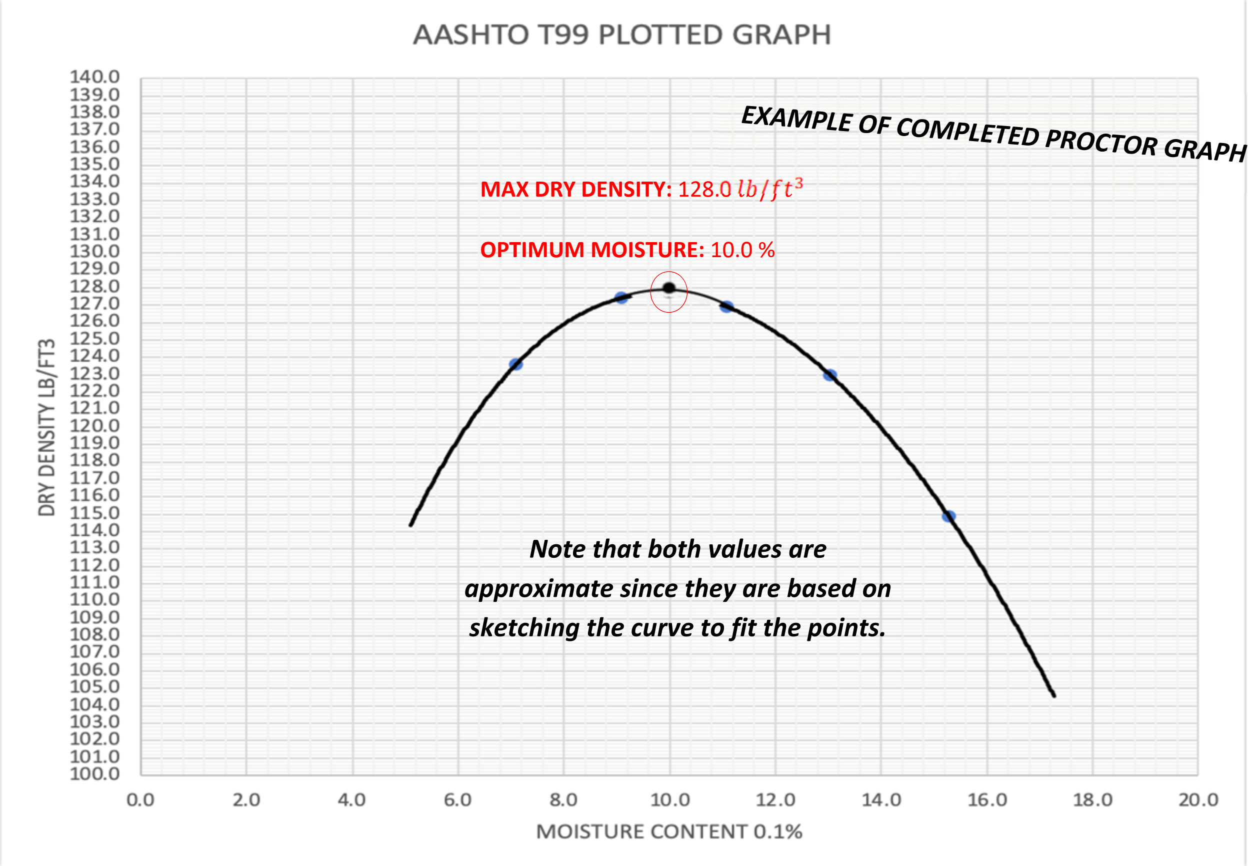
(IF APPLICABLE) ADJUSTED MAX DRY DENSITY (NEAREST 0.1 %)

(IF APPLICABLE) ADJUSTED MAX DRY DENSITY (NEAREST 0.1 lb/ft^3)

SEE PROCEDURE AND / OR AGENCY REQUIREMENTS FOR ADDITIONAL INFORMATION TO REPORT.

VOLUME OF MOLD:	0.0333				METHOD:	A / B / C / D	
	1	2	3	4	5	6	7
MASS OF SOIL, MOLD, & BASEPLATE	2100	2200	2230	2200	2100		
MASS OF MOLD & BASEPLATE	100	100	100	100	100		
WET DENSITY:	**132.4**	**139.0**	**141.0**	**139.0**	**132.4**		
MOISTURE CONTENT CONTAINER ID	A	B	C	D	E		
MASS MC CONTAINER & WET SOIL	300.0	300.0	399.9	387.7	400.0		
MASS MC CONTAINER & DRY SOIL	280.0	275.0	360.0	343.0	347.0		
TARE MC CONTAINER	0	0	0	0	0		
MOISTURE:	**7.1**	**9.1**	**11.1**	**13.0**	**15.3**		
DRY DENSITY:	**123.6**	**127.4**	**126.9**	**123.0**	**114.9**		

EXAMPLE OF COMPLETED PROCTOR



EXAMPLE OF COMPLETED PROCTOR GRAPH

MAX DRY DENSITY: 128.0 lb/ft^3

OPTIMUM MOISTURE: 10.0 %

Note that both values are approximate since they are based on sketching the curve to fit the points.

AASHTO ANNEX T99:

CORRECTION FOR MAX. DRY DENSITY & OPTIMUM MOISTURE CONTENT FOR OVERSIZED PARTICLES.

SCOPE:

A1.1.

This section corrects the max dry density & optimum moisture of material retained on #4 screen (Method A & Method B) or the material retained on ¾" screen (Method C & Method D).

PROCEDURE:

- The **correction can be applied** to the **sample on which the maximum dry density is performed.** A1.1.1.
- **Bulk Specific Gravity (G_{sb})** of the oversized particles is required to determine the corrected Maximum dry density. Use AASHTO T85 for this, although assumed **coarse specific gravities for construction projects are generally 2.600.** A1.2.
- **The dry mass of the oversized and fine fraction of the material must first be determined.** A1.3.

2 WAYS TO DO THIS

A1.3.1

ii. **Dry the fraction, fine and oversized (coarse),** in air or by use of a drying apparatus that is maintained at a temperature **not exceeding 140 ° F.**

If there is no minimum specified then correction will be applied to samples with more than 5 % by weight of oversized particles.

A1.3.2.1

i. Determine the dry mass of the coarse & fine material from the sample by **the calculation for Dry Mass (A1.3.2.1).**

To calculate the optimum moisture correction the moisture content of the coarse aggregate will need to be known (Many agencies assume this to be 2.0%).

CALCULATION FOR DRY MASS OF OVERSIZED & FINE PARTICLES

MD = $\frac{MM}{(1+MC)}$

MD = mass of dry material (fine or oversized particles);
MM = mass of wet material (fine or oversized particles);
MC = moisture content of respective fine or oversized particles (0.1%);

A1.3.2.2

i. **Determine** the **wet mass of both the fine and coarse material** then **obtain moisture samples from each** and determine the **moisture content by T265 or T255 (if mostly aggregate like Aggregate base).** (*If the moisture content is generally known for the coarse material you can substitute this into the equation. Many agencies assume the Moisture Content for Coarse aggregate to be approximately 2.0% but it is better to dry the sample according to the procedure).*

Example:

Lab Proctor: **128.0 lb/ft^3 @ 10.0 % Optimum moisture content.**
Amount of DRIED Fine Material: **9979 grams.**
Amount of DRIED Coarse Material: **3629 grams.**
Gsb: **2.600**
Moisture Content Coarse: **2.0%**

SAMPLE HAS BEEN DRIED

Proctor calculated in grams.

CALCULATION FOR THE PERCENTAGE OF OVERSIZED & FINE PARTICLES:

PF = $\frac{(100*MDF)}{(MDF+MDC)}$

PC = $\frac{(100*MDC)}{(MDF+MDC)}$

PF = Percent of dry fine particles;

PC = percent of oversized particles of sieve used;

MDF = mass of dry fine particles **(nearest 1 gram or in lbs. to the nearest 0.005 lbs.);**

MDC = mass of dry oversized particles **(nearest 1 gram or in lbs. to the nearest 0.005 lbs.);**

CALCULATION FOR THE PERCENTAGE OF OVERSIZED & FINE PARTICLES

PF = $\frac{(100 * 9979\ grams)}{(9979\ grams + 3629\ grams)}$

ANSWER:

PF = 73%.

PC = $\frac{(100 * 3629\ grams)}{(9979\ grams + 3629\ grams)}$

ANSWER:

PC = 27%

CALCULATION FOR THE CORRECTED OPTIMUM MOISTURE:

MCT = $\frac{(MCF*PF)+(MCC*PC)}{100}$

MCT = corrected optimum moisture content of the total sample, as a decimal;

MCF = optimum moisture content of the fine particles, as a decimal;

PF = percent of fine particles of sieve used;

PC = percent of oversized particles of sieve used;

MCC = moisture content of the oversized particles.

CALCULATION FOR THE CORRECTED OPTIMUM MOISTURE:

MCT = $\frac{(10.0\% * 73\%) + (2.0\% * 27\%)}{100}$

ANSWER:

MCT = 7.8 %.

CALCULATION FOR THE CORRECTED DRY DENSITY:

DD = $\frac{(100*DF*k)}{(DF*PC+k*PF)}$

DD = corrected maximum dry density of the total sample (lb/ft^3);

DF = maximum dry density of the fine particles, (lb/ft^3);

k = 62.4 X Bulk Specific Gravity (oven dry basis) of coarse particles (lb/ft^3);

PC = percent of oversized particles of sieve used;

PF = percent of fine particles of sieve used;

CALCULATION FOR THE CORRECTED DRY DENSITY:

DD = $\frac{(100 * 128.0\ lb/ft^3 * 162.2\ lb/ft^3)}{(128.0\ lb/ft^3 * 27\%)+(162.2\ lb/ft^3*73\%)}$

ANSWER:

DD = **135.7** lb/ft^3)

How to weigh a sample to the nearest 0.005 lbs.:

- Units on the balance must be set to lbs.
- Record out 3 spots after the decimal. **EX: 1.237 lbs.**
- Divide the number by 0.005. **EX:** $\frac{1.237}{0.005}$ **= 247.4**
- Round your result to the nearest whole number. **EX: 247.4 = 247.**
- Multiply the new rounded number by 0.005. **EX: 247 X 0.005 = 1.235 lbs. rounded weight to record.**

AASHTO T288:

DETERMINING MINIMUM LABORATORY SOIL RESISTIVITY

DEFINITIONS:

Corrosion - is the gradual deterioration of materials (usually a metal but can be concrete also) by chemical or electrochemical reaction with their environment.

Resistivity - how strongly it resists electric current. A low resistivity indicates a material that readily allows electric current.

Electrode - a conductor through which electricity enters or leaves an object, substance, or region.

EXAMPLES OF SOIL BOXES

Soil resistivity influences the rate of corrosion in underground pipelines and other subterranean structures. Lower soil resistivity can lead to accelerated corrosion. The principal use of this test method is to determine a soil's corrosivity and thereby identify the conditions under which the corrosion of metals in soil may be sharply accentuated. When less than 5 % of a material passes the #10 screen this method may not be indicative of the corrosion potential of the material.

SCOPE:

1.1

This method covers the laboratory procedure for determining the minimum resistivity of a soil sample.

EQUIPMENT:

3.

- **SIEVES-** a set containing ¼", #4, and #10 (with pan).
- **PULVERIZING APPARATUS –** either a mortar and rubber tipped pestle (or any other suitable apparatus for breaking up aggregations).
- **RESISTIVITY METER –** alternating current (ac) or direct current (dc) meter capable of performing 4-point measurements over a range of at least 0.01 Ω to 3.3 MΩ with a minimum accuracy of ±10 %. (100, 200, 500, and 900Ω with 1% tolerance.
- **SOIL BOX –** available in 2 pin or 4 pin configurations. The design of the soil box must be easy to clean constructed using durable non corrosive materials with electrodes made from corrosion resistant material.
- **CONTAINERS -** suitable made of material that is resistant to corrosion and not subject to change in mass or disintegration on repeated heating & cooling. Must have close fitting lids.
- **DRYING APPARATUS –** a device capable of drying samples at a temperature not exceeding 140 °F.
- **BALANCE –** Readable to at least 0.1 % of the sample mass.
- **SAMPLE SPLITTER –** riffle splitter or sample splitter for splitting of sample into representative
- **MIXING PANS**
- **GRADUATED CYLINDER –** 100mL capacity.
- **DISTILLED WATER –** resistivity greater than 20000 Ω X cm.
- **STRAIGHTEDGE**

SAMPLE:

- The sample used for this test will be obtained **according to AASHTO R90**. Testing amount size is approximately **1500 grams of passing #10 material**.

4.1

PREP OF TEST SAMPLES:

- The sample received from the field will be **dried in air or by a drying apparatus not exceeding 140 °F**.

5.1

- Obtain the **representative test sample using a splitter or by quartering** in **accordance with AASHTO R76**.

5.1

- Use a pulverizing apparatus to **break up any aggregation** of soil particles until the material is **separated into individual grains**. **Avoid reducing the natural size** of the individual particles when pulverizing.

5.1

Samples dried in an oven or other drying apparatus at a temperature not exceeding 140 °F are considered air dried.

The portion of dried sample selected for minimum soil resistivity testing will be separated into fractions by one of the following methods:

5.2.1

🟥 ***ALTERNATIVE METHOD (#10 SIEVE):***

- Separate the dried sample into **two fractions using the #10 screen over a pan**.
- The **fraction retained** on the sieve will be **pulverized** until the aggregations of the soil particles are broken into separate grains.
- Reintroduce the ground material **onto the #10 sieve over the pan**. Use the **material passing** for your **test sample (approximately 1500 grams).**

5.2.2

🟥 ***ALTERNATIVE METHOD (#4 & #10 SIEVE):***

- Separate the dried sample into **two fractions using the #4 screen over a pan**.
- The **fraction retained** on the sieve will be **pulverized** until the aggregations of the soil particles are broken into separate grains.
- **Reintroduce** the ground material **onto the #4 sieve**, remove the material from the pan **(material that passes the #4) mix thoroughly and split (or quarter)** to obtain an approximate representative testing amount.
- **Introduce this new material** onto the **#10 screen over a pan**. **Repeat** the **pulverizing** procedure on the material **retained on the #10 screen**.
- Reintroduce the ground material **onto the #10 sieve over the pan**. Use the **material passing** for your **test sample (approximately 1500 grams).**

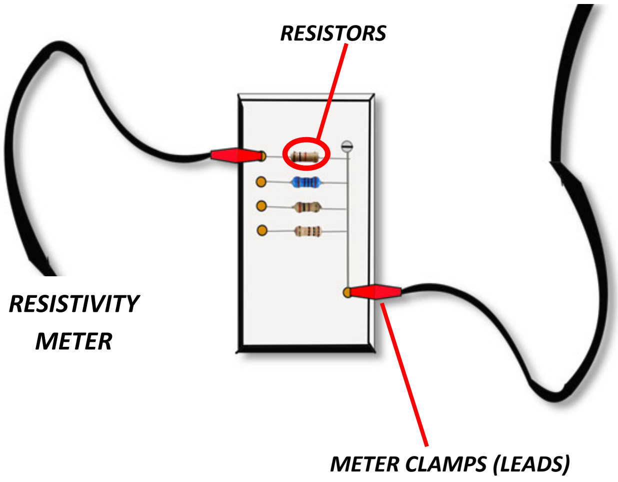
ALTERNATIVE METHOD (1/4" & #10 SIEVE): 5.2.3

- Separate the dried sample into **two fractions using the ¼" screen over a pan**.
- The **fraction retained** on the sieve will be **pulverized** until the aggregations of the soil particles are broken into separate grains.
- **Reintroduce** the ground material **onto the ¼" sieve**, remove the material from the pan **(material that passes the ¼") mix thoroughly and split (or quarter)** to obtain an approximate representative testing amount.
- **Introduce this new material** onto the **#10 screen over a pan**. **Repeat** the **pulverizing** procedure on the material **retained on the #10 screen**.
- Reintroduce the ground material **onto the #10 sieve over the pan**. Use the **material passing** for your **test sample (approximately 1500 grams).**

VERIFICATION OF METER:

- Make sure the resistivity **meter is zeroed out**. (***See manufacturer's instructions***) 6.1
- **Next, check the resistance readings**. **Connect** the leads of the resistivity meter **to the 100 Ω resistor** and read the meter. **Repeat the process with the 200 Ω , 500 Ω , 900 Ω resistors.** 6.2
- If the **readings** are within **10% of the resistor** the meter is verified. **If it is not within 10% consult manufacturer's instructions on how to calibrate.** 6.3

ILLUSTRATION OF A VERFICATION BLOCK



PROCEDURE:

1 Obtain your representative sample ***(See SECTION 5. for more detail).*** Test sample must be **approximately 1500 grams of material passing the #10 screen**. 7.1

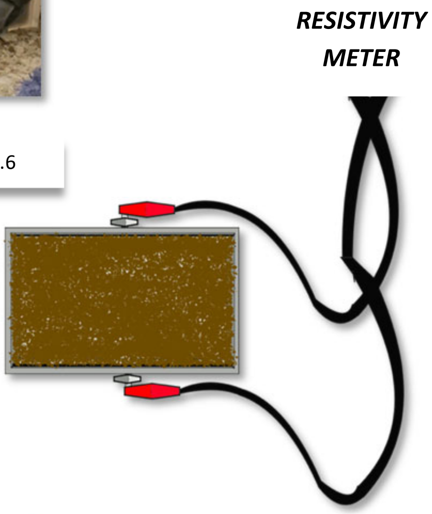
2 **Add 150 mL** of **distilled water** to the prepared soil sample. Mix thoroughly and **cover the sample** with a damp cloth or tight-fitting lid, if using a container, and allow to stabilize until **equilibrium has been reached** or allow to **cure a minimum of 12 hours.** 7.2

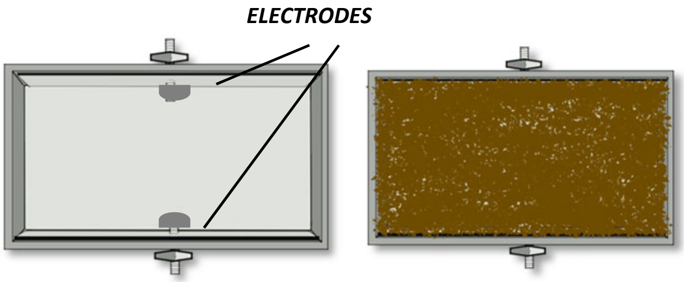
3 **Zero** the meter ***(See manufacturer's Instructions).*** 7.3

4 **Clean** the **soil box** thoroughly with **distilled water**. 7.4

5 **Thoroughly mix the sample** one more time and begin placing it in the soil box, **compacting in layers** with **your fingers**. Once the material **has been compacted** and has reached the top of the soil box **trim off the excess with the straightedge**. 7.5

6 **Connect** the **leads** of the soil resistivity apparatus **onto the pins (or screws)** that are connected to the **electrodes *(See equipment section for some examples different style of boxes available)*** of the soil box and **measure the resistance, record the value and calculate the soil resistivity.** 7.6





The minimum soil resistivity can occur at any moisture content. 8.0

7 **Remove the soil** from the box, after the reading has been recorded, and introduce back into the remaining material. **Add an additional 100 mL** and **mix thoroughly**. **Clean the soil box with distilled water prior to the next test.**

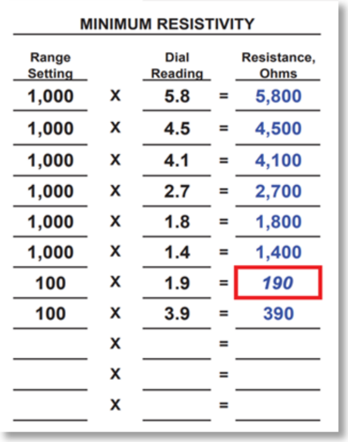
7.7

8 **Repeat the process** of placing, compacting, then measuring the resistance and calculating the soil resistivity.

7.8

9 Repeat the procedure until the minimum value is determined and recorded. ***The results will gradually decrease; minimum will be the lowest value immediately before the value that increases***.

7.9 / 7.10



MINIMUM RESISTIVITY

Range Setting		Dial Reading		Resistance, Ohms
1,000	X	5.8	=	5,800
1,000	X	4.5	=	4,500
1,000	X	4.1	=	4,100
1,000	X	2.7	=	2,700
1,000	X	1.8	=	1,800
1,000	X	1.4	=	1,400
100	X	1.9	=	*190*
100	X	3.9	=	390
	X		=	
	X		=	
	X		=	

MINIMUM RESISTANCE READING

What do you do if the specimen is a slurry before achieving minimum resistivity?

Thoroughly mix the soil slurry and then pour the slurry water into the soil box until full. If the soil box doesn't reach its capacity with the addition add just enough of the mixed soil into the box until the soil box is filled then take the reading.

8.0

CALCULATION:

7.11

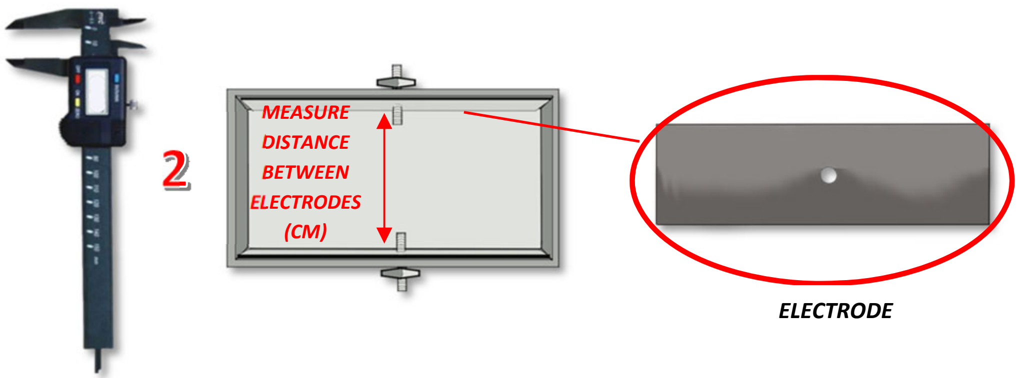
MINIMUM RESISTANCE READING (Ω) ✖ **MULTIPLYING CONSTANT (CM)** = **MINIMUM SOIL RESISTIVITY**

The reading taken directly from the resistivity meter.

***SOIL BOX FACTOR (MULTIPLYING CONSTANT)* RECORDED TO 0.01:**

$$\begin{matrix} 1 \\ 2 \end{matrix}\ \frac{\textit{Surface area of one outer electrode } (CM^2)}{\textit{Measured average distance between electrodes } (CM)}$$

8.1



1 **LENGTH X WIDTH (MEASURE IN CENTIMETERS) =** ***SURFACE AREA OF ONE OUTER ELECTRODE (CM^2)***

REPORT

8.0

MINIMUM SOIL RESISTIVITY IN UNITS (Ω) X (CM) to the nearest whole number.

AASHTO T289:

DETERMINING pH OF SOIL FOR USE IN CORROSION TESTING

DEFINITIONS:

pH - is a measure of how acidic or basic (alkaline) a solution is.

Watch Glass - is a small, concave circular piece of glass that's commonly used in laboratories. It looks like a shallow glass dish or a curved lens.

Standard Buffer Solution - is a solution that resists changes in pH when small amounts of acid or base are added, and it has a precisely known and stable pH.

SCOPE:

1.1

This test method describes the procedures and equipment used for determining a pH value for corrosion testing by use of a pH meter. Part I describes the dry preparation of samples for determining a soil's pH. Part II describes the actual procedure for determining the pH of soil.

AASHTO T289 focuses on determining the pH of soil, which is a critical issue when evaluating the corrosiveness of soil areas, particularly for buried metals like steel used in pipelines, foundations, and reinforcements. Soil pH is a major factor influencing corrosion rates of metals. Acidic soils (low pH) are generally more corrosive, especially to steel and galvanized materials. High pH can also be destructive under certain conditions (e.g., promoting alkali-silica reactions or affecting coatings). Understanding the level of pH in the area is essential in construction projects that have buried substructures.

PART I – INITIAL PREPERATION OF TEST SAMPLES

EQUIPMENT:

4.

- **SIEVES-** a set containing ¼", #4, and #10 (with pan).
- **PULVERIZING APPARATUS –** either a mortar and rubber tipped pestle (or any other suitable apparatus for breaking up aggregations).
- **DRYING APPARATUS –** a device capable of drying samples at a temperature not exceeding 140 °F. If the drying apparatus is an oven the heating and drying range of the oven is required to be between 77°F to 248°F within ± 9 °F.
- **THERMOMETER (used for monitoring oven) –** with a temperature range of at least 32 °F to 266°F with an accuracy of ± 2.25 °F.
- **BALANCE –** Readable to at least 0.1 % of the sample mass.
- **SAMPLE SPLITTER –** riffle splitter or sample splitter for proportional splitting of the sample and capable of obtaining representative portions without appreciable loss of fines. The width of the container, used to feed the sample into the riffle splitter, should be equal to the total combined width of the riffle chutes.

SAMPLE:

- The sample used for this test will be obtained **according to AASHTO R90**. Testing amount size is **approximately 100 grams of passing #10 material**. **5.1**

PREP OF TEST SAMPLES:

- If the sample is too wet, when received from the field, dry in air or by a drying apparatus not exceeding 140 °F prior to test sample selection. **6.1**
- Obtain the **representative test sample using a splitter or by quartering** in **accordance with AASHTO R76**. **6.1**
- Use a pulverizing apparatus to **break up any aggregation** of soil particles until the material is **separated into individual grains**. **Avoid reducing the natural size** of the individual particles when pulverizing. **6.1**

Samples dried in an oven or other drying apparatus at a temperature not exceeding 140 °F are considered air dried.

The portion of dried sample selected for pH testing will be separated into fractions by one of the following methods:

Is identical to the test prep methods for AASHTO T288. SEE PROCEDURE. **6.2**

- Testing amount size is **approximately 100 grams of passing #10 material after the test prep method has been completed**.

PART II – DETERMINATION OF SOIL pH

EQUIPMENT:

8.0

- **pH METER-** suitable for laboratory or field with either one or two electrodes.
- **SUITABLE CONTAINER–** a 50 mL wide mouth glass beaker or another suitable container.
- **GLASS STIRRING ROD**
- **WATCH GLASS –** of suitable size to cover the beaker or other container.
- **BALANCE –** Readable to at least 0.1 of a gram.
- **STANDARD BUFFER SOLUTIONS –** pH of 4.0, 7.0, & 10.0.
- **DISTILLED WATER**
- **THERMOMETER (used for monitoring oven) –** with a temperature range of at least 50 °F to 104 °F with an accuracy of ± 1.0 °F.
- **SMALL SCOOP**
- **SIEVES –** a #10 sieve screen with pan.

PROCEDURE:

1 Of the 100 grams obtained, place **30.0 ± 0.1 gram**, of soil from the testing portion, **into the glass beaker** (or another suitable container) **9.1**

2 **Add 30.0 ± 0.1 grams, of distilled water to the soil sample**. Stir well in order to **create a soil slurry**. **Cover** the sample with the **watch glass (or suitable glass plate)**. **9.2**

3 Allow the sample to **stand for a minimum of 1 hour**, **stirring every 10 to 15 minutes**. **9.3**

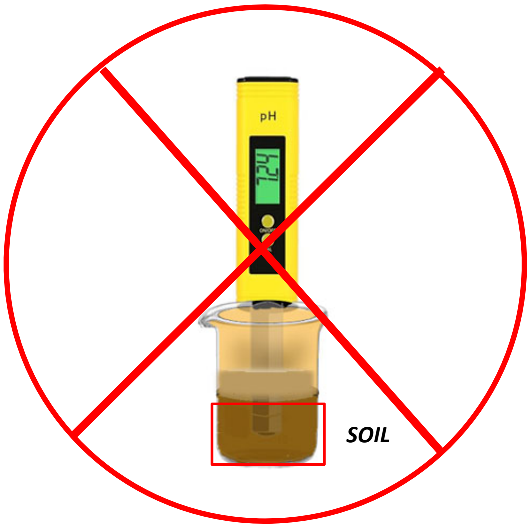
4 **If the pH meter does not have automatic temperature control**, measure the temperature of the solution. Adjust the temperature controller on the meter to match the temperature of the solution. Perform this step before testing ***(See manufacturer's instructions).*** **9.4**

5 **Standardize the pH meter with the standard solutions.** ***(See manufacturer's instructions)***. Make sure temperature is taken and adjustments made according to section 9.4. **9.5**

6 **Stir the sample well** with the glass rod **immediately before** placing the **electrode into the soil slurry solution**. 9.6

7 Place the **electrode(s) into** the **slurry portion** of the test sample. Gently turn the glass beaker (or container) to make sure good contact is made between the electrode and soil slurry solution. 9.6

8 **DO NOT** place the electrode (s) into the **soil**; place **ONLY** in the **soil slurry**. 9.6.



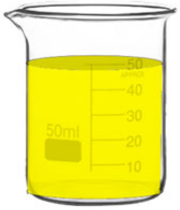
9 **Electrode (s) require immersion for 30 seconds** or longer in the sample before **stabilization**. If the meter has an auto read system, it will automatically signal when stabilized. 9.7

10 Once stabilized, **read and record the pH value** to the **nearest 0.1 (tenth) of the whole number** displayed. If the readout reads to the hundredth round appropriately. 9.8

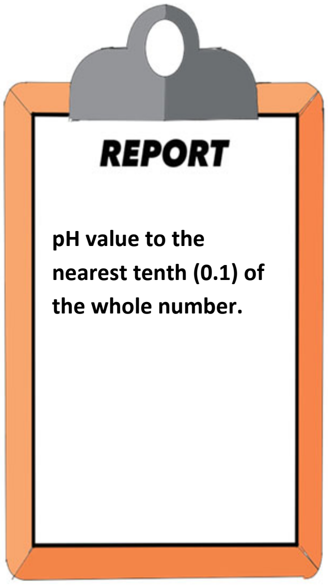
11 **Rinse off the electrode (s) well with distilled water**, then dab lightly with tissues to remove any film formed on the electrode (s). 9.9

DO NOT wipe the electrode (s) as this may result in polarization and consequently a slow response. 9.9

NOTE 6: To standardize the pH meter, use the 7.0 pH buffer standard solution plus the other standard solution that is nearest the estimated pH value of the sample to be tested. **If the manufacturer's instructions indicate a method other than noted in note 6 then those instructions must be followed.**



7 pH Standard Buffer Solution



REPORT

pH value to the nearest tenth (0.1) of the whole number.

AASHTO T265:

STANDARD METHOD OF TEST FOR LABORATORY DETERMINATION OF MOISTURE CONTENT OF SOILS

SCOPE:

1.1.

This method covers the procedure for determining the moisture content of soils.

EQUIPMENT:

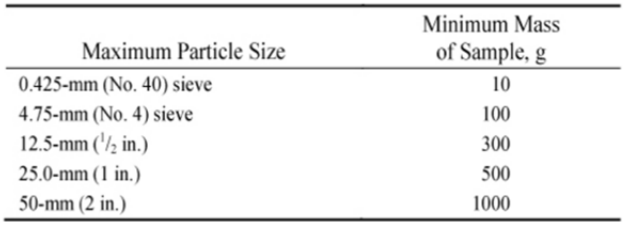
4.

- **OVEN –** an oven that maintains a uniform temperature of 230 ± 9 °F. The heating and drying range of the oven is required to be between 212°F to 248°F within ± 9 °F.
- **THERMOMETER (used for monitoring oven) –** with a temperature range of at least 194°F to 266°F with an accuracy of ± 2.25 °F.
- **BALANCE –** Readable to at least 0.1 % of the sample mass.
- **CONTAINERS –** Made of material resistant to corrosion and not subject to change in mass by repeated heating and cooling. Shall have close-fitting lid to prevent loss of moisture.

SAMPLE:

- **Test sample quantity** is **generally indicated in the test method**. **If** it is **not**, **then find the minimum mass from the table in the procedure**. Seen here:

5.1.



Maximum Particle Size	Minimum Mass of Sample, g
0.425-mm (No. 40) sieve	10
4.75-mm (No. 4) sieve	100
12.5-mm ($^{1}/_{2}$ in.)	300
25.0-mm (1 in.)	500
50-mm (2 in.)	1000

PROCEDURE:

1 **Weigh** a clean, dry **container** with its **lid** and record this weight.

6.1.

2 Place the **moisture content sample** in the container and place the **lid immediately on** and **weigh.** Record this weight. **6.1.**

CAN A CONTAINER WITHOUT A LID BE USED?

It can be used if the sample is weighed immediately after being taken and weighed immediately after being removed from the oven.

3 When ready to put in the oven remove the lid and place the container with the sample in the oven at **230 ± 9°F** and dry until the mass loses no more than **0.1% after 1 hour** of additional **drying**. **6.1.**

4 After removing from the oven **place the lid on** the sample and allow to cool to **room temperature**. **6.1.**

5 **Weigh** the **container** including the lid and the **dried sample**. **6.1.**

Dried samples cannot be placed in the same oven as wet samples.

CALCULATION OF MOISTURE CONTENT

$$W = \left[\frac{(W1-W2)}{(W2-Wc)}\right] \text{ X } 100$$

W = Moisture content in percent.
W1 = Mass of the container and sample in grams.
W2 = Mass of the container and oven-dried sample in grams.
Wc = Mass of the container in grams.

How to calculate 0.1% of a sample mass?

First convert the percentage to a decimal.

$(\frac{0.1\%}{100}) = 0.001$

Then multiply the decimal by the sample mass.

Ex1: 34.55 grams X 0.001 = 0.03455 grams
Ex2: 2000.5 grams X 0.001 = 2.0005 grams.

For example1: the sample can't lose more than 0.03455 grams to be considered dry.

For example2: the sample can't lose more than 2.0005 grams to be considered dry.

PRACTICE QUESTIONS:

1. Test sample must be **approximately ____ grams of material passing the #10 screen** (according to AASHTO T288)?

    a. 1200 grams
    b. 100 grams
    c. 1500 grams

ANSWERS:

1. c
2. b
3. a
4. b
5. b
6. c
7. b

2. Test sample must be **approximately ______ grams of passing #10 material**. (according to AASHTO T289)?

    a. 50 grams
    b. 100 grams
    c. 150 grams

3. Constant mass is achieved when a sample loses no more than **_____ after 1 hour** of additional **drying**. (according to AASHTO T265)?

    a. 0.1%
    b. 0.1 grams
    c. 10 %

4. ______. ______ utilizes a **4” mold** on material that was broken down over the **¾” screen**. (according to AASHTO T99)?

    a. Method A
    b. Method C
    c. Method B

5. When spreading the sample in the liquid limit cup achieve a **depth of ________** at point of **max thickness**. (according to AASHTO T89).

    a. 11 mm
    b. 10 mm
    c. 3 mm

6. The **thread** must roll to **_______** at least **once** to be considered **plastic** (according to AASHTO T90)?

    a. 5 mm
    b. 10 mm
    c. 3 mm

7. METHOD A: Using the rammer, compact **each layer** with **___** evenly distributed blows from a free fall height of **____inch height**.?

    a. 25, 5.5
    b. 25, 12
    c. 56, 12

AGGREGATE TESTING

Aggregate testing in construction ensures the quality, durability, and suitability of aggregates for specific construction applications by verifying their physical, and mechanical properties. They are utilized in many applications in earthworks, and retaining walls. In base layers, sub-base layers, and in asphalt mixes. Aggregates provide load-bearing capacity and drainage. Aggregates make up 60–80% of concrete volume and provide strength, bulk, and durability to concrete.

All aggregate testing procedures that are covered during the ATTI Certification process.

Learning objectives for these sections are:

- ***How to perform and calculate the ratio of clay and sand in a fine aggregate sample.***
- ***How to properly calibrate a volume measure and how to determine the unit weight and voids in aggregates.***
- ***How to perform fine and coarse specific gravities.***
- ***How to determine the percentage of fractured aggregate and how to determine the angularity or roundedness of particles.***
- ***How to determine if there are organics in fine aggregates.***

- **AASHTO T176:** *PLASTIC FINES IN GRADED AGGREGATES AND SOILS BY USE OF THE SAND EQUIVALENT TEST*
- **AASHTO T84:** *SPECIFIC GRAVITY AND ABSORPTION OF FINE AGGREGATE*
- **AASHTO T85:** *SPECIFIC GRAVITY AND ABSORPTION OF COARSE AGGREGATE*
- ***AASHTO T21:*** *ORGANIC IMPURITIES IN FINE AGGREGATES FOR CONCRETE*
- **AASHTO T304:** *UNCOMPACTED VOID CONTENT OF FINE AGGREGATE*
- **AASHTO T335:** *DETERMINING THE PERCENTAGE OF FRACTURED PARTICLES IN COARSE AGGREGATE*
- ***AASHTO T19:*** *UNIT WEIGHT AND VOIDS IN AGGREGATES / SECTION 8 CALIBRATION OF MEASURE.*
- ***AASHTO T255:*** *TOTAL EVAPORABLE MOISTURE CONTENT OF AGGREGATES BY DRYING.*

PLEASE REFER TO THE SECTION FOUND IN THE PROCEDURE FOR MORE DETAIL.

AASHTO T176:

PLASTIC FINES IN GRADED AGGREGATES AND SOILS BY USE OF THE SAND EQUIVALENT TEST

SCOPE: 1.1

This method is intended to serve as a rapid test to show the relative proportions of fine dust or claylike material in soils or graded aggregates.

DEFINITIONS:

Plastic Fines - refers to very small soil particles—mostly clays and silts—that have plasticity, meaning they can deform without cracking or breaking when moist.

EQUIPMENT: 4.

- **TIMER**
- **THERMOMETER (used for temp control of working solution) –** with a temperature range of at least 61°F to 93°F with an accuracy of ± 1.35°F.
- **STRAIGHTEDGE / SPATULA –** to strike off excess material from the measure.
- **SIEVE -** #4 sieve screen.
- **QUARTERING CLOTH –** Quartering or splitting cloth approximately 2ft square, not absorbent material such as plastic.
- **BALANCE –** Readable to 0.1 % of the sample mass.
- **MEASURE –** a tinned measure, with a capacity of 3 oz and approximately 2.25 inches in diameter.

EQUIPMENT: 4.

- **SAND EQUIVALENT APPARATUS (EQUIPMENT) –**
  - **a.** a graduated cylinder with a height (minus base) of approximately 17 inches with graduations up to 15 inches.
  - **b.** rubber stopper
  - **c.** irrigator tube / siphon assembly, ***(see procedure for critical dimensions)***
  - **d.** weighted foot assembly (1000 ± 5 grams)
  - **e.** 1 gallon of working calcium carbide solution placed on a shelf 36 ± 1 inch above the work surface (larger container made of plastic or glass may be used as long as the liquid level of the working solution is maintained at a height between 36 inches and 46 inches above the work surface. ***(see procedure for more detail)***
- **MANUAL SHAKER –** manual shaker that provides an oscillating motion at the rate of 100 complete cycles (back and forth = complete cycle) in 45 ± 5 secs. With a hand assisted stroke length of 5.0 ± 5 inches. The shaker must be fastened and secure to firm and level mount with bolts or clamps if a large number of determinations are to be made.
- **MECHANICAL SHAKER –**shaker that has a throw of 8.00 ± 0.04 inches and operates at 2.92 ± 0.03 Hz. Rate must be maintained at 100 complete cycles (back and forth = complete cycle) in 45 ± 5 secs. The shaker must be fastened and secure to firm and level mount.
- **FUNNEL –** approximately 4-inch diameter at the mouth.
- **OVEN –** an oven that maintains a uniform temperature of 230 ± 9 °F. The heating and drying range of the oven is required to be between 212°F to 248°F within ± 9 °F.
- **THERMOMETER (used for monitoring oven) –** with a temperature range of at least 194°F to 266°F with an accuracy of ± 2.25 °F.

The purpose of the Sand Equivalent Test is to determine the cleanliness and quality of fine aggregates. The method provides an indication of the relative proportions of clay-like plastic fines and dust in granular soils. The test's simplicity makes it suitable for providing rapid results. Generally, A higher sand equivalent value indicates cleaner fine aggregate (i.e. lower clay particles) and a lower number indicates a dirtier stockpile of material.

WORKING SOLUTION / TEMP CONTROL:

- **Calcium Chloride Working Solution-** dilute **85 ± 5 mL of stock calcium chloride solution** with **water** until it reaches a volume of **approximately 1 gallon**. This can be accomplished by filling the container with half a gallon of water add the stock solution and mix vigorously. Next add the remainder of the water to the container and agitate vigorously. Use distilled or demineralized water**. Discard working solution more than 30 days old.** **4.9**

- The **temperature of the working solution** should be **maintained at 72 ± 5°F** when performing the sand equivalent test **5.1**

SAMPLING:

- **Obtain a sample** of material to be tested according to **AASHTO R90**. **6.1**

- **Reduce that sample** down to **testing size according to AASHTO R76**. **6.2**

- **Sieve the sample over #4 screen**. Make sure that all material that is clumped together (aggregations) shall be pulverized to pass the #4. All fines that are adhering to the **particles retained on the #4 screen** should be **cleaned off using a brush** (or other suitable means) **6.3**

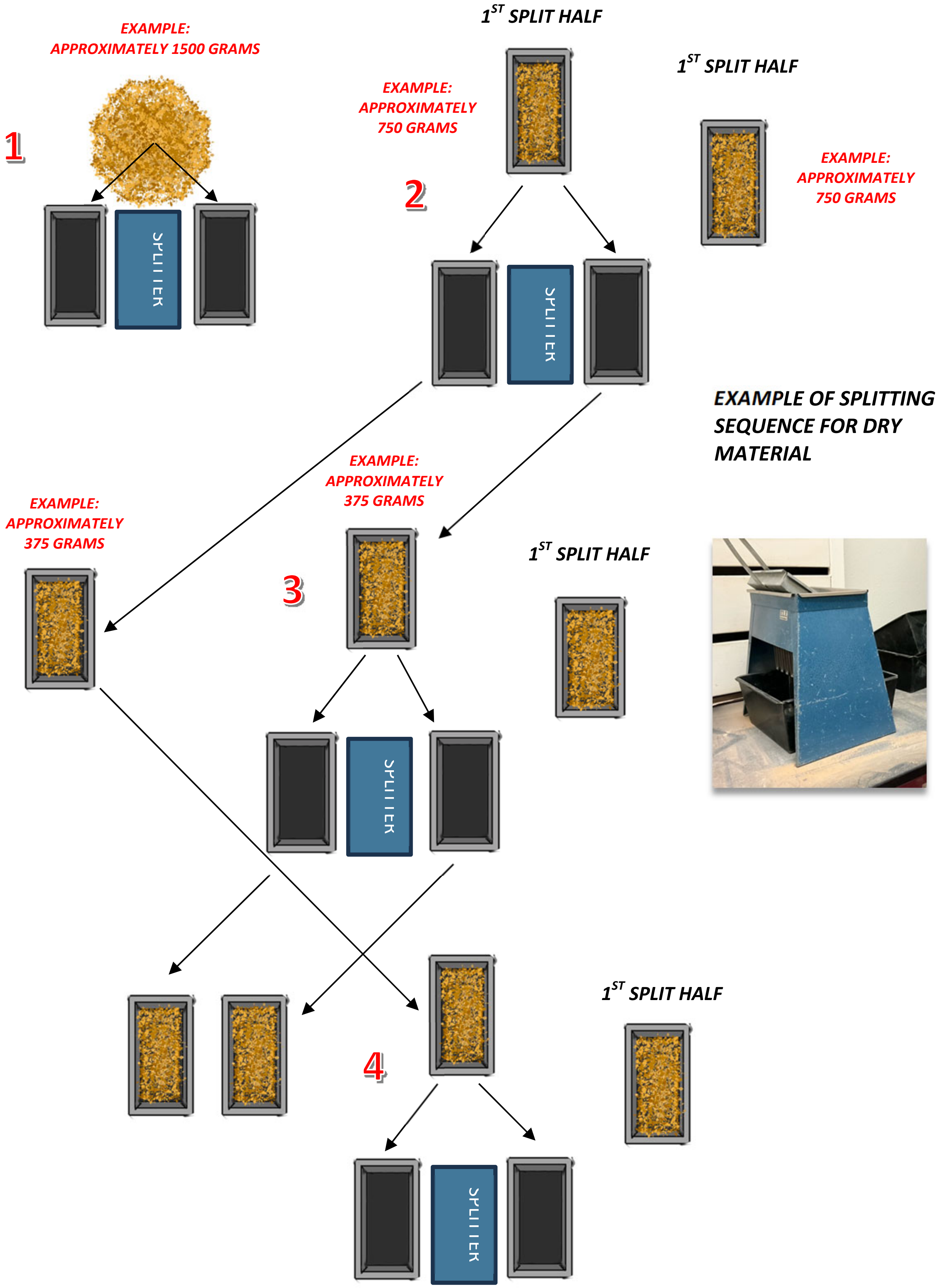
- **Split or quarter the material passing the #4.** The result of the reducing process will be **1000 to 1500 grams**. Take care to split or quarter the material carefully and avoid losing fines to obtain a truly representative sample. **6.4**

SAMPLE PREP:

🟥 *ALTERNATIVE METHOD #1 (AIR DRY METHOD):* **7.1.1**

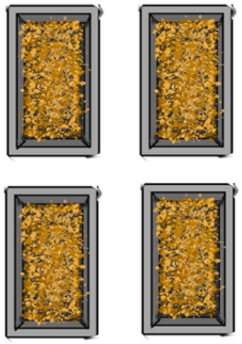
- **Split or quarter enough material, from the 1000 to 1500 grams** portion passing the #4, **to fill the 3 oz tin measure** so that there is a **slightly rounded amount above the brim with minimal slough**. **7.1.1.1**

SLIGHTLY ROUNDED AMOUNT ABOVE



EXAMPLE OF SPLITTING SEQUENCE FOR DRY MATERIAL

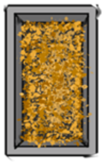
1ST SPLIT HALF split 4 ways



THIS WILL BE THE APPROXIMATE AMOUNT FOR EACH 3 OZ TIN. 3 WILL BE FOR TESTING 1 WILL BE RESERVED FOR RETEST

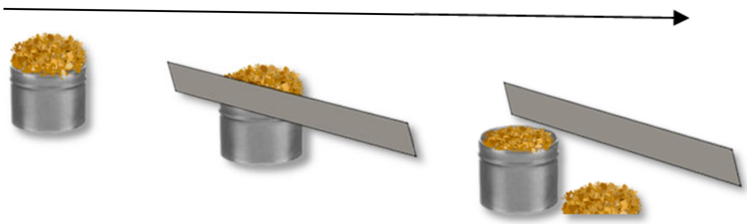
EXAMPLE: APPROXIMATELY 165-190 GRAMS EACH PAN.

1ST SPLIT HALF



- While filling, **tap the bottom edge of the measure** on the **worksurface** (usually done on the inside of a large flat pan) to consolidate the material allowing the maximum amount in the measure. **7.1.1.1**

- **Strike off the tin with the spatula so the material is level at the top of the measure**. **7.1.1.1**



🟥 ***ALTERNATIVE METHOD #2 (WET METHOD):***

- The sample must **first be checked that it is in the proper moisture condition**. This condition is determined by **tightly squeezing a small portion, of the thoroughly mixed sample, in the palm of the hand (Squeeze Test)**. If the **cast formed** allows the technician to carefully handle it without it breaking then the material is in the right condition. The **individual test sample** can be **obtained immediately** when determined to be in the right moisture condition. **7.1.2.1**

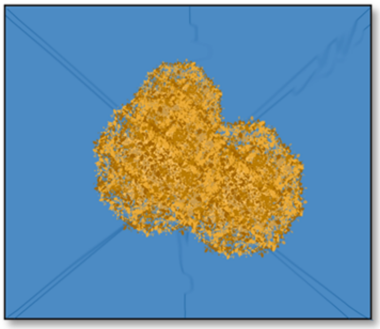
- If the material shows has any **free water** on the surface or when performing the squeeze test any free water is observed then **drain and air dry by mixing** the material frequently to ensure **drying uniformity**. The cast for overly wet material will be strong so continue drying until the cast is more fragile and delicate but still retains its shape. **7.1.2.1**

- If the sample material is **too dry** the **cast will crumble** immediately when tightly squeezed. When this occurs **add water, remix, and retest using the squeeze method**. **Repeat** this process until the **right moisture condition** is achieved. Once achieved place the material into a **pan (or other suitable container) covered with a lid or damp cloth (that does not touch the material) and allow to stand for a minimum of 15 minutes to temper.**

7.1.2.1

HOW TO OBTAIN AN INDIVIDUAL TEST SAMPLE (EITHER INITIALLY OR AFTER 15 MINUTE TEMPERING PERIOD)

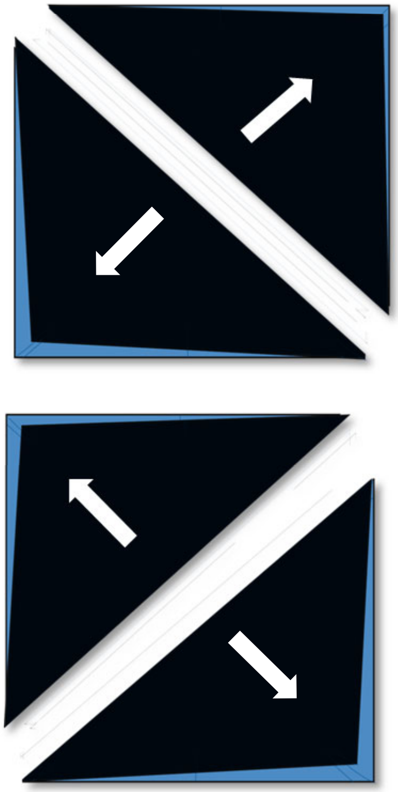
PLACE MATERIAL ON SPLITTING CLOTH / MAT



- Place the **material on a splitting cloth** and **mix by alternately lifting each corner** of the cloth and **pulling it over the sample toward the diagonally opposite corner causing the material to be rolled**.

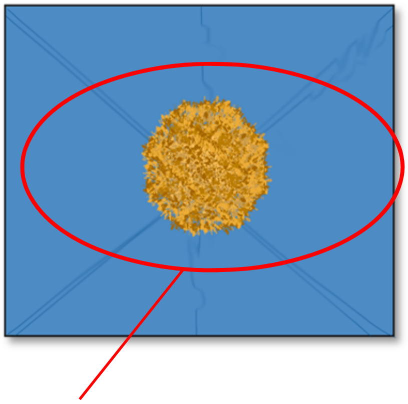
7.1.2.2

PULL EACH CORNER OVER THE SAMPLE TOWARD THE DIAGONALLY OPPOSITE CORNER (illustrated example)



- When the **material appears homogenous** finish the mixing where the **sample is in a pile near the center** of the cloth.

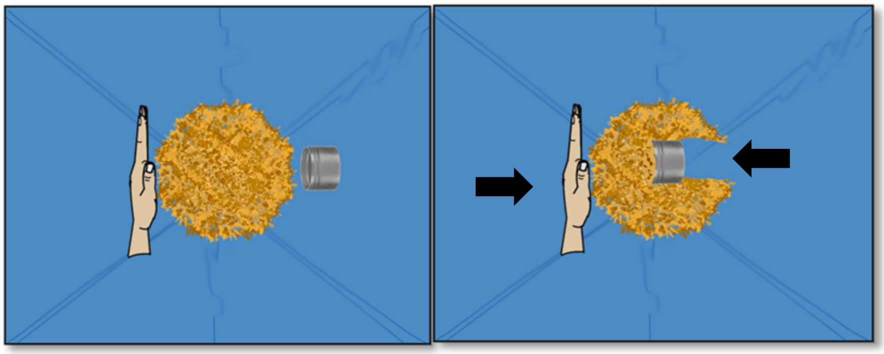
7.1.2.2



AT THE END OF MIXING MAKE SURE SAMPLE IS IN A PILE NEAR THE CENTER OF THE MAT

- **Fill the 3 oz tin** by **pushing it through the base of the pile** while exerting pressure with the hand on the side opposite the measure.

7.1.2.3

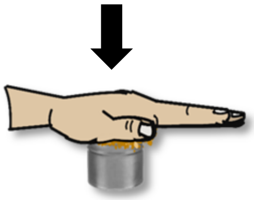


- As the tin is moved through the pile hold enough pressure with the opposite hand against the pile to **cause the material to fill the tin to overflowing**.

7.1.2.3

- Press **firmly with the palm of the hand, compacting** the material; allowing the maximum amount to be placed in the tin.

7.1.2.3



- **Strike off the tin** with the spatula or straightedge so the material is level with the top of the measuring tin.

7.1.2.3

DIFFERENT RESULTS BY METHOD

Results have shown that the procedure performed utilizing the wet method almost exclusively produces lower sand equivalent values than when performing the dry method.

EXAMPLE:

ALTERNATIVE METHOD #1 (DRY METHOD)

RESULTS FROM SAND EQUIVALENT OF SAMPLE #1

90 / 91 / 92

ALTERNATIVE METHOD #2 (WET METHOD)

RESULTS FROM SAND EQUIVALENT OF SAMPLE #1

84 / 85 / 86

■ ***ALTERNATIVE METHOD #3 (REFERENCE METHOD-MECHANICAL SHAKER):***

- Obtain the 3-oz tin measure of material by Alternative Method #1 or Alternative Method #2 then **dry the sample to constant mass at 230 ± 9°F** and cool to room temperature before testing.

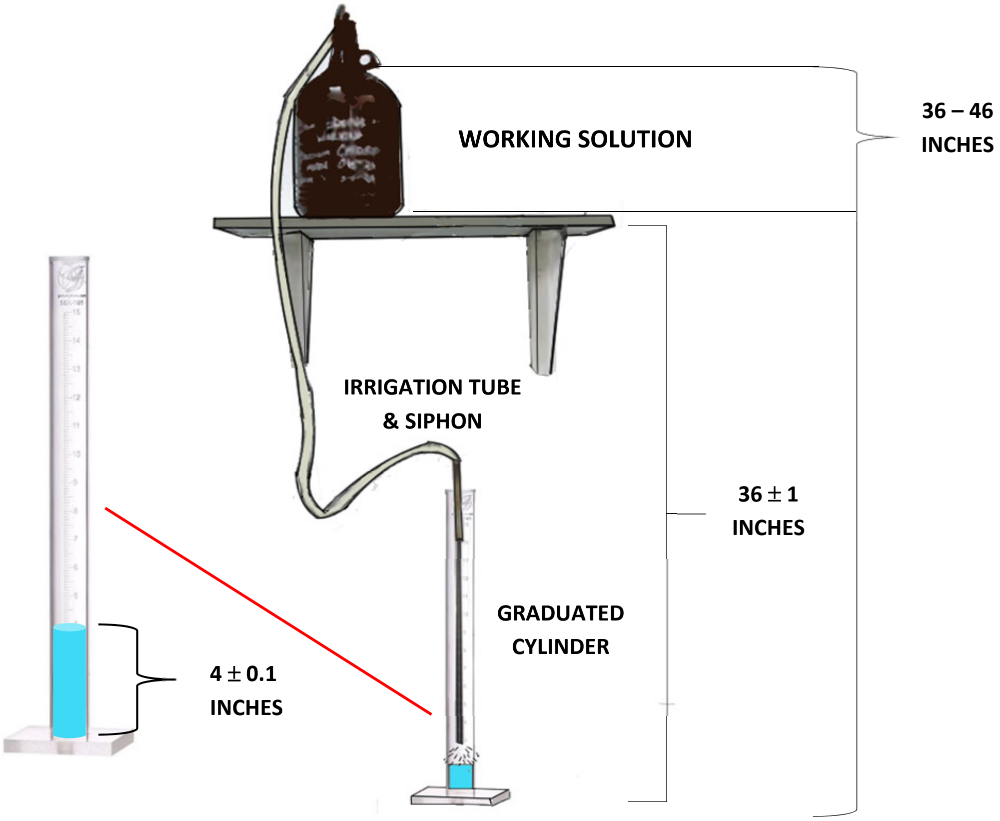
7.1.3

PROCEDURE:

1 **Start** the siphon and add **4 ± 0.1 inches** of **working calcium chloride solution** into the plastic cylinder.

8.2

ILLUSTRATED SAND EQUIVALENT EQUIPMENT SET UP



2 **Pour** the test **sample** from the measuring tin **into the plastic cylinder** using the funnel to avoid spillage.

8.2

3 **Tap the bottom of the cylinder sharply** with the heel of the hand several times to release air bubbles.

8.2

4 **Allow the sample to stand for 10 ± 1minutes.** At the end of the 10 minutes place a rubber stopper in the cylinder. Then **partially invert and shake the cylinder** to loosen the material from the bottom.

8.3

RUBBER STOPPER

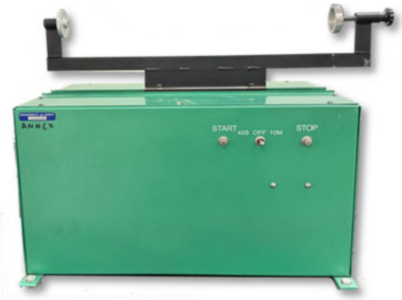
± 1

PERFORM ONE OF THE FOLLOWING SHAKING METHODS

MECHANICAL SHAKER METHOD (REFERENCE METHOD)

5 Place the cylinder, with the stopper in, into the mechanical sand equivalent shaker. Secure the cylinder and **allow the machine to shake the contents for 45± 1 seconds** ***(If the timing is not automated then set a timer for this step).***

8.4.1



MANUAL SHAKER METHOD

5 PLEASE REFER TO THE SECTION FOUND IN THE PROCEDURE FOR MORE DETAIL IF INTERESTED. THIS PROCEDURE IS NOT COVERED OR WILL BE TESTED ON DURING ATTI CERTIFICATION.

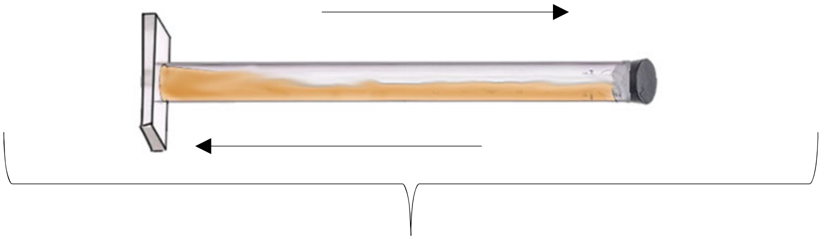
8.4.2

HAND METHOD

5 Take the cylinder, with the stopper in, and hold it in a **horizontal position.**

8.4.3

1 CYCLE



9 ± 1 inch.

Shake the cylinder vigorously in a **horizontal linear motion** from end to end. **Shake for 90 cycles in approximately 30 seconds** using a **throw of 9 ± 1 inch**. **One cycle is a complete back and forth motion.**

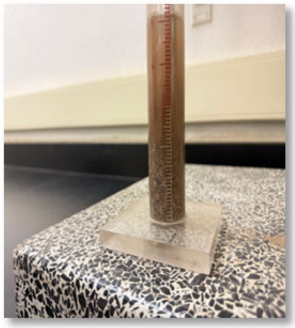
8.4.3

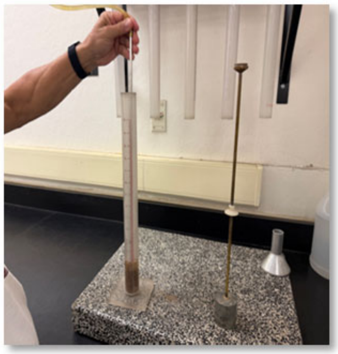
6 After the shaking operation is complete, set **the cylinder upright** on the work surface and **remove the stopper**. (***Attempt to remove the fines adhering to the bottom of the stopper by scrapping along the top edge of the cylinder as the stopper is removed***).

8.6.

7 **Insert the irrigation tube** in the cylinder and **rinse material** from the **cylinder walls** as the irrigator is lowered.

8.6





8 Force the irrigator through the material to the bottom of the cylinder by using a **gentle stabbing and twisting action while the working solution is flowing through the irrigator tube**.

8.6

9 This action flushes the **fine material above the coarser sand particles**. Continue to apply the stabbing and twisting motion while flushing the fines upward until the cylinder is filled to the **15-inch mark.**

8.6

10 Then **raise the irrigator slowly without shutting off the flow** so the liquid level is maintained at the 15 inch while being withdrawn.

8.6

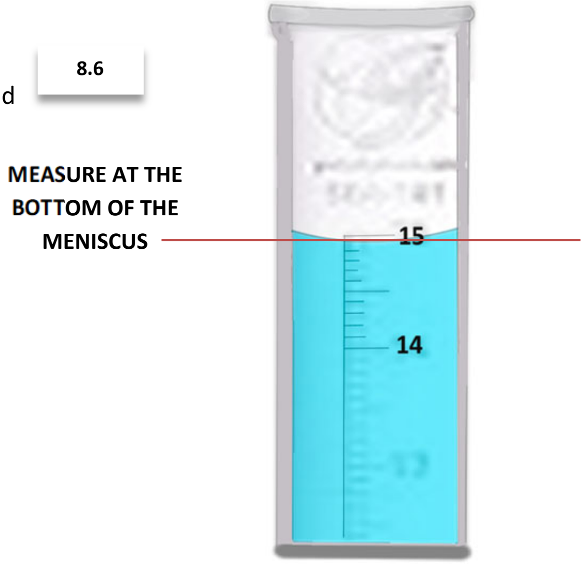
NOTE 9: For soils such as crushed materials the stabbing action may not be possible instead continue to apply a twisting action when forcing the irrigator into the material and as the irrigator is slowly withdrawn. Making sure the fines are flushed upward continue until the 15 inches is reached.

11 Regulate the flow just before the irrigator is entirely withdrawn and **adjust the final level to 15 inches.** The **final level** of the liquid will be **between** the **top 2 graduations on the cylinder** and but **can't be above the 15-inch mark** (when the liquid is read at the bottom of the meniscus).

8.6

What is the MENISCUS?

The meniscus is the concave curve in the upper surface of a liquid close to the surface of the container



± 15 sec.

12 Allow the sand in the cylinder to **stand undisturbed for 20 ± 15 seconds**. Start the **timing immediately after withdrawing** the irrigator tube.

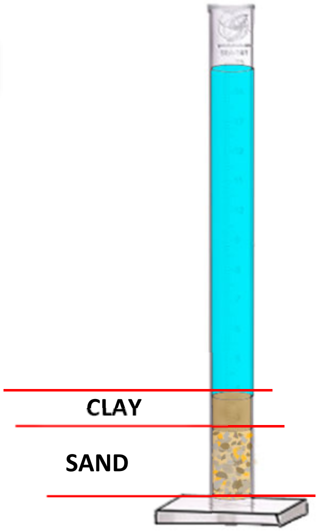
8.7

13 After the timer goes off indicating the **end of the 20-minute** period **read and record the top level of the clay suspension**. ***(This should be recorded as your clay reading)***.

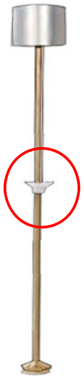
8.8

14 If by the **end of the 20 minutes** it is still cloudy and there is **no clear line of demarcation** formed allow the sample to stand undisturbed until a clay reading can be seen. Read and record the level of the top of the clay **AND** the total time it took. If the total sedimentation time **exceeds 30 minutes rerun with 3 samples of the same material**. (***Only record the clay reading of the sample with the shortest sedimentation period).***

8.8



WEIGHTED FOOT ASSEMBLY



SAND INDICATOR

15 **Next step** is to take the **sand reading** by placing the **weighted foot assembly**, with the sand indicator attached to the rod, over the cylinder and **gently lowering the assembly toward the sand.**

8.9.1

***DO NOT** allow the indicator to hit the mouth of the cylinder as it is being lowered.*

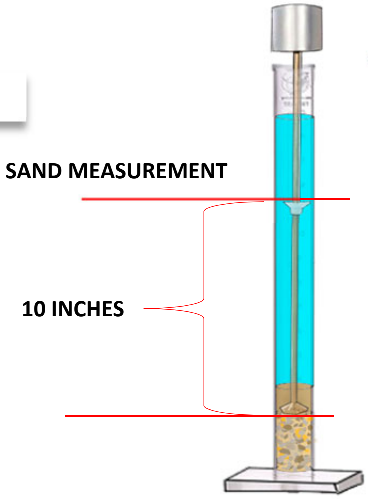
8.9.1

16 As the weighted foot assembly comes to rest on the sand **tip the assembly toward the graduation marks** on the cylinder until the indicator touches the inside of the cylinder.

8.9.1

17 **Subtract 10 inches from the level indicated** by the extreme top edge of the indicator and record this value as the **sand reading**.

8.9.1



18 If the **clay or sand readings** fall **between the 0.1-inch** demarcations **record the level of the higher graduation** as your reading.

8.10

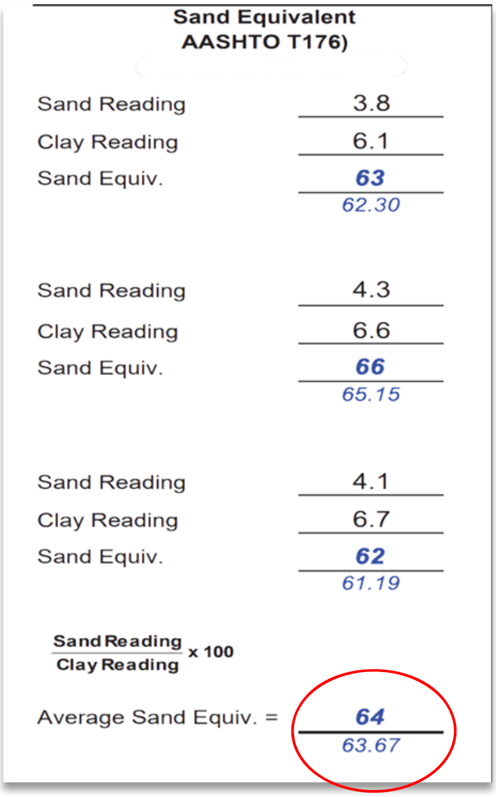
EXAMPLE:
A **SAND reading** that is **13.75** as measured from the indicator.
Subtract 10

13.75 – 10 = 3.75 round up to 3.8
Your recorded Sand Value is 3.8

Make sure to perform the test in a location that is free of vibrations.

CALCULATION:

Sand Equivalent (SE) = $\left(\frac{sand\ reading}{clay\ reading}\right)$ X 100



Sand Equivalent
AASHTO T176)

Sand Reading	3.8
Clay Reading	6.1
Sand Equiv.	***63*** *62.30*
Sand Reading	4.3
Clay Reading	6.6
Sand Equiv.	***66*** *65.15*
Sand Reading	4.1
Clay Reading	6.7
Sand Equiv.	***62*** *61.19*

$\frac{\text{Sand Reading}}{\text{Clay Reading}}$ x 100

Average Sand Equiv. = ***64*** *63.67*

- ***Calculate the sand equivalent to the nearest 0.1.*** **9.1**
- ***If the calculated sand equivalent is not a whole number, report it as the next higher whole number.*** **9.2**
- ***When averaging a series of sand equivalent values, average the whole number values. If the result of this average is not a whole number, raise it to the next higher whole number.*** **9.3**

64 (63.67) = $\left(\frac{63+66+62}{3}\right)$ X 100

AASHTO T84:

SPECIFIC GRAVITY AND ABSORPTION OF FINE AGGREGATE

DEFINITIONS:

Absorption - the increase in the mass of aggregate due to water in the pores of the material.

Bulk Specific Gravity (OD)- is calculated as the ratio of the weight of a unit volume of aggregate (including voids) to the weight of an equal volume of water, both at a stated temperature.

SSD Specific Gravity - is a measure of a material's density relative to water, where the material is saturated with water in its permeable voids, but its surface is dry.

Apparent Specific Gravity - is the ratio of the weight of a given volume of the impermeable portion of a material to the weight of an equal volume of distilled water at a stated temperature, essentially measuring the density of the solid material itself, excluding any voids or pores.

Saturated, Surface Dry (SSD) - a condition where the internal pores of a material, like concrete or aggregate, are fully saturated with water, but the surface is visibly dry.

SCOPE:

1.1

This method covers the determination of bulk and apparent specific gravity at (73.4/73.4 °F) and absorption of fine aggregate.

EQUIPMENT:

5.

- **BALANCE –** Readable to 0.1 grams of the sample mass.

- **PYCNOMETER –** a flask or other suitable container into which a fine aggregate test sample can be introduced and which the volume content can be reproduced with ± 100 mm^3. The volume of the container, filled to mark, shall be at least 50 % greater than the space required to accommodate the test sample. The volumetric flask of 500-mL capacity is satisfactory for 500-gram sample.

- **MOLD (CONE) –** a metal mold in the form of a frustum of a cone with the dimension of: 40 ± 3 mm inside diameter at the top, 90 ± 3 mm inside diameter at the bottom, and 75 ± 3 mm in height, with a minimum thickness of 0.8mm.

- **TAMPER –** a metal tamper having a mass of 340 ± 15 grams and having a flat circular tamping face 25 ± 3 mm in diameter.

- **THERMOMETER (MEASURING LIQUIDS) –** a thermometer for measuring the temperature of water and materials in solution shall have a temp range of at least 60°F to 80°F with an accuracy of ± 0.9°F.

- **OVEN –** thermostatically controlled capable of being heated continuously at a temperature of 230 ± 9°F. The oven shall be capable of a temperature range of 212 °F to 248 °F and has an accuracy of ± 9 °F.

- **THERMOMETER (VERIFYING OVEN) -** a thermometer that has a temp range of at least 194 °F to 266°F with an accuracy of ± 2.25 °F.

In construction, specific gravity is significant because it helps determine the density, quality, and suitability of materials like concrete, soil, and aggregates. Bulk specific gravity is the characteristic generally used for calculation of the volume occupied by the aggregate in various mixtures including Portland cement concrete, bituminous material and other mixtures. The bulk specific gravity SSD is used if the aggregate is wet; that is if its absorption has been satisfied. Where the bulk specific gravity is determined on an oven-dry basis and is used for calculation when the aggregate is dry or assumed to be dry.

4.

Apparent specific gravity is the relative density of solid material making up the component particles not including the pore space within particles that is accessible to water. This value is not widely used in construction processes.

SAMPLING:

- **Obtain a sample** to be tested **according to AASHTO R90**. **6.1**

SAMPLE PREP:

- **Reduce** sample to approximately **1000 grams (1 kg)** of fine aggregate according to **AASHTO R76.** **7.1**
- **Dry the 1000-gram (1 kg) test sample** in a suitable pan to **constant mass** at a temperature of **230 ± 9°F**. Allow it to cool to a comfortable handling temperature. **7.1.1**
- **Cover** with **water** either by **immersion or by the addition of at least 6 % moisture** to the fine aggregate and allow to stand for **15 to 19 hours**. **7.1.1**
- **Decant the excess water** taking care to avoid losing fines. **7.2**
- **Spread the sample** on a **flat, nonabsorbent surface** exposed to a **gently moving current of warm air stirring frequently** to secure homogenous drying. **7.2**
- As the material begins to dry it may be necessary to **work the material** with the hands in a **rubbing motion** to break up any conglomerates or lumps. **7.2**
- **Continue** these steps until the material is in a **free-flowing condition**. Perform the **cone test for surface moisture** to determine whether or not surface moisture is present on the fine aggregate particles. The **first trial** of the cone test will be made with **some surface water on in the specimen**. **7.2**

Where the absorption and specific gravity values are to be used in proportioning concrete mixtures with aggregates used in their naturally moist condition, the requirement for initial drying to constant mass may be eliminated and if the surfaces of the particles have been kept wet, the required soaking may also be eliminated. **7.1.2**

Values for absorption and for specific gravity in the SSD condition may be significantly higher for aggregate not oven dried before soaking. **7.1.2 NOTE 3**

AASHTO T255

CONSTANT MASS: Sample is dry when further heating causes less than 0.1% additional loss in mass.

- **Continue drying with constant stirring**, and if necessary, work the material with a hand rubbing motion testing at frequent intervals until the cone test indicates that the specimen has reached a **surface dry condition**. 7.2

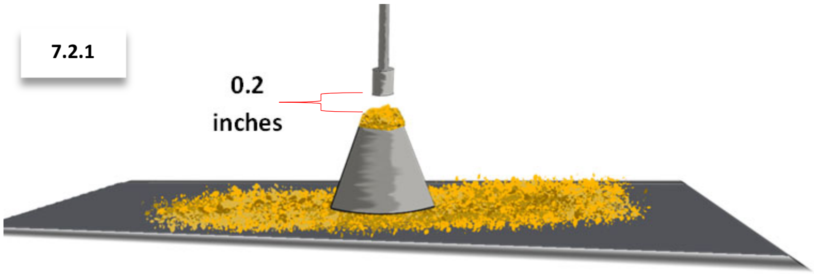
- If the **first trial** of the surface moisture test indicates that **moisture is NOT present** on the surface (***According to CONE TEST***: ***If the molded shape does not hold its shape when the cone is removed see cone test section)*** then the material has been dried **past the SSD condition**. If this occurs **mix a few milliliters of water** with the fine aggregate and allow the specimen to stand in a **covered container for 30 minutes.** Then resume the process of drying and testing until the material reaches SSD condition. 7.2

CONE TEST FOR SURFACE MOISTURE

- **Hold the cone mold firmly** on a smooth nonabsorbent surface with the **large diameter down.** 7.2.1

- **Place a portion** of the partially dried fine aggregate **loosely in the mold** filling until **overflow** occurs. ***Holding the base firmly with one hand and heaping additional material over top with the other hand.*** 7.2.1

- **Lightly tamp** the fine aggregate into the mold with **25 light drops** of the tamper. Each drop should start **approximately 0.2 inches above the top surface** of the fine aggregate. Allow the tamper to **drop freely** without putting any force downward. 7.2.1



- **Adjust the starting height** to the new surfaced elevation after **each drop** and **distribute the drops over the surface**. 7.2.1

- **Remove loose sand** from around the base and **lift the mold up vertically.** 7.2.1

- If **surface moisture is still present (too much moisture)**, the fine aggregate will **retain the molded shape.** 7.2.1

- When the fine aggregate **slumps slightly** it indicates that it has reached a **surface- dry condition**. 7.2.1

- If the molded shape does not hold its shape (***mostly)*** the sample is **dried past SSD** and is too **dry**.

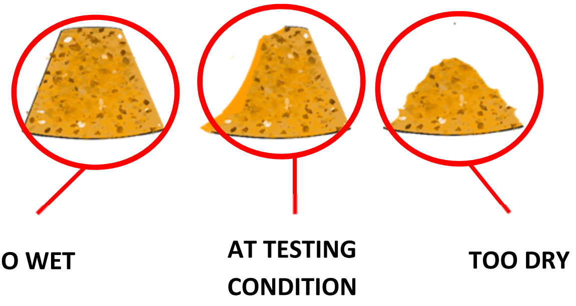
7.2.1

FOLLOWING CRITERIA USED ON MATERIALS THAT DON'T READILY SLUMP:

- ***Provisional Cone Test***
- ***Provisional Surface Test***
- ***Colorimetric Procedures***
- ***Paper Towels on Single Sized Material That Slumps When Wets***

NOTE 4: *Refer to Procedure on details about each of these criteria.*

ILLUSTRATED STAGES OF CONE TEST



Some angular fine aggregate or material with a high proportion of fines may not slump in the cone test when reaching SSD. If fines become airborne when dropping a handful of the sand onto the work surface from 100 to 150mm. then SSD condition should be considered as the point when one side of the fine aggregate slumps slightly upon removing the mold.

7.2.1

PROCEDURE:

1 Partially fill the pycnometer with water. Immediately **introduce 500 ± 10 grams of SSD material** into the **pycnometer**. Then **fill** with additional water to **approximately 90%** of capacity.

8.2

Weigh and record all mass determinations to 0.1 grams.

8.1

MANUAL METHOD

2 **Manually roll, invert, and agitate** the pycnometer or use a combination of all these actions to **eliminate all air bubbles**.

8.2

3 It generally **takes about 15 to 20 minutes** to eliminate air bubbles **by manual method**.

8.2 NOTE 5

MECHANICAL METHOD

2 **Mechanical method** is the **agitation** of the material by **external vibration** of the pycnometer in a manner that will **not degrade** the aggregates.

8.2

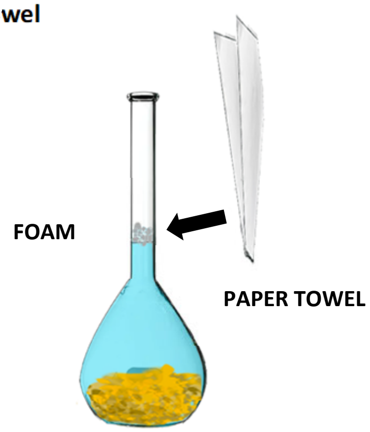
3 A mechanical agitator is **acceptable if comparison tests** are done **every six months** that show variations less than the acceptable **range** of **2 results** indicated in in **TABLE 1 of the procedure** from results of manual agitation on the same material.

8.2

How do we get rid of the foam that builds up after agitation?

8.2 NOTE 5

- **If foam develops while eliminating air bubbles dipping the tip of a paper towel into the pycnometer is useful in dispersing that foam.**
- **Adding a few drops of isopropyl alcohol, after removal of air bubbles and just prior to bringing the water level to its calibrated capacity, will disperse the foam on the water surface.**



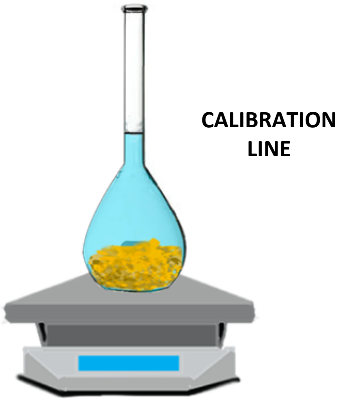
4 **Measure** the **temperature of the water**, in the flask, and **adjust to 73.4 ± 3°F** if necessary. The temperature is adjusted by **immersing** the flask in **circulating water**. Next bring the **water level** in the pycnometer up to its **calibrated capacity**.

8.2

5 **Weigh and record** the **total mass** of the **pycnometer, specimen, and water to 0.1 grams**.

8.2

WEIGH THE PYCNOMETER,
SPECIMEN, AND WATER
(0.1 GRAMS)



6 **Remove** the fine aggregate from the pycnometer, **dry to constant mass at a temperature of 230 ± 9°F**. **Cool** the sample in air at **room temperature for 1.0 ± 0.5 hours** and weigh and record the mass.

8.3

ALTERNATIVELY… one can determine the **total quantity of added water** necessary to fill the pycnometer **volumetrically** (at the required temperature) using a **burette accurate to 0.15 mL.** ***Compute the total mass of pycnometer, specimen, and water by the following equation:***

$$C = 0.9975V_a + S + W$$

8.2.1

C = mass of pycnometer with specimen and water to calibration mark, g.
V_a = volume of water added to pycnometer, mL;
W = mass of the pycnometer empty, g;
S = mass of SSD specimen, g;

INSTEAD…*A second portion of the SSD sample may be used to determine the oven-dry mass. This sample must be obtained at the same time and be within 0.2 grams of the mass of the sample that is introduced into the pycnometer.*

8.3 NOTE 7

7 **Weigh and record the mass** of the **pycnometer filled with water to its calibration line (capacity)**. Be certain that the **water is at 73.4 ± 3°F**.

8.4

Alternative procedure is the Le Chatelier method. Refer to the procedure for details.

ALTERNATIVELY…the quantity of water necessary to fill the **empty pycnometer** at the **required temperature** may be determined **volumetrically using a burette accurate to 0.15 mL.** ***Compute the mass of the pycnometer filled with water as follows:***

8.4.1

$$B = 0.9975V + W$$

B = mass of pycnometer filled with water, g.
V = volume of pycnometer, mL;
W = mass of the pycnometer empty, g;

CALCULATIONS:

9.

BULK SPECIFIC GRAVITY (OD)

$$BS_g = \left(\frac{(A)}{(B+S-C)}\right)$$

BS_g = Bulk specific gravity;
A = mass of oven-dry specimen in air, g;
B = mass of pycnometer filled with water, g;
S = mass of SSD specimen, g;
C = mass of pycnometer with specimen and water to calibration mark, g.

EXAMPLE:

A = 500.1 g

B = 680.5 g

S = 502.2 g

C = 993.5 g

$$\frac{A = 500.1\text{ g}}{\left[\,B = 680.5\text{ g} + S = 502.2\text{ g} - C = 993.5\text{ g}\,\right]}$$

$$BS_g = 2.643$$

Report specific gravity results to the nearest 0.001.
Report absorption to the nearest 0.1%.

SSD SPECIFIC GRAVITY

$$SSDS_g = \left(\frac{(S)}{(B+S-C)}\right)$$

$SSDS_g$ = Saturated surface- dry specific gravity;
A = mass of oven-dry specimen in air, g;
B = mass of pycnometer filled with water, g;
S = mass of SSD specimen, g;
C = mass of pycnometer with specimen and water to calibration mark, g.

10.

EXAMPLE:
A = 500.1 g
B = 680.5 g
S = 502.2 g
C = 993.5 g

$$\frac{S = 502.2\ g}{\left[\,B = 680.5\ g + S = 502.2\ g - C = 993.5\ g\,\right]}$$

$SSDS_g = 2.654$

APPARENT SPECIFIC GRAVITY

$$AS_g = \left(\frac{(A)}{(B+A-C)}\right)$$

AS_g = Apparent specific gravity;
A = mass of oven-dry specimen in air, g;
B = mass of pycnometer filled with water, g;
S = mass of SSD specimen, g;
C = mass of pycnometer with specimen and water to calibration mark, g.

11.

EXAMPLE:
A = 500.1 g
B = 680.5 g
S = 502.2 g
C = 993.5 g

$$\frac{A = 500.1\ g}{\left[\,B = 680.5\ g + A = 500.1\ g - C = 993.5\ g\,\right]}$$

$AS_g = 2.673$

ABSORPTION

$$Abs = \left(\frac{(S-A)}{(A)}\right)$$

Abs = Absorption;
A = mass of oven-dry specimen in air, g;
B = mass of pycnometer filled with water, g;
S = mass of SSD specimen, g;
C = mass of pycnometer with specimen and water to calibration mark, g.

12.

EXAMPLE:
A = 500.1 g
B = 680.5 g
S = 502.2 g
C = 993.5 g

$$\frac{\left[\,S = 502.2\ g - A = 500.1\ g\,\right]}{A = 500.1\ g} \times 100$$

Abs = 0.4 %

AASHTO T85:

SPECIFIC GRAVITY AND ABSORPTION OF COARSE AGGREGATE

DEFINITIONS:

Absorption - the increase in the mass of aggregate due to water in the pores of the material.

Bulk Specific Gravity (OD)- is calculated as the ratio of the weight of a unit volume of aggregate (including voids) to the weight of an equal volume of water, both at a stated temperature.

SSD Specific Gravity - is a measure of a material's density relative to water, where the material is saturated with water in its permeable voids, but its surface is dry

Apparent Specific Gravity - is the ratio of the weight of a given volume of the impermeable portion of a material to the weight of an equal volume of distilled water at a stated temperature, essentially measuring the density of the solid material itself, excluding any voids or pores.

Saturated, Surface Dry (SSD) - a condition where the internal pores of a material, like concrete or aggregate, are fully saturated with water, but the surface is visibly dry.

SCOPE:

1.1

This method covers the determination of specific gravity and absorption of coarse aggregate. The specific gravity may be expressed as bulk specific gravity, SSD specific gravity, apparent gravity.

EQUIPMENT:

6.

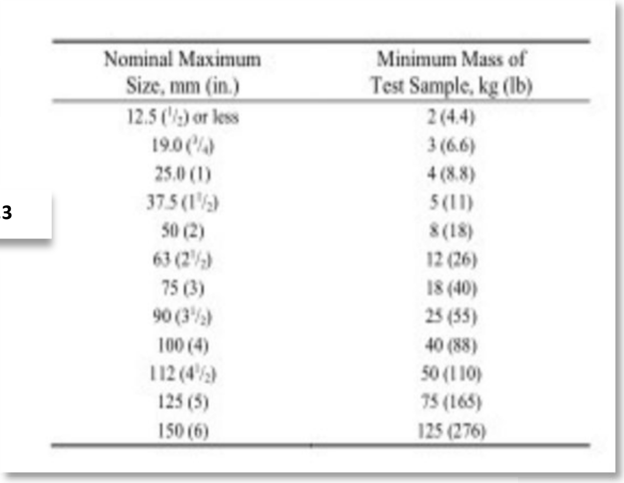
- **BALANCE –** Readable to 0.1 grams of the sample mass. The balance will be equipped with suitable apparatus for suspending the sample container in water from the center of the weighing platform or pan of the balance.
- **SAMPLE CONTAINER –** A wire basket #6 or finer mesh or bucket of approximately equal breadth and height with a capacity of 1 ½ inch nominal maximum size aggregate or smaller and a larger container as needed for testing larger maximum size aggregate. The container shall be constructed so as to prevent trapping air when the container is submerged.
- **WATER TANK –** A watertight tank into which the sample and container are placed for complete immersion while suspended below the balance, equipped with an overflow outlet for maintaining a constant water level.
- **SUSPENDED APPARATUS–** Wire suspending the container shall be of the smallest practical size to minimize any possible effects of a variable immersed length.
- **SIEVES–** A #4 sieve or other sizes needed.
- **OVEN –** Thermostatically controlled capable of being heated continuously at a temperature of 230 ± 9°F. The oven shall be capable of a temperature range of 212 °F to 248 °F.
- **THERMOMETER (VERIFYING OVEN) -** a thermometer that has a temp range of at least 194 °F to 266°F with an accuracy of ± 2.25 °F.
- **THERMOMETER (MEASURING LIQUID) –** with a temperature range of at least 60°F to 80°F with an accuracy of ± 0.9°F.

In construction, specific gravity is significant because it helps determine the density, quality, and suitability of materials like concrete, soil, and aggregates. Bulk specific gravity is the characteristic generally used for calculation of the volume occupied by the aggregate in various mixtures including Portland cement concrete, bituminous material and other mixtures. The bulk specific gravity SSD is used if the aggregate is wet; that is if its absorption has been satisfied. Where the bulk specific gravity is determined on an oven-dry basis and is used for calculation when the aggregate is dry or assumed to be dry.

Apparent specific gravity is the relative density of solid material making up the component particles not including the pore space within particles that is accessible to water. This value is not widely used in construction processes.

SAMPLING:

- **Obtain a sample** to be tested **according to AASHTO R90**. **7.1**
- **Thoroughly mix** the sample of aggregate and **reduce** it to the approximate amount needed **according to AASHTO R76.** **7.2**
- **Reject all material** that **passes the #4 sieve** by dry sieving. **7.2**
- **Thoroughly wash the aggregate** to remove dust or other coatings from the surface. Re-sieve, if necessary, after wash. **7.2**
- **If the coarse aggregate contains** a substantial amount **of material finer than the #4 sieve** use the **#8 sieve in place of the #4 screen sieve**. **ALTERNATIVELY:** separate the material finer than the #4 sieve and **test the finer material according to AASHTO T84**. **7.2**
- The **minimum mass** of the test sample is given in **the table in the procedure**. **7.3**
- If desirable to **test** coarse aggregate in **several separate size fractions**; and if the sample **contains more than 15% retained on the 1 ½”** sieve, test the material larger than 1 ½” aggregate in one or more size fractions separately from the smaller size fractions. **7.3**



Nominal Maximum Size, mm (in.)	Minimum Mass of Test Sample, kg (lb)
12.5 (½) or less	2 (4.4)
19.0 (¾)	3 (6.6)
25.0 (1)	4 (8.8)
37.5 (1½)	5 (11)
50 (2)	8 (18)
63 (2½)	12 (26)
75 (3)	18 (40)
90 (3½)	25 (55)
100 (4)	40 (88)
112 (4½)	50 (110)
125 (5)	75 (165)
150 (6)	125 (276)

- When aggregate is tested in separate size fractions, the **minimum mass** of test sample for each fraction shall be the difference between the masses prescribed for the **maximum and minimum sizes of the fraction**. **7.3**

PROCEDURE:

AASHTO T255

1 Dry the test sample to **constant mass** according to **AASHTO T255 at 230 ± 9°F**.

8.1

CONSTANT MASS: *Sample is dry when further heating causes less than 0.1% additional loss in mass.*

2 **Cool in air at room temperature for 1 to 3 hours** for a test sample with **1 ½ inch nominal maximum size** or longer for larger sizes. Cool until the aggregate has cooled to a temperature that **is comfortable to handle.**

8.1

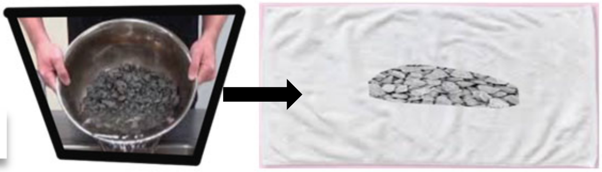
Where the absorption and specific gravity values are to be used in proportioning concrete mixtures with aggregates used in their naturally moist condition, the requirement for initial drying to constant mass may be eliminated and if the surfaces of the particles have been kept wet, the required soaking may also be eliminated.

3 **Immerse the aggregate sample** in water at **room temperature** for a **period of 15 to 19 hours**.

8.1

4 **Remove** the test sample from the **water** and **roll it in a large absorbent cloth** until all **visible films of water are removed.** Wipe the larger particles individually.

8.3



5 **A moving stream of air may be used** to assist in drying. Take care to avoid evaporation of water from aggregate pores during the surface dry process.

8.3

FREE WATER SEEN

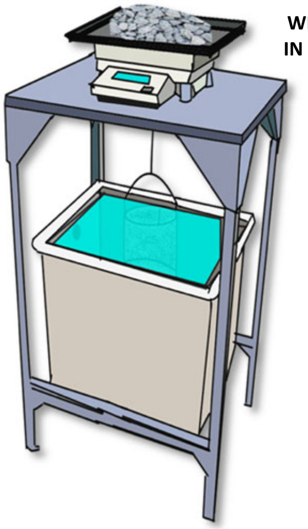
SSD (MATTE COLORED)

6 If the test sample dries past the SSD condition, **immerse in water for 30 minutes** then resume the process of surface-drying.

8.3

7 **Weigh and record** the mass of the test sample in the **SSD condition**. Record the mass of the sample to the **nearest 1.0 grams *(or 0.1 % of the sample mass whichever is greater).* All calculations and or questions for ATTI will reference the nearest 1.0 grams.**

8.3

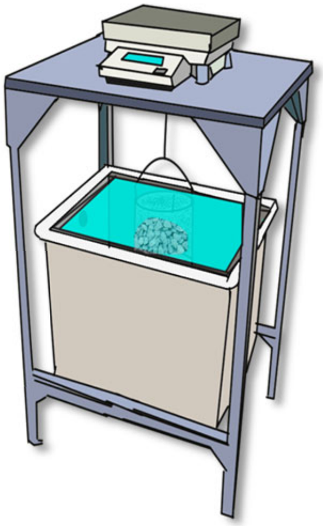


WEIGH MATERIAL IN SSD CONDITION

Values for absorption and SSD bulk specific gravity may be significantly higher for aggregate not oven dried before soaking than for the same aggregate treated in accordance with section8.1. Especially true of particles larger than 3 inches because the water may not be able to penetrate the pores to the center of the particle in the required soaking period.

8 After weighing the mass immediately place the SSD test sample **in the sample container** and **weigh and record its mass** the **nearest 1.0 grams *(or 0.1 % of the sample mass whichever is greater).* All calculations and or questions for ATTI will reference the nearest 1.0 grams, in water at 73.4± 3°F.** Allow the container to stabilize in the water and take care to remove all entrapped air (by shaking the container) before determining the mass.

8.4



WEIGH MATERIAL IN WATER

9 **Maintain the water level in the bath at the overflow depth** to obtain a constant water level throughout the test.

8.4

How deep should the container be submerged when determining the samples water weight?

It should be immersed to a depth sufficient to cover it and the test sample when determining the weight of the sample mass. The wire suspending the container must be the smallest practical size.

When testing coarse aggregate of large nominal maximum size requiring large test samples it is more convenient to perform the test on two or more subsamples and the values obtained combined for the calculation from section 9.2 seen at the bottom of this section.

NOTE 3

10 **Dry the test sample** to constant mass **according to AASHTO T255 at 230 ± 9°F.**

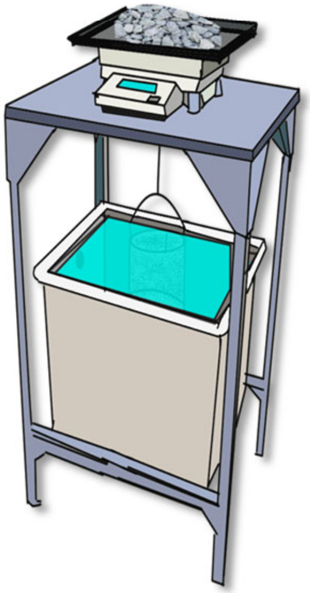
8.5

WEIGH THE DRIED MATERIAL

230 ± 9 ° F

11 **Cool in air at room temperature for 1 to 3 hours** or until the aggregate has cooled to a temperature that is comfortable to handle. **Weigh and record the mass of the sample.**

8.5



CALCULATIONS:

BULK SPECIFIC GRAVITY (OD)

$$BS_g = \left(\frac{A}{(B-C)}\right)$$

BS_g = Bulk specific gravity;
A = mass of oven-dry sample in air, g;
B = mass of SSD specimen in air, g;
C = mass of saturated test sample in water, g.

EXAMPLE:
A = 2035 g
B = 2048 g
C = 1311 g

$$\frac{A = 2035\ g}{\left[\ B = 2048\ g - C = 1311\ g\ \right]}$$

BS_g = 2.761

REPORT:
Report specific gravity results to the nearest 0.001.
Report absorption to the nearest 0.1%.

SSD BULK SPECIFIC GRAVITY

$$SSDBS_g = \left(\frac{B}{(B-C)}\right)$$

$SSDBS_g$ = Bulk specific gravity;
A = mass of oven-dry sample in air, g;
B = mass of SSD specimen in air, g;
C = mass of saturated test sample in water, g.

EXAMPLE:
A = 2035 g
B = 2048 g
C = 1311 g

$$\frac{B = 2048\ g}{\left[\ B = 2048\ g - C = 1311\ g\ \right]}$$

$SSDBS_g$ = 2.779

APPARENT SPECIFIC GRAVITY

$$AS_g = \left(\frac{A}{(A-C)}\right)$$

AS_g = Bulk specific gravity;
A = mass of oven-dry sample in air, g;
B = mass of SSD specimen in air, g;
C = mass of saturated test sample in water, g.

EXAMPLE:
A = 2035 g
B = 2048 g
C = 1311 g

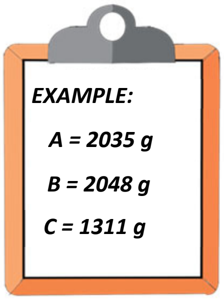
$$\frac{A = 2035\ g}{\left[\ A = 2035\ g - C = 1311\ g\ \right]}$$

AS_g = 2.811

ABSORPTION

$$\textbf{Abs} = \left(\frac{(B-A)}{A}\right)$$

Abs= absorption of aggregate;
A = mass of oven-dry sample in air, g;
B = mass of SSD specimen in air, g;
C = mass of saturated test sample in water, g.



EXAMPLE:

A = 2035 g

B = 2048 g

C = 1311 g

$$\frac{\left[\ B = 2048\ g\ -\ A = 2035\ g\ \right]}{A = 2035\ g} \times 100$$

Abs = 0.6%

IF…*the sample is tested in separate size fractions, the average value for bulk specific gravity or SSD bulk specific gravity or apparent gravity is calculated by the following equation:*

AVERAGE SPECIFIC GRAVITY

$$\textbf{GS}_g = \frac{1}{\left(\frac{P_1}{(100*G_1)} + \frac{P_2}{(100*G_2)} + \ldots\right)}$$

$\textbf{GS}_g$ = average specific gravity (whichever is being calculated);
$\boldsymbol{P_1}$, $\boldsymbol{P_2}$ … = mass percentages of each size fraction present in the original sample;
$\boldsymbol{G_1}$, $\boldsymbol{G_2}$ … = appropriate specific gravity values for each size fraction depending on the type of specific gravity being averaged.

IF…*the sample is tested in separate size fractions, the absorption is calculated by the following equation:*

AVERAGE ABSORPTION

$$\textbf{GS}_g = \left(\frac{(P_1*A_1)}{(100)}\right)+\left(\frac{(P_2*A_2)}{(100)}\right)+\ldots$$

A = average absorption, percent;
$\boldsymbol{P_1}$, $\boldsymbol{P_2}$ … = mass percentages of each size fraction present in the original sample;
$\boldsymbol{A_1}$, $\boldsymbol{A_2}$ … = absorption percentages of each size fraction;

AASHTO T21:

ORGANIC IMPURITIES IN FINE AGGREGATES FOR CONCRETE

DEFINITIONS:

Organic Impurities- typically originate from decomposed plant material, including decaying leaves, bark, and roots, or other organic matter like soil.

Color Standard - a system used to visually assess and quantify the color of transparent liquids.

Reagent - is a substance or compound added to a system to cause a chemical reaction, or test if one occurs.

Supernatant - the usually clear liquid overlying material deposited by settling, precipitation, or centrifugation.

SCOPE:

1.1

This test method covers two procedures for an approximate determination of the presence of injurious organic compounds in fine aggregates that are to be used in hydraulic cement mortar or concrete. One procedure uses a glass color standard and the other uses a standard color solution.

EQUIPMENT:

4.

- **GLASS BOTTLES –** Colorless glass graduated bottles, approximately 8 to 16 oz nominal capacity, equipped with watertight stoppers or caps, not soluble in the specified reagents. In no case shall the maximum outside dimension of the bottles, measured along the line of sight used for the color comparison be greater than 2.5 inch or less than 1.5 inches. The graduations on the bottles shall be in milliliters or ounces.

- **STANDARD COLOR SOLUTION LEVEL –** 75mL (2 ½" OZ).

- **FINE AGGREGATE LEVEL IN THE BOTTLE –** 130 mL (4 ½" OZ).

- **NaOH SOLUTION LEVEL–** 200 mL (7 OZ).

- **GLASS COLOR STANDARD–** Glass color standard will be used as described in ASTM D1544.

The test serves as a preliminary check for the presence of injurious organic compounds in fine aggregates (like sand) that could negatively impact the strength and durability of cement mortar or concrete. The test typically involves mixing a fine aggregate test sample with a sodium hydroxide solution in a special bottle and observing the color of the resulting liquid comparing it to a standard color and determining if the sample mixture is darker than the standard.

REAGENT AND STANDARD COLOR SOLUTION:

5.1

- **Consult the procedure on how to obtain information on the regulatory information on all liquid materials from the method.**

NaOH Solution Level

5.2

Reagent Sodium Hydroxide Solution (3%) – Dissolve 3 parts by mass of sodium hydroxide in 97 parts of water.

Standard Color Solution

5.3

Dissolve reagent grade potassium dichromate in concentrated sulfuric acid at the rate of 100mL of acid. The solution must be freshly made for color comparison using gentle heat if necessary to effect solution. ***Refer to procedure for more details.***

Preparation of the reference standard color solution is unnecessary when the glass color standard procedure is used to determine the color value.

5.3

SAMPLE:

- The **sample will be obtained according to AASHTO R90.** Reduce the fine aggregate material to the testing amount of **approximately 450 grams (1 lb.)** according to **AASHTO R76. Sample drying** prior to testing, if necessary, shall be done by **air drying only.**

6. / 7.

PROCEDURE:

1 Fill a glass bottle to the **130 mL (approximately 4 ½ fluid ounces)** with the sample of the **fine aggregate** to be tested and level the surface.

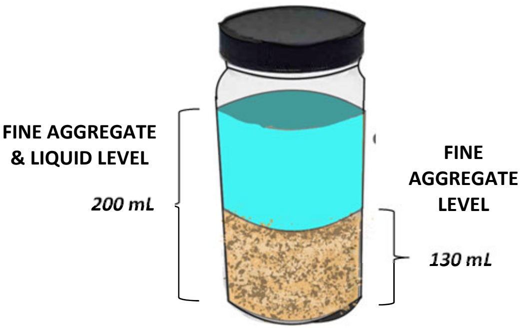
8.1

2 Add a **3% NaOH solution in water** until the **volume of the fine aggregated and liquid,** indicated after shaking **is 200 mL (approximately 7 fluid ounces).**

8.2

3 Stopper the bottle, **shake vigorously**, and then allow to **stand for 24 hours**.

8.3



COLOR VALUE DETERMINATION:

4 ***After the 24-hour standing period …***

GLASS COLOR STANDARD PROCEDURE ***OR*** ***STANDARD COLOR SOLUTION PROCEDURE***

GLASS COLOR STANDARD PROCEDURE

5 Visually **compare the color standards** to the **color of the supernatant liquid ABOVE** the test sample in the bottle.

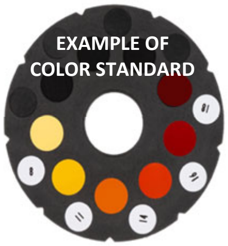
9.1

6 **Report the organic plate number** corresponding to the Gardner color standard number that is **nearest the color of the liquid above** the test sample.

9.1

7 To **define the color** of the liquid of the test sample, use **6 glass standard** colors as **described in TABLE 1 in ASTM D1544.**

9.1.1



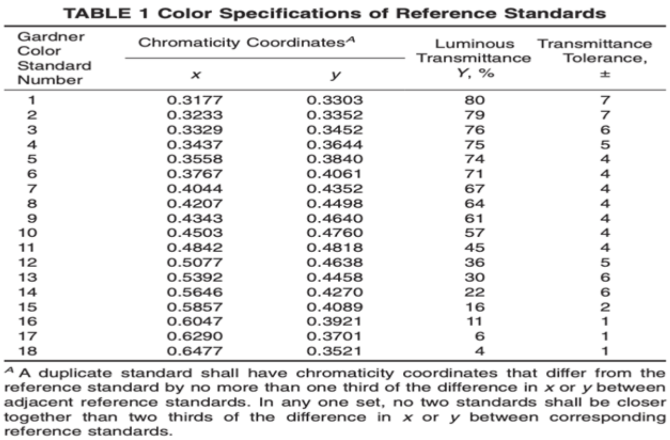


TABLE 1 Color Specifications of Reference Standards

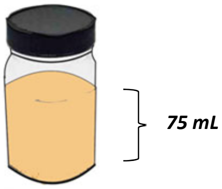
Gardner Color Standard Number	Chromaticity Coordinates[A]		Luminous Transmittance Y, %	Transmittance Tolerance, ±
	x	y		
1	0.3177	0.3303	80	7
2	0.3233	0.3352	79	7
3	0.3329	0.3452	76	6
4	0.3437	0.3644	75	5
5	0.3558	0.3840	74	4
6	0.3767	0.4061	71	4
7	0.4044	0.4352	67	4
8	0.4207	0.4498	64	4
9	0.4343	0.4640	61	4
10	0.4503	0.4760	57	4
11	0.4842	0.4818	45	4
12	0.5077	0.4638	36	5
13	0.5392	0.4458	30	6
14	0.5646	0.4270	22	6
15	0.5857	0.4089	16	2
16	0.6047	0.3921	11	1
17	0.6290	0.3701	6	1
18	0.6477	0.3521	4	1

[A] A duplicate standard shall have chromaticity coordinates that differ from the reference standard by no more than one third of the difference in x or y between adjacent reference standards. In any one set, no two standards shall be closer together than two thirds of the difference in x or y between corresponding reference standards.

STANDARD COLOR SOLUTION PROCEDURE

5 Fill a glass bottle to the **75 mL level (approximately 2 ½ fluid ounces)** with **FRESH** standard color solution. ***Solution CAN NOT be prepared any longer than 2 hours before testing.***

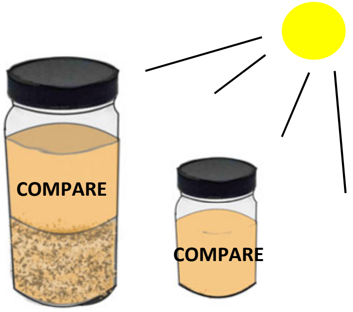
≤ 2 hours



9.2

6 Hold the bottle with the test solution and the bottle with the standard color solution side by side and **compare the color of light transmitted through the supernatant liquid of the test sample and the light transmitted through the standard solution.**

9.2



7 **Record if it's lighter, darker, or equal color** to that of reference standard.

9.2

RESULTS:

- If the color of the liquid above the test sample is **darker than that of Circular Disk No. 14, standard organic plate #3, Gardner Color Standard #14** or the **standard color solution** the fine aggregate being tested shall be considered to **possibly contain injurious organic compounds** and further tests should be done before approving.

AASHTO T304:

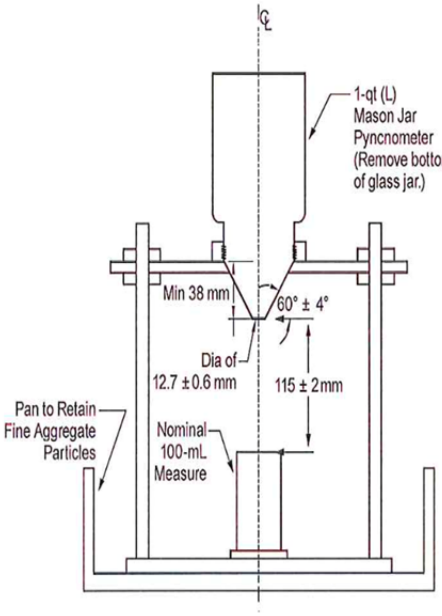
UNCOMPACTED VOID CONTENT OF FINE AGGREGATE

DEFINITIONS:

Angularity- is a description of the degree of roughness, surface irregularities or sharp angles of the aggregate particles.

Void Content - the volume of empty space (voids) between individual aggregate particles, expressed as a percentage of the total volume.

Grading *(aggregates)* - refers to the particle size distribution within a sample of aggregate materials. It describes how well the aggregate particles are mixed and how many of each size are present.



SCOPE:

1.1

This test method describes the determination of the loose uncompacted void content of a sample of fine aggregate. When measured on any aggregate of known grading, void content provides an indication of that aggregate's angularity, sphericity, and surface texture compared with other fine aggregates tested in the same grading.

EQUIPMENT:

6.

- **CYLINDRICAL MEASURE –** a cylinder of approximately 100 mL capacity having an inside diameter of approximately 39mm and an inside height of approximately 86 mm. ***(See Procedure for more detail and all critical dimensions)***
- **FUNNEL –** a metal funnel with an opening 12.7 ± 0.6mm diameter. It shall be at least 38mm high with a volume of at least 200 mL**.** ***(See Procedure for more detail and all critical dimensions)***
- **FUNNEL STAND –** three- or four-legged support capable of holding the funnel firmly in position. The funnel opening shall be 115 ± 2 mm above the top of the cylinder measure. ***(See Procedure for more detail and all critical dimensions)***
- **GLASS PLATE–** a square glass plate approximately 60 mm by 60 mm with a minimum 4 mm thickness.
- **PAN –** a flat metal or plastic pan of sufficient size to contain the funnel stand and to prevent loss of material.
- **METAL SPATULA –** with a blade approximately 100 mm long and at least 20 mm wide. The blade will have straight edges and the end will be cut at a right angle to the edges.
- **BALANCE –** accurate and readable to ± 0.1 grams.
- **THERMOMETER (MEASURING LIQUID) -** with a temperature range of at least 60.8 F to 78.8 F (16 C to 26 C) with an accuracy of an accuracy of ± 0.9°F.

There are 3 methods within this procedure that provide percent void content determined under standardized conditions. An increase in void content determined by these methods indicates greater angularity, less sphericity, or rougher surface texture or some combination of these. A decrease in void content is associated with more rounded, spherical, smooth surfaced fine aggregate, or any combination of these. Each method has its own strengths and weaknesses and should be applied according to agency requirements or procedures.

SAMPLE:

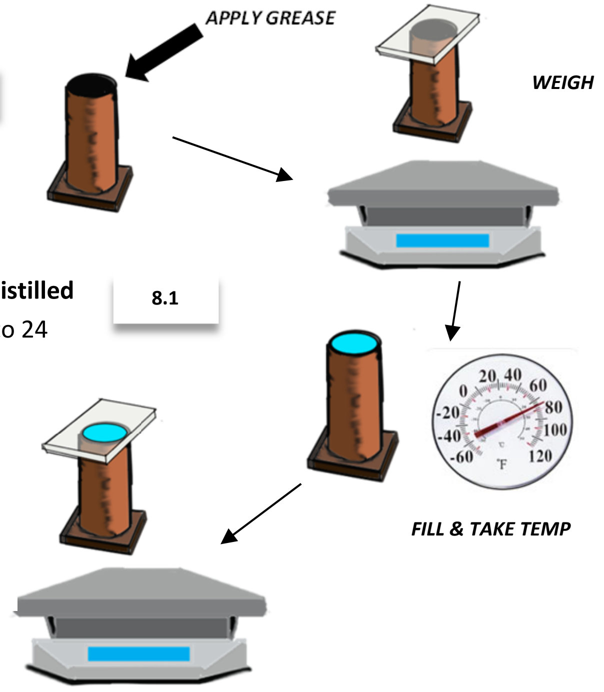
- The sample used for this test will be obtained **according to AASHTO R90** and brought to testing size **according AASHTO R76 OR** from **sieve analysis** samples used for **AASHTO T27**, **OR aggregate extracted** from a **bituminous concrete specimen**. **7.1**
- For **METHODS A & B**, the sample is **washed over a #100 or #200 sieve** according to AASHTO T11 and then dried and **sieved into separate size fractions** according to AASHTO T27. **7.1**
- Place the necessary **different size fractions** obtained from one (or more) sieve analysis in a **dry condition in separate containers.** **7.1**
- For **METHOD C**, **dry a split of the as received sample** according to the drying procedures from **AASHTO T27.** **7.1**

CALIBRATION OF CYLINDRICAL MEASURE:

1 Apply a **light coat of grease** to the **top edge** of the dry, empty cylindrical measure. **Weigh the measure, grease, and glass plate** to the nearest **0.1 grams**. **8.1**

2 **Fill** the measure with **freshly boiled, deionized OR distilled water** at a temperature of **64.4 °F to 75.2 °F** (18 °C to 24 °C). **Record the temperature of the water.** **8.1**

3 Cover the **measure with the plate glass** in a way so as **not to have air bubbles**. Dry the outer surfaces of the measure and **weigh the combined mass of measure glass plate grease, and water** to the nearest **0.1 grams**. **8.1**



4 Following the final weighing **remove the grease and determine the mass** of the **clean, dry, empty measure** for subsequent tests.

8.1

BULK SPECIFIC GRAVITY

8.2

$$V = 1000\left(\frac{M}{D}\right)$$

V = volume of cylinder, mL;
M= net mass of water, g;
D = density of water (see Table 3 in AASHTO T19 SECTION 8), kg/m^3

Determine the volume to the nearest 0.1 mL.

PREPARATION OF SAMPLES

■ ***METHOD A- STANDARD GRADED SAMPLE:*** Weigh out and combine the following quantities of fine aggregate which has been dried and sieved in accordance with AASHTO T27.

METHOD A WILL BE DEMONSTRATED & TESTED ON DURING ATTI

INDIVIDUAL SIZE FRACTION:

Passing #8 screen and retained on #16 screen	**44 ± 0.2 grams**
Passing #16 screen and retained on #30 screen	**57± 0.2 grams**
Passing #30 screen to retained on #50 screen	**72 ± 0.2 grams**
Passing #50 screen to retained on #100 screen	**17 ± 0.2 grams**
	190 ± 0.2 grams

■ ***METHOD B- INDIVIDUAL SIZE FRACTIONS:*** Prepare a separate 190-gram sample of fine aggregate, dried and sieved in accordance with AASHTO T27 in the following table:

INDIVIDUAL SIZE FRACTION:

Passing #8 screen and retained on #16 screen	**190 ± 0.1 grams**
Passing #16 screen and retained on #30 screen	**190 ± 0.1 grams**
Passing #30 screen to retained on #50 screen	**190 ± 0.1 grams**

DO NOT mix these samples together. Each size is tested separately.

- ***METHOD C- AS RECEIVED GRADING:*** Pass the sample (dried in accordance with AASHTO T27) through a #4 sieve. Obtain a 190 ± 1 gram sample of the material passing the #4 screen for testing.

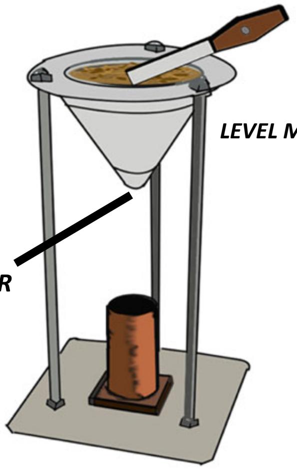
SPECIFIC GRAVITY OF FINE AGGREGATE:

If the bulk dry specific gravity of fine aggregate from the source is unknown, determine it on the material passing the #4 sieve according to AASHTO T84.

PROCEDURE:

1 **Mix** each **test sample** with the spatula until it appears to be **homogenous**. Position the cylinder centered under the funnel ***(See procedure for more detail on equipment set up).*** **10.1**

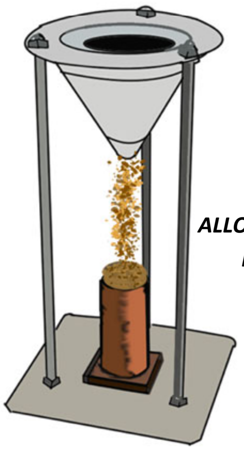
2 Use a **finger to block the opening** of the **funnel** then **pour the test sample into the funnel**. **Level** the material in the funnel with the spatula. **10.1**



3 **Remove the finger and allow the sample to fall freely** into the cylinder measure. **10.1**

4 After the funnel empties, **strike off excess** heaped fine aggregate from the cylinder measure by a **rapid single pass** of the spatula. While striking off keep **width of the blade vertical**, keeping the **straight part of its edge horizontal** and in **light contact with top of the measure**. **10.2**

5 **Brush adhering grains** from the outside of the container and **weigh the mass of the cylinder measure and contents** to the **nearest 0.1 grams**. *Retain all fine aggregate particles for a second run.* **10.2**



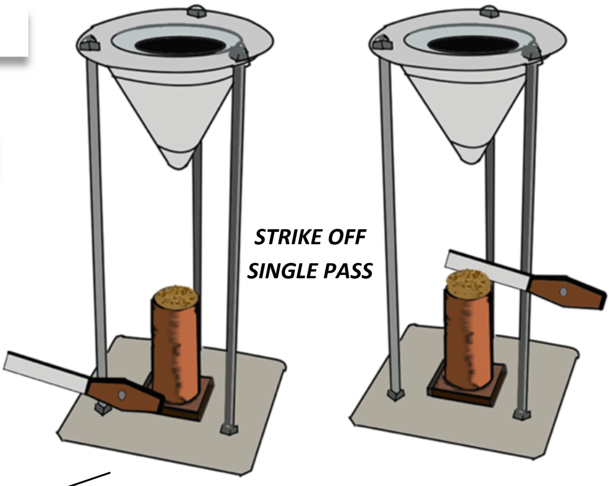
Until this operation is complete avoid vibration or any disturbance that could cause compaction of the fine aggregate in the measure.

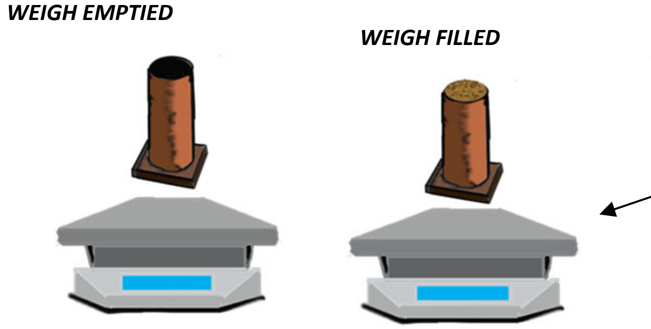
6 **Recombine the material** from the retaining pan and cylinder measure and repeat the procedure. The results of the **2 runs are averaged**.

10.3

7 **Record the mass of the empty measure.** ***(THIS CAN BE DONE BEFORE THE PROCEDURE IS PERFORMED OR AFTER)***

10.3





CALCULATIONS:

METHOD A:

- **For the standard graded sample (Method A) calculate the average uncompacted voids for the two determinations and report the result.**

UNCOMPACTED VOIDS

$$U = \left(\frac{V - \left(\frac{F}{G}\right)}{V}\right) \text{X } 100$$

V = volume of cylinder, mL;
F = net mass, g, of fine aggregate in measure ***(Weight of measure with material – Weight of measure empty)***;
G* = *bulk dry specific gravity of fine aggregate;
U* = *uncompacted voids, percent, in material.

EXAMPLE:

V = 99.9 mL

F = 146.3 g / 146.2 g

G = 2.600

EXAMPLE:

WEIGHT OF EMPTY MEASURE = 187.1 grams

1 ***FIRST RUN***

FIRST RUN = 333.4 grams (measure & material)

333.4 grams – 187.1 grams =

Net Mass (F) = 146.3 grams

$$U = \left(\frac{99.9 - \left(\frac{146.3}{2.600}\right)}{99.9}\right) \text{X } 100$$

UNCOMPACTED VOID CONTENT (U_1) = 43.7% (rounded)

SECOND RUN = 333.3 grams (measure & material)

333.3 grams – 187.1 grams =

Net Mass (F) = 146.2 grams

2 ***SECOND RUN***

$$U = \left(\frac{99.9 - \left(\frac{146.2}{2.600}\right)}{99.9}\right) \text{X } 100$$

UNCOMPACTED VOID CONTENT (U_2) = 43.7% (rounded)

AVERAGE BOTH UNCOMPACTED VOID RESULTS

3 ***AVERAGE*** $= \left(\frac{(43.7+43.7)}{2}\right)$

AVERAGE RESULT = 43.7 %

METHOD B:

- **For the individual size fractions (Method B) calculate:**

First, the average uncompacted voids for the determination made on each of the 3 size fraction samples: EXAMPLE:

U_1 = uncompacted voids #8 to #16 screen, percent;
U_2 = uncompacted voids #16 to #30 screen, percent;
U_3 = uncompacted voids #30 to #50 screen, percent;

AVERAGE (U) = $(\frac{(U_1 + U_2 + U_3)}{3})$

METHOD C:

- **For METHOD C, calculate the average uncompacted voids for the two determinations and report the result.**

AASHTO T335:

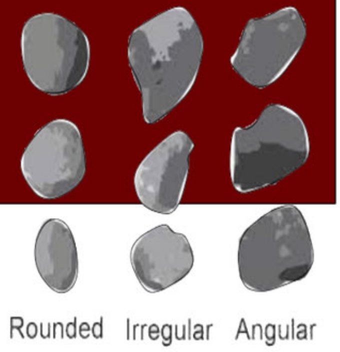
DETERMINING THE PERCENTAGE OF FRACTURE IN COARSE AGGREGATE

DEFINITIONS:

Fractured Face- an angular, rough, or broken surface of an aggregate particle created by crushing or by other means.

Fractured Particle - a particle of aggregate having at least the minimum number of fractured faces specified *(usually one or two).*

Aggregate - a mass or body of rock particles, mineral grains, or a mixture of both.



SCOPE:

1.1

This test method covers the determination of the percentage by mass of a coarse aggregate sample that consists of fractured particles meeting specified requirements.

EQUIPMENT:

5.

- **SIEVES –** sieve set that reflects the sizes indicated in the tables of the procedure.
- **SPLITTER-** meeting the requirements of AASHTO R76.
- **BALANCE –** is at least readable to at least 0.1 percent of the sample mass.

Fractured face materials testing is a quality control method used to assess the degree of crushing or angularity in aggregate. This test is crucial in construction especially for pavement applications because the presence of fractured faces contributes to the interlock and strength of aggregate mixtures.

SAMPLING:

- **Obtain the aggregate** sample according to **AASHTO R90** & **reduce the sample** to the appropriate testing size **according to AASHTO R76.**

6.1

SAMPLE PREP:

- Where the specifications list **only a total fracture percentage**, the sample will be prepared in accordance with **METHOD 1**. When the specification requires that the **fracture be counted and reported on each sieve**, the sample will be prepared in accordance with **METHOD 2.**

7.1

METHOD 1: TOTAL FRACTURE PERCENTAGE

1 **Dry the sample** sufficiently and **sieve over the #4 screen** (or the appropriate sieve listed in the agency specification for the material). The goal is to obtain a **clean separation of fine and coarse material** when sieving. ***(Sieve in accordance with AASHTO T27)*** 7.2.1

Note 1*: where necessary, wash the sample over the sieve designated for the determination of fractured particles to remove any remaining fine material and dry the sample to a constant mass in accordance with AASHTO T255.* 7.2.1

2 **Reduce the sample** using a **splitter according to AASHTO R76** to the appropriate size for testing. The test sample should be **slightly larger** in **mass** than that shown in **Table 1** in the procedure to account for additional loss of fines after washing. 7.2.2

TABLE 1 – Sample Size (Method 1, Combined Sieve Fracture)

Nominal Max Aggregate Size		***Minimum sample mass retained #4 sieve***
1 ½”	◄──►	*2500 grams (6 lbs.)*
1”	◄──►	*1500 grams (3.5 lbs.)*
3/4”	◄──►	*1000 grams (2.2 lbs.)*
1/2”	◄──►	*700 grams (1.5 lbs.)*
3/8”	◄──►	*400 grams (0.9 lbs.)*
#4	◄──►	*200 grams (0.5 lbs.)*

METHOD 2: INDIVIDUAL SIEVE FRACTURE DETERMINATION

1 **Dry the sample** sufficiently. The goal is to obtain a **clean separation of fine and coarse material** when sieving. 7.3.1

2 A **washed sample** from a **gradation determination** (AASHTO T11 and AASHTO T27) may be used. **IF NOT**, sieve the sample according to AASHTO T27 over the **appropriate sieves**. **Select** a **representative portion from each sieve** by **splitting or quartering** according to AASHTO R76 to the appropriate size for testing. The size of the test sample for each sieve should be **at least as large as shown in TABLE 2**. 7.3.1

TABLE 2 – Sample Size (Method 2, Individual Sieve Fracture)

Nominal Max Aggregate Size

1 1/4”	↔	*1500 grams (3.5 lbs.)*
1”	↔	*1000 grams (2.2 lbs.)*
3/4”	↔	*700 grams (1.5 lbs.)*
1/2”	↔	*300 grams (0.7 lbs.)*
3/8”	↔	*200 grams (0.5 lbs.)*
1/4 “	↔	*100 grams (0.2 lbs.)*
#4	↔	*100 grams (0.2 lbs.)*
#8	↔	*25 grams (0.1 lbs.)*
#10	↔	*25 grams (0.1 lbs.)*

***Note 2**: where necessary, wash the sample over the sieve designated for the determination of fractured particles to remove any remaining fine material and dry the sample to a constant mass in accordance with T255.*

7.3.1

***Note 3**: if fracture is determined on a sample obtained for gradation, use the mass retained on the individual sieves unless less than 5 percent of the total mass is retained on that sieve. In that case, place the material with that retained on the next smaller sieve size. If a smaller specification sieve does not exist, this material shall not be included in the fracture determination.*

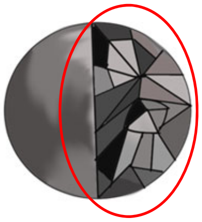
7.3.1

PROCEDURE:

3 Spread the **dried cooled test sample on a clean flat surface** large enough for careful inspection of each particle. To **verify t**hat the particle meets the **fracture criteria** hold the aggregate so the **face is viewed directly**.

8.1

ILLUSTRATION OF FRACTURE FACE OF AGGREGATE



½ OR MORE OF THE AREA OF THE FACE VIEWED DIRECTLY IS FRACTURED = 1 FRACTURED FACE. THEN REPEAT FOR EACH FACE.

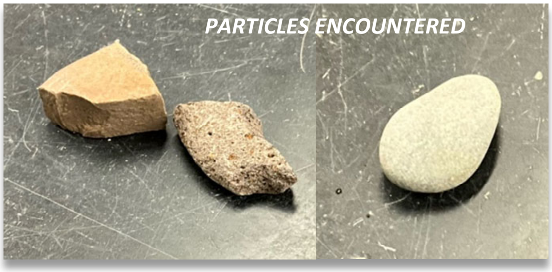
FRACTURED FACE: an angular, rough, or broken surface of an aggregate particle created by crushing, or other means. A face is considered **fractured** whenever **½ or more of the projected area**, when viewed normal to that face, is fractured with **sharp and well-defined edges**. ***(This excludes small nicks)***

3.

4 Separate the sample into **3 categories**: **1.** Fractured particles (as determined by fractured criteria). **2.** Particles not fractured. **3.** Questionable or borderline particles.

8.2

EXAMPLES OF AGGREGATE PARTICLES ENCOUNTERED



5 **Weigh and record the mass of the particles** in the **fractured category**, the mass of **questionable particles**, and the mass of the **unfractured particles** ***(either to the nearest 1 gram or 0.1 lbs.).***

8.3

> *If more than 15% of the total mass of the sample is placed in the questionable category, then reassess your determination and repeat the process until no more than 15% is present in that category.*

CALCULATION:

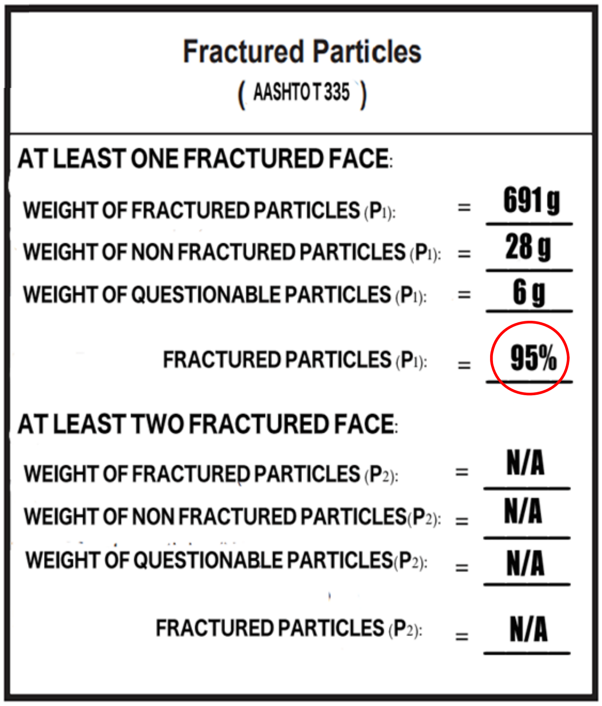
PERCENTAGE OF FRACTURED FACES

$$P = \left(\frac{\left(F-\left(\frac{Q}{2}\right)\right)}{F+Q+N}\right) X\ 100$$

P = percentage of fractured particles (nearest 1%);
F = mass of fractured particles;
***Q** = mass of questionable particles;*
***N** = mass of non-fractured particles.*

95% (rounded to the nearest 1 %) = $\left(\frac{\left(691-\left(\frac{6}{2}\right)\right)}{691+6+28}\right)$X 100

EXAMPLE:



Fractured Particles
(AASHTO T 335)

AT LEAST ONE FRACTURED FACE:

WEIGHT OF FRACTURED PARTICLES (P_1): = 691 g
WEIGHT OF NON FRACTURED PARTICLES (P_1): = 28 g
WEIGHT OF QUESTIONABLE PARTICLES (P_1): = 6 g
FRACTURED PARTICLES (P_1): = 95%

AT LEAST TWO FRACTURED FACE:

WEIGHT OF FRACTURED PARTICLES (P_2): = N/A
WEIGHT OF NON FRACTURED PARTICLES(P_2): = N/A
WEIGHT OF QUESTIONABLE PARTICLES(P_2): = N/A
FRACTURED PARTICLES (P_2): = N/A

AASHTO T19:

BULK DENSITY (“UNIT WEIGHT”) AND VOIDS IN AGGREGATE

DEFINITIONS:

Unit Weight *(Bulk Density)*– is weight per unit volume (or more correctly, mass per unit volume, or density)

Voids – in unit volume of aggregate, the space between particles in an aggregate mass not occupied by solid mineral matter.

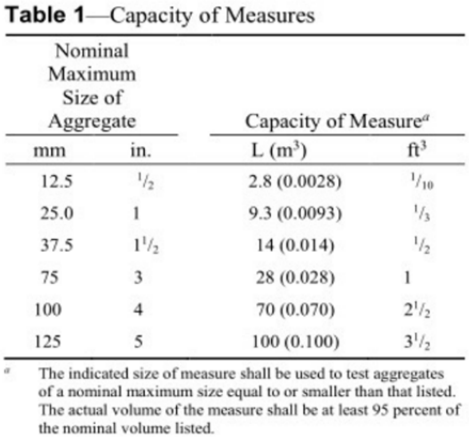


Table 1—Capacity of Measures

Nominal Maximum Size of Aggregate mm	Nominal Maximum Size of Aggregate in.	Capacity of Measure[a] L (m³)	Capacity of Measure[a] ft³
12.5	1/2	2.8 (0.0028)	1/10
25.0	1	9.3 (0.0093)	1/3
37.5	1 1/2	14 (0.014)	1/2
75	3	28 (0.028)	1
100	4	70 (0.070)	2 1/2
125	5	100 (0.100)	3 1/2

[a] The indicated size of measure shall be used to test aggregates of a nominal maximum size equal to or smaller than that listed. The actual volume of the measure shall be at least 95 percent of the nominal volume listed.

Bulk density (Unit Weight) values are necessary for use in many methods of selecting proportions for concrete mixtures. This value can also be used for determining mass / volume relationships for conversions in purchase agreements. AASHTO T19 also includes a way to compute the percentage of voids between the aggregate particles (this does not include voids either permeable or impermeable) based on the bulk density.

SCOPE:

1.1

This test method covers the determination of bulk density (“unit weight”) of aggregate in a compacted or loose condition and calculated voids between particles in fine, coarse, or mixed aggregates based on the same determination.

Procedure not applicable to aggregates not exceeding 5 inches in nominal maximum size.

EQUIPMENT:

5.

- **BALANCE-** That is readable to at least 0.1*lb*.
- **TAMPING ROD –** a round, straight steel rod, 5/8 inch in diameter and approximately 24 inch in length having one end rounded to a hemispherical tip of the same diameter as the rod.
- **MEASURE –** A cylindrical container made of steel or another suitable material preferably with handles. Water tight, with the top and bottom true and even and sufficiently rigid to retain its form under rough usage. The height should be approximately equal to the diameter but in no case shall the height be less than 80% nor more than 150% of the diameter. ***See procedure for full dimensions and requirements.***
- **OVEN –** Thermostatically controlled capable of being heated continuously at a temperature of 230 ± 9°F. The oven shall be capable of a temperature range of 212 °F to 248 °F.
- **THERMOMETER (VERIFYING OVEN) -** a thermometer that has a temp range of at least 194 °F to 266°F with an accuracy of ± 2.25 °F.
- **SHOVEL or SCOOP**
- **PLATE GLASS –** A piece of glass at least ¼” and at least 1 inch larger than the diameter of the measure.
- **GREASE-** A grease that is normally used for water pumps, chassis, or similar.
- **THERMOMETER (LIQUID) -** Having a range of at least 50°F to 90°F with an accuracy of ±0.9°F.

SAMPLING:

- **Obtain the aggregate sample** according to the procedure described in **AASHTO R90** & **reduce the sample** to the appropriate testing size according to **AASHTO R76.**

6.1

TEST SAMPLE:

- The **size of the sample will be approximately 125 to 200 percent of the quantity required to fill the measure** and shall be handled in a manner to avoid segregation.

7.1

- Dry the aggregate **sample** to **constant mass according to AASHTO T255**. **AASHTO T19 definition of constant mass:** when the difference in mass between 2 consecutive weighing's taken 1 hour apart is less than 0.1 percent of the last weighing.

7.1

CALIBRATION:

- Determine the **volume of the measure** when initially obtained and at a frequency not to **exceed 12 months** or whenever there is reason to question the accuracy. **Retain the calibration record in accordance of R18.**

8.1.

8.2.

- First place a thin layer of grease on the rim of the measure.

8.3.

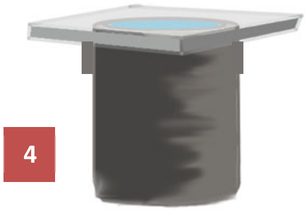
- Determine the mass of the Glass Plate AND Determine the mass of the Measure (*with grease on it)* to the **nearest 0.1*lb or refer to your agencies procedure.***

8.4.

- Fill the measure with water that is room temperature.

8.4.

- Cover the measure with the plate glass in a way so as not to have air bubbles and excess water.



8.5.

- Determine the mass of the water, glass plate, and water to the **nearest 0.1*lb or your agencies procedure.***

8.6.

- Measure the temperature of the water to the **nearest 1°F.**

- **Refer to the capacity of measures (Table 1) to know how many decimal places to record your volume value.**
- **Density of Water Table:** ***(INTERPOLATE WHEN NECESSARY)***

CALCULATION OF VOLUME OR FACTOR:

$$V = \frac{(B-C)}{(D)} \quad \textbf{OR} \quad F = \frac{(D)}{(B-C)}$$

V = Volume of the measure (ft^3);
B = Mass of the water, glass plate, and measure, **(*lb.*)**;
C = Mass of the glass plate, and measure, **(*lb.*)**;
D = Density of the water for the measure, **(lb/ft^3)**;
F = factor for the measure, **($1/ft^3$)**;

°C	°F	kg/m^3	lb/ft^3
15.6	60	999.01	62.366
18.3	65	998.54	62.336
21.1	70	997.97	62.301
23.0	73.4	997.54	62.274
23.9	75	997.32	62.261
26.7	80	996.59	62.216
29.4	85	995.83	62.166

SELECTION OF PROCEDURE:

- **Weigh and record** the mass of the **empty measure** to the **nearest 0.1 lbs. (or 0.05 kg).** 9.1
- The **SHOVELING METHOD *(METHOD C)*** shall be used only when specifically stipulated. Otherwise, the compact bulk density shall be determined by the **RODDING METHOD *(METHOD A)*** for aggregates having a nominal maximum **size of 1 ½" or less** or by the **JIGGING METHOD *(METHOD B)*** for aggregates having a nominal maximum **size greater than 1 ½" BUT not exceeding 5 inches.** 9.2

RODDING METHOD
↓
1 ½" OR LESS
(*NOMINAL MAXIMUM SIZE)*

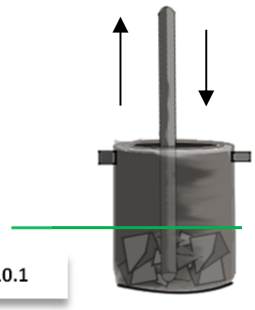
JIGGING METHOD
↓
GREATER THAN 1 ½" LESS THAN 5"
(*NOMINAL MAXIMUM SIZE)*

~~SHOVELING METHOD~~

UNLESS SPECIFICALLY ASKED FOR.

RODDING METHOD (PROCEDURE):

1. **Fill the measure 1/3 full** and **level the surface** with the fingers. 10.1
2. **Rod** the layer of aggregate **with 25 strokes** of the tamping rod **evenly distributed over the surface**. 10.1



Fill 1/3 of the Measure

Rod 25 Times

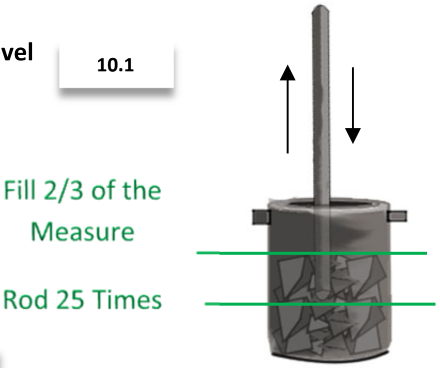
Do not allow the rod to strike the bottom of the measure forcibly when rodding the first layer.

3 Fill the **measure 2/3 full** and **level the surface** with the fingers.

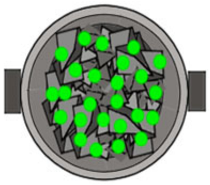
10.1

4 **Rod** the layer of **aggregate with 25 strokes** of the tamping rod **evenly distributed** over the surface.

10.1



TOP VIEW



STROKES EVENLY DISTRIBUTED OVER THE SURFACE

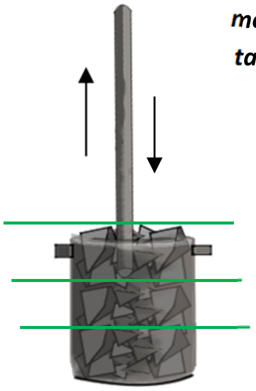
Use vigorous effort but not more force than to cause the tamping rod to penetrate to the previous layer of the second and third layers.

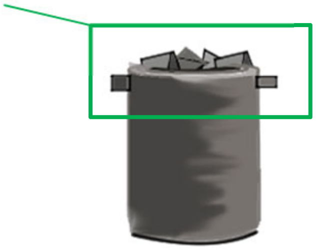
5 **Finally, fill the measure to overflowing**, and repeat rodding.

10.1

6 Level the surface of the aggregate with the fingers or a straightedge in such a way that any slight **projections of the larger pieces of the coarse aggregate (approximately) balance the larger voids in the surface below the top of the measure.**

10.1





7 **Weigh** the mass of the **measure plus the contents**, and record to the **nearest 0.1lbs. (or 0.05 kg).**

10.3

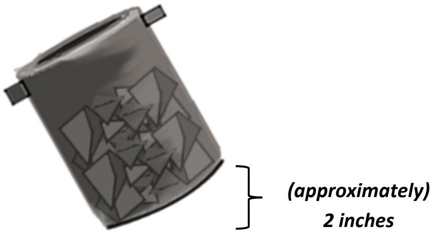
10.2

NOTE 6 – *When rodding the larger sizes of coarse aggregate it may not be possible to penetrate the layer. Just perform the test with vigorous effort. The intent of the procedure will be accomplished when this is done.*

JIGGING METHOD (PROCEDURE)

1 Place the **measure** on a **firm base** (such as a cement floor) and **fill the measure 1/3 full** and **level the surface** with the fingers.

11.1



2 **Compact that layer** by **raising one side about 2 inches** and allowing the measure to drop in such a manner as to hit with a sharp **slapping blow**.

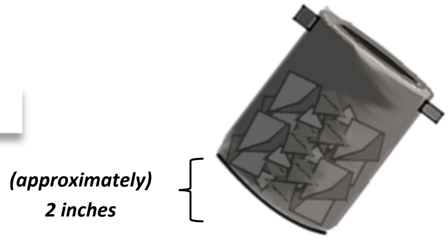
11.1

3 **Repeat on the alternate side**, **raising the measure** about **2 inches** and allowing it to drop in such a manner as to hit with a sharp slapping blow.

11.1

4 **Compact EACH layer** by **dropping** the measure **50 times total, 25 times on each side.**

11.1



5 **Fill** the **measure 2/3 full** and **level the surface** with the fingers and **repeat the above steps.**

11.1

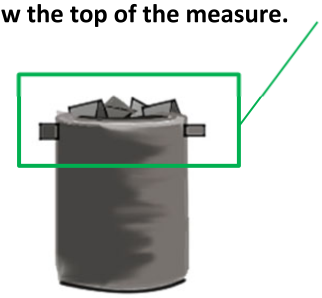
6 **Finally**, **fill the measure to overflowing**, and **continue** the **procedure as outlined above**.

11.1

7 Level the surface of the aggregate with the fingers or a straightedge in such a way that any slight **projections of the larger pieces of the coarse aggregate approximately balance the larger voids in the surface below the top of the measure.**

11.1

..... 25 TIMES EACH SIDE. FOR A TOTAL OF 50 BLOWS. REPEAT FOR EACH LAYER



8 **Weigh** the mass of the **measure plus the contents**, and record to the **nearest 0.1lbs. (or 0.05 kg).**

11.2

SHOVEL METHOD (PROCEDURE):

1 **Fill the measure to overflowing with a shovel or scoop.** **12.1**

2 Discharge the material from a height **not to exceed 2 inches** above the **top of the measure**. **12.1**

3 **Exercise care** to **prevent segregation of the particle sizes** of the sample when placing the test sample into the measure. **12.1**

4 Level the surface of the aggregate with the fingers or a straightedge in such a way that any slight **projections of the larger pieces of the coarse aggregate approximately balance the larger voids in the surface below the top of the measure.** **12.1**

5 **Weigh** the mass of the **measure plus the contents**, and record to the **nearest 0.1lbs. (or 0.05 kg).** **12.2**

CALCULATIONS:

CALCULATION OF BULK DENSITY (UNIT WEIGHT):

$$M = \frac{(G-T)}{(V)} \quad \textbf{OR} \quad M = (G-T) \times F$$

V = Volume of the measure, (ft^3 or m^3);

G = Mass of aggregate plus measure, (*lb. or kg*);

T = Mass of the measure, (*lb. or kg*);

F = Factor for measure, (ft^3 or m^3);

M = Bulk density of aggregate, (lb/ft^3);

EXAMPLE:

VOLUME OF MEASURE: **0.0993**

MASS OF MEASURE: **15.1 lbs.**

MASS OF MEASURE & CONTENTS: **24.7 lbs.**

BULK SPECIFIC GRAVITY (DRY BASIS ACCORDING TO AASHTO T85): **2.600**

$$M = \frac{(24.7-15.1)}{(0.0993)}$$

$M = 97\ lb/ft^3$

- **Report the bulk density** to the **nearest 1** (lb/ft^3) **OR 10** (kg/m^3)

CALCULATION OF VOID CONTENT:

%Voids = $\frac{100[(S*W)-M]}{(S*W)}$

W = Density of water, **(62.3**lb/ft^3 or **998** kg/m^3 **);**
S = Bulk specific gravity (oven dry basis) as determined by AASHTO T84 or AASHTO T85**;**
M = Bulk density of aggregate, **(**lb/ft^3 or kg/m^3);

% Voids = $\frac{100[(2.600*62.3)-97]}{(2.600*62.3)}$

% Voids = 40%

- **Report the percent voids** to the **nearest 1 percent.**

- **This procedure outlines the method of determining the bulk density of aggregate in the oven-dry condition. If the bulk density in terms of saturated surface-dry (SSD) condition is desired, use the exact procedure in AASHTO T19 and then calculate using the following formula:**

CALCULATION OF BULK DENSITY SSD (UNIT WEIGHT):

Mssd = M [1 + ($\frac{A}{100}$ **)]**

Mssd = Bulk density in SSD condition of aggregate, **(**lb/ft^3 or kg/m^3);
A = Absorption, percent, as determined by AASHTO T84 or AASHTO T85**;**
M = Bulk density of aggregate, **(**lb/ft^3 or kg/m^3);

AASHTO T255:

STANDARD METHOD OF TEST FOR TOTAL EVAPORABLE MOISTURE CONTENT OF AGGREGATE BY DRYING.

SCOPE:

1.1.

This test method covers the determination of the percentage of evaporable moisture in a sample of aggregate by drying both surface moisture and moisture in the pores of the aggregate.

EQUIPMENT:

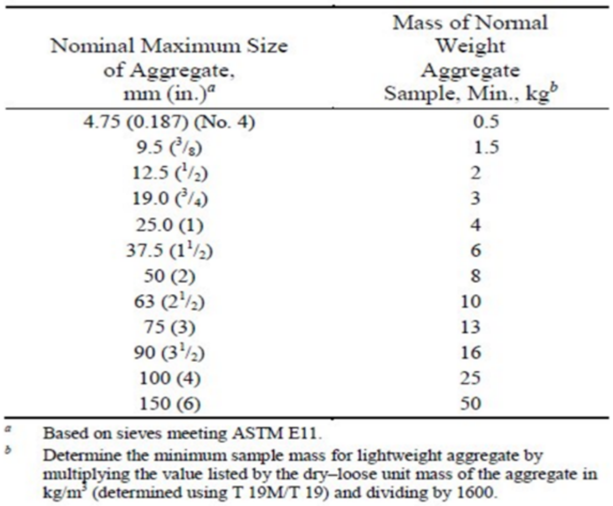
5.

- **SOURCE OF HEAT –** Thermostatically controlled AND ventilated oven capable of being heated continuously at a temperature of 230 ± 9°F. Other sources of heat can be used such as a hot plate, electric heat lamps and a ventilated microwave oven.
- **BALANCE –** Readable to at least 0.1 % of the sample mass.
- **CONTAINERS –** Made of material resistant to corrosion and not subject to change in mass by repeated heating and cooling. Volume enough to contain the sample without spilling and where the sample depth that will not exceed one-fifth of the least lateral dimension.
- **STIRRER**

SAMPLE:

- For sampling utilize **R90 & the sample shall conform to Table 1** in the procedure.

6.1.



Nominal Maximum Size of Aggregate, mm (in.)[a]	Mass of Normal Weight Aggregate Sample, Min., kg[b]
4.75 (0.187) (No. 4)	0.5
9.5 ($^{3}/_{8}$)	1.5
12.5 ($^{1}/_{2}$)	2
19.0 ($^{3}/_{4}$)	3
25.0 (1)	4
37.5 (1$^{1}/_{2}$)	6
50 (2)	8
63 (2$^{1}/_{2}$)	10
75 (3)	13
90 (3$^{1}/_{2}$)	16
100 (4)	25
150 (6)	50

[a] Based on sieves meeting ASTM E11.

[b] Determine the minimum sample mass for lightweight aggregate by multiplying the value listed by the dry–loose unit mass of the aggregate in kg/m^3 (determined using T 19M/T 19) and dividing by 1600.

- Obtain the representative aggregate sample having a mass that is **at least minimum amount** that is outlined in the table. 6.1.

- **Protect** the sample from a **loss of moisture** before determining the mass of the sample. 6.2.

EXAMPLE OF WAY TO PROTECT SAMPLE FROM LOSS OF MOISTURE

PROCEDURE:

Rapid heating may make particles explode losing material. Use controlled heating. If not possible then stir constantly to avoid over localized heating.

1 **Weigh and record** the **mass** of the moist sample to the nearest **0.1%.** 7.1.

2 **Dry** the sample in the sample container by means of the selected **source of heating**. Avoid loss of particles. 7.2.

Contant Mass:
Sample is dry when further heating causes less than 0.1% additional loss in mass.

3 Once dried weigh and record the mass of the dried sample to the **nearest 0.1%** after it has cooled to the point where it won't damage the balance. 7.4.

CALCULATION:

TOTAL EVAPORABLE MOISTURE CONTENT CALCULATION

$$P = \frac{100*(W-D)}{D}$$

P = total evaporable moisture content of sample (percent);
W = mass of original sample (grams);
D = mass of dried sample (grams)

WHAT IS THE SURFACE MOISTURE CONTENT?

It's the difference between the total evaporable moisture content result and the absorption. All values are based on the mass of a dry sample. Absorption can be determined by T85 or T84

PRACTICE QUESTIONS:

1. When performing **AASHTO T255** what does the technician determine the mass of the dried sample to?
   a. 0.01%
   b. 0.001%
   c. 0.1%

2. When performing **AASHTO T19 RODDING METHOD** how many times is **EACH** layer rodded?
   a. 50 times
   b. 25 times
   c. 75 times

3. According to **AASHTO T335** an aggregate face is considered **fractured** whenever **______ or more of the projected area**, when viewed normal to that face, is fractured with **sharp and well-defined edges**.
   a. 1/2
   b. 3/4
   c. 25%

4. When performing AASHTO T304 when the funnel empties into the measure how many passes with the spatula should the technician make to remove **the excess** heaped fine aggregate from the cylinder measure?
   a. As many as it takes
   b. Up to 2 passes
   c. 1 pass

5. When performing **AASHTO T176**, split or quarter enough material, from ______ to _______ grams portion passing the #4.
   a. 300, 500
   b. 1000, 1500
   c. 50, 100

ANSWERS:

1. c
2. b
3. a
4. c
5. b