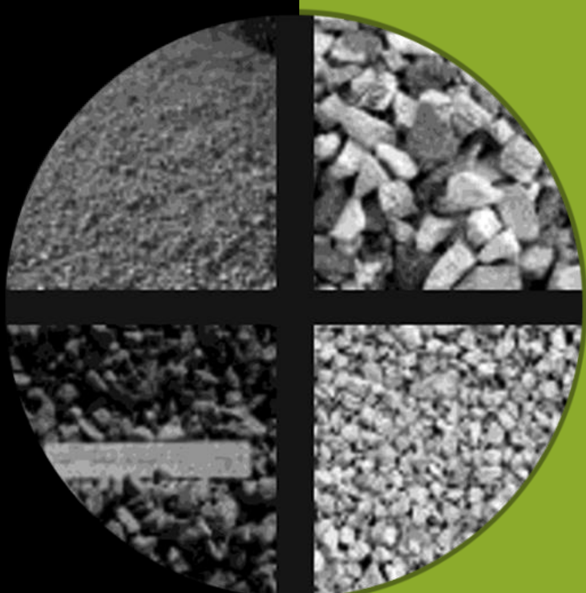
HMEC

Highway Materials Engineering Course

INDEPENDENT STUDY



Laboratory Experience: Physical Properties of Aggregates

MODULE

D

U.S.Department of Transportation
Federal Highway Administration

Table of Contents

Important Note

You must complete Module D Lesson 1 and Lesson 2 before visiting your state or district laboratory in this lesson, Module D Lesson 3.

Using This Independent Study Workbook

This self-guided workbook contains the information you need to complete this lesson. Throughout the workbook, instructions are provided that explain how to complete each section. Following the instructions provided ensures that you will successfully complete the independent study lesson. Make sure that you read all required information, complete exercises, document observations, and answer knowledge check questions as instructed.

Be sure to have your completed workbook available when you attend the Web-conference training (WBT) portion of this module, as the information and your answers, observations, and findings will be reviewed and discussed.

Lesson 3 Introduction

Welcome to Module D: Aggregates for Transportation Construction Projects, Lesson 3: Laboratory Experience: Physical Properties of Aggregates. In this lesson, you will be visiting your State or district laboratory to observe or perform basic tests. By the end of this lesson, you will be able to:

- List the most commonly specified gradation parameters and how they are determined in the lab;
- List the most commonly specified cleanliness parameters and how they are determined in the lab;
- List the most commonly specified strength parameters and how they are determined in the lab;
- List the most commonly specified hardness parameters and how they are determined in the lab;
- List the most commonly specified abrasion, wear, and degradation parameters and how they are determined in the lab;
- List the most commonly specified aggregate shape characteristics parameters and how they are determined in the lab;
- List the most commonly specified pore properties parameters and how they are determined in the lab; and
- List the most commonly specified volume stability parameters and how they are determined in the lab.

This lesson will take approximately 8 hours to complete.

References

To complete this lesson, you will need the following resources:

- Your agency’s standard specifications for highway and bridge construction (or equivalent)
- American Association of State Highway and Transportation Officials (AASHTO) Standard Specifications for Transportation Materials and Methods of Sampling and Testing, 33rd (or most current) Edition and AASHTO Provisional Standards, 2013 (or most current) Edition
- American Society for Testing and Materials (ASTM) Annual Book of Standards, Volume 04.02 (most current), Concrete and Aggregates

Instructions: Preparing for Your Lab Visit

This independent study lesson requires you to visit your State or district laboratory to either participate or watch a demonstration of select aggregate tests for key physical properties of coarse and fine aggregates.

The key physical properties or characteristics are:

- Gradation
- Cleanliness
- Hardness
- Abrasion, wear, and degradation
- Aggregate shape

The goal of this lesson is that you participate in at least one lab related to each key aggregate characteristic. Additional tests outside of these characteristics are also possible, depending on the capabilities of your laboratory and the time available. Ideally, you will be able to either participate in or observe all of the routine aggregate tests performed by your agency laboratory.

The "Master List of Aggregate Tests" table lists the tests that are included in this independent study manual. You will only complete the labs available at your State or district laboratory. However, because each laboratory has different capabilities, driven by the different needs of each State or district, this workbook provides a comprehensive list of tests above and beyond what you will need.

When you contact your State or district lab (see the section "Contacting Your State/District Laboratory"), you should receive a list of the specific tests that will be completed during your visit as well as the laboratory data sheets for each test. These data sheets not only allow efficient data entry, but also put the information in the proper format for analysis. You can use this list of tests to prepare for your visit to the lab. In the Master List of Aggregate Tests table, there are preparation activities for each test. Make sure that you complete the preparation activities for each lab you will participate in before your lab visit.

In addition, make sure that you review the agency specifications you compiled in Lesson 1.

Finally, prepare a list of questions you have concerning any of the procedures you will observe or participate in during your laboratory visit.

	After you complete your lab visit, answer the knowledge check questions at the end of this lesson to prepare for Lesson 4: Introduction to Web-Conference Training (WCT) Session #1.

Tests to Be Demonstrated

The following Master List of Aggregate Tests lists the tests that are included in this independent study manual. Use this table to indicate the specific tests that will be conducted during your visit to the State/district laboratory. Then, complete any preparation activities for the tests you will participate in during your visit.

The following tests are required for basic understanding of aggregate properties:

- Aggregate sampling (AASHTO T 2)
- Sample preparation (AASHTO T 248)
- Aggregate gradation of both fine and coarse aggregates (AASHTO T 27)
- Wash loss (determination of minus No. 200) (AASHTO T 111)
- Moh's Hardness (using the supplied kit)
- Los Angeles abrasion (AASHTO T 96)
- Bulk specific gravity of fine and coarse aggregates (AASHTO T 84 and T 85)

The remainder of the tests shown in the following table should be performed or observed, if possible, in addition to specific tests routinely performed by your Agency laboratory.

Master List of Aggregate Tests

Test Y/N	Aggregate Property	Other Terminology	AASHTO Standard	ASTM Standard	Test Name	Test Preparation Activities
	Sampling		T 2	D 75	Sampling of Aggregates	• Read the AASHTO T 2 procedure in its entirety.
	Sample Preparation	Sample Splitting	T 248		Reducing Samples of Aggregate to Testing Size	• Read the AASHTO T 248 procedure in its entirety.
	Gradation	Sieve Analysis Gradation Test	T 27	C 136	Sieve Analysis of Fine and Coarse Aggregates	• Read the AASHTO T 27 procedure in its entirety. • Obtain the laboratory data sheets or review the procedure template in the laboratory analysis software, if applicable. This information should be available from your agency laboratory.

Test Y/N	Aggregate Property	Other Terminology	AASHTO Standard	ASTM Standard	Test Name	Test Preparation Activities
	Gradation	Wash Loss	T 11	C 117	Materials Finer than Materials Finer than 75-µm (#200) Sieve in Mineral Aggregates by Washing	• Read the AASHTO T 11 procedure in its entirety. • Obtain the laboratory data sheets or review the procedure template in the laboratory analysis software, if applicable. This information should be available from your agency laboratory.
	Gradation	Hydrometer Test	T 88		Particle Size Analysis of Soils: Hydrometer Test	• Read the AASHTO T 88 procedure in its entirety. • Obtain the laboratory data sheets or review the procedure template in the laboratory analysis software, if applicable. This information should be available from your agency laboratory.
	Cleanliness	Sand Equivalent	T 176	D 2419	Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test	• Read the AASHTO T 176 procedure in its entirety. • Obtain the laboratory data sheets or review the procedure template in the laboratory analysis software, if applicable. This information should be available from your agency laboratory.

Test Y/N	Aggregate Property	Other Terminology	AASHTO Standard	ASTM Standard	Test Name	Test Preparation Activities
	Cleanliness	Clay Content in Fine Aggregates	T 330	C 837	The Qualitative Detection of Harmful Clays of the Smectite Group in Aggregates Using Methylene Blue	• If this test is performed by your laboratory, read the AASHTO T 330 procedure in its entirety. • Obtain the laboratory data sheets or review the procedure template in the laboratory analysis software, if applicable. This information should be available from your agency laboratory.
	Cleanliness	Plasticity Index (PI)	T 89 and T 90		Determining the Liquid Limit, Plastic Limit and Plasticity Index of Soils	• If this test is performed by your laboratory for aggregate fines, read the AASHTO T 89 and 90 procedures in their entirety. • Obtain the laboratory data sheets or review the procedure template in the laboratory analysis software, if applicable. This information should be available from your agency laboratory.

Test Y/N	Aggregate Property	Other Terminology	AASHTO Standard	ASTM Standard	Test Name	Test Preparation Activities
	Cleanliness	Adherent Coatings of Coarse Aggregates			Method of Test for Evaluating Cleanness of Aggregate (California CT 227 Standard)	• If this test is performed by your laboratory, read the CT 227 procedure in its entirety. • Obtain the laboratory data sheets or review the procedure template in the laboratory analysis software, if applicable. This information should be available from your agency laboratory.
	Strength and Deformation	Resilient Modulus	T 307		Determining the Resilient Modulus of Soils and Aggregate Minerals	• If this test is performed by your laboratory, read AASHTO T 307 sections pertaining to unbound aggregate testing as this will be an increasingly important test protocol in the future. • Obtain the laboratory data sheets or review the procedure template in the laboratory analysis software, if applicable. This information should be available from your agency laboratory.
	Hardness	Mohs Hardness				• No advance preparation is required for this exercise. • A Mohs hardness test kit will be provided for your use in the lab; however, if you received the test kit directly, please bring it to the laboratory session.

Test Y/N	Aggregate Property	Other Terminology	AASHTO Standard	ASTM Standard	Test Name	Test Preparation Activities
	Hardness	Polished Stone Value	T 279		Accelerate Polishing of Aggregates Using the British Wheel	• If this test is performed by your laboratory, read AASHTO T 279 procedure in its entirety. • Obtain the laboratory data sheets or review the procedure template in the laboratory analysis software, if applicable. This information should be available from your agency laboratory.
	Abrasion, Wear, and Degradation	LA Abrasion	T 96	C 131	Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine	• Read the AASHTO T 96 procedure in its entirety. • Obtain the laboratory data sheets or review the procedure template in the laboratory analysis software, if applicable. This information should be available from your agency laboratory.
	Abrasion, Wear, and Degradation	LA Abrasion		C 535	Resistance to Degradation of Large-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine	• Read the ASTM C 535 procedure in its entirety. • Obtain the laboratory data sheets or review the procedure template in the laboratory analysis software, if applicable. This information should be available from your agency laboratory.

Test Y/N	Aggregate Property	Other Terminology	AASHTO Standard	ASTM Standard	Test Name	Test Preparation Activities
	Abrasion, Wear, and Degradation	Micro Deval	T 327	D 6928	Resistance of Coarse Aggregate to Degradation by Abrasion in the Micro-Deval Apparatus	• If this test is performed by your laboratory, read the AASHTO T 327 (ASTM D 6928) procedure in its entirety. • Obtain the laboratory data sheets or review the procedure template in the laboratory analysis software, if applicable. This information should be available from your agency laboratory.
	Abrasion, Wear, and Degradation			D 7428	Resistance of Fine Aggregate to Degradation by Abrasion in the Micro-Deval Apparatus	• If this test is performed by your laboratory, read the ASTM D 7428 procedure in its entirety. • Obtain the laboratory data sheets or review the procedure template in the laboratory analysis software, if applicable. This information should be available from your agency laboratory.
	Shape Characteristics	Fractured Faces	T 335	D 5821	Determining the Percent of Fracture in Coarse Aggregate	• Read the AASHTO T 335 procedure in its entirety. • Obtain the laboratory data sheets or review the procedure template in the laboratory analysis software, if applicable. This information should be available from your agency laboratory.

Test Y/N	Aggregate Property	Other Terminology	AASHTO Standard	ASTM Standard	Test Name	Test Preparation Activities
	Shape Characteristics	Elongated Particles		D 4791	Standard Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate	• Read the ASTM D 4791 procedure in its entirety. • Obtain the laboratory data sheets or review the procedure template in the laboratory analysis software, if applicable. This information should be available from your agency laboratory.
	Shape Characteristics	Uncompacted Voids in Coarse Aggregate	T 326		Uncompacted Void Content of Coarse Aggregate (as Influenced by Particle Shape, Surface Texture, and Grading)	• If this test is performed by your laboratory, read the AASHTO T 326 procedure in its entirety. • Obtain the laboratory data sheets or review the procedure template in the laboratory analysis software, if applicable. This information should be available from your agency laboratory.
	Pore Properties	Bulk Specific Gravity of Fine Aggregate	T 84		Specific Gravity and Absorption of Fine Aggregate	• Read the AASHTO T 84 procedure in its entirety. • Obtain the laboratory data sheets or review the procedure template in the laboratory analysis software, if applicable. This information should be available from your agency laboratory.

Test Y/N	Aggregate Property	Other Terminology	AASHTO Standard	ASTM Standard	Test Name	Test Preparation Activities
	Pore Properties	Bulk Specific Gravity of Coarse Aggregate	T 85		Specific Gravity and Absorption of Coarse Aggregate	• Read the AASHTO T 85 procedure in its entirety. • Obtain the laboratory data sheets or review the procedure template in the laboratory analysis software, if applicable. This information should be available from your agency laboratory.
	Volume Stability of Aggregate Particles	Coefficient of Thermal Expansion	T 336		Coefficient of Thermal Expansion of Hydraulic Cement Concrete	• This test will not be performed in the lab as part of Lesson 3. • Review the reference information provided for this test in this document.
	Volume Stability of Aggregate Particles	Alkali-Silica Reactivity Rest		C 1260	Test Method for Potential Reactivity of Aggregates (Mortar-Bar Test)	• This test will not be performed in the lab as part of Lesson 3. • Review the reference information provided for this test in this document.
	Volume Stability of Aggregate Particles	Alkali-Carbonate Reactivity Test		C 295	Standard Guide for Petrographic Examination of Aggregates for Concrete	• This test will not be performed in the lab as part of Lesson 3. • Review the reference information provided for this test in this document.

Contacting Your State/District Laboratory

At least two weeks prior to your lab visit (earlier if possible), contact your State or district laboratory to arrange for a day-long visit to either perform or have demonstrated key aggregate tests. Note that the list of tests provided is not all inclusive and you should consult with the laboratory manager to determine what other tests might be applicable.

The important points to discuss with the laboratory manager include the following:

- Explain briefly the basis for the visit (i.e. part of a comprehensive training course).
- Ask what is the best day (date) to visit?
- Establish which tests will be performed. This should be based on the tests listed in this lesson and the recommendation of the laboratory manager. Ideally, you would like to observe the entirety of the tests they routinely perform.
- Discuss which tests you will actually participate in and which you will simply observe. When you have agreed on the specific tests, make certain that you have the specification designation and data sheet for each test.
- Provide the Laboratory with the "Suggested Guidelines for the Highway Materials Engineering Course (HMEC) Student Visit and Lab Experience" document which provides guidelines and recommendations for maximizing your laboratory experience. Request that in the interest of time, the sample preparation for each test will be completed before your visit.

Schedule your visit.

During your visit, use this workbook and the applicable standards and laboratory data sheets to take notes during each lab.

Aggregate Sampling and Preparation

Proper sampling and sample preparation is required for all aggregate tests in order to ensure that the tests are performed on representative materials. Improper sampling and preparation will still provide results but they will not be meaningful.

The following sampling and preparation procedures are provided in this workbook.

AASHTO Standard	ASTM Standard	Test Name
T 2		Sampling of Aggregates
T 248		Reducing Samples of Aggregate to Testing Size

AASHTO T 2 Standard Test Method for Sampling Aggregates	
Background Information	The validity of aggregate test results is dependent on the sampling. Obtaining a representative sample of sufficient quantity for all of the tests to be performed is the initial step in aggregate characterization.
Summary of Test Method	A YouTube video produced by the Oklahoma Department of Transportation is available that describes the entire sampling process. The video can be downloaded at: http://www.youtube.com/watch?v=qmCBnteY7NA
Significance and Use	The AASHTO T 2 procedure is used to obtain representative aggregate samples from a variety of sources including stockpiled aggregates and those on conveyor belts. The test results are only as valid as the sample on which they are performed. Obtaining a truly representative sample is sometimes challenging particularly for large aggregate stockpiles. However, using proper procedures as outlined in AASHTO T 2 will result in the most representative sample available.
Related Tests and Specifications	All aggregate tests
Timeline for Completion	Preparation Time: 5–15 minutes Assemble necessary equipment and choose location for sampling. Test (Sampling) Time: 15–30 minutes Obtain sample, note that the minimum sample size is dictated by the tests to be performed and the maximum aggregate size. Calculation Time: None Total Test (Sampling) Time: 20–45 minutes
Notes for Independent Study	Obtain samples for the fine and coarse aggregate tests selected to be performed in the laboratory.

AASHTO T 248 Standard Test Method for Reducing Sample to Testing Size	
Background Information	The aggregate sampling process (AASHTO T 2) results in a sample that is a multiple of the amount needed to perform routine tests (typically four times as much, or more). The AASHTO T 248 procedure is used to divide the sample into the required amount for performing each test.
Summary of Test Method	A YouTube video produced by the Oklahoma Department of Transportation is available that describes the entire testing process. The video can be downloaded at: http://www.youtube.com/watch?v=95_j9RDTeME
Significance and Use	The AASHTO T 248 procedure is used to obtain representative aggregate samples from the larger amount of material sampled in AASHTO T 2. Each aggregate test procedure has a specific minimum sample requirement. In order for the tests to provide valid results, the sample must be representative of the overall aggregate source (stockpile, hopper, etc.). The AASHTO T 248 procedure provides a method to obtain the proper sample size for any test procedure.
Related Tests and Specifications	All aggregate tests
Timeline for Completion	Preparation Time: 5–10 minutes Assemble necessary equipment Test (Splitting) Time: 5–15 minutes Split sample using either a sample splitter or by manually dividing sample. Calculation Time: None Total Test (Splitting) Time: 10–25 minutes

Notes for Independent Study	Split samples for coarse and fine aggregate gradation tests. Retain excess sample for possible use in other tests.

Aggregate Gradation Tests

Gradation tests are the most widely used quality control and quality assurance tests for aggregates, regardless of end use. Grading is important to almost all uses of aggregates; it is the most often specified property, and it can be modified through processing.

Sieve analysis is covered in the soils module; however, there are differences in the way aggregates are tested for grading compared to the testing of a granular soil.

The following gradation tests are provided in this workbook.

AASHTO Standard	ASTM Standard	Test Name
T 27	C 136	Sieve Analysis of Fine and Coarse Aggregates
T 11	C 117	Materials Finer than 75-µm (#200) Sieve in Mineral Aggregates by Washing
T 88		Particle Size Analysis of Soils: Hydrometer Test

AASHTO T 27 Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates	
Background Information	Aggregate gradation is used for a variety of purposes, including Portland cement concrete (PCC) and asphalt concrete (AC) mix design and proportioning, suitability as a base/subbase layer, quality control and quality assurance during processing, and a variety of related purposes.
Summary of Test Method	A YouTube video produced by the Oklahoma Department of Transportation is available that describes the entire testing process. The video can be downloaded at: http://www.youtube.com/watch?v=MKb8V8e7Ne8 Prior to beginning the analysis, verify that the sieves are clean and assembled according to the appropriate specification. For example, when performing the sieve analysis on fine aggregate used for PCC, the following sieves must be present in order to calculate fineness modulus: #s 4, 8, 16, 30, 50, and 100. In addition to these required sieves, a 3/8 in. and #200 would also be present, at a minimum. Consult your agency specifications regarding the appropriate sieve sizes to use, noting that these may differ depending on end use. The following terms are used to describe common gradation parameters: Percent retained: Generally understood to be the amount retained on a sieve in the sieve analysis and which amount has passed through the next coarser sieve. Some agencies use the term percent retained to refer to cumulative percent retained. Percent passing: Generally understood to be the amount passing the sieve on a cumulative basis. So the amount is not just the material passing that sieve and retained on the next size down, but the total amount of all the material passing the sieve. Cumulative percent retained: The sum of the retained amounts on the sieve size and all of the coarser sieves above it that retain material. Occasionally, a specified grading may be given in terms of percent retained, and it will have to be determined whether it is intended to be cumulative percent retained or refers to

	specified amounts retained within a particular sieve fraction—passing one sieve and retained on the next size lower.
Significance and Use	The AASHTO T 27 procedure is used to determine the grading (particle size distribution) of aggregates. Overall gradation is based on the maximum aggregate size and additional size fractions as identified in the appropriate specification and based on intended use. Note that material finer than the #200 sieve cannot be accurately determined by this test and will require the T 11 procedure to be performed separately. However, the minus #200 material is still determined and recorded in T 27 and will be added to the T 11 results. The laboratory gradation test is indicative of actual field conditions only if the aggregate stockpiles are thoroughly blended with no segregation. Quality control measures at most PCC and AC production plants ensure that the gradations closely adhere to stockpile conditions. Aggregates used for bases, subbases, select fill, and other similar uses may experience some level of segregation in processing, handling, and placement and may differ somewhat from the laboratory determined gradation.
Related Tests and Specifications	**AASHTO T 2**, Sampling of Aggregates **AASHTO T 248**, Reducing Samples of Aggregate to Testing Size **AASHTO T 11**, Materials Finer Than 75-µm (#200) Sieve in Mineral Aggregates by Washing **AASHTO M 43 (ASTM 448)**, Sizes of Aggregates for Road and Bridge Construction
Timeline for Completion	Preparation Time: 10–20 minutes The sieves must be inspected prior to use and cleaned if necessary. The sieves should be stacked according to the specification requirements for end use. Test Time: 20–40 minutes

	The sieve analysis is performed on oven dry samples. Note that when emptying each sieve, no material should be left, including those that may be trapped in the sieve. Calculations: 5 minutes Total Test Time: 35–65 minutes *The times stated assume that the samples are prepared prior to the test.
Notes for Independent Study	In this exercise, we are going to perform a sieve analysis on both coarse and fine aggregate samples. These materials should be prepared ahead of the lab by using proper sampling, splitting, and drying.

Apparatus

- Sieves used for fine aggregate sieve analysis

Figure 1: Sieves

- Sieve stack in the shaker

Figure 2: Sieve stack in the shaker

- Sieves used for coarse aggregate sieving

Figure 3: Sieves used for coarse aggregates

Sample Preparation

Aggregate samples should be obtained according to AASHTO T 2 and reduced to the appropriate sample size according to AASHTO T 248.

For a #57 gradation, this would equate to a minimum 88-lb. sample split to a sample size of at least 22 lbs. For the fine aggregate portion, a minimum of 2 lbs. is generally required based on maximum aggregate size.

The sample must be dried to a constant weight at 230 °F ± 9° and cooled prior to performing the analysis. In order to complete the analysis in the allotted time, the samples should be dried and cooled prior to your visit.

Common Errors

The most common errors in performing a sieve analysis include:

- Improper cleaning of the sieves prior to testing
- Failure to remove all of the aggregates retained on each sieve
- Damaged or worn sieves
- Mistakes in entering data or in calculation

AASHTO T 11 Standard Test Method for Materials Finer than 75-µm (#200) Sieve in Mineral Aggregates by Washing	
Background Information	Material passing the 75-µm (#200) sieve is often referred to as fines. The fines can have a significant impact on performance of PCC, AC, and aggregates used as a pavement support layer. The surface area of the fines is very large relative to their weight or volume. Therefore, the water demand or the water required to wet the surface is much larger than an equivalent weight of larger particles.
Summary of the Test Method	A YouTube video produced by the Oklahoma Department of Transportation is available that describes the entire testing process. The video can be downloaded at: http://www.youtube.com/watch?v=e3yG7EzI21A The following methods are used to determine the minus #200 size fraction: Dry sieving: Normally, a #200 sieve is included in a dry sieve analysis of fine aggregate. However, dry sieving is not effective in causing all of the finest sizes to pass the #200 screen during the shaking process. Fines tend to be retained on the coarser screens due to static charges and the tendency of these fines to become airborne during shaking. Wet sieving: Where accurate determination of the percent passing the #200 (0.075 um) sieve is required, wet sieving in accordance with AASHTO Method T 11 (ASTM C 117) should be used. This is especially important in characterizing samples of graded aggregate or soil aggregate base or subbase material. Wetting agents such as Calgon or other detergents may be needed to promote adequate separation of the finest particles. A wetting agent is optional in both the AASHTO and ASTM test standards. Normally, the minus #200 determination by wet sieving will be done on the sample prior to dry sieving. The amount of minus #200 by washing then is added to any additional minus #200 picked up in the dry sieving process. In that case, the reported minus #200 value is the sum by washing and dry sieving. This procedure is used only to determine the amount of materials finer than the 75-µm (#200) sieve and is typically performed in concert with the AASHTO T 27 dry sieve procedure.

	Due to the nature of the fines adhering to the larger aggregates, water is required to remove them. The test is widely referred to as the “wash loss” test for this reason. This test is performed on a representative sample of aggregates that will typically be used in for the dry sieve analysis.
Significance and Use	Depending on the nature of the fines, the fines may have a number of different consequences. For instance, plastic fines in AC may lead to poor adhesion of the liquid asphalt cement to the aggregates. In the case of base material, plastic fines may increase the moisture sensitivity. The decision to use a wetting agent or only water is clearly defined in the AASHTO procedure. It is important to remember that the minus #200 material from the wash loss must be added to the dry sieve results. Since we are doing this as a standalone test, it will provide a good comparison between the T 11 and T 27 results. The laboratory gradation test is indicative of actual field conditions if the aggregate stockpiles are thoroughly blended with no segregation. Quality control measures at most PCC and AC production plants ensure that the gradations closely adhere to stockpile conditions. Aggregates used for bases, subbases, select fill, and other similar uses may experience some level of segregation and may differ somewhat from the laboratory determined gradation.
Related Tests and Specifications	**AASHTO T 2**, Sampling of Aggregates **AASHTO T 248**, Reducing Samples of Aggregate to Testing Size **AASHTO T 27**, Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates
Timeline for Completion	Preparation Time: 5–10 minutes The sieve(s) must be inspected prior to use and cleaned if necessary. Test Time: 15–25 minutes The wash loss test is performed on an oven dry sample. Note that when emptying the #200 sieve, pay particular attention to material that may be trapped on the sieve. Use a brush to remove these particles.

	Calculations: 5 minutes Total Test Time: 25–40 minutes *The times stated assume that the samples are prepared prior to the test.
Notes for Independent Study	This test is performed prior to the dry sieve analysis (T 27) in cases where an accurate determination of the minus #200 material is required. For purposes of this lab, perform the T 11 procedure only on the coarse aggregate sample that will be used for the T 27 sieve analysis.

Apparatus

- Rotating drum – for washing of a coarse aggregate sample (Figure 4)

Figure 4: Rotating drum

- Sieve – Final stages of washing over the #200 sieve for a fine aggregate sample (Figure 5)

Figure 5: Final stages of washing over the #200 sieve for a fine aggregate sample

Sample Preparation

An aggregate sample should be obtained according to AASHTO T 2 and reduced to the appropriate sample size according to AASHTO T 248.

The sample must be dried to a constant mass at 230 °F ± 9° and cooled prior to performing the analysis.

The sieves should be cleaned and then assembled according to the appropriate specification with the smallest screen being the #200 sieve.

Common Errors

The most common errors in performing a wash loss analysis include:

- Improper cleaning of the #200 sieve prior to testing
- Failure to remove all of the particles retained on the #200 sieve
- Insufficient washing to remove fines
- Damaged or worn sieves
- Mistakes in entering data or in calculation

AASHTO T 88 Particle Size Analysis of Soils: Hydrometer Test	
Background Information	The hydrometer analysis is intended to provide the relative size distribution of materials passing the #10 sieve. This test is used primarily for soils and soil-aggregate mixes.
Summary of Test Method	A YouTube video produced by the Missouri University of Science and Technology is available that describes both dry sieve and hydrometer testing. The video can be downloaded at: http://www.youtube.com/watch?v=QqxfwpUtEoQ
Significance and Use	The test is used to determine the relative amounts of material passing the #10 sieve for soil aggregate blends used in subbase applications, but particularly for the minus #200 fraction. Note that this test is not required if the particle size distribution of the minus #200 material is not required.
Related Tests and Specifications	**AASHTO T 2**, Sampling of Aggregates **AASHTO T 248**, Reducing Samples of Aggregate to Testing Size **AASHTO T 27**, Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates **AASHTO T 11**, Standard Test Method for Materials Finer than 75-µm (#200) Sieve in Mineral Aggregates by Washing
Timeline for Completion	Preparation Time: 10 minutes The sample must be prepared by sieving for the specific gradation being tested. Test Time: 1 day The time series of readings will take approximately 1 day to complete Calculations: 5 minutes Total Test Time: Greater than 1 day

	*The times stated assume that the samples are prepared prior to the test.
Notes for Independent Study	This test will likely not be performed in the laboratory as part of this lesson due to the time requirements and somewhat limited use for aggregates.

Apparatus

- Equipment most frequently used in T 88 procedure (Figure 6)

Figure 6: Equipment most frequently used in the T 88 procedure

- An actual test in progress showing multiple materials being evaluated (Figure 7)

Figure 7: An actual test in progress showing multiple materials being evaluated

Common Errors

The most common errors in performing a hydrometer analysis include:

- Improper sample preparation
- Inadequate mixing
- Not taking readings at the designated times
- Inaccurate reading of the hydrometer scale
- Mistakes in entering data or in calculation

Aggregate Cleanliness Tests

The cleanliness of aggregates is important since the material adhering to the surface of the coarser particles are generally claylike fines minus #200 material. These fines can adversely affect the bond between asphalt cement and the aggregates resulting in potential stripping and loss of stability.

Cleanliness of aggregates can be measured by methods other than minus #200, such as those listed below.

For blended aggregate gradations, the initial sample is often dry sieved on coarse aggregate sieves and then a split on the #4 sieve. The material is then tested according to the fine aggregate tests shown below.

Fine aggregate methods include sand equivalent, plasticity index, and the methylene blue value test to detect the presence of active clays in the fines.

For coarse aggregates, the minus #200 can be determined by the T 11 procedure. Other cleanliness tests include adherent fines and the California cleanliness value (CV).

The following cleanliness tests are provided in this workbook.

AASHTO Standard	ASTM Standard	Test Name
T 176	D 2419	Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test
T 330		The Qualitative Detection of Harmful Clays of the Smectite Group in Aggregates Using Methylene Blue
T 89 and 90	D 4318	Determining the Liquid Limit, Plastic Limit and Plasticity Index of Soils
		California Department of Transportation CT 227 Method of Test for Evaluating Cleanliness of Coarse Aggregate

AASHTO T 176 Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test	
Background Information	The purpose of this test is to show the relative proportions of fine dust and claylike particles in graded aggregates. The basis for this test is that the material passing the #4 sieve, referred to as fine aggregate, is comprised of the larger sand size particles and the undesirable dust or claylike particles. The test is performed only on material passing the #4 sieve.
Summary of Test Method	A YouTube video produced by the Oklahoma Department of Transportation is available that describes the entire testing process. The video can be downloaded at: http://www.youtube.com/watch?v=KSG83gr7Q00
Significance and Use	This rapid test is performed on aggregates to be used in AC mixes where a high percentage of fines has been shown to correlate with rutting and stripping. Because we are dealing with fines (minus #200), it is very important to obtain a representative sample of the material to be tested and that the fines do not separate during handling and sample preparation.
Related Tests and Specifications	**AASHTO T 2**, Sampling of Aggregates **AASHTO T 248**, Reducing Samples of Aggregate to Testing Size
Timeline for Completion	Preparation Time: 10–15 minutes The sample must be prepared by sieving on the #4 sieve. Test is performed on materials passing the #4 sieve. Test Time: 30–40 minutes The time required is dependent on the settling rate of the sample. Calculations: 5 minutes Total Test Time: 35–60 minutes *The times stated assume that the samples are prepared prior to the test.

Notes for Independent Study	Note that this test may not be used by your agency.

Apparatus

- Graduated cylinder with sample already shaken and settled (as shown in Figure 8)

Figure 8: Graduated cylinder with sample already shaken and settled

- Graduated cylinder close up – with sample already shaken and settled (as shown in Figure 9).

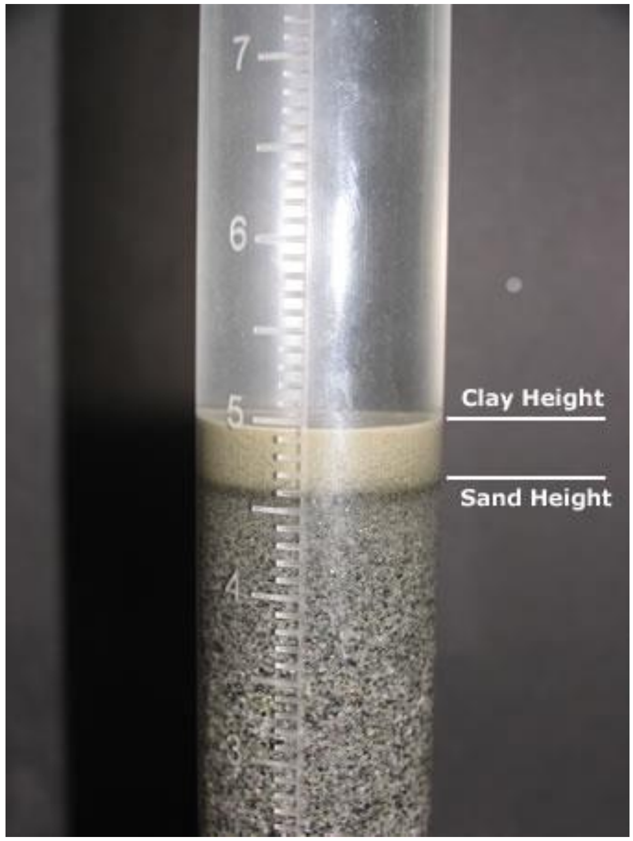


Figure 9: Graduated cylinder close up

- A typical mechanical shaker used to thoroughly disperse the sample in the cylinder (as shown in Figure 10)

Figure 10: A typical mechanical shaker used to thoroughly disperse the sample in the cylinder

Sample Preparation

This test is performed on a representative sample of the graded aggregates that have been sampled and split in accordance with AASHTO T 2 and T 248, respectively.

An aggregate sample should be obtained according to AASHTO T 2 and reduced to the appropriate sample size according to AASHTO T 248.

The sample should be split on the #4 sieve. A minimum of 1,000 grams of the material passing the #4 sieve is required.

A sufficient amount of stock solution must be available for the test (refer to the specification for the specifics regarding the solution).

Common Errors

The most common errors in performing a sand equivalent analysis include:

- Improper sample preparation
- Inadequate mixing
- Inaccurate reading of the graduated cylinder scale
- Mistakes in entering data or in calculation

AASHTO T 330 The Qualitative Detection of Harmful Clays of the Smectite Group in Aggregates Using Methylene Blue	
Background Information	The purpose of this test is to identify the presence of harmful clays of the smectite group. It is also used to determine the presence of organic matter in aggregates.
Summary of Test Method	The results of this test have been correlated with the stripping potential of AC mixes. This rapid test procedure involves adding quantities of a standard aqueous solution of methylene blue dye to a sample of dry fine aggregate passing the #200 (0.075 mm) sieve until adsorption of the dye ceases. From this, a methylene blue value is calculated.
Significance and Use	A high number for the methylene blue value (MBV) indicates a large amount of organic or clay in the sample. A MBV from 13-19 is indicative of problems and possible failures while a value in excess of 20 constitutes failure. These values are in regards to the potential moisture sensitivity of the aggregates for use in hot mix asphalt (HMA).
Related Tests and Specifications	**AASHTO T 2**, Sampling of Aggregates **AASHTO T 248**, Reducing Samples of Aggregate to Testing Size
Timeline for Completion	Preparation Time: 10–15 minutes The sample used for this test is the material collected from the wash loss test (T 11) or minus #200 material. Test Time: 45–60 minutes The time required is dependent on the experience of the operator with titration procedures. Calculations: 5 minutes Total Test Time: 60–80 minutes *The times stated assume that the samples are prepared prior to the test.

Notes for Independent Study	Note that this test may not be used by your agency. If this test is to be performed, use the minus #200 material from the T 11 test.

Apparatus

- Equipment required to perform the methylene blue test (as shown in Figure 11). The filter papers on the left are used to determine the end point of the test. Note that not all of the equipment pictured in the photo is required for this test.

Figure 11: Equipment required to perform the methylene blue test

Sample Preparation

The material from the T 11 procedure can be used to perform this test. However, a minimum of 30 grams of the minus #200 will be required.

Distilled water and reagent grade methylene blue will be required.

Common Errors

The most common errors in performing the T 330 procedure include:

- Improper sample preparation
- Improper titration procedures (i.e. missing the endpoint)
- Mistakes in entering data or in calculation

AASHTO T 89 and T 90 Determining the Liquid Limit, Plastic Limit and Plasticity Index of Soils	
Background Information	The Atterberg limits are a basic measure of the critical water contents of a fine-grained soil, such as its shrinkage limit, plastic limit, and liquid limit.
Summary of Test Method	A YouTube video produced by the Missouri University of Science and Technology is available that describes the entire testing process. The video can be downloaded at: http://www.youtube.com/watch?v=EcXJ961qjGA As a dry, clayey soil takes on increasing amounts of water, it undergoes dramatic and distinct changes in behavior and consistency. Depending on the water content of the soil, it may appear in four states: solid, semi-solid, plastic, or liquid.
Significance and Use	In each state, the consistency and behavior of a soil is different and consequently so are its engineering properties.
Related Tests and Specifications	**AASHTO T 2**, Sampling of Aggregates **AASHTO T 248**, Reducing Samples of Aggregate to Testing Size
Timeline for Completion	Preparation Time: 20–30 minutes Two tests are required to determine the plasticity index (PI) of the fine material, the liquid limit (LL), and the plastic limit (PL). The times estimates include performing both tests. Test Time: 80–100 minutes The time required is dependent on the experience of the operator. Calculations: 5 minutes Total Test Time: 105–135 minutes *The times stated assume that the samples are prepared prior to the test.
Notes for Independent Study	Note that this test may not be used by your agency for aggregate characterization.

Apparatus

- Liquid limit (as shown in Figure 12)

Figure 12: Liquid limit

- Plastic limit of the minus #40 size fraction (as shown in Figure 13)

Figure 13: Plastic limit of the minus # 40 size fraction

Sample Preparation

Approximately 40 grams of material passing the #40 sieve are required for this procedure. This material should be air dried prior to the beginning of the test.

Common Errors

The most common errors in performing the Atterberg limit procedures include:

- Improper sample preparation
- Difficulties in determining LL and PL endpoints
- Mistakes in entering data or in calculation

California Department of Transportation CT 227 Method of Test for Evaluating Cleanliness of Coarse Aggregate	
Background Information	This test is used to determine the cleanliness or clay-sized fines clinging to coarse aggregates or screenings.
Summary of Test Method	The CT 227 specification may be downloaded at: http://www.dot.ca.gov/hq/esc/ctms/pdf/CT_227.pdf
Significance and Use	The cleanness test provides an indication of the relative proportions of clay-sized material clinging to coarse aggregates or screenings.
Related Tests and Specifications	**AASHTO T 2**, Sampling of Aggregates **AASHTO T 248**, Reducing Samples of Aggregate to Testing Size
Timeline for Completion	Unknown
Notes for Independent Study	This test is not routinely performed.

Aggregate Strength and Deformation Tests

There are many types of strength including compressive, tensile, and shear. It is difficult to measure strength of individual aggregate particles; and, for many common uses, strength itself does not greatly influence performance. Examples of uses where strength is not overly important include: (1) aggregate base and subbase, (2) aggregate for moderate strength Portland cement concrete, and (3) aggregate for asphalt base and binder layers.

However, aggregate particle strength can be important in some applications, such as high strength concrete, surface courses on heavily trafficked pavements, and aggregate interlock for load transfer in plain-jointed concrete pavement. Generally, the strength of aggregate is evaluated from the performance of a mixture containing the aggregate, from previous experience using the aggregate in similar applications, or from subjective petrographic evaluation of the performance of minerals and rocks present.

High strength and elasticity are desirable in aggregate base and surface courses.

These qualities minimize the rate of disintegration and maximize the stability of the compacted material. The best results for PCC may be obtained by compromising between high and low strength, and elasticity. This permits volumetric changes to take place more uniformly throughout the PCC.

The compressive or tensile strength of a bulk aggregate sample is rarely measured. However, the resilient modulus, which is a measure of the strength and deformation properties (measured by means of a triaxial test) for granular base/subbase applications, is becoming more common. The resilient modulus of the support layers for highways is an important input in the Mechanistic-Empirical Pavement Design Guide (MEPDG).

	The following strength test is provided in this workbook. <table><tr><td>AASHTO Standard</td><td>ASTM Standard</td><td>Test Name</td></tr><tr><td>T 307</td><td></td><td>Determining the Resilient Modulus of Soils and Aggregate Materials</td></tr></table>

<table>
<tr><td colspan="2">AASHTO T 307

Determining the Resilient Modulus of Soils and Aggregate Materials</td></tr>
<tr><td>Background Information</td><td>The resilient modulus test is applicable to soils, aggregates, and soil aggregate mixtures.</td></tr>
<tr><td>Summary of Test Method</td><td>The resilient modulus test is a repeated load test that allows great flexibility in altering the moisture state of the sample, compaction, and stress state to simulate a variety of expected in-service conditions.</td></tr>
<tr><td>Significance and Use</td><td>The test procedure involves subjecting a cylindrical sample of the material to be tested to a confining pressure and repeated axial compressive loads. The basis for the test is to simulate the in-service loading conditions found in base, subbase, and subgrade materials comprising flexible pavements.

The resilient modulus test conditions are tailored to the material type and location within the pavement structure (i.e. unbound aggregate base or subbase for our purposes). The higher stress states are located near surface and diminish with depth.

The complexity of the test and the extent of equipment required to perform the analysis on unbound aggregates were prohibitive for many years. However, many agency laboratories are now equipped to perform this test.

The Mechanistic-Empirical Pavement Design Guide methodology requires a resilient modulus for all pavement support layers in both flexible and rigid pavements. In cases where this value is not available, correlations to other aggregate properties are frequently used.</td></tr>
<tr><td>Related Tests and Specifications</td><td>AASHTO T 226, Triaxial Compressive Strength of Undrained Rock Core Specimens without Pore Pressure Measurements</td></tr>
<tr><td>Timeline for Completion</td><td>Preparation Time: 3–4 hours

Sample preparation is time-consuming due to the relatively large sample required for most aggregates. A 6 in. x 12 in. cylindrical sample is common.</td></tr>
</table>

	Test Time: 3–7 days The time required is dependent on the number of load cycles and the loading criteria. Calculations: 15 minutes Total Test Time: Greater than 3 days *The times stated assume that the samples are prepared prior to the test.
Notes for Independent Study	The preparation time for a triaxial test specimen and the time required to actually perform a complete test far exceeds the time available for Lesson 3. If your laboratory routinely performs resilient modulus testing, you may be able to observe either a test in progress or sample preparation. If neither is available, you should examine the equipment and ask the technician to explain the steps involved in the test procedure. Note that this test will also be discussed during the soils lab experience in Module B: Soils and Foundations.

Apparatus

- Load frame, linear actuator, triaxial cell with sample in place and the data acquisition system (as shown in Figure 14)

Figure 14: Load frame, linear actuator, triaxial cell with sample in place and the data acquisition system

Sample Preparation

The sample preparation for triaxial testing is a very involved process involving enveloping a prepared sample in an elastic membrane. The aggregate material is adjusted to the correct moisture content, paced in a specialty sample mold and compacted to the target density. A rubber membrane is then placed on the sample (there are numerous variations to this process) and the sample placed in a triaxial cell for testing.

The load conditioning of the sample and the testing regimen is dependent on the sample characteristics. A comprehensive test to determine resilient modulus is performed at various confining pressures and axial loads applied to the sample.

Common Errors

The most common errors in performing a triaxial test on aggregates include:

- Improper sample preparation
- Leakage of the membrane encasing the sample
- Leakage of the triaxial cell
- Improper load sequencing
- Calibration errors in the test apparatus – load cell and Linear Variable Displacement Transducer (LVDT)
- Mistakes in entering data or in calculation

Aggregate Hardness and Abrasion Tests

Aggregate hardness is related to the polishing potential of aggregates used in surface courses, especially asphalt layers. Polishing prone aggregates reduce the skid resistance of the pavement due to repeated tire wear.

There are several methods to determine the hardness of aggregates. One of the simplest and least expensive methods is the Mohs hardness test that requires little more than a sample kit and an understanding of the basic procedure.

The British wheel test is more oriented towards actual wear, as would be experienced under traffic. This test, however, requires more specialized equipment and requires more time to perform the test.

The following hardness tests are provided in this workbook.

AASHTO Standard	ASTM Standard	Test Name
		Mohs Hardness
T 279		Accelerated Polishing of Aggregates Using the British Wheel
T 278		Surface Frictional Properties Using the British Pendulum Tester
	D 3042	Standard Test Method for Insoluble Residue in Carbonate Aggregates

<table>
<tr><th colspan="2">Mohs Hardness</th></tr>
<tr><td>Background Information</td><td>The Mohs scale of hardness is based on the ability of one mineral sample to scratch another mineral. Minerals are pure substances found in nature, and rocks (aggregates) are comprised of one or more minerals. Diamonds were, at the time the test was devised, the hardest known naturally occurring mineral and were assigned a value of 10.</td></tr>
<tr><td>Summary of Test Method</td><td>A brief overview of the Mohs hardness test can be found in the following video: http://www.youtube.com/watch?v=R-bw7_u3gSQ</td></tr>
<tr><td>Significance and Use</td><td>The hardness of an aggregate sample is measured against the scale by finding the hardest material that the sample can scratch, and/or the softest material that can scratch the given material.

The Mohs scale is shown in the following two tables (Figure 15 and Error! Reference source not found.). The test is easily conducted by scratching successively harder (or weaker) samples in the test kit. For example, if the sample you are testing is scratched by apatite but not by fluorite, its hardness on the Mohs scale would fall between four and five.

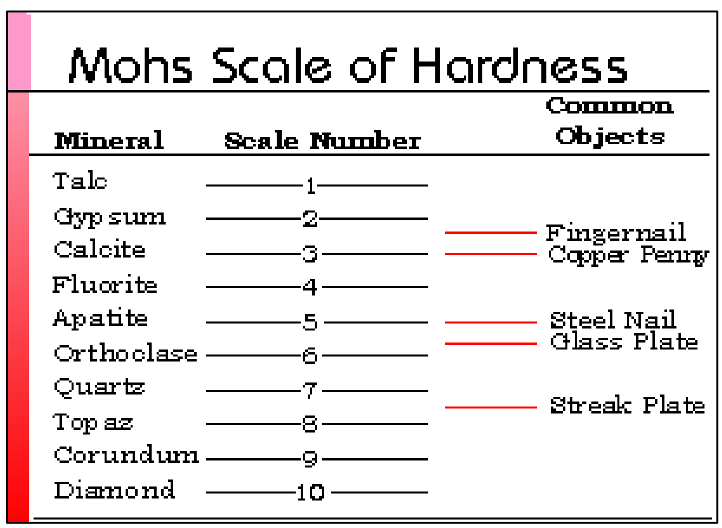


Figure 15: Mohs scale of hardness</td></tr>
</table>

Mineral	Mohs Hardness	Image
Talc	1	
Gypsum	2	
Calcite	3	
Fluorite	4	
Apatite	5	
Feldspar	6	
Quartz	7	
Topaz	8	
Corundum	9	
Diamond	10	

Figure 16: Mohs scale of hardness examples

Related Tests and Specifications	None that directly correspond.
Timeline for Completion	Total Test Time: 3–5 minutes per aggregate specimen
Notes for Independent Study	No advance preparation is required for this exercise. A Mohs hardness test kit will be provided for your use in the lab. You may also use the Rock and Mineral Identification for Engineers (FHWA Publication available at https://www.fhwa.dot.gov/pavement/pccp/fhwahi91205.pdf) for rock and mineral identification purposes, as needed.

Apparatus

The materials needed to perform these evaluations are contained in the test kit that was provided to you.

Sample Preparation

Sample preparation is not required. It is only necessary to have the aggregates you wish to test and the test kit.

Common Errors

The most common errors in performing a Moh’s test on aggregates include:

- Incorrect reporting

AASHTO T 279 Accelerated Polishing of Aggregates Using the British Wheel	
Background Information	High speeds and traffic can smoothen surface aggregates in a pavement surface over time. This leads to a reduction in the frictional properties of the roadway, which can lead to unsafe driving conditions. The British Wheel test is used in conjunction with the British Pendulum test to evaluate aggregate materials for their suitability in a pavement surface course and to evaluate their resistance to polishing.
Summary of Test Method	Coarse aggregate specimens are molded into 14 curved specimen segments which are mounted to a test wheel. The samples are subjected to abrasive polishing under a loaded rubber tire to simulate aggregate polishing. At the conclusion of the test procedures, the polish value of the aggregate is determined by use of a British Pendulum tester (AASHTO T 278). No photos of this test are available.
Significance and Use	The British Wheel test simulates the polishing action of traffic on the coarse aggregates used in asphalt surfaced pavements at an accelerated rate. This laboratory procedure can be used to classify aggregates based on their ability to resist polishing under traffic.
Related Tests and Specifications	**AASHTO T 278**, Surface Frictional Properties Using the British Pendulum Tester
Timeline for Completion	Sample Preparation: 1 hour Aggregate samples are molded and clamped to the test wheel. Testing: 10.5 hours Samples are subjected to polishing action for 10 hours and are then tested in accordance with AASHTO T 278. Total Time: 11.5 hours
Notes for Independent Study	Note that this test may not be used by your agency for aggregate characterization.

	If this device is to be demonstrated in the laboratory, a premade sample may be used. Time will not permit the actual sample preparation and performance of the test.

Apparatus

- Accelerated Polishing Machine – an accelerated polishing machine consisting of a cylindrical wheel (road wheel) in which test specimens are mounted, a rotating rubber tire, and a method of feeding silicon carbide grit and water continuously to the specimen (as shown in Figure 17)

Figure 17: British Polishing Wheel

- Metal Molds – to prepare the test specimens

Sample Preparation

Samples passing the ½ inch sieve and retained on the 3/8 inch sieve are washed and dried to constant mass. Each of the 14 molds is collated with release agent, and a single layer of aggregate is placed on the mold surface. After the bonding material has stiffened, the molded specimens are marked and then clamped into the test wheel.

AASHTO T 278 **Surface Frictional Properties Using the British Pendulum Tester**	
Background Information	The British Pendulum Tester is used to estimate the skid resistance of both laboratory specimens prepared by the T 279 procedure as well as in-service pavements.
Summary of Test Method	The pendulum (see photo of apparatus) is positioned such that it lightly contacts the surface of a laboratory prepared test specimen or an in-service pavements when dropped. The surface is pre-wetted and the pendulum is swung so that it contacts the surface and then stopped. The polish value or British Pendulum Number (BPN) is recorded. This value provides an estimation of the frictional characteristics of the material tested.
Significance and Use	This test considers the frictional properties of the material rather than macro texture of the pavement. The pendulum tester may be used to determine the relative effects of various polishing techniques on materials or material combinations
Related Tests and Specifications	**AASHTO T 279**, Accelerated Polishing of Aggregates Using the British Wheel
Timeline for Completion	Sample Preparation: 30-60 minutes The device must be placed and leveled prior to testing. Testing: 30-60 minutes Multiple measurements are recorded for each sample and then averaged. Calculation: 5 minutes Total Time: 65-125 minutes
Notes for Independent Study	Note that this test may not be used by your agency for aggregate characterization. If this device is to be demonstrated in the laboratory, a premade sample may be used. Time will not permit the actual sample preparation and performance of the test.

Apparatus

The British Pendulum Tester is used in this test (as shown in Figure 18*: British Pendulum Tester* and Figure 19). If field testing is performed, no other equipment is required

Figure 18: British Pendulum Tester

Figure 19: British Pendulum Tester in Use

Sample Preparation

If laboratory samples are used, a 3-1/2 x 6 inch flat sample is required. Sample preparation depends on the type of material being tested.

Common Errors

The most common errors in performing the British Pendulum Test include:

- Improper leveling of the device.
- Insufficient cleaning of the surface prior to testing
- Incorrect reading of the device.
- Incorrect reporting

ASTM D 3042 Standard Test Method for Insoluble Residue in Carbonate Aggregates	
Background Information	This method of test covers a procedure for determining the percent of acid insoluble residue in limestone and dolostone sedimentary rock. The procedure is intended to establish the amount of chert, sand, clay and other noncarbonate materials in limestone and carbonate rock.
Summary of Test Method	This test method involves sieving a sample of aggregate such that a minimum of 100 g per test of the material passing the 3/8 inch sieve but retained on the No. 4 sieve is available. The oven dry sample is weighed and then submerged in a 6N hydrochloric acid solution until all of the carbonate compounds are dissolved. The solution is then poured through filter paper where the non-carbonate materials are retained and weighed.
Significance and Use	The amount and size distribution of non-carbonate (insoluble) material in carbonate aggregates is of interest to those conducting research on the polish susceptibility of stone used in pavements or on the friction properties of pavement surfaces. In addition, some agencies utilize the test for acceptance purposes to delineate carbonate aggregates that polish excessively and become slippery and those that will not.
Related Tests and Specifications	None
Timeline for Completion	Preparation Time: 10-20 minutes Primarily equipment set-up Test Time: 1-4 hours The test time is dependent on the dissolution rate of the carbonate rock. And is difficult to predict. Calculations: 5 minutes Total Time: 75 minutes to greater than 4 hours
Notes for Independent Study	This test can be performed with materials from the T 27 analysis if a sufficient amount is available.

Apparatus

The apparatus required includes, 3/8 inch and No. 4 sieves, flasks electronic scale, funnel, ring stand, filter paper, drying oven and other incidental equipment, some of which is shown in Figure 20.

Figure 20: Incidental equipment used in ASTM D 3042

Sample Preparation

The sample must be a minimum of 100 g. of oven dry, minus 3/8 inch, plus no. 4 material.

Common Errors

The most common errors in performing the insoluble residue test include:

- Incorrect weighing of the initial sample and/or filter papers
- Not allowing sufficient time for complete dissolution of the carbonate rock
- Incorrect reporting

Aggregate Abrasion, Wear, and Degradation Tests

The abrasion, wear, and degradation of aggregates is an important physical property when the materials are subjected to repetitive loads and tire wear. The coarse aggregate fraction is typically of the most concern. However, fine aggregate, with its much greater surface area can cause problems due to degradation and production of minus #200 fines through wear. This can happen during aggressive mixing or handling procedures where the particles of fine aggregate rub together, an example being the mixing of PCC.

Two types of tests are used to evaluate the potential for abrasion, wear, and degradation as shown below:

- Dry degradation: Both AASHTO and ASTM have standardized procedures for small-size coarse aggregate using the Los Angeles (LA abrasion machine). ASTM has a similar procedure for large-size coarse aggregates using the LA abrasion machine.
- Wet degradation: The Micro-Deval test is used to determine the wet abrasion resistance of coarse aggregates.

The following abrasion, wear, and degradation tests are provided in this workbook.

AASHTO Standard	ASTM Standard	Test Name
T 96	C 131	Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
	C 535	Resistance to Degradation of Large-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
T 327	D 6928	Resistance of Coarse Aggregate to Degradation by Abrasion in the Micro-Deval Apparatus
	D 7428	Resistance of Fine Aggregate to Degradation by Abrasion in the Micro-Deval Apparatus

AASHTO T 96 (ASTM C 131) Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine	
Background Information	The Los Angeles abrasion test is a measure of degradation of mineral aggregates resulting from a combination of abrasion, impact, and grinding in a rotating steel drum containing a specified number of steel spheres (dependent upon the test sample's grading). The AASHTO 96 (ASTM C 131) test is intended for aggregates smaller than 1–1/2 in. Note the ASTM C 535 procedure is very similar and is intended for larger-size coarse aggregates.
Summary of Test Method	As the drum rotates, a shelf plate picks up the sample and the steel spheres, carrying them around until they are dropped to the opposite side of the drum, causing an impact-crushing effect. The contents then roll within the drum with an abrading and grinding action until the shelf plate impacts and the cycle is repeated. After the prescribed number of revolutions, the contents are removed from the drum and the aggregate portion is sieved to measure the degradation as percent loss (before and after is shown in Figure 21). A video of the LA abrasion test is available at the following Web site: http://www.pavementinteractive.org/article/los-angeles-abrasion/

	 *Figure 21: Before/after picture of a sample subjected to the LA abrasion test*
Significance and Use	The results of this test are important for aggregates used in asphalt mixes (particularly surface courses), granular bases, open-graded asphalt and bases, chip seals, and wherever aggregates are exposed to high wear and impact.
Related Tests and Specifications	**AASHTO T 2**, Sampling of Aggregates **AASHTO T 248**, Reducing Samples of Aggregate to Testing Size
Timeline for Completion	Preparation Time: 15–30 minutes Sample preparation involves sieving and weighing the sample according to the test specifications. Test Time: 3–4 hours The time required is dependent on the equipment used, the aggregate type and amount, and the skill of the operator. Calculations: 5 minutes Total Test Time: 3 hrs 20 min–4 hrs 35 min *The times stated assume that the samples are prepared prior to the test.

Notes for Independent Study	For demonstration purposes, the coarse aggregate sample used for the T 27 gradation analysis may be used for this test if a sufficient amount exists.

Apparatus

- LA abrasion machine (as shown in Figure 22)

Figure 22: LA abrasion machine

- Steel ball charge (as shown in Figure 23) used to impact and abrade the aggregate sample in the drum

Figure 23: Steel ball charge

Sample Preparation

First obtain the required amount of material for the test and process according to T 2 and T 248. The sample should be washed to remove fine material adhering to the surface of the aggregates.

The sample should then be dried to a constant mass according to the T 96 specification.

Note that for demonstration purposes, the coarse aggregate sample used for the T 27 gradation analysis may be used for this test if a sufficient amount exists.

Common Errors

The most common errors in performing an LA abrasion test on smaller aggregates include:

- Improper weighing of the before and after sample
- Improper charge of steel balls
- Improper number of revolutions
- Improper sieving
- Incorrect reporting

AASHTO T 327 Resistance of Coarse Aggregate to Degradation by Abrasion in the Micro-Deval Apparatus	
Background Information	Similar to the LA abrasion test, the Micro-Deval test uses a rotating drum with steel spheres. However, the sample size, drum and spheres are much smaller. The other significant difference is that the Micro-Deval test is run on a wet sample while the LA abrasion test is run on a dry sample. The Micro-Deval test tends to polish aggregate particles while the LA abrasion test tends to break them. The AASHTO 327 procedure is intended for aggregates smaller than 1–1/2 in. Note that the ASTM D 7428 procedure is very similar and is intended for fine aggregates.
Summary of Test Method	A video of the Micro-Deval test is available at the following Web site: http://www.youtube.com/watch?v=c3fzHxau2jw&feature=player_embedded  *Figure 24: Micro-Deval Test specimen*
Significance and Use	As was the case with the LA abrasion test, this test is primarily for asphalt mixes, particularly surface courses.

Related Tests and Specifications	**AASHTO T 2**, Sampling of Aggregates **AASHTO T 248**, Reducing Samples of Aggregate to Testing Size
Timeline for Completion	Preparation Time: 15–30 minutes Sample preparation involves sieving and weighing the sample according to the test specifications. Test Time: 2.5–3 hours The time required is dependent on the equipment used, the aggregate type and amount, and the skill of the operator. Calculations: 5 minutes Total Test Time: 2 hrs 50 min–3 hrs 35 min *The times stated assume that the samples are prepared prior to the test.
Notes for Independent Study	For demonstration purposes, the coarse aggregate sample used for the T 27 gradation analysis may be used for this test if a sufficient amount exists.

Apparatus

- Micro Deval machine (as shown in Figure 25)

Figure 25: Micro-Deval machine

- Steel ball charge (as shown in Figure 26) used in the drum to abrade the sample

Figure 26: Steel ball charge

Sample Preparation

First obtain the required amount of material for the test and process according to T 2 and T 248. The sample should be washed to remove fine material adhering to the surface of the aggregates.

The sample should then be dried to a constant mass according to the T 327 specification.

Note that for demonstration purposes, the coarse aggregate sample used for the T 27 gradation analysis may be used for this test if a sufficient amount exists.

Common Errors

The most common errors in performing a Micro-Deval test include:

- Improper weighing of the before and after sample
- Improper charge of steel balls
- Improper number of revolutions
- Improper sieving
- Incorrect reporting

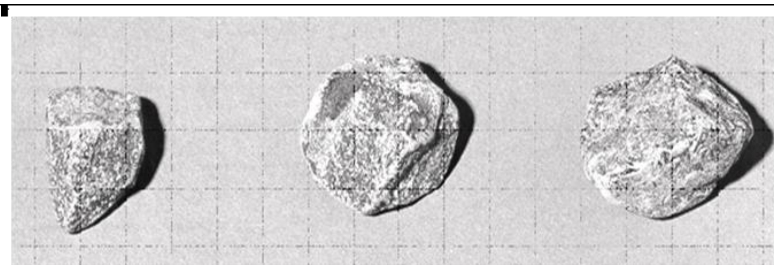
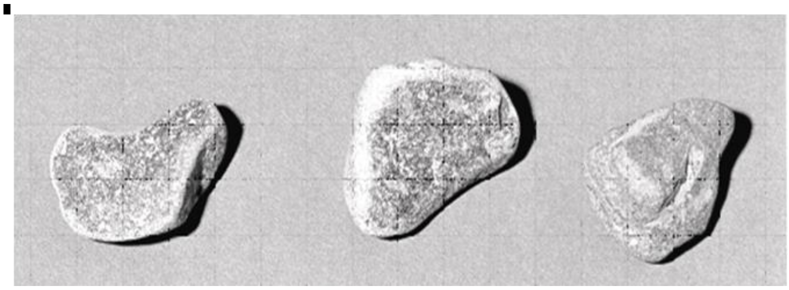
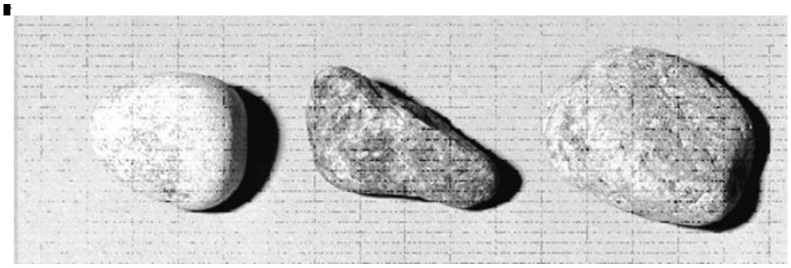
Aggregate Shape Characteristic Tests

Aggregate shape characteristics are an important parameter for asphalt mixes and other end uses where particle-to-particle interaction is necessary for good performance. The number of fractured faces are generally indicative of the level of processing and surface friction and correlate somewhat with the "locking" together of the aggregate particles. Elongated pieces tend to be weaker, depending on orientation, than more cubical shapes. Therefore a higher number of fractured faces and a lower amount of elongated particles are desirable.

The following aggregate shape characteristic tests are provided in this workbook.

AASHTO Standard	ASTM Standard	Test Name
T 335	D 5821	Determining the Percentage of Fracture in Coarse Aggregate
	D 4791	Standard Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate
T 326	D 6928	Uncompacted Void Content of Coarse Aggregate (as Influenced by Particle Shape, Surface Texture, and Grading)

AASHTO T 335 Determining the Percentage of Fracture in Coarse Aggregate	
Background Information	The percent crushed face test is a process that physically identifies the presence of a fracture face on each aggregate particle. The grading rule is that the face must be a mechanical fracture and must cover at least ¼ of the particle's projected area.
Summary of Test Method	The process of identifying the aggregate particles having the specified number of fractured faces is subjective. It depends on the experience of the tester. The standard procedure allows for some uncertainty in the judgment of the tester. If the tester is not certain about whether or not the fractured face meets the specified criteria (shape and surface area), the aggregate particle being tested is placed in a "questionable" category. Tests with a large questionable category are not desired (maximum 15% of total sample weight). It is recommended that tests for one or two fractured faces be done independently. The following photos illustrate four different aggregate classifications based on particle shape and surface texture. Complete descriptions of how to differentiate these differences are described in the specification.  *Figure 27: Crushed particles (sharp edges, smooth surfaces)*

	 *Figure 28: Crushed particles (round edges, rough surfaces)*  *Figure 29: Non-crushed particles (round edges, smooth surfaces)*  *Figure 30: Non-crushed particles (rounded particles, smooth surfaces)*
Significance and Use	The objective of the test is to identify the percentage of coarse aggregates that have a specified number of fractured faces. The test can identify aggregates with one fractured face or two fractured faces. Aggregates are washed, separated on a flat surface and observed individually. The specifications contain requirements for percentage of crushed aggregate particles, with the purpose of maximizing shear strength in either bound or unbound aggregate mixtures. This method may be used in determining the acceptability of coarse dense-graded and open-graded aggregates with respect to these requirements.

	This procedure is used primarily for hot mix asphalt aggregates.
Related Tests and Specifications	**ASTM D 4791**, Standard Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate **AASHTO T 326**, Uncompacted Void Content of Coarse Aggregate (as Influenced by Particle Shape, Surface Texture, and Grading)
Timeline for Completion	Preparation Time: 5–10 minutes Sample preparation involves obtaining a representative sample to visually examine. Test Time: 45–60 minutes The time required is dependent on the skill of the operator and the sample size. Calculations: 5 minutes Total Test Time: 55–75 minutes *The times stated assume that the samples are prepared prior to the test.
Notes for Independent Study	A sample containing a minor portion of fractured faces should be prepared prior to the lab.

Apparatus

This is a visual examination so the only equipment required is an electronic scale and #4 scalping screen.

Sample Preparation

A representative sample of the aggregates should be air dried prior to the required gradation process so that there is a clean separation of the particles. A total plus #4 (4.75 mm) sample could be used for testing but more commonly the plus #4 (4.75 mm) material will be split into representative fractions. The minimum size of samples is provided in the test.

Common Errors

The most common errors in performing a fractured faces test include:

- Improper weighing of the sample
- Improper characterization of fractured faces
- Incorrect reporting

ASTM D 4791 Standard Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate	
Background Information	Flat and elongated particles are undesirable in HMA mixtures and the Superpave system limits their percentages.
Summary of Test Method	This test method involves the determination of flat and elongated aggregate particles. The test is primarily a visual determination but calipers, as shown below, are used to remove some of the inconsistencies in measurement.
Significance and Use	Flat and elongated particles are not desired in HMA mixtures because they lead to numerous problems during construction and throughout the pavement life. Flat and elongated particles are defined as coarse aggregates that have a ratio of the longest dimension to the shortest dimension equal or greater than 5:1. This ratio is the Superpave criterion. Some State highway agencies may require a higher ratio such as 3:1.
Related Tests and Specifications	**AASHTO T 335**, Determining the Percentage of Fracture in Coarse Aggregate **AASHTO T 326**, Uncompacted Void Content of Coarse Aggregate (as Influenced by Particle Shape, Surface Texture, and Grading)
Timeline for Completion	Preparation Time: 5-–10 minutes Sample preparation involves obtaining a representative sample to examine. Test Time: 45–60 minutes The time required is dependent on the skill of the operator and the sample size. Calculations: 5 minutes Total Test Time: 55–75 minutes *The times stated assume that the samples are prepared prior to the test.

Notes for Independent Study	A sample containing a minor portion of flat and elongated pieces should be prepared prior to the lab.

Apparatus

- The main apparatus to test flat and elongated particles is the caliper (shown in Figure 31). It is a mechanical device that can be set for multiple ratios. The numbers on the caliper represent the ratios. For example, the number five represents the 5:1 ratio.

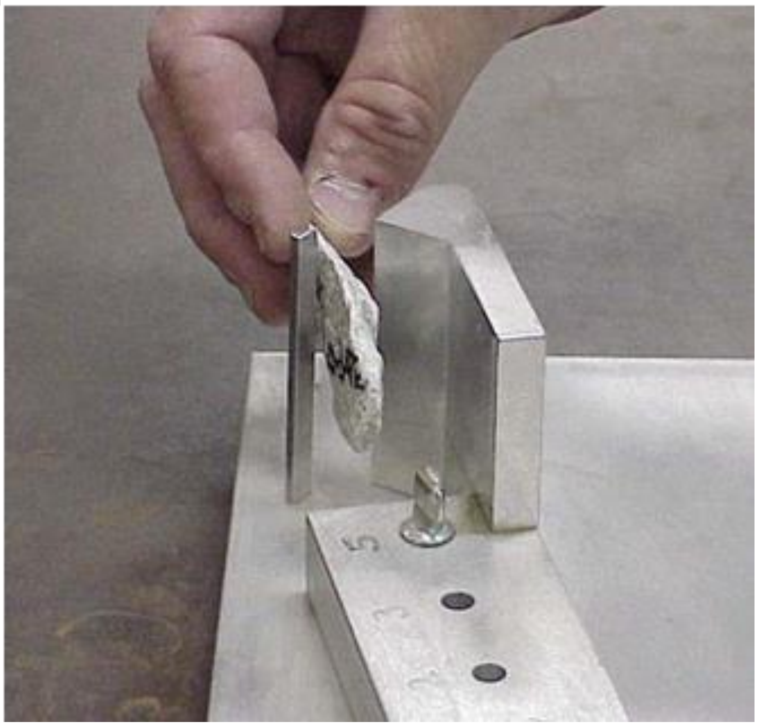


Figure 31: Adjustable caliper used to determine compliance with the specification

Sample Preparation

A representative sample of the aggregates should be air dried prior to the required gradation process so that there is a clean separation of the particles.

Each size fraction above the 3/8-in. sieve present in the amount of 10% or more of the original sample is reduced until approximately 100 particles are obtained for each size fraction.

Common Errors

The most common errors in performing a flat and elongated test include:

- Improper weighing of the sample

- Improper characterization of flat and elongated pieces
- Incorrect measurement of particles
- Incorrect reporting

AASHTO T 326 Uncompacted Void Content of Coarse Aggregate (as Influenced by Particle Shape, Surface Texture, and Grading) **AASHTO T 304** Uncompacted Void Content of Fine Aggregate	
Background Information	Because it is difficult to examine aggregate particles for the presence of fractured faces, their angularity is indirectly measured through evaluating the content of internal voids. More angular aggregates experience larger internal voids because they are harder to compact. The test uses a representative bulk aggregate sample obtained from the combined gradation. The bulk-specific gravity of the combined fine aggregates is needed to convert the measured weight into volume. Note that the basic procedures for AASHTO T 326 and T 304 are similar. These tests are covered together in this write-up but do have a few procedural differences. Be certain to consult the specifications prior to performing either test.
Summary of Test Method	For the both the T 326 and T 304 procedures,, there are three methods of test that are allowed by the specification. Carefully read the criteria for each method to determine the most appropriate procedure for your purposes.
Significance and Use	The test requires a number of special devices, such as a cylindrical measure, funnel, and stand. Because the test is an empirical measure of angularity, the use of exact devices is critical. The dimensions of the funnel stand also are important because they control the aggregate drop height, which is critical to the void formation. The aggregate must be allowed to free fall into the cylinder without any external vibrations. Tapping the cylinder to loosen extra materials should be done slightly to avoid extra compaction of the materials in the cylinder.
Related Tests and Specifications	**AASHTO T 335**, Determining the Percentage of Fracture in Coarse Aggregate

Timeline for Completion	Preparation Time: 10–15 minutes Sample preparation involves obtaining a representative sample in the various size fractions following the T 27 sieve analysis. Test Time: 15–30 minutes The time required is dependent on the skill of the operator. Calculations: 5 minutes Total Test Time: 30–50 minutes *The times stated assume that the samples are prepared prior to the test.
Notes for Independent Study	Assuming that sufficient material exists from the T 27 procedure, this material may be used for this test.

Apparatus

The test apparatus shown in

Figure *32* consists of a cylindrical measure, funnel, funnel stand, class plate, pan, metal straightedge, and an electronic scale. These components are shown in the following photo.

Figure 32: Equipment for T 326

The test apparatus shown in Figure 36 is the equivalent test apparatus as that pictured above except this version is for fine aggregate characterization (AASHTO T 304)

Figure 33: Equipment for T 304

Sample Preparation

A representative aggregate sample is first oven dried and sieved according to the AASHTO T 27 procedure. The individual size fractions are then recombined into the following combined gradations:

3/4–1/2 in., 1/2–3/8 in., and 3/8 in. to #4 for a maximum aggregate size (MAS) of 3/4 inch. Other combined gradations are specified in the test protocol for a different MAS.

Common Errors

The most common errors in performing an uncompacted void determination test include:

- Improper weighing of the sample
- Improper sieving and recombining the size fractions
- Incorrect reporting

Aggregate Pore Properties Tests

Internal pore characteristics are a very important physical property of aggregates. The size, the number, and the continuity of the pores through an aggregate particle may affect the strength of the aggregate, abrasion resistance, surface texture, specific gravity, bonding capabilities, and resistance to freezing and thawing action.

Absorption relates to the particle's ability to take in a liquid. Porosity is a ratio of the volume of the pores to the total volume of the particle. Permeability refers to the particle's ability to allow liquids to pass through. If the rock pores are not connected, a rock may have high porosity and low permeability.

Pores in aggregate particles and in rock are distributed in a size range that is related to mineral composition, the method of creation of the rock, and weathering. An equally important characteristic is the interconnectivity of the pores in the rock or aggregate particles. Pores that are isolated will not transmit fluids as readily as those that are interconnected and can allow water and ions to penetrate or pass through the material. Pores that become saturated are more vulnerable to freezing and thawing damage in concrete and to stripping in HMA. The faster transmission of ions in aggregate particles can speed alkali-aggregate reactions in concrete and speed corrosion of reinforcing steel in concrete if chlorides are present.

Pore structure of aggregate particles can range in size from a few angstroms (which is smaller than a water molecule) up to very large holes of one mm or more, which can be easily seen with the unaided eye. Pore size distributions have been determined down to 0.01 micrometers by mercury intrusion methods. The sizes of pores that are generally thought to cause freeze-thaw durability problems are those in the 0.1 to 5 micrometer range. Smaller pores are too small for water to freeze in great quantity and large pores are somewhat like air entertainment in concrete. The larger voids rarely become fully saturated with water.

The following aggregate pore properties tests are provided in this workbook.

AASHTO Standard	ASTM Standard	Test Name
T 84		Specific Gravity and Absorption of Fine Aggregate
T 85		Specific Gravity and Absorption of Coarse Aggregate

AASHTO T 84 Specific Gravity and Absorption of Fine Aggregate **AASHTO T 85** Specific Gravity and Absorption of Coarse Aggregate	
Background Information	Determining the actual pore structure of aggregates is a very difficult process and is typically done for research purposes (for instance, mercury porosimetry measurements). However, measuring the practical effects of porosity is relatively easy to determine using the method provided by AASTHTO T 84 and T 85.
Summary of Test Method	Specific gravity is the ratio of the weight of a given volume of aggregate to the weight of an equal volume of water. Water, at a temperature of 73.4 °F (23 °C), has a specific gravity of 1.
Significance and Use	Specific gravity is important for several reasons. Some deleterious particles are lighter than the good aggregates. Tracking specific gravity can sometimes indicate a change of material or possible contamination. Differences in specific gravity may be used during production to separate the deleterious particles from the good using a heavy media liquid. Specific gravity is critical information for the hot mix asphalt design engineer. The value is used in calculating air voids, voids in mineral aggregate (VMA), and voids filled by asphalt (VFA). All are critical to a well performing and durable asphalt mix. Water absorption can also be an indicator of asphalt absorption. A highly absorptive aggregate may lead to a low durability asphalt mix. In Portland cement concrete, the specific gravity of the aggregate is used in calculating the percentage of voids and the solid volume of aggregates in computations of yield. The absorption is important in determining the net water-cement ratio in the concrete mix. Knowing the specific gravity of aggregates is also critical to the construction of water filtration systems, slope stabilization projects, railway bedding, and many other applications.

Related Tests and Specifications	**AASHTO T 19**, Bulk Density ("Unit Weight") and Voids in Aggregate
Timeline for Completion	Preparation Time: 5–10 minutes Sample preparation involves obtaining a representative sample of the material in the oven dry state (initial step). Test Time: 90–120 minutes The time required is dependent on the skill of the operator. Calculations: 5 minutes Total Test Time: 100–135 minutes *The times stated assume that the samples are prepared prior to the test.
Notes for Independent Study	Due to time limitations, the sample may need to be prepared prior to your laboratory visit to perform the test. If sufficient material is available from the T 27 procedure, it may be used as both the coarse and fine aggregate samples.

Apparatus

- Weighing basket (as shown in Figure 34)

Figure 34: Prepared sample being placed in the weighing basket

- Basket with sample being weighed in water (as shown in Figure 35)

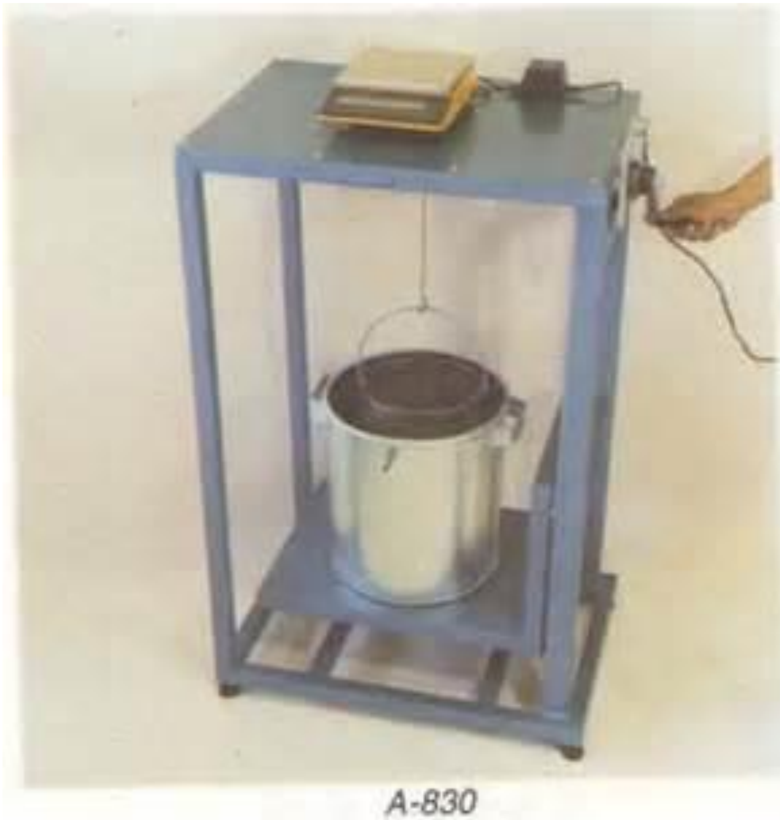


Figure 35: Basket with sample being weighed in water

Sample Preparation

The oven dry sample of coarse aggregate that was initially used for the T 27 procedure may be used for this test. Refer to the AASHTO T 85 procedure to determine the quantity required and the processing required.

Common Errors

The most common errors in performing a specific gravity and absorption test include:

- Improper weighing of the sample
- Improper moisture state of the sample
- Incorrect reporting

Volume Stability of Aggregate Particles Tests

Volume stability of aggregate particles is most important in PCC but must be considered in base/subbase materials or AC mixtures if large volume changes may occur. Volume change of aggregates or mixtures can be caused by one or more of the following: thermal movement, moisture induced movement, and adverse chemical reactions.

The amount of movement is highly variable and basically involves mineralogy, pore structure, permeability, strength, and numerous other factors depending on the intended use and environmental conditions.

The actual volume stability of aggregates is rarely determined in the laboratory. However, the composite material, generally PCC, is tested to determine the effects of the volume stability of the aggregate particles. For instance, the thermal coefficient of expansion of PCC is strongly influenced by the aggregate properties although it is the overall coefficient of thermal expansion (CTE) of the PCC that is actually measured. In a similar fashion, the expansive properties of certain aggregates are not problematic unless they chemically react with the alkalis in the cement and expand in the hardened PCC.

AASHTO Standard	ASTM Standard	Test Name
T 336		Coefficient of Thermal Expansion of Hydraulic Cement Concrete
	C 1260	Test Method for Potential Reactivity of Aggregates (Mortar-Bar Test)
	C 295	Standard Guide for Petrographic Examination of Aggregates for Concrete

AASHTO T 336 Coefficient of Thermal Expansion of Hydraulic Cement Concrete	
Background Information	Concrete expands when its temperature increases and contracts when its temperature decreases. The measure of how concrete changes in volume in response to temperature change is called the coefficient of thermal expansion (CTE) of concrete, defined as the change in unit length per degree of temperature change. The CTE of a concrete paving mixture depends on the aggregate type and degree of saturation.
Summary of Test Method	This test method involves measuring the length change in a PCC cylinder due to temperature changes. The PCC is ideally subjected to the range of temperatures that the material will experience in service, however, the CTE is generally thought of as being linear within this range.
Significance and Use	Since coarse aggregate makes up the bulk of the volume of concrete, the most influential factor in the CTE of the concrete is the CTE of the coarse aggregate. Quartz has the highest CTE of the coarse aggregate types commonly used in concrete pavement construction, and the CTEs of other commonly used coarse aggregate types depend largely on their quartz content.
Related Tests and Specifications	The tests corresponding to this parameter will be discussed in the PCC module.
Timeline for Completion	Preparation Time: 20–30 minutes Sample preparation involves obtaining an intact PCC cylinder and placing it into the test apparatus. Test Time: Approximately 1 day The time required is dependent on temperature rise and fall and the rate of change. Total Test Time: Greater than 1 day *The times stated assume that the samples are prepared prior to the test.

Notes for Independent Study	This test will not be performed as part of Lesson 3 but may be observed if a test is underway in the lab.

Apparatus

The apparatus, as shown below in Figure 36 consists of a temperature regulated water bath, a computer or data logger, a sample holder, and a reference bar for calibration of the device.

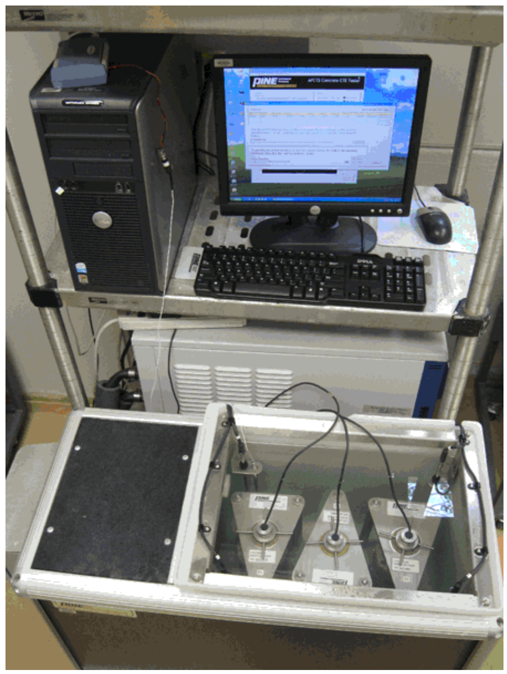


Figure 36: Equipment for T 336

Figure 37

Sample Preparation

The sample preparation consists of casting a PCC specimen, curing under laboratory controlled conditions, and placing the cylinder in the test apparatus.

Common Errors

The most common errors in performing a coefficient of thermal expansion include:

- Improper calibration of the test apparatus
- Using an outdated test protocol
- Incorrect reporting

ASTM C 1260 Test Method for Potential Reactivity of Aggregates (Mortar-Bar Test)	
Background Information	Alkali-silica reactivity (ASR) is a serious problem when reactive aggregates containing amorphous silica are used in a high alkali cement PCC mix. The resulting expansive gel that forms around the aggregate particles is generally sufficient to cause internal cracking and deterioration of the PCC.
Summary of Test Method	This test method provides a means to detect potential aggregate reactivity when used in PCC mixes. Mortar bars are prepared and subjected to an aqueous sodium hydroxide solution to promote a relatively rapid reaction of the aggregates resulting in internal expansion.
Significance and Use	This test is used to rapidly determine the reactivity of aggregates for use in PCC. This test is used for new aggregate sources, where significant changes in the aggregates occur and where potential reactivity is suspected. ASR may take a number of years to develop in-service so this test provides a simple and relatively rapid assessment of potential reactivity. Although mitigation techniques are available, such as adding supplemental cementitious materials (SCMs) to the PCC mix, the level of reactivity must be determined.
Related Tests and Specifications	**ASTM C 227**, Test Method for Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar-Bar Method) **ASTM C 1293**, Test Method for Concrete Aggregates by Determination of Length Change of Concrete Due to Alkali-Silica Reaction
Timeline for Completion	Preparation Time: 2 days Sample preparation involves casting a Portland cement-based mortar bar with the aggregates to be tested, curing the bars prior to placement in the test bath. Test Time: Approximately 14 days

	The time is based on a series of measurements over the course of 14 days. Total Test Time: Greater than 16 days
Notes for Independent Study	This test will not be performed as part of Lesson 3 but may be observed if a test is currently underway.

Apparatus

The required apparatus consists of the equipment required to cast the mortar bars, a water bath, and a means to measure sample length. The device shown in Figure 38 makes use of a dial indicator.

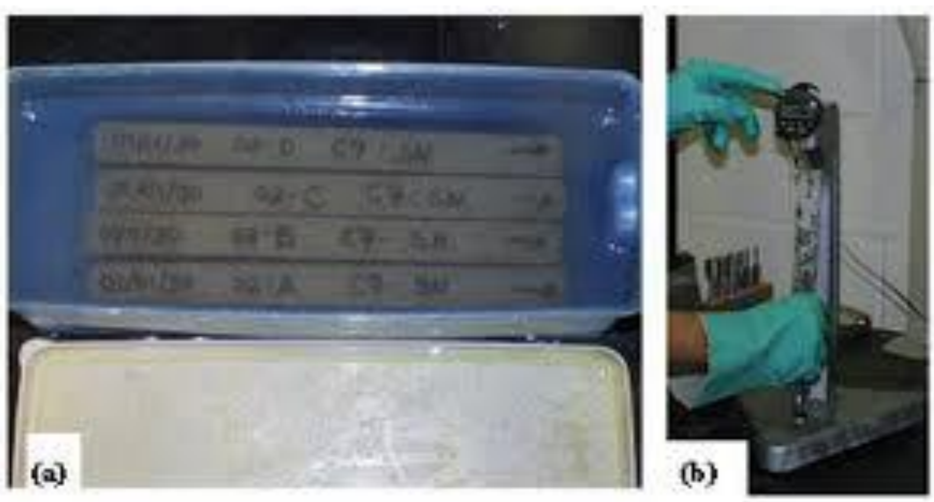


Figure 38: This figure includes two photos of 1260 testing. The first photo shows the mortar specimens placed submerged in NaOH solution within a blue storage container. The second photo shows a mortar bar specimen's length being measured.

Sample Preparation

Sample preparation consists of casting mortar bars using a reference Portland cement and carefully graded aggregates. The bars are cast and cured prior to undergoing the actual test procedure.

Common Errors

The most common errors in performing a mortar bar expansion test include:

- Improper sample preparation
- Incorrect sodium hydroxide concentration
- Incorrect reading of test apparatus
- Incorrect reporting

ASTM C 295 Standard Guide for Petrographic Examination of Aggregates for Concrete	
Background Information	The specific procedures employed in the petrographic examination of any sample will depend to a large extent on the purpose of the examination and the nature of the sample. In most cases the examination will require the use of optical microscopy. Complete petrographic examinations for particular purposes and to investigate particular problems may require examination of aggregates or of selected constituents by means of additional procedures, such as X-ray diffraction (XRD) analysis, differential thermal analysis (DTA), infrared spectroscopy, or other scanning electron microscopy (SEM) energy dispersive x-ray analysis (EDX). In some instances, such procedures are more rapid and more definitive than are microscopical methods.
Summary of Test Method	The basic test method involves a visual inspection the sample to determine structure, mineralogical make-up, cracking, voids and other features. Note that the additional procedures listed in the background information may also be employed depending on the required results.
Significance and Use	Petrographic analysis is used to determine the physical and chemical characteristics of the material that may be observed by petrographic methods and that have a bearing on the performance of the material in its intended use.
Related Tests and Specifications	**ASTM C 294**, Descriptive Nomenclature for Constituents of Concrete Aggregates
Timeline for Completion	Preparation Time: 4 hours Sample preparation involves cutting a core or other specimen resulting in a flat surface. Depending on the technique used, the surface is then polished and in some instances treated with various chemicals (dyes) to sharpen the contrast between the features to be examined. Test Time: Approximately 4 hours to 1 day depending on the tests performed. Total Test Time: approximately 1 day

Notes for Independent Study	This test will not be performed as part of Lesson 3 but may be observed if the test is currently being performed.

Apparatus

The basic apparatus consists of a high resolution optical microscope and a movable carriage to hold the sample, as shown in Figure 39. The sample preparation equipment includes, at a minimum, a rock saw and polishing equipment.

Figure 39: High Resolution Optical Microscope and a Movable Carriage

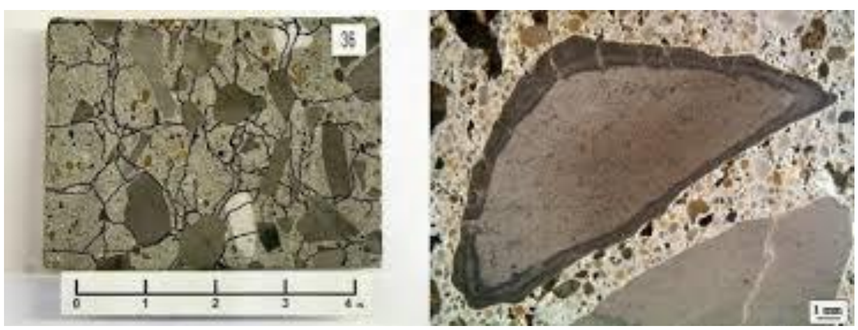


Figure 40

Sample Preparation

The sample is cut to the proper dimensions for the test being performed. Note that this varies depending on whether a purely visual observation will be used or higher level analyses such as XRF (X-ray Fluoresce-Analysis) and XRD (X-ray Micro-Analsis) will be employed.

Common Errors

The most common errors in performing a petrographic examination of aggregates for concrete include:

- Lack of skill of the person performing the analysis

Knowledge Check

Answer the following questions. Be prepared to discuss your answers with the class in Lesson 4: Introduction to WCT Session #1.

What is your agency's process for accepting unbound base and subbase materials?

What testing is required?

Knowledge Check

Answer the following questions. Be prepared to discuss your answers with the class in Lesson 4: Introduction to WCT Session #1.

What is your agency's process for accepting stabilized base materials?

What testing is required?

Knowledge Check

Answer the following questions. Be prepared to discuss your answers with the class in Lesson 4: Introduction to WCT Session #1.

How does your agency determine the appropriate stabilizer?

What testing is required?

Summary

This completes Lesson 3: Laboratory Experience: Physical Properties of Aggregates.

You are now able to:

- List the most commonly specified gradation parameters and how they are determined in the lab;
- List the most commonly specified cleanliness parameters and how they are determined in the lab;
- List the most commonly specified strength parameters and how they are determined in the lab;
- List the most commonly specified hardness parameters and how they are determined in the lab;
- List the most commonly specified abrasion, wear, and degradation parameters and how they are determined in the lab;
- List the most commonly specified aggregate shape characteristics parameters and how they are determined in the lab;
- List the most commonly specified pore properties parameters and how they are determined in the lab; and
- List the most commonly specified volume stability parameters and how they are determined in the lab.