A. T. T. I.

SOILS & AGGREGATE TECHNICIAN CERTIFICATION

WORKBOOK

ARIZONA TECHNICAL TESTING INSTITUTE

Revised January 2020

FORWARD

The Arizona Technical Testing Institute (ATTI) is a nonprofit organization formed to promote the highest standard in highway construction materials sampling and testing through certification of technicians. ATTI certifications emphasize a hands-on approach, that is, applicants must satisfactorily demonstrate test methods as well as pass a written exam to receive certification.

The organization is represented by members from the Arizona Department of Transportation (ADOT), highway contractors, material suppliers, materials testing laboratories, Arizona Rock Products Association (ARPA), Federal Highway Administration (FHWA), and Arizona General Contractors (AGC).

ATTI certifications satisfy ADOT and federal requirements which specify that technicians performing materials sampling and testing on ADOT projects are properly qualified.

ATTI provides the following certifications:

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

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

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

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CERTIFICATION INFORMATION SECTION

INTRODUCTION

The ATTI Laboratory Soils/Aggregate Technician Certification program evaluates the competency of applicants performing testing of soils and aggregates in a laboratory. Certification is based on satisfactory demonstration of all specified sampling and testing methods, as well as passing a written examination. Applicants are advised to receive training or have experience performing the test methods and calculations before attempting to obtain certification.

This workbook provides information regarding the requirements for ATTI Laboratory Soils/Aggregate Technician certification, administration of the certification process, and topics covered during the certification examinations. Brief coverage is given to safety issues, representative samples, record keeping, and soils and aggregates properties. Most importantly, the workbook contains copies of the applicable testing methods which a certified ATTI Soils/Aggregate Technician must be able to perform.

PERFORMANCE EXAMINATION

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

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

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

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

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

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

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

WRITTEN EXAMINATION

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

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

RETESTING

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

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

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

CERTIFICATION

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

CANCELLATION OR NO-SHOW

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

APPEALS

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

Appeals should be made in the following sequence:

1. Senior Examiner
2. Executive Director
3. Technical Advisory Board
4. ATTI Board of Directors

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

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

TECHNICAL SECTION

SAFETY

Some of the test methods in this manual may involve hazardous materials operations, and/or equipment. This manual does not claim to address all relevant safety issues which may be encountered or which may be associated with its use or with the performance of test procedures introduced here. It is the responsibility of the technician to determine, establish, and follow appropriate health and safety practices. The technician must also determine the applicability of any regulatory limitations of test equipment and chemicals.

THE OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION (OSHA)

OSHA has established safety requirements for individuals working in various environments. In the field and laboratory these requirements include such measures as wearing hard hats, eye protection, and protective footwear as well as the need to observe certain precautions when operating machinery and other equipment. There are also regulations pertaining to the handling and storage of chemicals, nuclear devices, and other hazardous materials. This short discussion on safety is not meant to preclude or to include OSHA requirements. **It is up to the individual technician to be acquainted with OSHA regulations that apply to their particular job assignment.**

REPRESENTATIVE SAMPLES

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

SAMPLING AND TESTING RECORDS

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

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

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

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

SAMPLE TICKETS

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

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

TEST RESULTS

Field sampling and testing must always be done according to test methods. Precise and reliable sampling and testing directly impacts the acceptance and payment of a product. If sampling and testing are not performed correctly, a substandard product could be accepted at full compensation or an acceptable product could be rejected. Test methods used most frequently are contained in the ADOT Materials Testing Manual and the AASHTO Standard Specifications, Part II, Tests. These methods describe how large a sample should be, step-by-step procedures, what data is to be collected, what calculations are to be performed, and what test results are reported.

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

Occasionally, an unreasonable test result may be encountered. Unreasonable test results should not simply be labeled as outliers and discarded. Results should only be discarded if they are outside of the range of possible results or if they are determined statistically to be outliers. ASTM E178 gives a common method for determining outliers in the highway construction industry.

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

TEST METHODS

ARIZ 105f
December 4, 2014
(8 Pages)

SAMPLING SOILS AND AGGREGATES

(An Arizona Method)

1. SCOPE

1.1 This method describes the methods which are to be used when sampling soils and aggregates.

1.2 Sampling is equally as important as the testing, and the individual doing the sampling shall use every precaution to obtain samples that will be representative of the materials being sampled.

1.3 This test method may involve hazardous material, operations, or equipment. This test method does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user to consult and establish appropriate safety and health practices and determine the applicability of any regulatory limitations prior to use.

1.4 Table 1 shall be used to determine minimum sample weights based on the size of aggregate. The amount of material required may be greater depending on the tests that are to be performed on the material.

Table 1
Minimum Sample Sizes

Nominal Maximum Aggregate Size *	Sample Mass	
	lbs	kg
Fine Aggregate		
#8	22	10
#4	22	10
Coarse Aggregate		
3/8”	22	10
1/2”	35	15
3/4”	55	25
1”	110	50
1-1/2”	165	75
2”	220	100
2-1/2”	275	125
3”	330	150

* The smallest sieve opening through which the entire amount of material, by specification, is permitted to pass.

2. SAMPLING FROM STOCKPILES

2.1 In sampling materials from stockpiles it is difficult to ensure unbiased samples, due to the segregation which often occurs when the material is stockpiled with coarser particles rolling to the outside base of the pile. If power equipment is available then it would be advantageous to enlist the use of that equipment to develop a separate, small sampling pile composed of materials drawn from various levels and locations in the main stockpile. Once a small sampling pile has been established then a sample shall be taken from that pile by taking several increments and combining.

2.2 The stockpile may also be sampled by placing a wood or metal shield upslope from the point of sampling to prevent loose aggregate from sliding down into the sampling area. Remove approximately 3 to 6 inches of material from the sampling area. Utilizing a square point shovel, take a sample near the top, at the middle and near the bottom of the stockpile. The sample taken at each location shall be one shovelful of material. Repeat this operation at the sampling locations as shown in Figure 1, and combine all samples taken from the stockpile.

3. SAMPLING FROM BINS

3.1 A sample shall be taken by passing a sampling device through the entire cross-section of the flow of material as it is being discharged (see Figures 2 and 3). Sufficient material shall be allowed to pass at the beginning of discharge to ensure uniformity of material before the sample is taken. Repeat sampling procedure as necessary until the desired amount of material from each bin is obtained. Material from each bin shall be properly identified.

4. SAMPLING FROM A CONVEYOR BELT

4.1 Sampling from a conveyor belt may be performed either while the conveyor belt is running (by using a sampling device which diverts or intercepts the flow of material) or by taking a sample while the conveyor belt is stopped. The stopped belt method is also used when approving a sampling device used for sampling while the belt is running.

4.1.1 If the sample is obtained while the conveyor belt is running, samples of the aggregate shall be taken utilizing a sampling device to divert or intercept the entire flow of material in such a manner that all portions of the flow are diverted or intercepted for an equal amount of time.

4.1.2 Samples may be obtained by stopping the conveyor belt and sampling the full width of the belt utilizing a template which is shaped to the same contour of the belt. All material which is within the template area shall be removed, utilizing a brush to obtain all the fine aggregate material.

5. SAMPLING FROM A WINDROW

5.1 Figure 4 illustrates the method used to sample a windrow. At each point in the windrow where a sample is to be taken, remove sufficient material from the top of the windrow so that a representative sample can be obtained from the center of the freshly exposed top of the windrow using a square point shovel. The sample taken at each sampling location shall be one shovelful of material. Repeat the sampling as necessary, at the required number of locations in the windrow, to obtain the desired amount of material. The samples taken shall be combined.

6. SAMPLING FROM THE ROADWAY

6.1 In the case of sampling material in-place from the roadway, at least 3 samples shall be taken with a shovel at equally distributed locations across the width of the roadway. It may be necessary to use a hammer and chisel or similar tools to cut the hole in the compacted roadway. Care shall be taken to obtain all material from the hole which is dug. The samples taken shall be combined.

7. REDUCING FIELD SAMPLES TO TESTING SIZE

7.1 The reduction of samples to obtain the amount required for particular tests shall be performed in accordance with AASHTO R 76.

8. SAMPLE IDENTIFICATION

8.1 Each sample shall be identified by an accompanying sample ticket. Sample tickets shall be filled out as required to provide necessary information. The remarks area of the sample ticket shall be used as necessary to provide additional information, including the phone number of an individual who can be contacted regarding the sample.

8.2 The source of the sample shall be the "original source" of the material, as indicated on the sample ticket.

8.3 An example of a completed sample ticket used by ADOT for construction projects is shown in Figure 5. Commonly used codes for filling out the sample ticket are shown on the back side of the sample ticket (see Figure 6).

8.4 The sample ticket consists of three copies. The center copy in kept by the person submitting the sample, the original copy is included inside the sample container, and the third copy is attached to the sample container. When filling out sample tickets, make certain information is clear and easily read on all three copies.

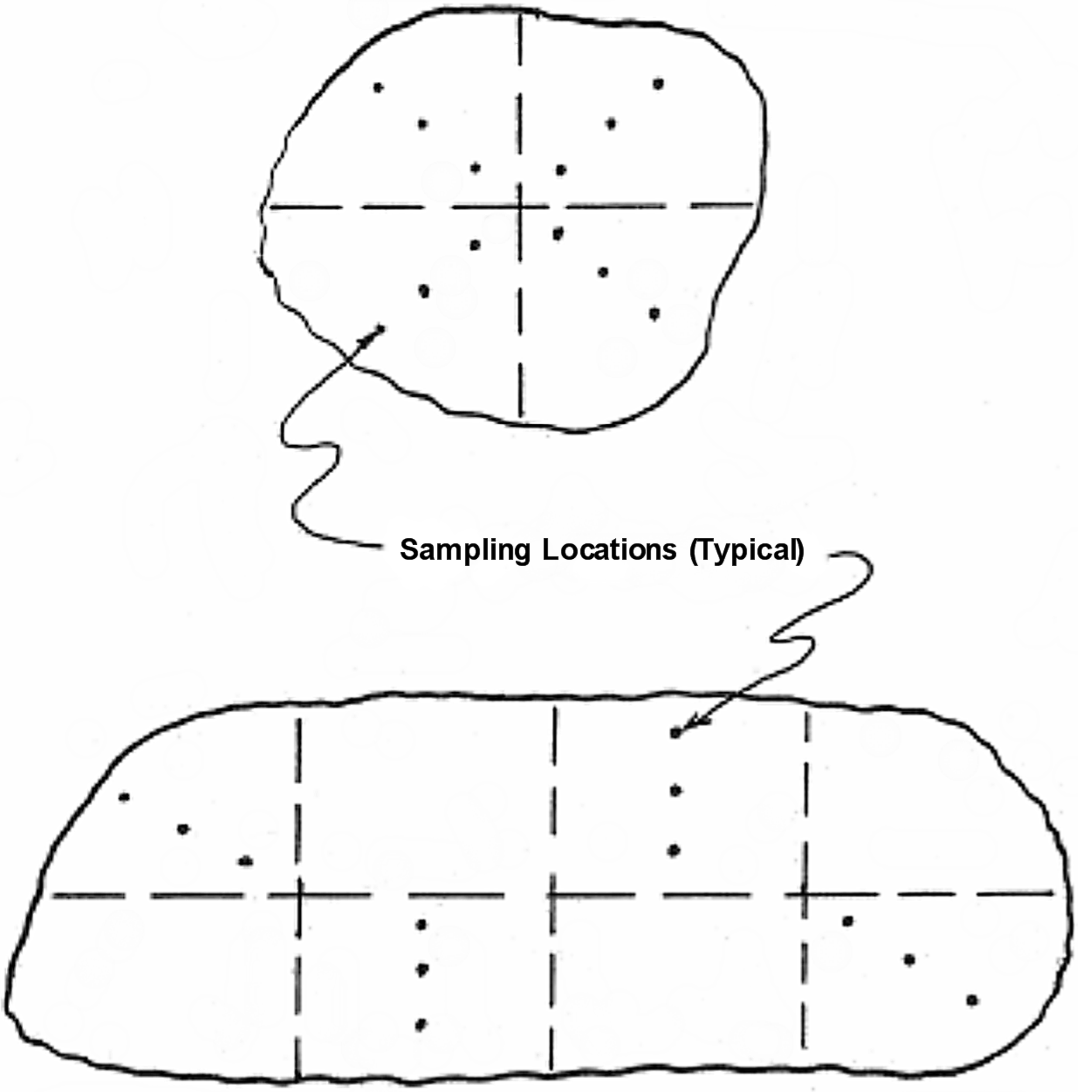
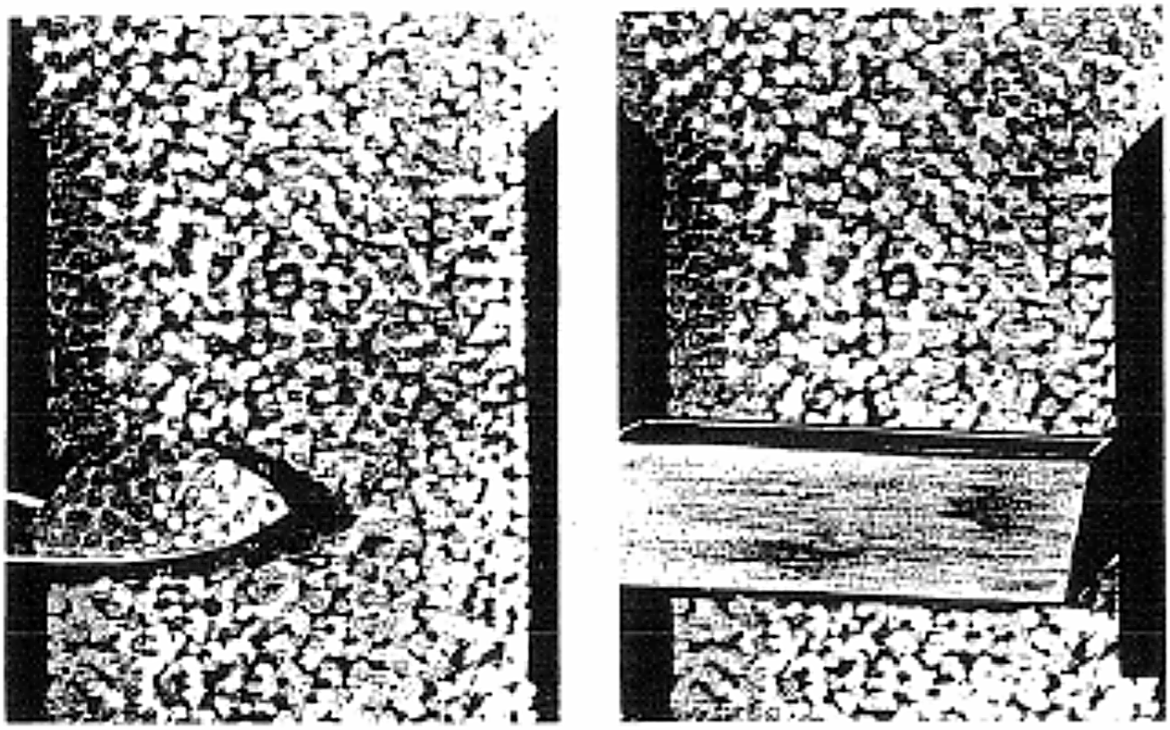


Illustration of Sampling Locations for Different Stockpile Types

FIGURE 1



WRONG

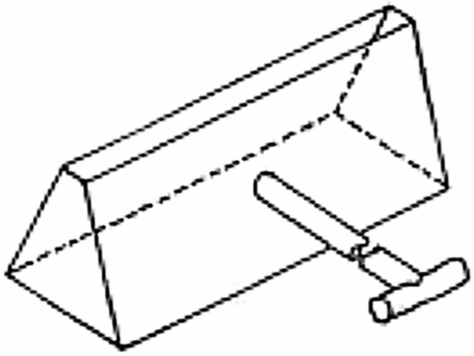
When aggregate is passed over a screen, the fines tend to drop through immediately and accumulate on one side of the hopper. A sample taken with a shovel or other small container will not be representative.

RIGHT

A sample taken by inserting the sampling device through the full flow of material will yield a representative sample. The restricted opening prevents the sampling device from filling all at once.

Illustration of Bin Sampling

FIGURE 2



Typical Bin Sampler

FIGURE 3

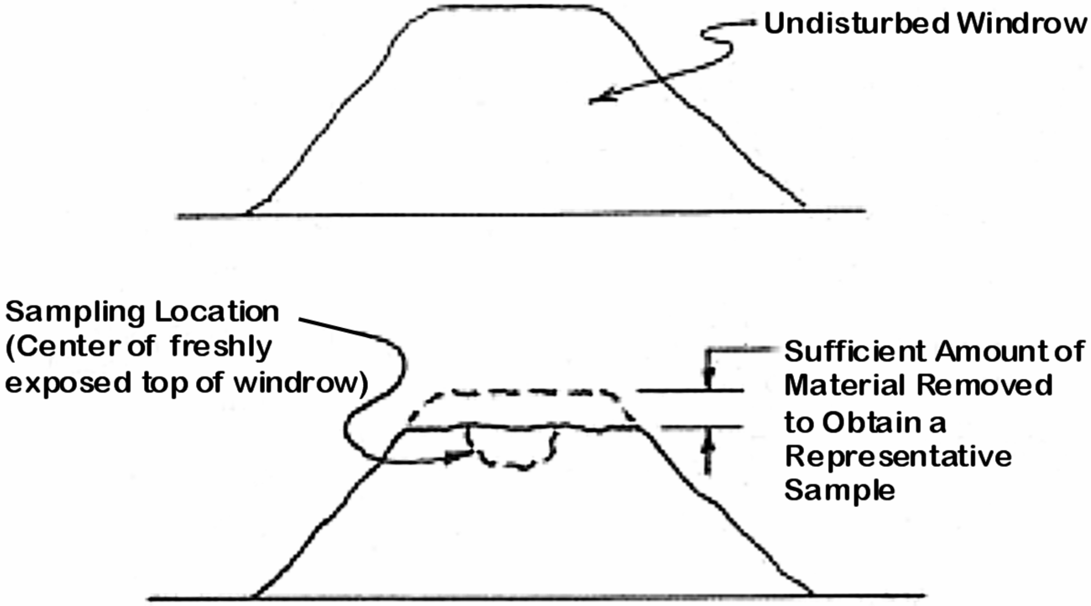
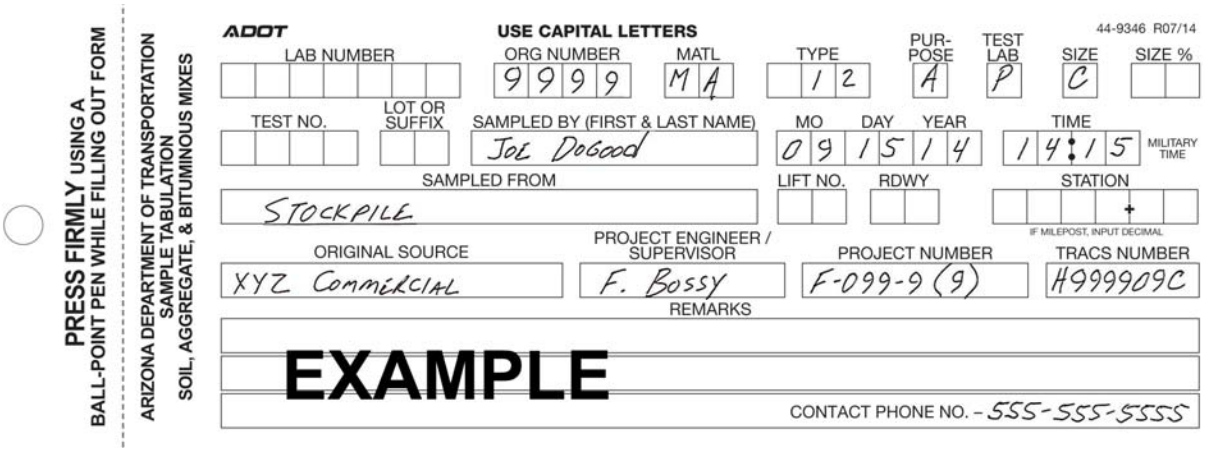


Illustration of Sampling From a Windrow

FIGURE 4



PRESS FIRMLY USING A
BALL-POINT PEN WHILE FILLING OUT FORM

ARIZONA DEPARTMENT OF TRANSPORTATION
SAMPLE TABULATION
SOIL, AGGREGATE, & BITUMINOUS MIXES

ADOT

USE CAPITAL LETTERS

44-9346 R07/14

LAB NUMBER:
ORG NUMBER: 9999
MATL: MA
TYPE: 12
PUR-POSE: A
TEST LAB: P
SIZE: C
SIZE %:
TEST NO.:
LOT OR SUFFIX:
SAMPLED BY (FIRST & LAST NAME): JoE DoGood
MO: 09 DAY: 15 YEAR: 14
TIME: 14:15 MILITARY TIME
SAMPLED FROM: STOCKPILE
LIFT NO.:
RDWY:
STATION: + IF MILEPOST, INPUT DECIMAL
ORIGINAL SOURCE: XYZ CommERCIAL
PROJECT ENGINEER / SUPERVISOR: F. Bossy
PROJECT NUMBER: F-099-9 (9)
TRACS NUMBER: H999909C
REMARKS:

EXAMPLE

CONTACT PHONE NO. – 555-555-5555

FIGURE 5

Roadway Codes:

NB	NORTHBOUND
SB	SOUTHBOUND
EB	EASTBOUND
WB	WESTBOUND
RA	RAMP A
RB	RAMP B
RC	RAMP C
RD	RAMP D
FR	FRONTAGE ROAD
XR	CROSS ROAD
DE	DETOUR

Purpose Codes:

A	ACCEPTANCE
C	CORRELATION
P	INDEPENDENT ASSURANCE
I	INFORMATIONAL

Testing Lab Codes:

C	CENTRAL LAB
R	REGIONAL LAB
P	PROJECT LAB

Bituminous Mixes:

AC	ASPHALTIC CONCRETE	
MA	MINERAL AGGREGATE	
	34	3/4" ASPHALTIC CONCRETE
	34F	3/4" FINE BAND 417 AC
	34K	3/4" COARSE BAND 417 AC
	12	1/2" ASPHALTIC CONCRETE
	12F	1/2" FINE BAND 417 AC
	12K	1/2" COARSE BAND 417 AC
	BM	BASE MIX
	FC	ACFC
	RD	ASPHALT - RUBBER ASPHALTIC CONCRETE
	RF	ASPHALT - RUBBER A.C. FRICTION COURSE
	409MI	MISC. STRUCTURAL
	409SP	MISC. STRUCTURAL (Special Mix)

Soils and Aggregates:

AB	AGGREGATE BASE (CLASS 1, 2, or 3)		
AS	AGGREGATE SUBBASE (CLASS 4, 5, or 6)		
CM	COVER MATERIAL (CLASS 1 or 2)		
CA	COARSE AGGREGATE	FA	FINE AGGREGATE
SG	SUBGRADE	SB	STRUCTURE BACKFILL
BW	BORROW	NG	NATURAL GROUND
BL	BLOTTER MATERIAL	EM	EMBANKMENT
DG	DECOMPOSED GRANITE	TS	TOP SOIL
BF	BACKFILL*	BM	BEDDING MATERIAL*
	*AP ALUMINUM PIPE		
	*CP CONCRETE PIPE		
	*MP METAL PIPE		
	*PP PLASTIC PIPE		
	*PV PVC PIPE		
	*SL SLURRY		
	*TR TRENCH BACKFILL		

Other Codes:

RP	RECLAIMED ASPHALT PAVEMENT
	C COARSE
	F FINE
	O OTHER
GR	GRANULATED RUBBER
CB	CRASH BARREL SAND
RR	RIP RAP

Not all codes used by FAST are listed above. (See Appendix C of Series 900 of the ADOT Materials Testing Manual for a listing of other codes used by FAST. FAST may revise codes, delete codes, or add codes at various times. Individuals must assure that they are utilizing the current FAST codes.

44-9346 R07/14

FIGURE 6

ADOT
Infrastructure Delivery and Operations

ARIZ 201e
November 2, 2018
(19 Pages)

SIEVING OF COARSE AND FINE GRADED SOILS AND AGGREGATES

(An Arizona Method)

1. SCOPE

1.1 This procedure describes the method for sieving and determining the sieve analysis of fine and coarse graded soils and aggregates, including the determination of minus No. 200 material by elutriation.

1.2 The procedure for sample preparation, sieving, and calculating the sieve analysis which is given in Sections 3 through 10 applies in general for all sieving operations. Section 11 gives a brief outline of the procedure for performing the sieve analysis when the sample is dried to constant weight prior to sieving. Section 12 gives an outline and description of the procedure for performing the sieve analysis when the sample is not dried to constant weight prior to sieving. Additional methods are given in Arizona Test Method 248, “Alternate Procedures for Sieving of Coarse and Fine Graded Soils and Aggregates”.

1.3 A washed gradation, utilizing an appropriate alternate procedure as described in either Alternate #1, 3, 4, or 5 of ARIZ 248, is to be used for all soil and aggregate materials with specification requirements for gradation. The washing requirement may be waived if the Engineer determines that it is unnecessary. However, in cases of dispute, the referee method shall be a washed gradation. Composited samples of mineral aggregate for bituminous mix designs shall be tested in accordance with either Alternate #3, 4, or 5 of ARIZ 248. If desired, the washed gradation of samples from individual stockpiles or bins may be determined and used in calculating the composite gradation.

1.4 This test method may involve hazardous materials, operations, or equipment. This test method does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user to consult and establish appropriate safety and health practices and determine the applicability of any regulatory limitations prior to use.

2. APPARATUS

2.1 Requirements for the frequency of equipment calibration and verification are found in Appendix A3 of the Materials Testing Manual.

2.2 Sieves of sizes as required for screening, conforming to the requirements of ASTM E11.

2.3 Any mechanical shaker may be used which produces the required thoroughness of sieving, as specified in Subsection 4.5.

2.4 Balances or scales - Conforming to the requirements of AASHTO M 231, except when determining weights of 5000 grams or less, the readability and sensitivity shall be at least one gram; and when determining weights of greater than 5000 grams, the readability and sensitivity shall be at least 20 grams.

2.5 Sample splitters - Shall conform to the requirements of, and be used in accordance with the procedures given in, AASHTO R 76.

2.6 Heating/Drying Device - An oven or suitable heating device which is capable of drying samples without aggregate breakage or loss of material due to splattering. A microwave oven may be used to dry materials, provided proper attention is given to the use of apparatus and the intensity of heat generated.

2.7 Brass wire brush for cleaning fine sieves coarser than No. 100, and a soft bristle brush for sieves No. 100 and No. 200.

2.8 A suitable mechanical washing device with No. 200 mesh wire (Similar to Figure 1) for performing washing of fine soils and aggregates as described in Section 6, equipped with a metal tube(s) connected to a water and an air outlet; or a vessel of sufficient capacity and a nest of No. 16 and No. 200 sieves for use with the hand washing method. When utilizing mechanical washing equipment, the provision for air may be eliminated if the water pressure provides adequate agitation to wash sample as specified in Section 6.

2.9 Miscellaneous pans, scoops, spatulas, brushes, pulverizing equipment, etc. for preparing, washing, and drying samples.

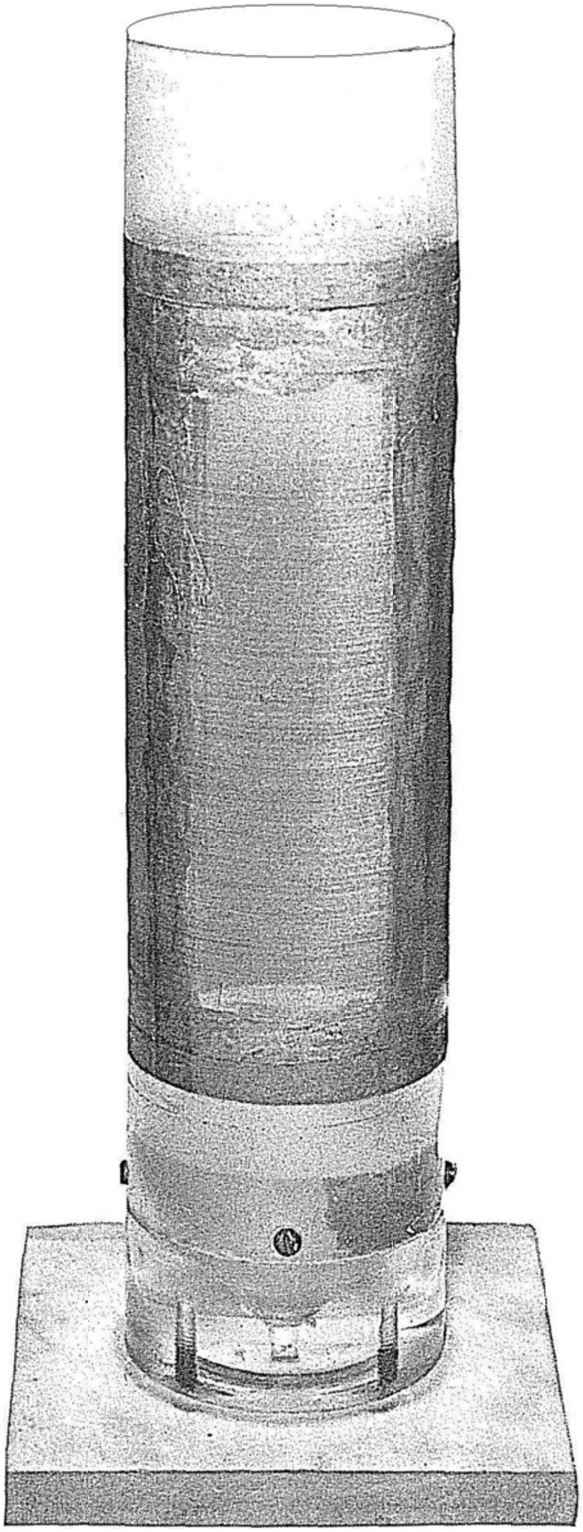


FIGURE 1

3. SAMPLE PREPARATION

3.1 A representative sample of the amount indicated in Subsection 3.2 below shall be obtained. Dry the sample sufficiently to permit separation of particles on the No. 4 and larger sieves, and to develop a free-flowing condition in the portion passing the No. 4 sieve. The use of sunlight, ovens, fans, or warm air are the most common drying methods. Turn the sample frequently to prevent formation of hard clay lumps. If the sample contains hard clods or coated coarse aggregate particles, break up the clods by means which will not reduce the size of any rock. (The use of a rubber covered mallet or the raking of the material over an old screen have been found to be satisfactory methods.) When subsequent testing is to be performed on the material, it shall be assured that any temperature restrictions, as given in the appropriate test method(s), are not exceeded. A number of soil and aggregate tests, such as plasticity index, proctor maximum density, and sand equivalent, require that samples not be heated in excess of 140 °F.

3.2 If necessary, samples shall be reduced in size in accordance with the splitting or quartering methods in AASHTO R 76 to obtain the appropriate sample size as shown below.

Nominal Maximum Size of Particle *	Minimum Weight of Sample, grams (lbs.)
3/8”	1000 (2.2)
1/2”	2000 (4.4)
3/4”	5000 (11)
1”	10000 (22)
1-1/2”	15000 (33)
2”	20000 (44)
2-1/2”	25000 (55)
3”	30000 (66)
3” Slot	35000 (77)

*The smallest sieve opening through which the entire amount of material, by specification, is permitted to pass.

3.3 If desired, the sample may be dried to constant weight. The sample may be considered to be at constant weight when, after an initial drying period of at least one hour, further drying causes or would cause less than 0.1% additional loss in weight within a five minute drying period. If desired, the material may be dried to constant weight utilizing a microwave oven in accordance with Subsection 2.6.

3.4 Allow the sample to cool, if necessary, and record the weight of the material.

4. COARSE SIEVING

4.1 Normally the coarse sieving of material is performed utilizing the No. 4 sieve as the smallest sieve.

4.2 When material being screened contains a large amount of passing No. 4 material, such that there may be overloading in the bottom pan during shaking operations, the sample shall be initially sieved over a No. 4 sieve to separate excess amounts of this material. This passing No. 4 material is saved and combined with the remaining portion of passing No. 4 material from subsequent coarse sieving. When material contains large rocks that are not to be sieved in the nest of coarse sieves during the actual shaking operation, the sample shall be pre-sieved to separate these particles. Unless all material will pass the largest sieve in the nested sieves, the material shall be pre-sieved over a sieve of the next larger size than that of the largest sieve size being utilized in the nested sieves. Large rocks separated in this manner are individually tested for passing the appropriate sieve, determining and recording the weight of any rock retained on these sieves.

4.3 Empty the sample into the nest of sieves that is to be used for screening material. If pre-sieving has not been performed, remove any particles which may be retained on the top sieve and test these for passing the appropriate sieve, determining and recording the weight of any rock retained on these sieves.

4.4 The material shall be subjected to sieving by hand or in a mechanical sieve shaker. The sieving action shall cause the particles to bounce and turn so as to present different orientations to the sieving surface. No particles shall be hand manipulated for passing any of the nested sieves. The sieving shall be of sufficient time to assure that the criteria for “thoroughness of sieving” described in Subsection 4.5 below is achieved.

4.5 The criteria for "thoroughness of sieving" is that after completion of sieving, not more than 0.5 percent by weight of the total sample passes any sieve during one minute of continuous hand sieving in an 8 inch or 12 inch sieve as appropriate. If the thoroughness of sieving is being determined for sieves larger than 12 inches, the material retained on the respective sieve, or portions of that material shall be placed in a 12 inch sieve of the same sieve size opening, so as to not overload the sieve. Hold the individual sieve, provided with a snug fitting pan and cover, in a slightly inclined position in one hand. Strike the side of the sieve sharply and with an upward motion against the heel of the other hand at the rate of about 150 times per minute, turn the sieve about one-sixth of a revolution at intervals of about 25 strokes. A frequent check should be performed to assure that the thoroughness of sieving specified is being maintained in sieving operations.

4.6 Overloading of sieves shall be avoided. The quantity of material on a given sieve at the completion of sieving shall not exceed the amount shown in the table below. As the weight retained on each individual sieve size is determined, it should be compared with the corresponding overloading criteria prior to combining the weighed material. If overloading occurs, proper corrective action to regulate the amount of material on a sieve shall be taken. This may be accomplished by splitting the material which is retained on the overloaded sieve, resieving each portion, and combining weights.

Sieve Size	Maximum Weight Allowed (grams/ sq. in.)	Maximum Weight Allowed (grams)	
		12” Dia. Sieve	14-3/4” x 22-3/4” Sieve
3”	*	*	*
2-1/2”	*	*	*
2”	*	*	*
1-1/2”	25	2827	8389
1”	18	2036	6040
3/4”	14	1583	4698
1/2”	10	1131	3356
3/8”	8	905	2685
1/4”	6	679	2013
No. 4	5	565	1678

*Normally particles of material retained on these sieves are tested individually, so no maximum weight allowed is specified.

4.7 Starting with the largest of the nested sieves, the material retained on each sieve and in the bottom pan is weighed and recorded.

4.8 Do not discard any of the sieved material until the sum of the individual weights is compared to the weight of sample prior to sieving. If the difference between the two weights is less than or equal to 1.0% of the weight of sample prior to sieving, an adjustment in weight shall be made on the sieve which has the largest weight retained, except no adjustments shall be made on the minus No. 4 material. If the difference is greater than 1.0%, the sample shall be recombined, resieved, and carefully reweighed.

5. SAMPLE FOR ELUTRIATION AND FINE SIEVING

5.1 A representative minimum 500 gram sample of the passing No. 4 material from the coarse sieving shall be obtained by the use of a splitter in accordance with AASHTO R 76. The selection of an exact predetermined weight shall not be attempted. The sample size may be reduced if the minimum of 500 grams is not obtained from coarse sieving, or if there is insufficient material for performing other desired tests utilizing the pass No. 4 material. When utilizing the mechanical washing device, the requirement for a minimum 500 gram sample may be reduced to a minimum of 200 grams for materials that tend to clog the No. 200 sieve (for example, fine soils such as blow sand, silty soils, or clay).

5.2 The weight of the sample for elutriation and fine sieving is recorded to the nearest gram as “Dry Wt. Pass No. 4 Split”.

5.3 Subject the sample to elutriation by either mechanical washing (Section 6) or hand washing (Section 7).

6. MECHANICAL WASHING

6.1 This method is generally utilized for passing No. 4 material, although it may also be used with the alternate procedure described in Section 2 of Arizona Test Method 248 for testing materials containing small amounts of Plus No. 4 material (100% passing 3/8"). Generally, a maximum of 600 grams may be tested utilizing the mechanical washing device.

6.2 Fill the washing device with water to the bottom of the windows. Transfer the sample to the washing device, and wash all material clinging to the sample container into the washing device. Utilizing the water tube, and air tube if necessary, agitate the sample vigorously enough so that it causes the material to go into suspension, but not enough to cause splattering to reach the top of the cylinder. Continue this washing action, taking care that there is no loss of sample by splattering or overflowing. (If the No. 200 sieve tends to plug excessively, this may be overcome to some extent by tapping the washing device with the palm of the hand or by washing down the inside of the sieve with a low stream of water.) Washing shall continue until the wash water becomes clear.

6.3 Turn off the water and compressed air and remove the metal tube(s), rinsing clinging material back into the sample. Wash the sample into a container of sufficient capacity to hold the water and sample; allow the particles to settle and decant the excess water.

6.4 Dry the sample to constant weight at a temperature that will not cause the material to be lost due to splattering.

6.5 Allow the sample to cool, reweigh and record to the nearest gram as the fine sieve “Total Dry Weight”.

6.6 Subtract the “Total Dry Weight” from the “Dry Wt. of Pass No. 4 Split”, and record as the “Elutriation”.

7. HAND WASHING (REFEREE METHOD)

7.1 Place the sample in a pan of sufficient size and capacity to allow washing without spillage. Cover with adequate water to thoroughly wash aggregate. Agitate the contents of the pan vigorously in order to completely separate all particles finer than the No. 200 sieve from the coarser particles, and to bring the finer material into suspension so that it will be removed by decantation of the water.

7.2 Decant the wash water through a nest of No. 16 and No. 200 sieves.

7.3 Repeat the washing and decanting cycle until the water becomes clear.

7.4 Thoroughly wash all material remaining on the No. 16 and the No. 200 sieves and return to the sample.

7.5 After the particles have settled in the pan, carefully decant any excess water, assuring that no particles are lost.

7.6 Dry the sample to constant weight at a temperature that will not cause material to be lost due to splattering.

7.7 Allow the sample to cool, reweigh and record to the nearest gram as the fine sieve “Total Dry Weight”.

7.8 Subtract the “Total Dry Weight” from the “Dry Wt. of Pass No. 4 Split”, and record as the “Elutriation”.

8. SIEVING OF FINE AGGREGATE

8.1 Place the washed and dried fine aggregate sample into the top of the nested sieves, close the nest of sieves with lid.

8.2 The material shall be subjected to sieving by hand or in a mechanical sieve shaker. The sieving action shall cause the particles to bounce and turn so as to present different orientations to the sieving surface. No particles shall be hand manipulated for passing any of the nested sieves. The sieving shall be of sufficient time to assure that the criteria for "thoroughness of sieving" described in Subsection 4.5 is achieved.

8.3 Overloading of sieves shall be avoided. The quantity of material on a given sieve at the completion of sieving shall not exceed 4 grams per square inch of sieving area (201 grams for an 8 inch diameter sieve and 452 grams for a 12 inch sieve). As the weight retained on each individual sieve size is determined, it should be compared with the corresponding overloading criteria prior to combining the weighed material. If overloading occurs, proper corrective action to regulate the amount of material on a sieve shall be taken. This may be accomplished by splitting the material which is retained on the overloaded sieve, resieving each portion, and combining weights.

8.4 Starting with the largest of the nested sieves, the material retained on the individual sieves and in the bottom pan shall be weighed and recorded.

8.5 Do not discard any of the sieved material until the sum of the individual weights is compared to the weight of sample prior to sieving. If the difference between the two weights is less than or equal to 1.0% of the weight of sample prior to sieving, an adjustment in weight shall be made on the sieve which has the largest weight retained, except no adjustments shall be made on the minus No. 200 material. If the difference is greater than 1.0% the sample shall be recombined, resieved, and carefully reweighed.

9. PRECAUTIONS

9.1 Check sieves at least daily for broken or distorted wire, and replace any sieves found to be damaged or excessively worn.

9.2 Sieves not conforming to AASHTO M 92 must be replaced.

9.3 Do not repair wire cloth.

9.4 Clean sieves carefully after each shaking, using the proper instrument to reduce chances of damaging the mesh.

9.5 All mechanical equipment shall be inspected frequently and maintained by greasing, cleaning, and repair of worn out parts.

10. CALCULATIONS

10.1 The calculations for determining the sieve analysis are as follows. Examples of these calculations are given in Figures 2 and 3.

10.2 The calculations to determine the % passing values for the coarse sieve anaylsis are performed as described below:

10.2.1 For the largest sieve which has no material retained, record the percent passing as 100. Determine a factor for calculating the coarse sieve analysis by the following. Record the coarse sieve factor to at least six decimal places.

$$\text{Coarse Sieve Factor} = \frac{100}{\text{Coarse Sieve Total}}$$

10.2.2 The percent passing for each sieve in the coarse sieve analysis is determined by multiplying the weight retained on that sieve times the coarse sieve factor, and subtracting the result from the unrounded % passing for the next larger sieve, as shown below. Values for “weight retained times the coarse sieve factor” and “percent passing each sieve” shall be determined and used in the calculations to at least six decimal places. The percent passing value for each sieve is recorded in the sieve analysis to the nearest whole percent.

$$\begin{matrix}\text{Percent}\\ \text{Passing}\\ \text{Desired}\\ \text{Sieve}\end{matrix} = \begin{pmatrix}\text{Unrounded}\\ \text{\% Pass for}\\ \text{next larger}\\ \text{sieve}\end{pmatrix} - \begin{pmatrix}\text{Weight} & & \text{Coarse}\\ \text{Retained on} & \text{x} & \text{Sieve}\\ \text{Desired Sieve} & & \text{Factor}\end{pmatrix}$$

10.2.3 As a check on the coarse sieve analysis, multiply the weight of minus No. 4 material times the coarse sieve factor, as shown below. The result of this calculation, rounded to the nearest whole percent, should be the same as the value for percent passing the No. 4 sieve determined in the paragraph above.

$$\begin{matrix}\text{Check for Percent} \\ \text{Passing No. 4}\end{matrix} = \begin{pmatrix}\text{Wt. of Pass} \\ \text{No. 4 sieve}\end{pmatrix} \text{ x } \begin{pmatrix}\text{Coarse} \\ \text{Sieve} \\ \text{Factor}\end{pmatrix}$$

10.3 The calculations to determine the % passing values for the fine sieve analysis are performed as described below:

10.3.1 Determine a factor for the fine sieve analysis by dividing the percent passing the No. 4 sieve (which has been recorded to the nearest whole percent) by the "Dry Weight of Pass #4 Split", as shown below. Record the fine sieve factor to at least six decimal places. If all the pass No. 4 material from coarse sieving was subjected to elutriation and fine sieving, a fine sieve factor is not determined. Rather, the coarse sieve factor is utilized and the calculation of the percent passing each sieve is continuous through the entire sieve analysis.

$$\text{Fine Sieve Factor} = \frac{\text{Rounded Percent Pass No. 4}}{\text{Dry Wt. of Pass No. 4 Split}}$$

10.3.2 The percent passing for each sieve in the fine sieve analysis is determined by multiplying the weight retained on that sieve times the fine sieve factor, and subtracting the result from the unrounded % passing the next larger sieve, with the exception of the percent passing the No. 4 which has previously been recorded to the nearest whole percent. The equation for determining the percent passing each sieve is shown below. Values for "weight retained times the fine sieve factor" and "percent passing each sieve" shall be determined and used in the calculations to at least six decimal places. The percent passing value for each sieve is recorded in the sieve analysis to the nearest whole percent, except the percent passing the No. 200 sieve is recorded to the nearest 0.1 percent.

$$\begin{matrix}\text{Percent} \\ \text{Passing} \\ \text{Desired} \\ \text{Sieve}\end{matrix} = \begin{pmatrix}\text{Unrounded} \\ \text{\% Pass for} \\ \text{next Larger} \\ \text{sieve}\end{pmatrix} - \begin{pmatrix}\text{Weight} & & \text{Fine} \\ \text{Retained on} & \text{x} & \text{Sieve} \\ \text{Desired Sieve} & & \text{Factor}\end{pmatrix}$$

10.3.3 As a check on the fine sieve analysis, the weight of material passing the No. 200 from sieving is added to the elutriation weight, and this total is multiplied times the fine sieve factor, as shown below. The result of this calculation, rounded to the nearest 0.1 percent, should be the same as the value for the percent passing the No. 200 determined in the paragraph above.

$$\begin{matrix}\text{Check for Percent}\\ \text{Passing No. 200}\end{matrix} = \left(\begin{matrix}\text{Weight of}\\ \text{Passing No. 200}\end{matrix} + \begin{matrix}\text{Elutriation}\\ \text{Weight}\end{matrix}\right) \text{x} \left(\begin{matrix}\text{Fine Sieve}\\ \text{Factor}\end{matrix}\right)$$

10.4 If desired, obtain the percent retained on each sieve by subtracting the rounded % passing value for that sieve from the rounded % passing value for the next larger sieve, as shown below.

$$\begin{matrix}\text{\% Retained}\\ \text{for Desired}\\ \text{Sieve}\end{matrix} = \left(\begin{matrix}\text{Rounded \%}\\ \text{Pass Next}\\ \text{Larger Sieve}\end{matrix}\right) - \left(\begin{matrix}\text{Rounded \%}\\ \text{Pass the}\\ \text{Desired Sieve}\end{matrix}\right)$$

10.5 Other methods may be used that differ from that specified in Subsections 10.2 and 10.3 above to determine % passing each sieve, so long as the method utilized has been proven to give equivalent results. However, any procedure which includes recording percent retained values prior to completing the calculation of all percent passing values is not allowed.

11. PROCEDURE WHEN SAMPLE IS DRIED TO CONSTANT WEIGHT PRIOR TO SIEVING

11.1 The following is a brief outline of the procedure to be used when the sample is dried to constant weight prior to sieving. An example of this procedure is shown in Figure 2.

11.2 Prepare sample, dry to constant weight, allow to cool, and record as “Coarse Sieve Total”, (3087 in the example).

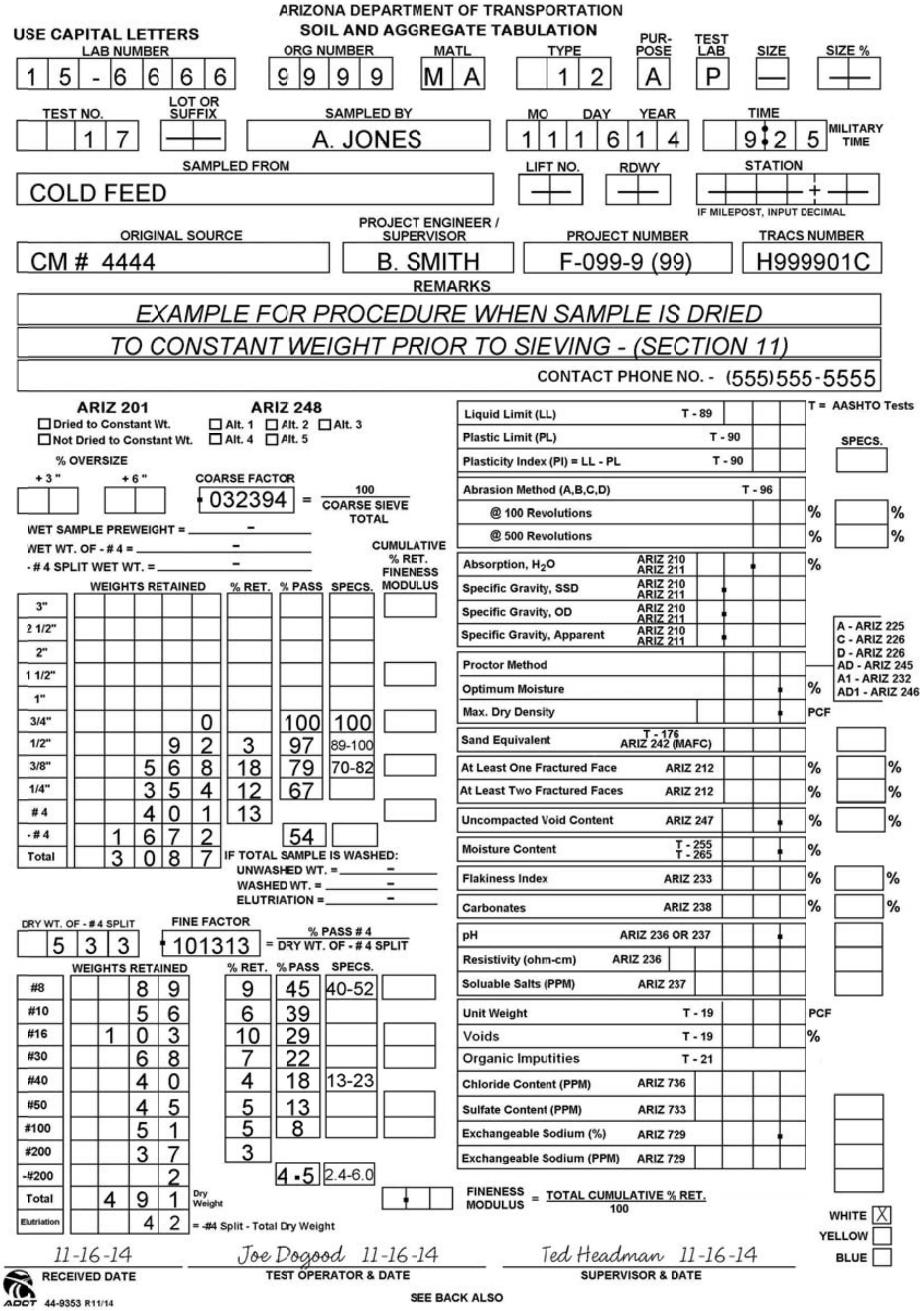
11.3 Perform coarse sieving.

11.4 Record the weight of the material in the appropriate “Weights Retained” box for each sieve and the pan.

11.5 Sum the individual weights retained for each sieve, compare to the weight of sample prior to sieving (Coarse Sieve Total), and adjust or resieve as necessary.

11.6 Split the pass No. 4 material to at least 500 grams and record as "Dry Wt. of Pass No. 4 Split", (533).

11.7 Perform elutriation on the dry - #4 split, dry back to constant weight, allow to cool, and record as the "Total Dry Weight", (491).



ARIZONA DEPARTMENT OF TRANSPORTATION
SOIL AND AGGREGATE TABULATION

USE CAPITAL LETTERS

LAB NUMBER: 15-6666
ORG NUMBER: 9999
MATL: MA
TYPE: 12
PURPOSE: A
TEST LAB: P
SIZE: —
SIZE %: —

TEST NO.: 17
LOT OR SUFFIX: —
SAMPLED BY: A. JONES
MO DAY YEAR: 11 16 14
TIME: 9:25 MILITARY TIME

SAMPLED FROM: COLD FEED
LIFT NO.: —
RDWY: —
STATION: — + — (IF MILEPOST, INPUT DECIMAL)

ORIGINAL SOURCE: CM # 4444
PROJECT ENGINEER / SUPERVISOR: B. SMITH
PROJECT NUMBER: F-099-9 (99)
TRACS NUMBER: H999901C

REMARKS
EXAMPLE FOR PROCEDURE WHEN SAMPLE IS DRIED
TO CONSTANT WEIGHT PRIOR TO SIEVING - (SECTION 11)
CONTACT PHONE NO. - (555)555-5555

ARIZ 201
☐ Dried to Constant Wt.
☐ Not Dried to Constant Wt.

ARIZ 248
☐ Alt. 1 ☐ Alt. 2 ☐ Alt. 3
☐ Alt. 4 ☐ Alt. 5

% OVERSIZE
+ 3 " ☐ + 6 " ☐

COARSE FACTOR .032394 = 100 / COARSE SIEVE TOTAL

WET SAMPLE PREWEIGHT = –
WET WT. OF - # 4 = –
- # 4 SPLIT WET WT. = –

	WEIGHTS RETAINED	% RET.	% PASS	SPECS.	CUMULATIVE % RET. FINENESS MODULUS
3"					
2 1/2"					
2"					
1 1/2"					
1"					
3/4"	0		100	100	
1/2"	92	3	97	89-100	
3/8"	568	18	79	70-82	
1/4"	354	12	67		
# 4	401	13			
- # 4	1672		54		
Total	3087				

IF TOTAL SAMPLE IS WASHED:
UNWASHED WT. = –
WASHED WT. = –
ELUTRIATION = –

DRY WT. OF - # 4 SPLIT: 533
FINE FACTOR .101313 = % PASS # 4 / DRY WT. OF - # 4 SPLIT

	WEIGHTS RETAINED	% RET.	% PASS	SPECS.
#8	89	9	45	40-52
#10	56	6	39	
#16	103	10	29	
#30	68	7	22	
#40	40	4	18	13-23
#50	45	5	13	
#100	51	5	8	
#200	37	3		
-#200	2		4.5	2.4-6.0
Total	491 Dry Weight			
Elutriation	42 = -#4 Split - Total Dry Weight			

FINENESS MODULUS = TOTAL CUMULATIVE % RET. / 100

T = AASHTO Tests

Test	Method	Result	Unit	SPECS.
Liquid Limit (LL)	T - 89			
Plastic Limit (PL)	T - 90			
Plasticity Index (PI) = LL - PL	T - 90			
Abrasion Method (A,B,C,D)	T - 96			
@ 100 Revolutions			%	%
@ 500 Revolutions			%	%
Absorption, H_2O	ARIZ 210 ARIZ 211		%	
Specific Gravity, SSD	ARIZ 210 ARIZ 211			
Specific Gravity, OD	ARIZ 210 ARIZ 211			
Specific Gravity, Apparent	ARIZ 210 ARIZ 211			
Proctor Method				
Optimum Moisture			%	
Max. Dry Density			PCF	
Sand Equivalent	T - 176 ARIZ 242 (MAFC)			
At Least One Fractured Face	ARIZ 212		%	%
At Least Two Fractured Faces	ARIZ 212		%	%
Uncompacted Void Content	ARIZ 247		%	%
Moisture Content	T - 255 T - 265		%	
Flakiness Index	ARIZ 233		%	%
Carbonates	ARIZ 238		%	%
pH	ARIZ 236 OR 237			
Resistivity (ohm-cm)	ARIZ 236			
Soluable Salts (PPM)	ARIZ 237			
Unit Weight	T - 19		PCF	
Voids	T - 19		%	
Organic Imputities	T - 21			
Chloride Content (PPM)	ARIZ 736			
Sulfate Content (PPM)	ARIZ 733			
Exchangeable Sodium (%)	ARIZ 729			
Exchangeable Sodium (PPM)	ARIZ 729			

A - ARIZ 225
C - ARIZ 226
D - ARIZ 226
AD - ARIZ 245
A1 - ARIZ 232
AD1 - ARIZ 246

WHITE ☒
YELLOW ☐
BLUE ☐

11-16-14
RECEIVED DATE

Joe Dogood 11-16-14
TEST OPERATOR & DATE

Ted Headman 11-16-14
SUPERVISOR & DATE

ADOT 44-9353 R11/14

SEE BACK ALSO

FIGURE 2

11.8 Determine and record "Elutriation" by subtracting the "Total Dry Weight" from the "Dry Wt. of Pass No. 4 Split", (533 - 491 = 42).

11.9 Perform fine sieving on the material left from elutriation using the No. 8 sieve down to the No. 200.

11.10 Record the weight of material in the appropriate “Weights Retained” box for each sieve.

11.11 Sum the individual weights retained for each sieve, compare to the weight of sample prior to sieving (fine sieve Total Dry Weight), and adjust or resieve as needed.

11.12 Determine the sieve analysis of the material as described in Section 10.

12. PROCEDURE WHEN SAMPLE IS NOT DRIED TO CONSTANT WEIGHT PRIOR TO SIEVING

12.1 The following is an outline and description of the procedure to be used when the sample is not dried to constant weight prior to sieving. An example of this procedure is shown in Figure 3.

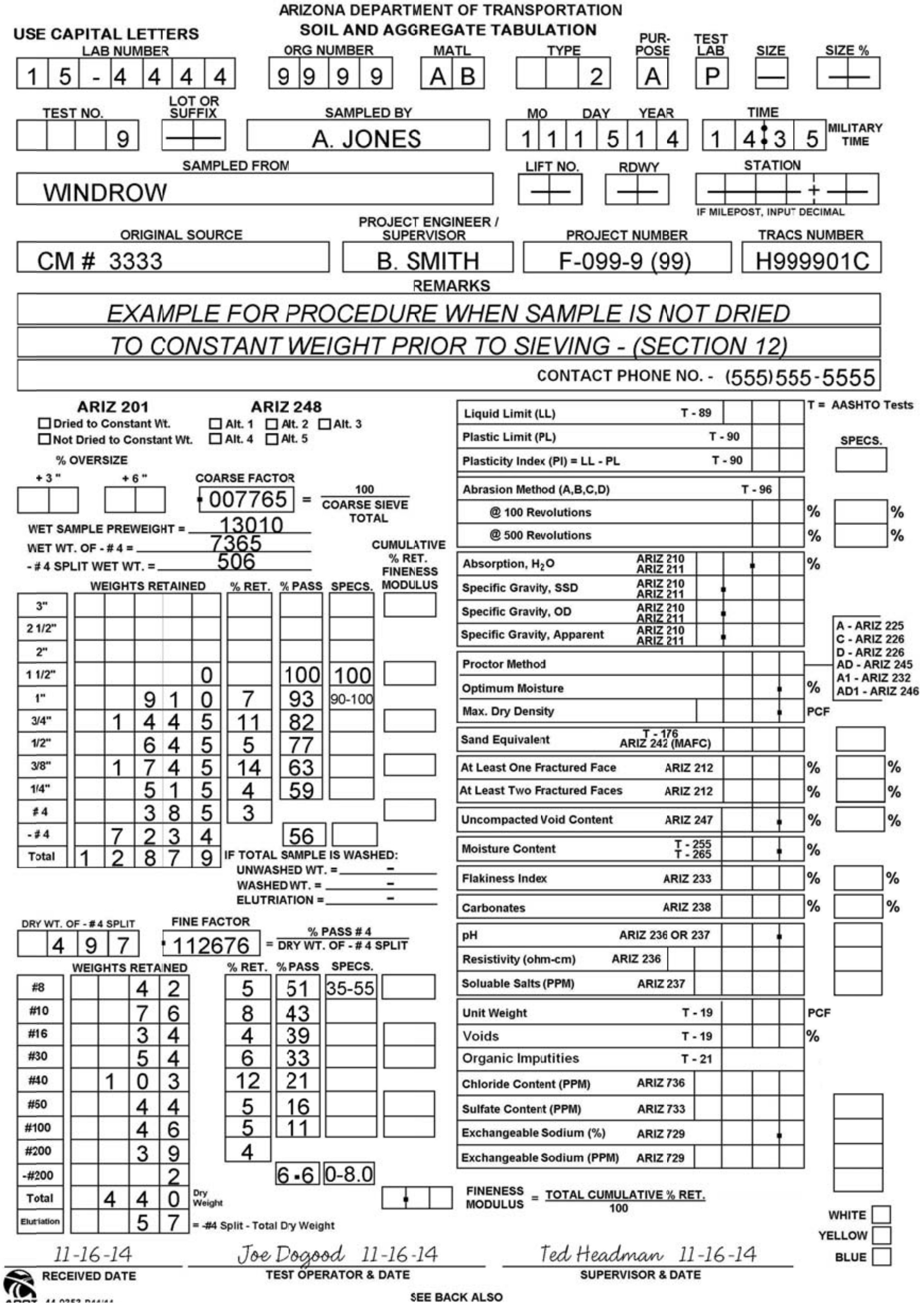
12.2 Prepare sample, dry to free flowing condition, and record this weight as “Wet Sample Preweight”, (13010 in the example).

12.3 Perform coarse sieving.

12.4 Record the weight of the material in the appropriate "Weights Retained" box for each sieve, except record the weight of pass No. 4 material as the "Wet Wt. of - #4", (7365).

12.5 Sum the individual weights retained for each sieve, compare to weight of sample prior to sieving (Wet Sample Preweight), and adjust or resieve as needed.

12.6 The wet weight of pass No. 4 material is corrected for moisture using either a split of, or the entire amount of, the pass No. 4 material.



ARIZONA DEPARTMENT OF TRANSPORTATION
SOIL AND AGGREGATE TABULATION

USE CAPITAL LETTERS

LAB NUMBER: 15-4444
ORG NUMBER: 9999
MATL: AB
TYPE: 2
PURPOSE: A
TEST LAB: P
SIZE: —
SIZE %: —

TEST NO.: 9
LOT OR SUFFIX: —
SAMPLED BY: A. JONES
MO DAY YEAR: 11 15 14
TIME: 14:35 MILITARY TIME

SAMPLED FROM: WINDROW
LIFT NO.: —
RDWY: —
STATION: +
IF MILEPOST, INPUT DECIMAL

ORIGINAL SOURCE: CM # 3333
PROJECT ENGINEER / SUPERVISOR: B. SMITH
PROJECT NUMBER: F-099-9 (99)
TRACS NUMBER: H999901C

REMARKS
EXAMPLE FOR PROCEDURE WHEN SAMPLE IS NOT DRIED
TO CONSTANT WEIGHT PRIOR TO SIEVING - (SECTION 12)

CONTACT PHONE NO. - (555)555-5555

ARIZ 201
☐ Dried to Constant Wt.
☐ Not Dried to Constant Wt.

ARIZ 248
☐ Alt. 1 ☐ Alt. 2 ☐ Alt. 3
☐ Alt. 4 ☐ Alt. 5

% OVERSIZE
+ 3" ☐ + 6" ☐

COARSE FACTOR .007765 = 100 / COARSE SIEVE TOTAL

WET SAMPLE PREWEIGHT = 13010
WET WT. OF - # 4 = 7365
- # 4 SPLIT WET WT. = 506

	WEIGHTS RETAINED	% RET.	% PASS	SPECS.	CUMULATIVE % RET. FINENESS MODULUS
3"					
2 1/2"					
2"					
1 1/2"	0		100	100	
1"	910	7	93	90-100	
3/4"	1445	11	82		
1/2"	645	5	77		
3/8"	1745	14	63		
1/4"	515	4	59		
# 4	385	3			
- # 4	7234		56		
Total	12879				

IF TOTAL SAMPLE IS WASHED:
UNWASHED WT. = –
WASHED WT. = –
ELUTRIATION = –

DRY WT. OF - # 4 SPLIT: 497
FINE FACTOR .112676 = % PASS # 4 / DRY WT. OF - # 4 SPLIT

	WEIGHTS RETAINED	% RET.	% PASS	SPECS.
#8	42	5	51	35-55
#10	76	8	43	
#16	34	4	39	
#30	54	6	33	
#40	103	12	21	
#50	44	5	16	
#100	46	5	11	
#200	39	4		
-#200	2		6.6	0-8.0
Total	440 Dry Weight			
Elutriation	57 = -#4 Split - Total Dry Weight			

FINENESS MODULUS = TOTAL CUMULATIVE % RET. / 100

T = AASHTO Tests

Test	Method	Unit	SPECS.
Liquid Limit (LL)	T - 89		
Plastic Limit (PL)	T - 90		
Plasticity Index (PI) = LL - PL	T - 90		
Abrasion Method (A,B,C,D)	T - 96		
@ 100 Revolutions		%	%
@ 500 Revolutions		%	%
Absorption, H_2O	ARIZ 210 ARIZ 211	%	
Specific Gravity, SSD	ARIZ 210 ARIZ 211		
Specific Gravity, OD	ARIZ 210 ARIZ 211		
Specific Gravity, Apparent	ARIZ 210 ARIZ 211		
Proctor Method			
Optimum Moisture		%	
Max. Dry Density		PCF	
Sand Equivalent	T - 176 ARIZ 242 (MAFC)		
At Least One Fractured Face	ARIZ 212	%	%
At Least Two Fractured Faces	ARIZ 212	%	%
Uncompacted Void Content	ARIZ 247	%	%
Moisture Content	T - 255 T - 265	%	
Flakiness Index	ARIZ 233	%	%
Carbonates	ARIZ 238	%	%
pH	ARIZ 236 OR 237		
Resistivity (ohm-cm)	ARIZ 236		
Soluable Salts (PPM)	ARIZ 237		
Unit Weight	T - 19	PCF	
Voids	T - 19	%	
Organic Imputities	T - 21		
Chloride Content (PPM)	ARIZ 736		
Sulfate Content (PPM)	ARIZ 733		
Exchangeable Sodium (%)	ARIZ 729		
Exchangeable Sodium (PPM)	ARIZ 729		

A - ARIZ 225
C - ARIZ 226
D - ARIZ 226
AD - ARIZ 245
A1 - ARIZ 232
AD1 - ARIZ 246

WHITE ☐
YELLOW ☐
BLUE ☐

11-16-14
RECEIVED DATE

Joe Dogood 11-16-14
TEST OPERATOR & DATE

Ted Headman 11-16-14
SUPERVISOR & DATE

SEE BACK ALSO

FIGURE 3

12.7 If a split of the pass No. 4 material is to be used to correct the weight of pass No. 4 material for moisture, immediately split the passing No. 4 material to at least 500 grams and record as the "- #4 Split Wet Wt.", (506). Dry the sample to constant weight, allow to cool, and record the weight as "Dry Wt. of Pass #4 Split", (497). If an elutriation and fine sieve analysis is to be performed, this split is used for that testing. Determine and record the "weight of pass No. 4 material" (7234) by the following:

$$\begin{matrix}\text{Weight of}\\ \text{Pass No. 4}\\ \text{Material}\end{matrix} = \begin{pmatrix}\text{Wet Wt.}\\ \text{of Pass}\\ \text{No. 4}\end{pmatrix} \text{ x } \left(\frac{\begin{matrix}\text{Dry Wt. of Pass}\\ \text{No. 4 Split}\end{matrix}}{\begin{matrix}\text{Pass No. 4 Split}\\ \text{Wet Wt.}\end{matrix}}\right)$$

12.8 If the entire amount of the pass No. 4 material is to be used to correct the weight of pass No. 4 material for moisture, the material is dried to constant weight and allowed to cool. The dry weight is recorded as the "weight of pass No. 4 material". If an elutriation and fine sieve analysis is to be performed on this material, the dry weight is also recorded as the "Dry Wt. of Pass No. 4 Split".

12.9 Determine and record the sample “Coarse Sieve Total”, (12879), by the following:

$$\begin{matrix}\text{Coarse}\\ \text{Sieve}\\ \text{Total}\end{matrix} = \begin{pmatrix}\text{Wet Sample}\\ \text{Preweight}\end{pmatrix} - \begin{pmatrix}\begin{matrix}\text{Wet Wt.}\\ \text{of Pass}\\ \text{No. 4}\end{matrix} & - & \begin{matrix}\text{Weight of}\\ \text{Pass No. 4}\\ \text{Material}\end{matrix}\end{pmatrix}$$

12.10 If required, perform elutriation on the dry - #4 split, dry back to constant weight, allow to cool, and record as the "Total Dry Weight", (440).

12.11 Determine and record “Elutriation” by subtracting the “Total Dry Weight” from the “Dry Wt. of Pass No. 4 Split”, (497 - 440 = 57).

12.12 Perform fine sieving on the material left from elutriation using the No. 8 sieve down to the No. 200.

12.13 Record the weight of material in the appropriate “Weights Retained” box for each sieve.

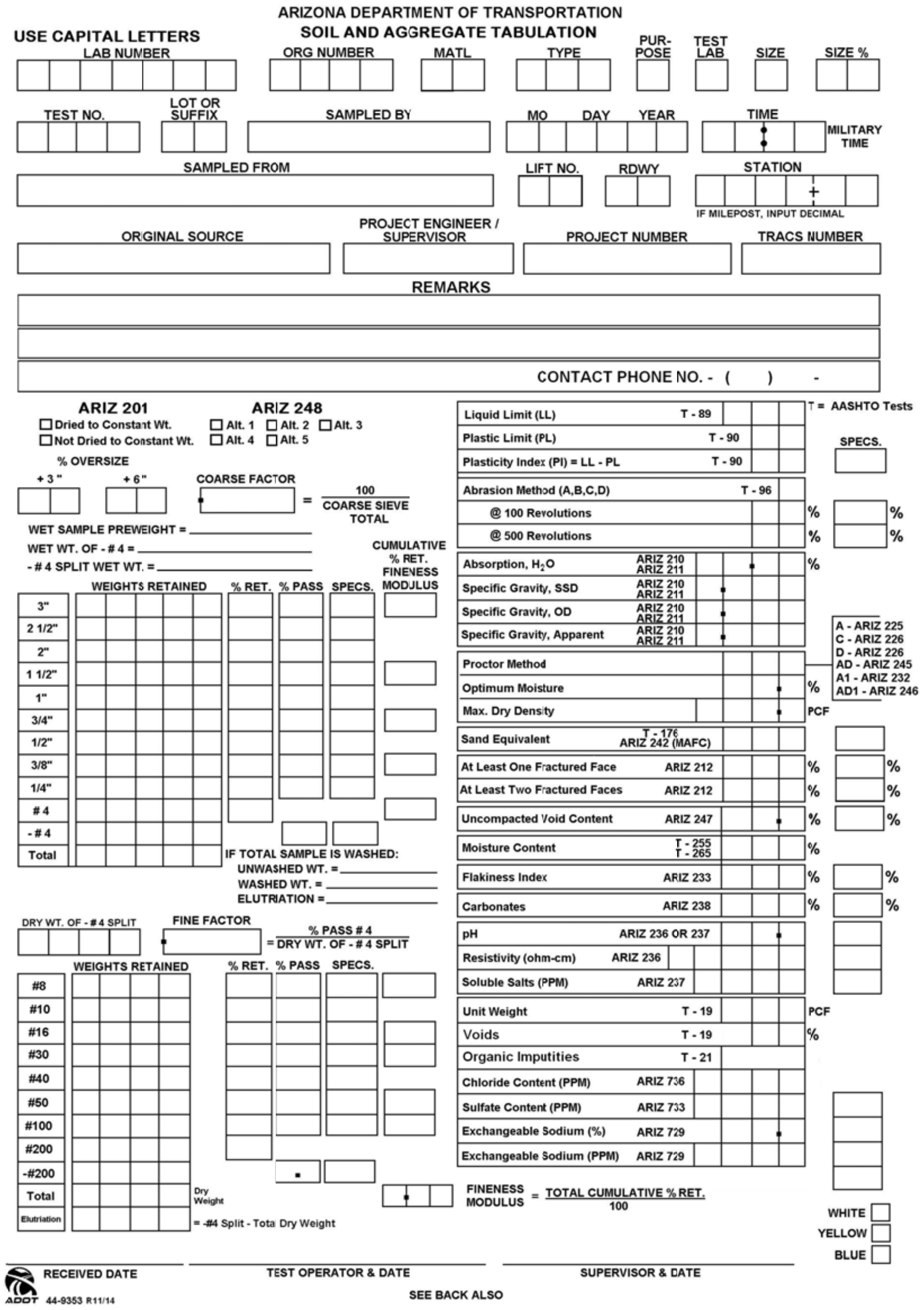
12.14 Sum the individual weights retained for each sieve, compare to the weight of sample prior to sieving (fine sieve Total Dry Weight), and adjust or resieve as needed.

12.15 Determine the sieve analysis of the material as described in Section 10.

13. REPORT

13.1 The sieve analysis shall be reported either as shown in the example given in Figure 2 for a sample which has been dried to constant weight prior to sieving, or as shown in the example given in Figure 3 for a sample which has not been dried to constant weight prior to sieving.

13.2 A blank Soils and Aggregate Tabulation laboratory card is provided in Figure 4.



ARIZONA DEPARTMENT OF TRANSPORTATION
SOIL AND AGGREGATE TABULATION

USE CAPITAL LETTERS

LAB NUMBER | ORG NUMBER | MATL | TYPE | PUR-POSE | TEST LAB | SIZE | SIZE %

TEST NO. | LOT OR SUFFIX | SAMPLED BY | MO DAY YEAR | TIME | MILITARY TIME

SAMPLED FROM | LIFT NO. | RDWY | STATION +

IF MILEPOST, INPUT DECIMAL

ORIGINAL SOURCE | PROJECT ENGINEER / SUPERVISOR | PROJECT NUMBER | TRACS NUMBER

REMARKS

CONTACT PHONE NO. - (   )   -

ARIZ 201
☐ Dried to Constant Wt.
☐ Not Dried to Constant Wt.

ARIZ 248
☐ Alt. 1 ☐ Alt. 2 ☐ Alt. 3
☐ Alt. 4 ☐ Alt. 5

% OVERSIZE
+ 3 " + 6 "

COARSE FACTOR = 100 / COARSE SIEVE TOTAL

WET SAMPLE PREWEIGHT = ____________
WET WT. OF - # 4 = ____________
- # 4 SPLIT WET WT. = ____________

	WEIGHTS RETAINED	% RET.	% PASS	SPECS.	CUMULATIVE % RET. FINENESS MODULUS
3"					
2 1/2"					
2"					
1 1/2"					
1"					
3/4"					
1/2"					
3/8"					
1/4"					
# 4					
- # 4					
Total					

IF TOTAL SAMPLE IS WASHED:
UNWASHED WT. = ____________
WASHED WT. = ____________
ELUTRIATION = ____________

DRY WT. OF - # 4 SPLIT

FINE FACTOR = % PASS # 4 / DRY WT. OF - # 4 SPLIT

	WEIGHTS RETAINED	% RET.	% PASS	SPECS.	
#8					
#10					
#16					
#30					
#40					
#50					
#100					
#200					
-#200					
Total	Dry Weight				
Elutriation	= -#4 Split - Total Dry Weight				

FINENESS MODULUS = TOTAL CUMULATIVE % RET. / 100

T = AASHTO Tests

Test	Method		Unit	SPECS.
Liquid Limit (LL)	T - 89			
Plastic Limit (PL)	T - 90			
Plasticity Index (PI) = LL - PL	T - 90			
Abrasion Method (A,B,C,D)	T - 96			
@ 100 Revolutions			%	%
@ 500 Revolutions			%	%
Absorption, H_2O	ARIZ 210 ARIZ 211		%	
Specific Gravity, SSD	ARIZ 210 ARIZ 211			
Specific Gravity, OD	ARIZ 210 ARIZ 211			
Specific Gravity, Apparent	ARIZ 210 ARIZ 211			
Proctor Method				A - ARIZ 225 C - ARIZ 226 D - ARIZ 226 AD - ARIZ 245 A1 - ARIZ 232 AD1 - ARIZ 246
Optimum Moisture			%	
Max. Dry Density			PCF	
Sand Equivalent	T - 176 ARIZ 242 (MAFC)			
At Least One Fractured Face	ARIZ 212		%	%
At Least Two Fractured Faces	ARIZ 212		%	%
Uncompacted Void Content	ARIZ 247		%	%
Moisture Content	T - 255 T - 265		%	
Flakiness Index	ARIZ 233		%	%
Carbonates	ARIZ 238		%	%
pH	ARIZ 236 OR 237			
Resistivity (ohm-cm)	ARIZ 236			
Soluble Salts (PPM)	ARIZ 237			
Unit Weight	T - 19		PCF	
Voids	T - 19		%	
Organic Imputities	T - 21			
Chloride Content (PPM)	ARIZ 736			
Sulfate Content (PPM)	ARIZ 733			
Exchangeable Sodium (%)	ARIZ 729			
Exchangeable Sodium (PPM)	ARIZ 729			

WHITE ☐
YELLOW ☐
BLUE ☐

RECEIVED DATE | TEST OPERATOR & DATE | SUPERVISOR & DATE

ADOT 44-9353 R11/14

SEE BACK ALSO

FIGURE 4

Infrastructure Delivery and Operations

ARIZ 210d
November 2, 2018
(11 Pages)

SPECIFIC GRAVITY AND ABSORPTION OF COARSE AGGREGATE

(A Modification of AASHTO Designation T 85)

1. SCOPE

1.1 This test method covers the determination of specific gravity and absorption of coarse aggregate. The specific gravity may be expressed as bulk oven dry (OD) specific gravity, bulk saturated surface dry (SSD) specific gravity, or apparent specific gravity. The bulk (SSD) specific gravity and absorption are based on aggregate after 15 to 19 hours soaking in water. This method is not intended to be used with lightweight aggregate.

1.2 The specific gravity and absorption of coarse aggregate is normally determined on Plus No. 4 Material. When corresponding fine aggregate specific gravity and absorption are determined on Minus No. 8 Material, in accordance with Arizona Test Method 211, the coarse aggregate specific gravity and absorption shall be performed on Plus No. 8 Material. "Coarse aggregate" as herein referenced will be for either Plus No. 4 or Plus No. 8 Material. Coarse aggregate specific gravity and absorption for mineral aggregates used in asphaltic concrete, other than asphaltic concrete friction course, shall be determined on Plus No. 4 Material.

1.3 This test method may involve hazardous material, operations, or equipment. This test method does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user to consult and establish appropriate safety and health practices and determine the applicability of any regulatory limitations prior to use.

1.4 See Appendix A1 of the Materials Testing Manual for information regarding the procedure to be used for rounding numbers to the required degree of accuracy.

1.5 Reference may be made to AASHTO T 85 for additional information, including: terminology, significance and use, precision and bias, development of equations, and interrelationships between specific gravities and absorption as defined in AASHTO T 85 and T 84.

2. APPARATUS

2.1 Requirements for the frequency of equipment calibration and verification are found in Appendix A3 of the Materials Testing Manual.

2.2 Balance - A balance capable of measuring the maximum weight to be determined and conforming to the requirements of AASHTO M 231, except the readability and sensitivity of any balance utilized shall be at least one gram. The balance shall be equipped with a suitable apparatus for suspending the sample container in water from the center of the weighing platform or pan of the balance.

2.3 Sample Container - A wire basket, of adequate size for the material being tested, and so constructed to prevent trapping of air when submerged. For test samples of Plus No. 4 Material, the wire mesh shall be No. 6 or finer. For test samples of Plus No. 8 Material, the wire mesh shall be No. 10 or finer. The wire for suspending the container from the balance shall be of the smallest practical size to minimize any possible effects of a variable immersed length.

2.4 Water Tank - A watertight tank into which the sample and container are placed for complete immersion while suspended below the balance, equipped with an overflow for maintaining a constant water level.

2.5 Sieves - Conforming to ASTM E11, and consisting of the necessary sieve sizes as described in Subsection 3.2 through 3.3.

3. SAMPLING

3.1 Sample the aggregate in accordance with Arizona Test Method 105.

3.2 The sample shall be sieved over the appropriate No. 4 or No. 8 sieve and the specific gravity and absorption determined as given in Subsections 5.3 and 5.5; or, testing may be performed on separate coarse size fractions, as described in Subsection 3.4 and the average values for specific gravity and absorption determined as given in Subsections 5.4 and 5.6. When testing is performed on separate size fractions of the coarse aggregate, a sieve analysis of the material shall be performed in accordance with Arizona Test Method 201. If the specific gravity and absorption of the fine aggregate is to be determined, save the appropriate Pass No. 4 or Pass No. 8 Material for testing in accordance with Arizona Test Method 211, otherwise it can be discarded.

3.3 If testing is <u>not</u> to be performed using separate size fractions, a representative test sample of the Plus No. 4 or Plus No. 8 Material with a minimum mass as shown below shall be obtained.

Nominal Maximum Sieve Size, inches	Minimum Mass of Test Sample, kilograms (pounds)
6	125 (276)
5	75 (165)
4-1/2	50 (110)
4	40 (88)
3-1/2	25 (55)
3	18 (40)
2-1/2	12 (26)
2	8 (18)
1-1/2	5 (11)
1	4 (8.8)
3/4	3 (6.6)
1/2 or less	2 (4.4)

3.4 It may be desirable to test the material in separate size fractions. An example is given below which illustrates the procedure to be followed. [If the sample contains more than 15 percent retained on the 1-1/2" sieve, test the Plus 1-1/2" Material in one or more size fractions separately from the smaller size fraction(s).] When an aggregate is tested in separate size fractions, the minimum mass of test sample for each fraction shall be the difference between the masses specified above for the largest and smallest sieve sizes of the fraction. The smallest size fraction tested shall meet the minimum mass requirements listed above, corresponding to the largest sieve size (passing) of the fraction. Size fractions of more than one sieve shall be proportionate with the sieve analysis for the sizes included.

Example: (A sample with the following sieve analysis is tested in the selected separate size fractions shown below.)

Sieve Size	% Retained	% Pass
2”	0	100
1-1/2”	16	84
1”	10	74
3/4”	8	66
1/2”	6	60
3/8”	4	56
1/4”	10	46
# 4	5	41

Size fraction of Pass 2” to Retained 1-1/2”: 8000 g - 5000 g = 3000 g

Size fraction of Pass 1-1/2” to Retained 3/4": 5000 g - 3000 g = 2000 g

For each sieve in this size fraction, the proportionate amount is determined:

Pass 1-1/2” to Retained 1”: [10 / (10 + 8)] x 2000 g = 1111 g
Pass 1” to Retained 3/4": [8 / (10 + 8)] x 2000 g = 889 g

Size fraction of Pass 3/4" to Retained No. 4: 3000 g

For each sieve in this size fraction, the proportionate amount is determined:

Pass 3/4" to Retained 1/2": [6 / (6 + 4 + 10 + 5)] x 3000 g = 720 g
Pass 1/2" to Retained 3/8”: [4 / (6 + 4 + 10 + 5)] x 3000 g = 480 g
Pass 3/8” to Retained 1/4": [10 / (6 + 4 + 10 + 5)] x 3000g = 1200g
Pass 1/4" to Retained No. 4: [5 / (6 + 4 + 10 + 5)] x 3000 g = 600 g

4. PROCEDURE

4.1 Thoroughly wash the test sample to remove dust or other coatings from the surface.

4.2 Dry the test sample in a suitable pan or vessel to constant mass (see Subsection 4.4 below) at a temperature of 230 ± 9 °F. Constant mass shall be determined as follows: Dry the sample for at least 1 hour at 230 ± 9 °F. Record the weight of the sample to at least the nearest 1.0 gram. Continue drying and weighing until the weight does not change more than 1.0 gram at drying intervals of a minimum of 30 minutes.

4.3 Cool in air at room temperature for 1 to 3 hours for test samples of 1-1/2" nominal maximum size, or longer for larger sizes until the aggregate has cooled to a temperature that is comfortable to handle (approximately 122 °F).

4.4 Subsequently immerse the aggregate in water at room temperature for a period of 15 to 19 hours.

Note 1: Where the absorption and specific gravity values are to be used in proportioning concrete mixtures in which the aggregates will be in their naturally moist condition, the requirement for initial drying to constant mass may be eliminated and, if the surfaces of the particles in the sample have been kept continuously wet until testing, the 15 to 19 hour soaking may also be eliminated.

Note 2: Values for absorption and bulk (SSD) specific gravity may be significantly higher for aggregate not oven dried before soaking than for the same aggregate which has been dried and soaked as specified in Subsections 4.2 through 4.4. This is especially true of particles larger than 3 inches since the water may not be able to penetrate the pores to the center of the particle in the prescribed soaking period.

4.5 Remove the test sample from the water and roll it in a large absorbent cloth or towel until all visible films of water are removed from the surface of the aggregate, wiping the larger particles individually as necessary. Take care to avoid loss of water from aggregate pores during surface-drying by completing the operation as quickly as possible. Immediately determine the mass of the test sample in the saturated surface-dry condition. Record this and all subsequent masses to at least the nearest gram.

4.6 After determining the saturated-surface-dry mass place the test sample in the sample container and determine its mass in water at 73 ± 3 °F. Take care to remove all entrapped air before determining the mass by shaking the container while immersed. The container shall be immersed to a depth sufficient to cover it and the test sample during mass determination.

4.7 Dry the test sample to constant mass at a temperature of 230 ± 9 °F. Constant mass shall be determined as described in Subsection 4.2. Cool in air at room temperature for 1 to 3 hours, or until the aggregate has cooled to a temperature that is comfortable to handle (approximately 122 °F) and determine the mass. Record the mass of the sample to at least the nearest gram.

5. CALCULATIONS

5.1 Calculate the bulk (OD) specific gravity as shown below:

$$\text{Bulk (OD) Specific Gravity} = \frac{A}{(B - C)}$$

Where: A = Mass of oven-dry test sample in air, grams.
B = Mass of saturated-surface-dry test sample in air, grams.
C = Mass of saturated test sample in water, grams.

5.2 Calculate the bulk (SSD) specific gravity as shown below:

$$\text{Bulk (SSD) Specific Gravity} = \frac{B}{(B - C)}$$

5.3 Calculate the apparent specific gravity as shown below:

$$\text{Apparent Specific Gravity} = \frac{A}{(A - C)}$$

5.4 When the sample is tested in separate size fractions, the average value for bulk (OD) specific gravity, bulk (SSD) specific gravity, or apparent specific gravity can be computed as the average of the respective specific gravities for the individual size fractions, weighted in proportion to the mass percentage of the size fractions in the original sample.

$$G = \frac{1}{\frac{P1}{100(G1)} + \frac{P2}{100(G2)} + \ldots + \frac{Pn}{100(Gn)}}$$

Where: G = Average specific gravity. All forms of expression of specific gravity can be averaged in this manner.
P1, P2, ... Pn = Mass percentage for each size fraction in original sample (total equals 100).
G1, G2, ... Gn = Respective specific gravity values for each size fraction for the type of specific gravity being averaged.

5.5 Calculate the percent absorption as shown below:

$$\text{Percent Absorption} = \frac{(B - A)}{A} \times 100$$

5.6 When the sample is tested in separate size fractions, the average value for percent absorption can be computed as the average of the individual percent absorption values for the respective size fractions, weighted in proportion to the mass percentage of the size fractions in the original sample.

$$A = \left[\frac{(P1)(A1)}{100}\right] + \left[\frac{(P2)(A2)}{100}\right] + \ldots + \left[\frac{(Pn)(An)}{100}\right]$$

Where: A = Average percent absorption.
P1, P2, ... Pn = Mass percentages for each size fraction in original sample (total equals 100).
A1, A2, ... An = Individual percent absorption values for the respective size fractions.

6. REPORT

6.1 Report specific gravity results to the nearest 0.001, and indicate the type of specific gravity, whether bulk (OD), bulk (SSD), or apparent.

6.2 Report the absorption result to the nearest 0.01%.

6.3 If the specific gravity and absorption values were determined without first drying the aggregate, as permitted in Subsection 4.4, it shall be noted in the report.

6.4 The size of the material tested shall be noted, i.e., Plus No. 4 or Plus No. 8.

7. PROCEDURE FOR DETERMINING COMBINED SPECIFIC GRAVITIES AND ABSORPTION FOR DIFFERENT SOURCES OF MATERIAL

7.1 Two methods are given below for determining the combined specific gravities and absorption for different sources of material, as described in Subsections 7.1.1 and 7.1.2.

7.1.1 The specific gravity and absorption may be determined for coarse aggregates from different sources which have been composited in the desired proportions and thoroughly blended.

7.1.2 The specific gravity and absorption of the coarse aggregate from each individual source may be determined and the combined specific gravity and absorption calculated as described in Subsections 7.1.3 through 7.1.7 below. (Refer to the example given in Subsection 7.1.7 for an illustration of the procedure and calculations.) The same size of material, either Plus No. 4 or Plus No. 8, shall be used to determine the individual specific gravities and absorption for each of the different sources.

7.1.3 For each individual material in the composite, its contribution to the total percent of coarse aggregate in the composite is determined and recorded to the nearest 0.01% as "IP":

$$\text{IP} = \frac{\begin{bmatrix}\text{Percent of Individual}\\ \text{Material in Composite}\end{bmatrix} \times \begin{bmatrix}\text{Percent of Coarse Aggregate}\\ \text{in Individual Material}\end{bmatrix}}{100}$$

Where: IP = Contribution by each individual material to the total percent of coarse aggregate in the composite.

7.1.4 For each individual source, the percent of coarse aggregate in the composite is determined by summing the values for "IP" for that source, and recording the total as "P".

7.1.5 The combined specific gravity is calculated by the following:

$$G = \frac{P1 + P2 + \ldots + Pn}{\frac{P1}{G1} + \frac{P2}{G2} + \ldots + \frac{Pn}{Gn}}$$

Where: P1, P2, ... Pn = For each individual source, the percent of coarse aggregate in the composite, "P".
G1, G2, .. Gn = The coarse specific gravity for each individual source.

7.1.6 The combined absorption is calculated by the following:

$$\text{Combined Absorption} = \frac{\begin{bmatrix}\text{Combined Bulk} \\ \text{(SSD) Specific} \\ \text{Gravity}\end{bmatrix} - \begin{bmatrix}\text{Combined} \\ \text{Bulk (OD) Specific} \\ \text{Gravity}\end{bmatrix}}{\begin{bmatrix}\text{Combined Bulk (OD)} \\ \text{Specific Gravity}\end{bmatrix}}$$

7.1.7 The following is an example of the procedure and calculations described in Subsections 7.1.2 through 7.1.6 above. The example given is for a composite consisting of 26% coarse aggregate, 12% intermediate, and 47% fines from the primary source; with 15% blend from a secondary source. The coarse aggregate has 98% Plus No. 4, the intermediate has 94% Plus No. 4, the fines have 9% Plus No. 4, and the blend has 24% Plus No. 4.

Specific gravity and absorption for each of the different sources:

Primary Source (Coarse, Intermediate, Fine):

Bulk (OD) Specific Gravity = 2.549
Bulk (SSD) Specific Gravity = 2.586
Apparent Specific Gravity = 2.651
Absorption = 1.45%

Secondary Source (Blend):

Bulk (OD) Specific Gravity = 2.665
Bulk (SSD) Specific Gravity = 2.724
Apparent Specific Gravity = 2.781
Absorption = 2.21%

Determination of "IP" for individual materials, and "P" for individual sources, for the Primary Source (Coarse, Intermediate, Fine) and the Secondary Source (Blend):

Primary Source:

$$\text{"IP" Coarse} = \frac{(26) \times (98)}{100} = 25.48\%$$

$$\text{"IP" Intermediate} = \frac{(12) \times (94)}{100} = 11.28\%$$

$$\text{"IP" Fine} = \frac{(47) \times (9)}{100} = 4.23\%$$

"P" for Primary Source = 40.99%

Secondary Source:

$$\text{"IP" Blend} = \frac{(15) \times (24)}{100} = 3.60\%$$

"P" for Secondary Source = 3.60%

[P (Primary)] + [P (Secondary)] = 44.59%

$$\begin{bmatrix} \text{Combined} \\ \text{Bulk (OD)} \\ \text{Specific} \\ \text{Gravity} \end{bmatrix} = \frac{44.59}{\dfrac{40.99}{2.549} + \dfrac{3.60}{2.665}} = 2.558$$

$$\begin{bmatrix} \text{Combined} \\ \text{Bulk (SSD)} \\ \text{Specific} \\ \text{Gravity} \end{bmatrix} = \frac{44.59}{\dfrac{40.99}{2.586} + \dfrac{3.60}{2.724}} = 2.597$$

$$\begin{bmatrix} \text{Combined} \\ \text{Apparent} \\ \text{Specific} \\ \text{Gravity} \end{bmatrix} = \frac{44.59}{\dfrac{40.99}{2.651} + \dfrac{3.60}{2.781}} = 2.661$$

$$\begin{bmatrix} \text{Combined} \\ \text{Absorption} \end{bmatrix} = \frac{2.597 - 2.558}{2.558} \times 100 = 1.52\%$$

EXAMPLE OF CALCULATIONS FOR COARSE SPECIFIC GRAVITY

Bulk Sp. Gr.
(O.D. basis) $= \frac{A}{B\ -\ C} \qquad \frac{(\ 4197\ )}{(\ 4291\ ) - (\ 2610\ )} =$ ***2.497***

Where: **A =** mass of oven-dry sample in air, g.
B = mass of saturated-surface-dry sample in air, g.
C = mass of saturated sample in water, g.

4197
4291
2610

Bulk Sp. Gr.
(SSD basis) = $= \frac{B}{B\ -\ C} \qquad \frac{(\ 4291\ )}{(\ 4291\ ) - (\ 2610\ )}$ ***2.553***

Apparent Sp. Gr. $= \frac{A}{A\ -\ C} \qquad \frac{(\ 4197\ )}{(\ 4197\ ) - (\ 2610\ )} =$ ***2.645***

Absorption, percent $= \frac{B\ -\ A}{A} \times 100 \qquad \frac{(\ 4291\ ) - (\ 4197\ )}{(\ 4197\ )} \times 100 =$ ***2.24*** %

FIGURE 1

SPECIFIC GRAVITY AND ABSORPTION OF FINE AGGREGATE

(A Modification of AASHTO Designation T 84)

1. SCOPE

1.1 This method covers the determination of specific gravity and absorption of fine aggregate. The specific gravity may be expressed as bulk oven dry (OD) specific gravity, bulk saturated surface dry (SSD) specific gravity, or apparent specific gravity.

1.2 The specific gravity and absorption of fine aggregate is normally determined on Minus No. 4 Material. When the fine aggregate sample (Minus No. 4) contains a substantial amount of Minus No. 4 to Plus No. 8 Material, such as in mineral aggregate for asphaltic concrete friction course, the fine aggregate specific gravity and absorption shall be performed on Minus No. 8 Material. The fine aggregate specific gravity and absorption for mineral aggregates used in asphaltic concrete, other than asphaltic concrete friction course, shall be determined on Minus No. 4 Material. "Fine aggregate" as herein referenced will be either Minus No. 4 or Minus No. 8 Material. Corresponding coarse aggregate specific gravity and absorption testing, utilizing the appropriate Plus No. 4 or Plus No. 8 Material, shall be performed in accordance with Arizona Test Method 210.

1.3 This test method may involve hazardous material, operations, or equipment. This test method does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user to consult and establish appropriate safety and health practices and determine the applicability of any regulatory limitations prior to use.

1.4 See Appendix A1 of the Materials Testing Manual for information regarding the procedure to be used for rounding numbers to the required degree of accuracy.

1.5 When the specific gravity and absorption of the fine aggregate and the coarse aggregate are known, the combined aggregate specific gravity and absorption is determined, if necessary, utilizing Arizona Test Method 251.

2. APPARATUS

2.1 Requirements for the frequency of equipment calibration and verification are found in Appendix A3 of the Materials Testing Manual.

2.2 Balance - A balance capable of measuring the maximum weight to be determined and conforming to the requirements of AASHTO M 231, except the readability and sensitivity of any balance utilized shall be at least 0.1 gram.

2.3 Pycnometer - A 500 mL volumetric flask into which the fine aggregate test sample can be readily introduced and in which the volume content can be reproduced within 0.2 mL. Figure 1 is an illustration of the type of flask that must be utilized. The volume of the flask filled to the mark shall be at least 50 percent greater than the space required to accommodate the test sample. If this requirement is not met for a particular aggregate, the normal sample size of 500 ± 10 grams may be reduced only enough to satisfy the requirement.

2.4 Mold - A metal mold in the form of a frustum of a cone with dimensions as follows: 40 ± 3 mm inside diameter at the top, 90 ± 3 mm inside diameter at the bottom, and 75 ± 3 mm in height, with the metal having a minimum thickness of 0.8 mm (See Figure 2).

2.5 Tamper - A metal tamper having a mass of 340 ± 15 grams, and having a flat circular tamping face 25 ± 3 mm in diameter (See Figure 2).

2.6 Oven - Capable of maintaining a temperature of 230 ± 9 °F.

3. SAMPLING

3.1 Sample the aggregate in accordance with Arizona Test Method 105.

4. PREPARATION OF TEST SAMPLE

4.1 Obtain a representative approximate 1200 gram test sample of the fine aggregate.

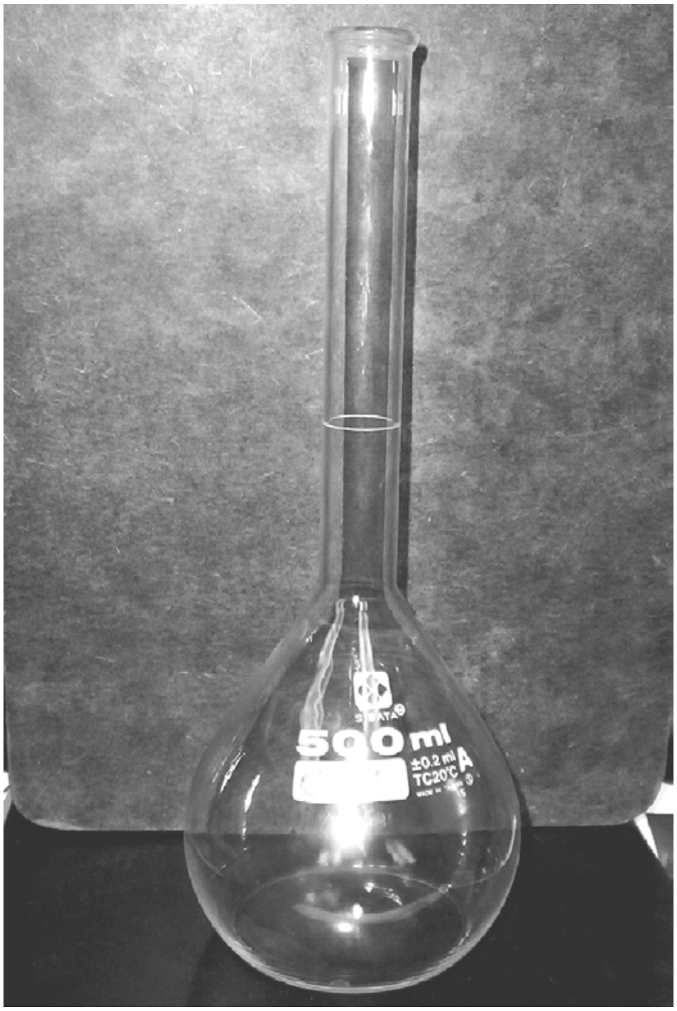


FIGURE 1

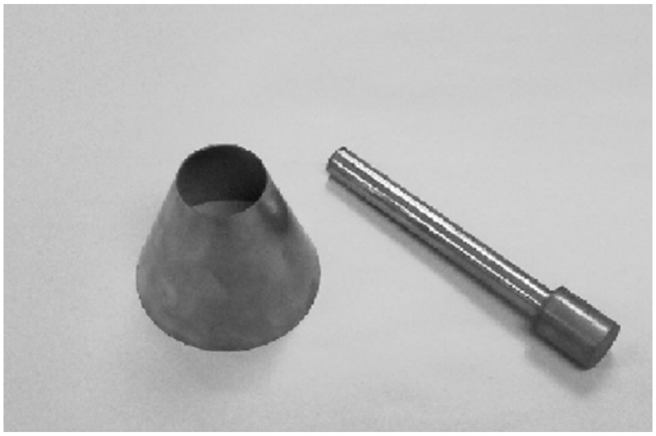


FIGURE 2

4.2 Dry the test sample in a suitable pan or vessel to constant mass (see Subsection 4.3 below) at a temperature of 230 ± 9 °F. (Constant mass shall be determined as follows: Dry the sample for a minimum of 1 hour at 230 ± 9 °F. Record the weight of the sample to the nearest 0.1 gram. Continue drying and weighing until the weight does not change more than 0.1 gram at drying intervals of a minimum of 30 minutes.) Allow the sample to cool to comfortable handling temperature, cover with sufficient water to completely immerse it throughout the soaking period, and permit to stand for 15 to 19 hours.

4.3 Where the absorption and specific gravity values are to be used in proportioning concrete mixtures in which the aggregates will be in their naturally moist condition, the requirement for initial drying to constant mass may be eliminated and, if the surfaces of the particles in the sample have been kept continuously wet until testing, the 15 to 19 hour soaking may also be eliminated.

Note: Values for absorption and bulk (SSD) specific gravity may be significantly higher for aggregate not oven dried before soaking than for the same aggregate which has been dried and soaked as specified in Subsection 4.2.

4.4 Decant excess water with care to avoid loss of fines, spread the sample on a flat nonabsorbent surface exposed to a gently moving current of ambient or warm air, and stir frequently to secure homogeneous drying. Continue stirring and drying until the sample approaches a free-flowing condition. As the material begins to dry sufficiently, it may be necessary to work it with the hands in a rubbing motion to break up any conglomerations, lumps, or balls of material that develop.

4.5 Follow the procedure (cone test for surface moisture) given in Subsection 4.6 below to determine whether or not surface moisture is present on the fine aggregate particles. It is intended that the first trial will be made with some surface water in the sample. Continue drying with constant stirring, working the material with a hand-rubbing motion as necessary, and test at frequent intervals until the test indicates that the sample has reached a surface-dry condition. If the first trial of the surface moisture test indicates that moisture is not present on the surface, it has been dried past the saturated surface-dry condition. In this case, thoroughly mix a few milliliters of water with the fine aggregate and permit the specimen to stand in a covered container for 30 minutes. Then resume the process of drying and testing at frequent intervals for the onset of the surface-dry condition.

4.6 With one hand, hold the mold firmly on a smooth nonabsorbent surface with the large diameter down. The mold must be held firmly in place throughout the process of filling the mold, tamping, and removal of excess material from around the base of the mold. With the other hand, place a portion of the partially dried fine aggregate loosely in the mold, filling it until overflowing occurs, and heaping additional material above the top of the mold. Lightly tamp the fine aggregate into the mold with 25 light drops of the tamper. Each drop should start about 0.2 inch above the top surface of the fine aggregate. Permit the tamper to fall freely on each drop. Adjust the starting height to the new surface elevation after each drop and distribute the drops over the surface. Remove loose material from around the base of the mold, and lift the mold vertically. If surface moisture is still present, the fine aggregate will retain the molded shape. When the fine aggregate slumps slightly, it indicates that it has reached a surface-dry condition. Some angular fine aggregate or material with a high proportion of fines may not slump in the cone test upon reaching a surface-dry condition. This may be the case if fines become airborne upon dropping a handful of the sand from the cone test 4 to 6 inches onto a surface. For these materials, the saturated surface-dry condition should be considered as the point that one side of the fine aggregate slumps slightly upon removing the mold.

5. PROCEDURE

5.1 Only a pycnometer calibrated in accordance with the requirements of Appendix A3 of the Materials Testing Manual shall be used to perform this test. The mass of the pycnometer filled to its calibration capacity with water at 73 ± 3 °F is determined and recorded to the nearest 0.1 gram. Prior to determining the mass of the pycnometer filled with water to the calibration mark, the inside of the neck of the pycnometer just above calibration level shall be dried with a rolled up paper towel.

5.2 Obtain a representative 500 ± 10 gram sample of the saturated surface-dry fine aggregate prepared as described in Section 4. Immediately determine and record the weight of the sample to the nearest 0.1 gram.

5.3 Partially fill the calibrated pycnometer with water. Introduce the sample into the pycnometer and fill with additional water to approximately 90 percent of total capacity so that the water level after the elimination of all air bubbles is above the bottom of the neck but below the calibration line. Roll and agitate the pycnometer to eliminate all air bubbles.

Note: Adding a few drops of 99% grade isopropyl alcohol (ASTM D 770), after removal of air bubbles and just prior to bringing the water level to its calibrated capacity, has been found useful in dispersing foam on the water surface.

5.4 Rinse the inside of neck of pycnometer with water and add sufficient water to bring the water level in the pycnometer to its calibrated capacity. Adjust its temperature to 73 ± 3 °F, if necessary by immersion in circulating water. With a rolled up paper towel, dry the inside neck of pycnometer just above the calibration level. Determine and record the mass of the pycnometer, sample, and water to the nearest 0.1 gram.

5.5. Remove the fine aggregate from the pycnometer and dry to constant mass at a temperature of 230 ± 9 °F. (Constant mass shall be determined as follows: Dry the sample for a minimum of 1 hour at 230 ± 9 °F. Record the weight of the sample to the nearest 0.1 gram. Continue drying and weighing until the weight does not change more than 0.1 gram at drying intervals of a minimum of 30 minutes.) Cool in air at room temperature for 1.0 ± 0.5 hours. Determine and record the mass to the nearest 0.1 gram.

Note: In lieu of drying and weighing the sample which has been removed from the pycnometer, a second portion of the saturated surface dry sample may be used to determine the oven dry weight. This sample must be obtained at the same time and shall weigh within ± 0.2 grams of the sample which is introduced into the pycnometer.

6. CALCULATIONS

6.1 Calculate the bulk (OD) specific gravity as shown below:

$$\text{Bulk (OD) Specific Gravity} = \frac{A}{(B + S - C)}$$

Where: A = mass of oven-dry test sample in air.
B = mass of pycnometer filled with water to calibration mark.
S = mass of saturated surface-dry test sample.
C = mass of pycnometer with test sample and water to calibration mark.

6.2 Calculate the bulk (SSD) specific gravity as shown below:

$$\text{Bulk (SSD) Specific Gravity} = \frac{S}{(B + S - C)}$$

6.3 Calculate the apparent specific gravity as shown below:

$$\text{Apparent Specific Gravity} = \frac{A}{(B + A - C)}$$

6.4 Calculate the percent absorption as shown below:

$$\text{Percent Absorption} = \frac{(S - A)}{A} \text{ x } 100$$

7. REPORT

7.1 Report specific gravity results to the nearest 0.001, and indicate the type of specific gravity, whether bulk (OD), bulk (SSD), or apparent.

7.2 Report the absorption result to the nearest 0.01%.

7.3 If the specific gravity and absorption values were determined without first drying the aggregate, as permitted in Subsection 4.3, it shall be noted in the report. The source of the sample and the procedures used to prevent drying prior to testing shall also be reported.

7.4 The size of the material tested shall be noted, i.e., Minus No. 4 or Minus No. 8.

8. PROCEDURE FOR DETERMINING COMBINED SPECIFIC GRAVITIES AND ABSORPTION FOR DIFFERENT SOURCES OF MATERIAL

8.1 Two methods are given below for determining the combined specific gravities and absorption for different sources of material, as described in Subsections 8.2 and 8.3.

8.2 The specific gravity and absorption may be determined for fine aggregates from different sources which have been composited in the desired proportions and thoroughly blended.

8.3 The specific gravity and absorption of the fine aggregate from each individual source may be determined and the combined specific gravity and absorption calculated as described in Subsections 8.3.1 through 8.3.4 below. (Refer to the example given in Subsection 8.4 for an illustration of the procedure and calculations) The same size of material, either Minus No. 4 or pass Minus No. 8, shall be used to determine the individual specific gravities and absorption for each of the different sources.

8.3.1 For each individual material in the composite, its contribution to the total percent of fine aggregate in the composite is determined and recorded to the nearest 0.01% as "IP":

$$\text{IP} = \frac{\begin{pmatrix}\text{Percent of Individual} \\ \text{Material in Composite}\end{pmatrix} \text{x} \begin{pmatrix}\text{Percent of Fine Aggregate in} \\ \text{Individual Material}\end{pmatrix}}{100}$$

Where: IP = Contribution by each individual material to the total percent of fine aggregate in the composite.

8.3.2 For each individual source, the percent of fine aggregate in the composite is determined by summing the values for "IP" for that source, and recording the total as "P".

8.3.3 The combined specific gravity is calculated by the following:

$$G = \frac{P1 + P2 + ... + Pn}{\frac{P1}{G1} + \frac{P2}{G2} + ... + \frac{Pn}{Gn}}$$

Where: P1, P2, ... Pn = For each individual source, the percent of fine aggregate in the composite, "P".
G1, G2, ... Gn = The fine specific gravity for each individual source.

8.3.4 The combined absorption is calculated by the following:

$$\text{Combined Absorption} = \frac{\left(\begin{array}{c}\text{Combined Bulk (SSD)}\\ \text{Specific Gravity}\end{array}\right) - \left(\begin{array}{c}\text{Combined Bulk (OD)}\\ \text{Specific Gravity}\end{array}\right)}{\left(\begin{array}{c}\text{Combined Bulk (OD)}\\ \text{Specific Gravity}\end{array}\right)}$$

8.4 The following is an example of the procedure and calculations described in Subsections 8.3.1 through 8.3.4 above. The example given is for a composite consisting of 26% coarse aggregate, 12% intermediate aggregate, and 47% fine aggregate from the primary source; with 15% aggregate from a secondary source. The coarse aggregate has 2% pass the No. 4 sieve, the intermediate aggregate has 6% pass the No. 4 sieve, the fine aggregate has 91% pass the No. 4 sieve, and the aggregate from the secondary source has 76% pass the No. 4 sieve.

Fine aggregate specific gravity and absorption for each of the different sources:

Primary Source (Coarse, Intermediate, Fine):

Bulk (OD) Specific Gravity = 2.576
Bulk (SSD) Specific Gravity = 2.611
Apparent Specific Gravity = 2.669
Absorption = 1.36%

Secondary Source:

Bulk (OD) Specific Gravity = 2.641
Bulk (SSD) Specific Gravity = 2.686
Apparent Specific Gravity = 2.764
Absorption = 1.70%

Determination of "IP" for individual materials, and "P" for individual sources:

Primary Source (Coarse, Intermediate, Fine):

$$\text{"IP" Coarse} = \frac{(26) \times (2)}{100} = 0.52\%$$

$$\text{"IP" Intermediate} = \frac{(12) \times (6)}{100} = 0.72\%$$

$$\text{"IP" Fine} = \frac{(47) \times (91)}{100} = 42.77\%$$

"P" for the Primary Source = IP (Coarse) + IP (Intermediate) + IP (Fine)

= (0.52%) + (0.72%) + (42.77%) = 44.01%

Secondary Source:

$$\text{"IP" (Secondary Source)} = \frac{(15) \times (76)}{100} = 11.40\%$$

"P" for Secondary Source = IP (Secondary Source) = 11.40%

Total fine aggregate in the composite = P(Primary Source) + P(Secondary Source)

= (44.01%) + (11.40%) = 55.41%

$$\text{Combined Bulk (OD) Specific Gravity} = \frac{55.41}{\frac{44.01}{2.576}+\frac{11.40}{2.641}} = 2.589$$

$$\text{Combined Bulk (SSD) Specific Gravity} = \frac{55.41}{\frac{44.01}{2.611}+\frac{11.40}{2.686}} = 2.626$$

$$\text{Combined Apparent Specific Gravity} = \frac{55.41}{\frac{44.01}{2.669}+\frac{11.40}{2.764}} = 2.688$$

$$\text{Combined Absorption} = \frac{2.626 - 2.589}{2.589} \text{ x } 100 = 1.43\%$$

EXAMPLE OF CALCULATIONS FOR FINE SPECIFIC GRAVITY

Bulk Sp. Gr. (O.D. basis) $= \frac{A}{B + S - C}$ $\frac{(\quad 499.9 \quad)}{(\quad 683.7 \quad) + (\quad 503.3 \quad) - (\quad 990.1 \quad)}$ = ***2.539***

2.538852

Where: **A =** mass of oven-dry sample in air, g.
B = mass of pycnometer filled with water, g.
C = mass of pycnometer with sample and water to calibration mark, g.
S = mass of saturated-surface-dry sample, g.

499.9
683.7
990.1
503.3

Bulk Sp. Gr. (SSD basis) = $= \frac{S}{B + S - C}$ $\frac{(\quad 503.3 \quad)}{(\quad 683.7 \quad) + (\quad 503.3 \quad) - (\quad 990.1 \quad)}$ = ***2.556***

2.556120

Apparent Sp. ($= \frac{A}{B + A - C}$ $\frac{(\quad 499.9 \quad)}{(\quad 683.7 \quad) + (\quad 499.9 \quad) - (\quad 990.1 \quad)}$ = ***2.583***

2.583463

Absorption, percent $= \frac{S - A}{A} \times 100$ $\frac{(\quad 503.3 \quad) - (\quad 499.9 \quad)}{(\quad 499.9 \quad)} \times 100$ = ***0.68*** %

0.680136

FIGURE 3

ADOT
Infrastructure Delivery and Operations

ARIZ 212g
November 2, 2018
(3 Pages)

PERCENTAGE OF FRACTURED COARSE AGGREGATE PARTICLES

(An Arizona Method)

1. SCOPE

1.1 This test method describes the procedure for determining the percentage of fractured particles in coarse aggregate. This test procedure is performed on plus No. 8 and larger material, unless otherwise specified.

1.2 When this test procedure is referenced for the determination of "crushed faces", such as in specifications or other test procedures, it shall be understood to be the determination of "fractured coarse aggregate particles".

1.3 A fractured face is defined as an angular, broken surface of an aggregate particle created by crushing, by other artificial means, or by nature. A face is only considered fractured if it has sharp and well defined edges and the projected area of the fractured face is at least 25 percent of the maximum projected area of the aggregate particle visible considering the particle's outline at all possible orientations of the aggregate particle.

1.4 This test method may involve hazardous material, operations, or equipment. This test method does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user to consult and establish appropriate safety and health practices and determine the applicability of any regulatory limitations prior to use.

1.5 See Appendix A1 of the Materials Testing Manual for information regarding the procedure to be used for rounding numbers to the required degree of accuracy.

2. APPARATUS

2.1 Requirements for the frequency of equipment calibration and verification are found in Appendix A3 of the Materials Testing Manual.

2.2 A balance or scale capable of measuring the maximum weight to be determined and conforming to the requirements of AASHTO M 231, except the readability and sensitivity of any balance or scale utilized shall be at least 1 gram.

2.3 A magnifying glass, preferably mounted on a stand and with a built-in light.

2.4 Sieves conforming to ASTM E11, of sizes necessary for the material being tested.

2.5 Miscellaneous pans, containers, spatulas, etc.

3. SAMPLE PREPARATION

3.1 A representative sample of the aggregate shall be obtained. The coarse aggregate test sample shall be proportionate for the gradation of the material being tested. The size of the test sample shall be such that it contains a minimum of 500 particles. It is not expected that an actual count of the number of particles be made to assure compliance with this requirement. It is required, however, that a reasonably accurate estimate be made to determine that the test sample contains at least 500 particles. Fractured face determination must be made on all particles in the test sample.

4. PROCEDURE

4.1 Weigh the test sample, and record the weight to the nearest gram as "Wa". To facilitate the inspection of the particles, the test sample may be washed and dried to constant weight prior to determining the test sample weight.

4.2 Spread the test sample onto a flat surface, and observe the aggregate particles under the magnifying glass with adequate light.

4.3 If not otherwise specified, separate aggregate particles having at least one fractured face from those that are unfractured. If specifications require that a percentage of the aggregate particles having at least two fractured faces be determined, separate aggregate particles having at least two fractured faces from those that have less than two fractured faces. A spatula or other blade-like tool may be helpful in separating particles.

4.4 Weigh the portion of fractured particles, and record the weight to the nearest gram. If aggregate particles with at least one fractured face have been determined, record the weight as "Wf". If aggregate particles with at least two fractured faces have been determined, record the weight as "W2".

5. CALCULATIONS

5.1 If aggregate particles with at least one fractured face have been determined, calculate the percentage of fractured particles, "FF", and record to the nearest percent as shown below:

$$FF = \frac{W_f}{W_a} \text{ x } 100$$

Where: FF = Percentage of fractured particles with at least one fractured face.

W_f = Weight of fractured particles with at least one fractured face.

W_a = Weight of test sample.

5.2 If aggregate particles with at least two fractured faces have been determined, calculate the percentage of fractured particles, "FF2", and record to the nearest percent as shown below:

$$FF_2 = \frac{W_2}{W_a} \text{ x } 100$$

Where: FF_2 = Percentage of fractured particles with at least two fractured faces.

W_2 = Weight of fractured particles with at least two fractured faces.

W_a = Weight of test sample.

MAXIMUM DRY DENSITY AND OPTIMUM MOISTURE OF SOILS BY PROCTOR METHOD A

(A Modification of AASHTO Designation T 99)

1. SCOPE

1.1 This test method describes the procedure for determining the maximum dry density and optimum moisture content for a soil by the Proctor Method A. Some materials may be more appropriately tested by Arizona Test Method 245, "Maximum Dry Density and Optimum Moisture of Soils by Proctor Alternate Method D ".

1.2 Method A may be used for all maximum dry density and optimum moisture content determinations except for volcanic cinders or light porous material on which the specific gravity cannot be determined with consistency or when the moisture absorption for the coarse aggregate is greater than 4.0%.

1.3 Method A may be used except when greater than 50% (60% for Aggregate Base) of the material is retained on the No. 4 sieve.

1.4 An example is provided in Figure 2 for the calculations and determinations referenced herein.

1.5 This test method may involve hazardous materials, operations, and equipment. This test method does not purport to address all of the safety problems associated with its use. It is the responsibility of whomever uses this test method to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

1.6 See Appendix A1 of the Materials Testing Manual for information regarding the procedure to be used for rounding numbers to the required degree of accuracy.

2. APPARATUS

2.1 Requirements for the frequency of equipment calibration and verification are found in Appendix A3 of the Materials Testing Manual.

2.2 4 inch proctor mold having a capacity of approximately 1/30 cubic foot, with an internal diameter of 4.000 plus 0.024 or minus 0.016 inches and a height of 4.584 plus 0.005 or minus 0.008 inches. The mold shall have a nominal wall thickness of 1/4 inch. It shall be equipped with an extension collar approximately 2-3/8 inches high. A baseplate as shown in Figure 1 shall be provided.

2.3 A hand or mechanical rammer weighing 5.50 ± 0.02 pounds, having a flat face, and equipped with a suitable arrangement to control the height of drop to a free fall of 12 ± 0.06 (1/16) inches above the elevation of the soil. The rammer face shall be circular with a diameter of 2.000 plus 0.010 or minus 0.015 inches. If a mechanical apparatus is used, it must be monitored through the ADOT proficiency sample program and maintain a rating of 3 or better based on the results of testing ADOT and AMRL proficiency samples.

2.4 Hard steel straightedge, at least 10 inches in length. It shall have one beveled edge, and at least one longitudinal surface (used for final trimming) shall be plane within 0.01 inch per 10 inches (0.1 percent) of length with the portion used for trimming the soil.

2.5 Scale or balance capable of measuring the maximum weight to be determined, accurate to at least one gram.

2.6 Scale or balance capable of measuring the maximum weight to be determined, accurate to at least 0.1 gram.

2.7 Oven capable of maintaining a temperature of 230 ± 9 °F.

2.8 No. 4 and 3 inch sieves conforming to the requirements of ASTM E11.

2.9 Miscellaneous mixing tools and pans.

2.10 Sample Extruder (optional) consisting of a jack, lever, frame, or other device for extruding the compacted sample from the mold.

3. CALIBRATION OF MOLD

3.1 Molds shall be calibrated in accordance with APPENDIX A of this procedure.

4. SAMPLE

4.1 Enough soil material shall be provided from the field to make five compacted specimens. A minimum sample size of 20,000 grams (approximately 45 lbs.) is normally required.

4.2 If the soil sample is damp when received from the field, dry it until it becomes friable under a trowel. Drying may be in air or by use of a slow fan or other drying apparatus such that the temperature of the sample does not exceed 140 °F.

4.3 Thoroughly break up the aggregations in such a manner as to avoid reducing the natural size of individual particles.

4.4 Weigh out an approximate 20,000 gram sample of representative soil. Record the weight of the sample, and sieve the material over a No. 4 sieve. If the percentage of coarse aggregate or rock retained on the No. 4 sieve is not already known from gradation testing, save any material retained on the No. 4 sieve and weigh. Calculate the percent of coarse aggregate or rock particles retained on the No. 4 sieve according to the following equation:

$$PR4 = \frac{WR4}{WT} \times 100$$

Where:

PR4 = Percentage of coarse aggregate or rock particles retained on the No. 4 sieve
WR4 = Weight of coarse aggregate or rock particles retained on the No. 4 sieve
WT = Total weight of material sieved

4.5 If "PR4" is greater than 50% (60% for Aggregate Base), Alternate Method D, Arizona Test Method 245, shall be used to determine the maximum dry density. If "PR4" is less than or equal to 50% (60% for Aggregate Base), blend material passing the No. 4 sieve thoroughly and proceed to Section 5 of this test method. If a specific gravity and absorption determination, in accordance with AASHTO T 85, is to be made for the plus No. 4 material, save an adequate amount of this material, otherwise, discard it.

5. PROCEDURE

5.1 From the thoroughly blended passing No. 4 material from Subsection 4.5, split out 5 representative approximate 2500 gram samples.

5.2 Select one sample and thoroughly mix with sufficient water to dampen it to approximately three percentage points below optimum moisture content.

Note: If desired, an additional three samples may be mixed at this time with approximate moisture contents of 1% below optimum, 1% over optimum, and 3% over optimum. The moisture in each of these samples shall be retained by covering with a damp cloth or being sealed in air tight containers until they are compacted. One of the five samples should be retained for future use since it is necessary to have at least two points defined on each side of the moisture-density curve.

5.3 Heavy clay soils or materials which tend to break down, or those in which it is difficult to incorporate water, shall require approximately 12 hours for uniform moisture absorption to be achieved. This shall be accomplished by preparing separate samples for each increment of water to be added, and then placing and sealing these samples in air tight containers for the 12-hour period.

5.4 Form a specimen by compacting the prepared soil in the four inch mold (with extension collar attached) in three equal layers to give a total compacted depth of about 5 inches. Compact each layer with 25 uniformly distributed blows from the rammer, dropping free from a height of 12 inches. While each layer is being compacted, the remainder of material shall be in a pan covered by a damp cloth. During compaction, the mold shall rest firmly on a dense, uniform, rigid and stable foundation.

Note: Each of the following has been found to be a satisfactory base on which to rest the mold during compaction of the soil: A block of concrete, weighing not less than 200 lbs., supported by a stable foundation; a sound concrete floor; and for field application, such surfaces as found in concrete box culverts, bridges, and pavements.

5.5 When compacting granular, free-draining materials, at moisture contents which are at or above optimum, the mold shall be prepared by first sealing the bottom of the mold with waterproofing grease. All excess grease shall be wiped from the mold and baseplate.

5.6 Following compaction, carefully remove the extension collar. It may be necessary to use a follower to retain the soil in the mold while removing the collar to prevent damage or disturbance of the soil below the top of the mold. Carefully trim the compacted soil even with the top of the mold by means of the straightedge. If any voids are created during trimming, these shall be filled with fine material and smoothed off. Determine the weight of compacted specimen and mold. Determine the wet density, "WD", of the compacted soil by the following:

$$\text{WD} = \frac{\text{M1 - M2}}{\text{VM x 453.6 (grams/lb.)}}$$

Where:
WD = Wet density of compacted soil, lb./cu. ft.
M1 = Weight of compacted specimen and mold, grams
M2 = Weight of the mold, grams
VM = Volume of the mold, cu. ft. (See Section 3 of this procedure.)

5.7 The estimated dry density, "ED", of the compacted soil may be calculated and recorded to the nearest 0.1 lb./cu. ft. as follows:

$$\text{ED} = \frac{\text{WD}}{\text{(Approx. \% of water added) + 100}} \text{ x 100}$$

Where:
ED = Estimated dry density of compacted soil, lb./cu. ft.
WD = Wet density of compacted soil, lb./cu. ft.

Note: These estimated densities are approximate only and will be corrected when final moisture results are obtained.

5.8 The estimated dry density is useful in deciding how much water to add in later trial batches, if the procedure described in the note following Subsection 5.2, for initially preparing three additional samples with varying moisture contents is not utilized. By carefully observing the estimated dry density of the compacted samples, the operator should be able to vary the moisture content as the test proceeds so that when the final moisture-density results are plotted, a curve will result that rises to a peak and then falls away.

5.9 Remove the material from the mold and slice vertically through the center. Take a representative minimum 300 gram sample from the full length and width of one of the cut faces. Weigh immediately, and dry to a constant weight in an oven at 230 ± 9 °F to determine the moisture content in accordance with AASHTO T 265. Record the weight of wet soil to the nearest 0.1 gram as "WW", and record the weight of oven dry soil to the nearest 0.1 gram as "DW".

5.10 For granular, free-draining materials, the moisture content shall be determined using the entire compacted proctor specimen. Determine the weight of wet soil, "WW", by subtracting the weight of the mold, "M2", from the weight of compacted specimen and mold, "M1". Record the weight of wet soil, "WW", and the weight of oven dry soil, "DW", to at least the nearest gram. All clinging material shall be removed from the inside of the mold and included with the specimen. To facilitate drying, the specimen may be broken up and spread out in a large pan, being careful to not lose any soil particles.

5.11 Select another of the samples which was split in Subsection 5.1, and if not already done, thoroughly mix with water in sufficient amount to increase the moisture content by approximately two percentage points.

5.12 Repeat the procedure in Subsections 5.3 through 5.10 for the sample at each moisture content, as necessary to establish a moisture-density curve which rises to a peak and then falls away.

6. CALCULATIONS

6.1 Calculate percent moisture and record to the nearest 0.1 percent by the following:

$$\%\ \text{Moisture} = \frac{\text{WW - DW}}{\text{DW}} \times 100$$

Where: WW = weight of wet soil, grams
DW = weight of oven dry soil, grams

6.2 Calculate dry density and record to the nearest 0.1 lb./cu. ft. by the following:

$$DD = \frac{WD}{\%\ Moisture + 100} \times 100$$

Where: DD = Dry density of compacted soil, lb./cu. ft.
WD = Wet density of compacted soil, lb./cu. ft.

7. MOISTURE-DENSITY RELATIONSHIP

7.1 The percent moisture and corresponding dry density for each of the compacted soil specimens shall be plotted on the graph provided on the proctor density test form shown in Figure 3. For a good plot, the majority of the graph is utilized. Normally, three increments on the horizontal axis shall equal one percent of moisture, and three increments on the vertical axis shall equal one lb./cu. ft. of dry density. If another number of increments other than three is utilized, the number of increments for one percent moisture and one lb./cu. ft. dry density shall always be the same.

7.2 On each side of the maximum density curve, at least two points should be utilized to form two straight lines. The intersection point of these two lines defines the peak point of the density-moisture content relationship, or the maximum density and optimum moisture content for the soil. In general it will be found that higher unit mass soils assume steeper slopes with high maximum dry densities at low optimum moisture contents, while the lower unit mass soils assume flatter, more gently sloped lines with high optimum moisture contents and low maximum dry densities. Figure 4 gives examples of moisture-density plots which show the different slopes associated with different maximum dry density ranges.

7.3 Optimum moisture content - The percent moisture content corresponding to the peak (intersection point of the two lines) of the moisture-density curve shall be termed the "optimum moisture content", and shall be reported as "OM" to the nearest 0.1 percent.

7.4 Maximum dry density - The dry density at optimum moisture content corresponding to the peak (intersection point of the two lines) of the moisture-density curve shall be termed the "maximum dry density", and shall be reported as "MD" to the nearest 0.1 lb./cu. ft.

Note: The optimum moisture and maximum dry density determinations above are for the material passing the No. 4 sieve. When testing field samples for comparison to proctor optimum moisture and maximum dry density, a correction to the proctor optimum moisture and maximum dry density must be made, in accordance with ARIZ 227, for the percent rock which the field sample contains.

8. REPORT

8.1 Record the moisture and density data on the laboratory test form along with the laboratory number, material source and type, and other information required. A blank laboratory test form is provided in Figure 3.

APPENDIX A

CALIBRATION OF PROCTOR MOLDS

1. CALIBRATION

1.1 Molds shall be calibrated at least once a year, or sooner if there is reason to question the accuracy of the calibration.

1.2 Lightly coat the bottom of the mold with a waterproofing grease. (Dow Corning High Vacuum Grease, or similar, has proven satisfactory for this application.) For split molds, waterproofing grease is also necessary on the edges of the split mold halves which join together.

1.3 Fit mold into baseplate and secure snugly into place.

1.4 Wipe excess grease from the mold and the baseplate.

1.5 Record weight of baseplate, empty mold, and glass plate to at least the nearest 0.1 gram.

Note: An example which illustrates the recording of calibration data and calculations is shown in Figure 5. Figure 6 is a blank calibration form.

1.6 With the mold and baseplate assembly on a flat and level surface fill the mold with distilled water at room temperature 77 ± 9 °F.

1.7 Determine and record the temperature of the water to the nearest one degree Fahrenheit.

1.8 With a small rod, remove any air bubbles that may be clinging to the sides or bottom of the mold. Add additional water to completely fill the mold, using a glass plate in such a way to ensure accurate filling of the mold, eliminating air bubbles and excess water. Check bottom of mold to assure there is no leakage.

1.9 Dry the base plate, glass and outside of mold with a dry, absorbent cloth. Care must be taken to not lose water from inside of mold during drying. Record weight of baseplate, mold filled with water, and glass plate to at least the nearest 0.1 gram.

APPENDIX A - (Continued)

1.10 Determine the weight of water to fill mold by subtracting the weight of baseplate, empty mold, and glass plate from the weight of the baseplate, mold filled with water, and glass plate.

1.11 For the temperature of the water, determine its corresponding unit weight from the table below.

Temperature	**Unit Weight of Water**
Temp °F	**lbs/cu. Ft.**
68	62.315
69	62.308
70	62.301
71	62.293
72	62.285
73	62.277
74	62.269
75	62.261
76	62.252
77	62.243
78	62.234
79	62.225
80	62.216
81	62.206
82	62.196
83	62.186
84	62.176
85	62.166
86	62.155

1.12 Calculate the volume of the mold, in cu. ft., as shown on the calibration form in Figures 5 and 6, and record to the nearest four decimal places.

1.13 Thoroughly clean grease from the mold and base plate. On the mold, record the identification of the mold, the date of calibration, and the volume of the mold.

1.14 Documentation of the calibration data shall be kept on file.

2. REQUIRED DOCUMENTATION

2.1 Record of weights, temperatures, and calculations required in the calibration procedure.

2.2 Identification of mold.

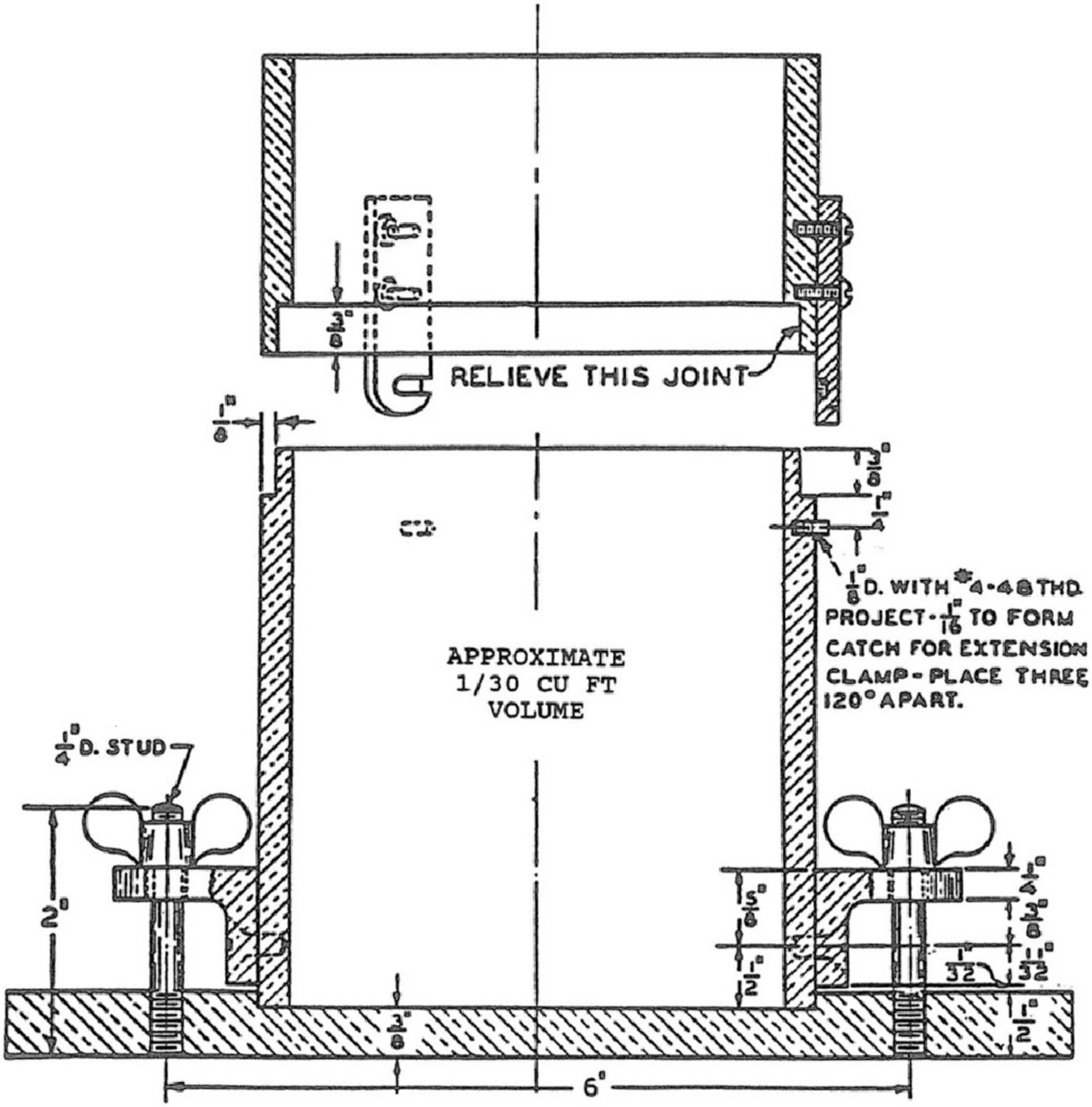
2.3 Date of calibration.

2.4 Volume of the mold.

2.5 Operator performing calibration.

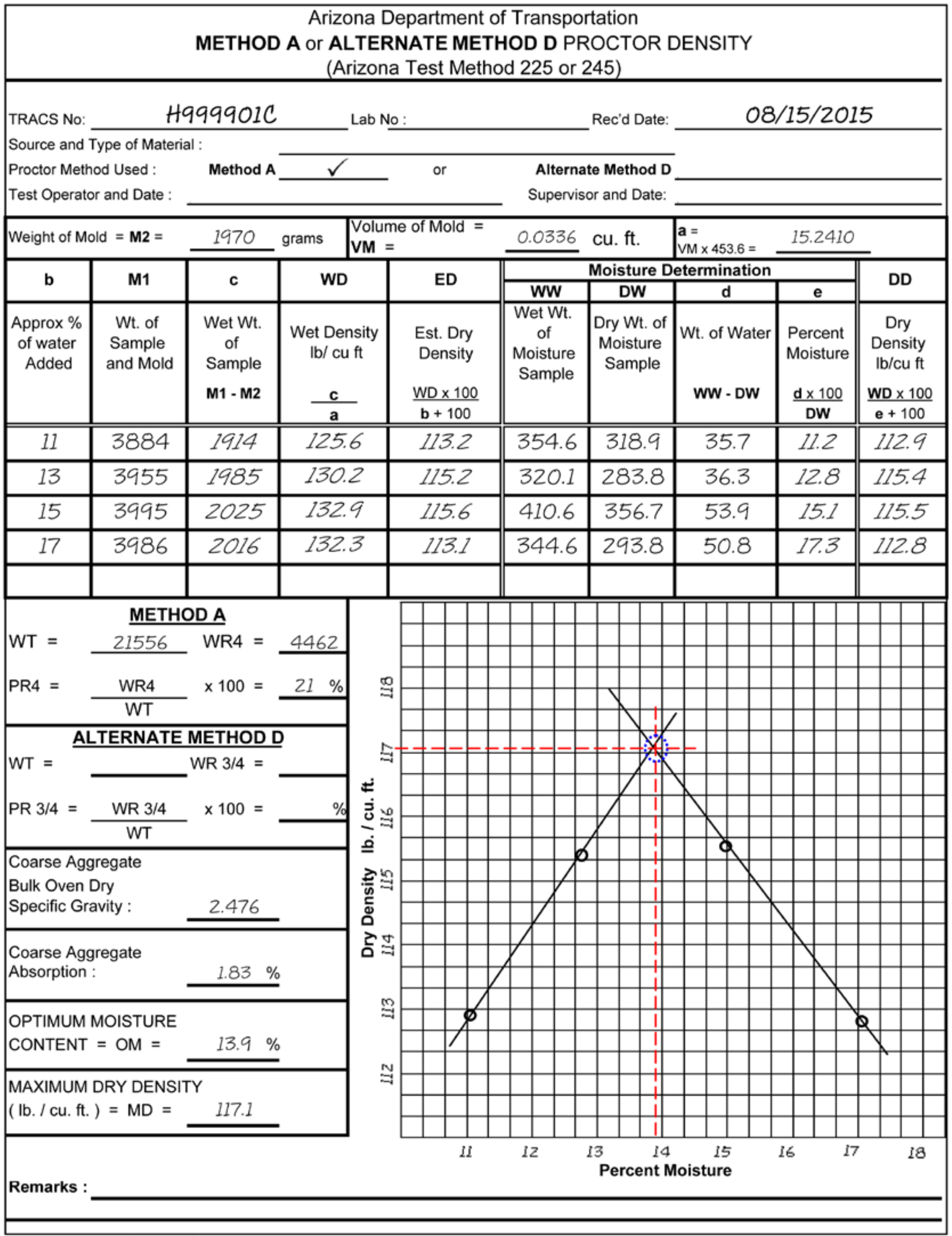
2.6 Supervisor check of calibration data.

2.7 Date of calibration expiration.



CYLINDRICAL MOLD, COLLAR,
AND BASEPLATE
(4 INCH MOLD)

FIGURE 1



Arizona Department of Transportation
METHOD A or **ALTERNATE METHOD D** PROCTOR DENSITY
(Arizona Test Method 225 or 245)

TRACS No: H999901C Lab No : Rec'd Date: 08/15/2015

Source and Type of Material :

Proctor Method Used : **Method A** ✓ or **Alternate Method D**

Test Operator and Date : Supervisor and Date:

Weight of Mold = **M2** = 1970 grams | Volume of Mold = **VM** = 0.0336 cu. ft. | **a** = VM x 453.6 = 15.2410

b	**M1**	**c**	**WD**	**ED**	**Moisture Determination**				**DD**
					WW	**DW**	**d**	**e**	
Approx % of water Added	Wt. of Sample and Mold	Wet Wt. of Sample **M1 - M2**	Wet Density lb/ cu ft **c / a**	Est. Dry Density WD x 100 / **b** + 100	Wet Wt. of Moisture Sample	Dry Wt. of Moisture Sample	Wt. of Water **WW - DW**	Percent Moisture **d** x 100 / **DW**	Dry Density lb/cu ft **WD** x 100 / **e** + 100
11	3884	1914	125.6	113.2	354.6	318.9	35.7	11.2	112.9
13	3955	1985	130.2	115.2	320.1	283.8	36.3	12.8	115.4
15	3995	2025	132.9	115.6	410.6	356.7	53.9	15.1	115.5
17	3986	2016	132.3	113.1	344.6	293.8	50.8	17.3	112.8

METHOD A

WT = 21556 WR4 = 4462

PR4 = WR4 / WT x 100 = 21 %

ALTERNATE METHOD D

WT = WR 3/4 =

PR 3/4 = WR 3/4 / WT x 100 = %

Coarse Aggregate Bulk Oven Dry Specific Gravity : 2.476

Coarse Aggregate Absorption : 1.83 %

OPTIMUM MOISTURE CONTENT = OM = 13.9 %

MAXIMUM DRY DENSITY (lb. / cu. ft.) = MD = 117.1

Remarks :

44-1002 Rev 11/15

FIGURE 2

Arizona Department of Transportation

METHOD A or **ALTERNATE METHOD D** PROCTOR DENSITY

(Arizona Test Method 225 or 245)

Project No: ____________ Lab No : ____________ Rec'd Date: ____________

Source and Type of Material : ____________

Proctor Method Used : **Method A** ____________ or **Alternate Method D** ____________

Test Operator and Date : ____________ Supervisor and Date: ____________

Weight of Mold = **M2 =** ________ grams

Volume of Mold = **VM =** ________ cu. ft.

a = VM x 453.6 = ________

					Moisture Determination				
b	**M1**	**c**	**WD**	**ED**	**WW**	**DW**	**d**	**e**	**DD**
Approx % of water Added	Wt. of Sample and Mold	Wet Wt. of Sample **M1 - M2**	Wet Density lb/ cu ft $\frac{c}{a}$	Est. Dry Density $\frac{WD \times 100}{b + 100}$	Wet Wt. of Moisture Sample	Dry Wt. of Moisture Sample	Wt. of Water **WW - DW**	Percent Moisture $\frac{d \times 100}{DW}$	Dry Density lb/cu ft $\frac{WD \times 100}{e + 100}$

METHOD A

WT = ________ WR4 = ________

PR4 = $\frac{WR4}{WT}$ x 100 = ________%

ALTERNATE METHOD D

WT = ________ WR 3/4 = ________

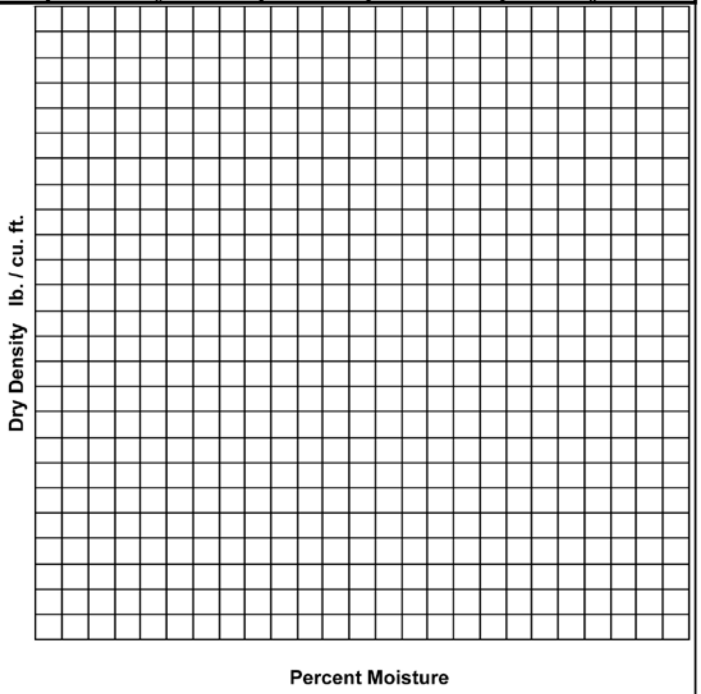
PR 3/4 = $\frac{WR\ 3/4}{WT}$ x 100 = ________%

Coarse Aggregate Bulk Oven Dry Specific Gravity : ________

Coarse Aggregate Absorption : ________%

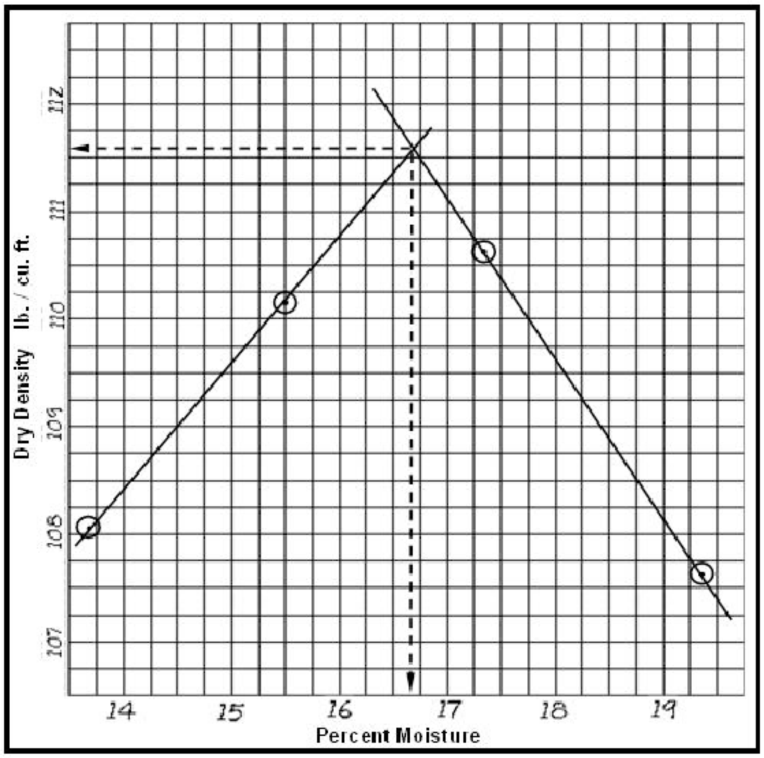
OPTIMUM MOISTURE CONTENT = OM = ________%

MAXIMUM DRY DENSITY (lb. / cu. ft.) = MD = ________



Remarks : ____________

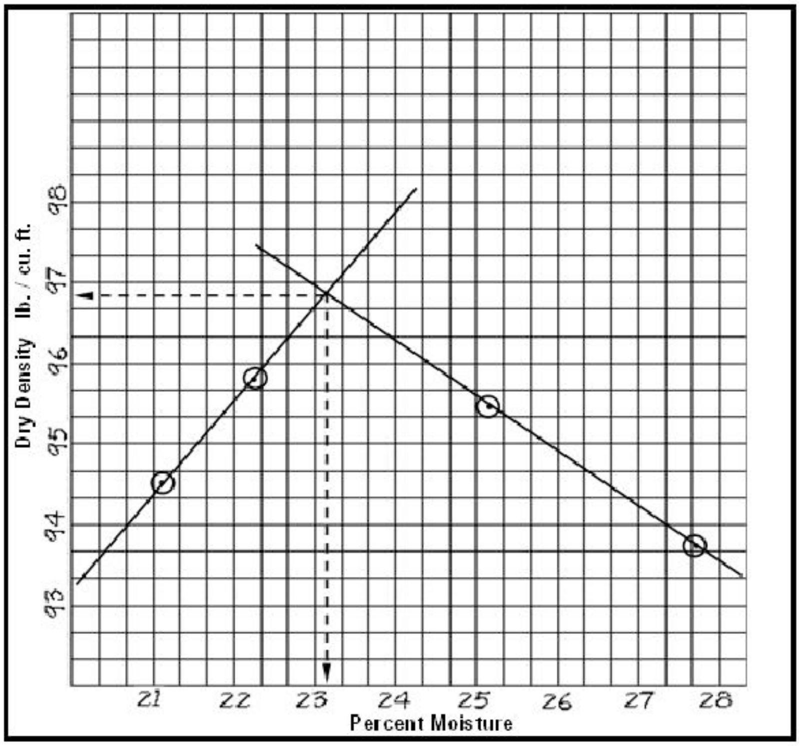
FIGURE 3



CLAYEY SAND

% Moisture	Dry Density
13.7	108.1
15.5	110.2
17.3	110.6
19.4	107.6

Maximum Density = 111.6 lb/cu ft
Optimum Moisture = 16.7%

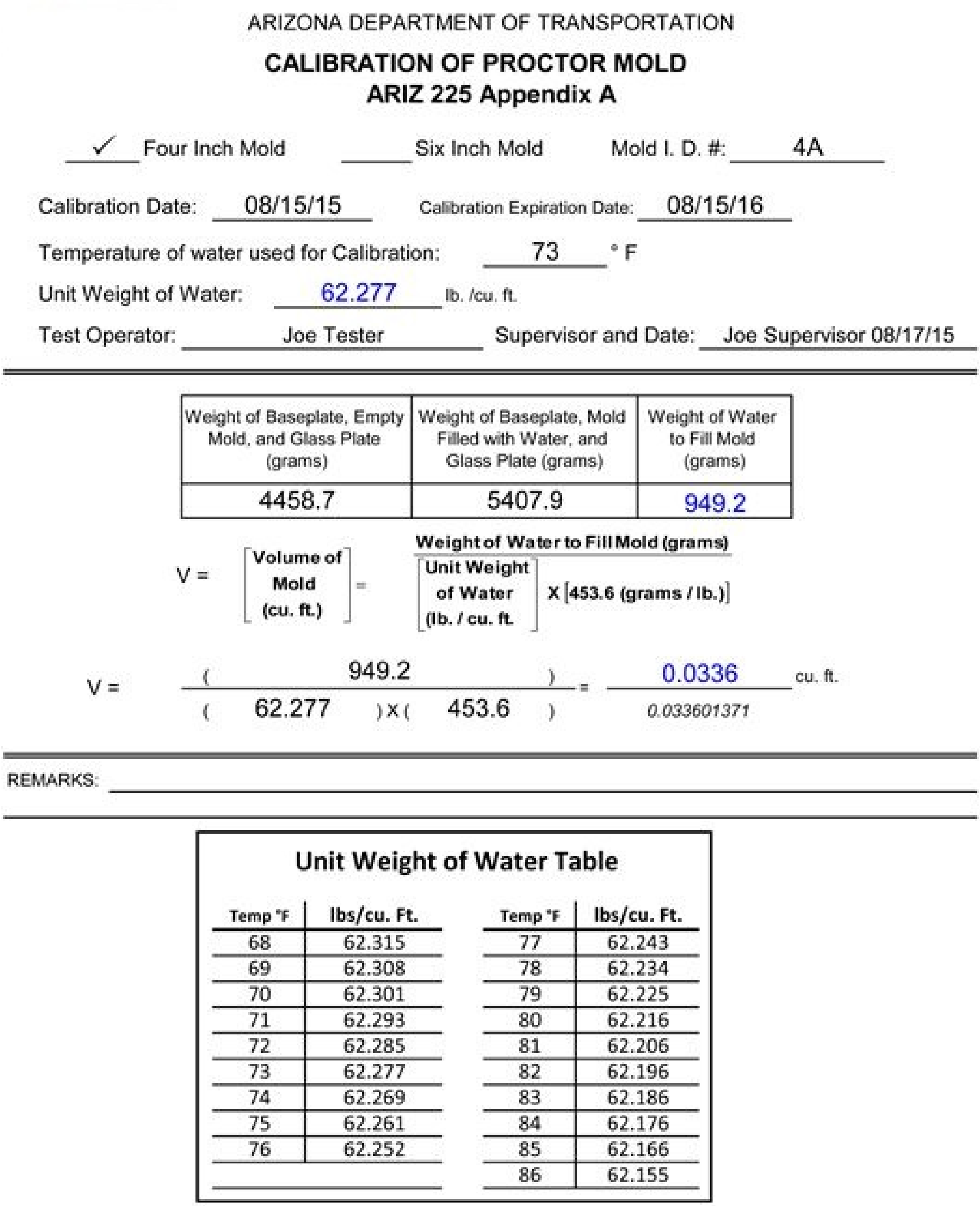


FINE CLAY

% Moisture	Dry Density
21.2	94.5
22.3	95.8
25.2	95.1
27.8	93.1

Maximum Density = 96.7 lb/cu ft
Optimum Moisture = 23.1%

FIGURE 4



ARIZONA DEPARTMENT OF TRANSPORTATION

CALIBRATION OF PROCTOR MOLD
ARIZ 225 Appendix A

✓ Four Inch Mold   ____ Six Inch Mold   Mold I. D. #: 4A

Calibration Date: 08/15/15   Calibration Expiration Date: 08/15/16

Temperature of water used for Calibration: 73 ° F

Unit Weight of Water: 62.277 lb. /cu. ft.

Test Operator: Joe Tester   Supervisor and Date: Joe Supervisor 08/17/15

Weight of Baseplate, Empty Mold, and Glass Plate (grams)	Weight of Baseplate, Mold Filled with Water, and Glass Plate (grams)	Weight of Water to Fill Mold (grams)
4458.7	5407.9	949.2

$$V = \left[\begin{array}{c}\text{Volume of} \\ \text{Mold} \\ \text{(cu. ft.)}\end{array}\right] = \frac{\textbf{Weight of Water to Fill Mold (grams)}}{\left[\begin{array}{c}\text{Unit Weight} \\ \text{of Water} \\ \text{(lb. / cu. ft.}\end{array}\right] \text{ X } [453.6 \text{ (grams / lb.)}]}$$

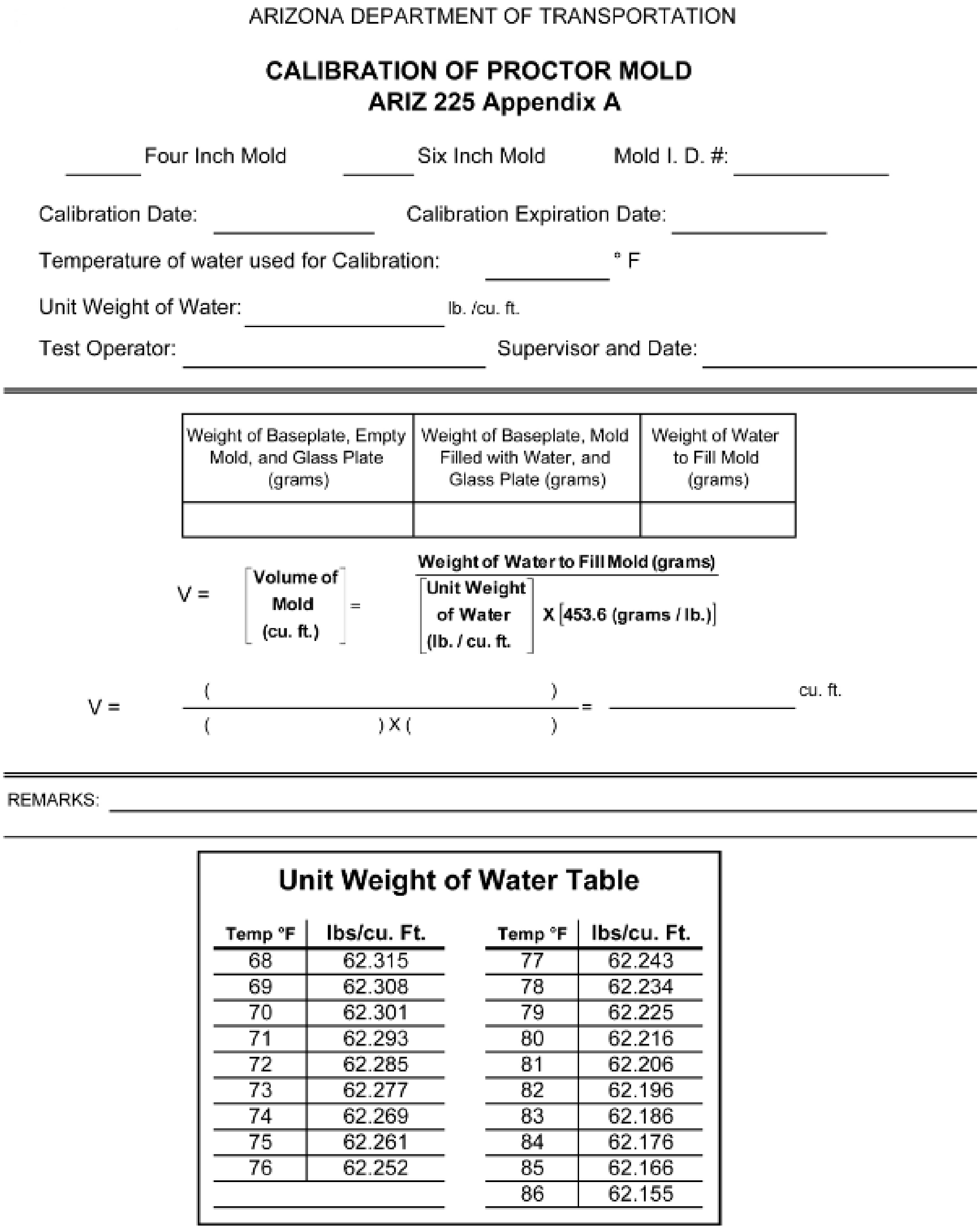
$$V = \frac{(\quad 949.2 \quad)}{(\quad 62.277 \quad) \text{ X } (\quad 453.6 \quad)} = \frac{0.0336}{0.033601371} \text{ cu. ft.}$$

REMARKS: ____

Unit Weight of Water Table

Temp °F	lbs/cu. Ft.	Temp °F	lbs/cu. Ft.
68	62.315	77	62.243
69	62.308	78	62.234
70	62.301	79	62.225
71	62.293	80	62.216
72	62.285	81	62.206
73	62.277	82	62.196
74	62.269	83	62.186
75	62.261	84	62.176
76	62.252	85	62.166
		86	62.155

FIGURE 5



ARIZONA DEPARTMENT OF TRANSPORTATION

CALIBRATION OF PROCTOR MOLD
ARIZ 225 Appendix A

______ Four Inch Mold ______ Six Inch Mold Mold I. D. #: ____________

Calibration Date: ____________ Calibration Expiration Date: ____________

Temperature of water used for Calibration: __________ ° F

Unit Weight of Water: ______________ lb. /cu. ft.

Test Operator: ______________________ Supervisor and Date: ______________

Weight of Baseplate, Empty Mold, and Glass Plate (grams)	Weight of Baseplate, Mold Filled with Water, and Glass Plate (grams)	Weight of Water to Fill Mold (grams)

$$V = \begin{bmatrix}\text{Volume of} \\ \text{Mold} \\ \text{(cu. ft.)}\end{bmatrix} = \frac{\textbf{Weight of Water to Fill Mold (grams)}}{\begin{bmatrix}\text{Unit Weight} \\ \text{of Water} \\ \text{(lb. / cu. ft.}\end{bmatrix} \text{X} \left[\text{453.6 (grams / lb.)}\right]}$$

$$V = \frac{(\qquad\qquad\qquad\qquad)}{(\qquad\qquad)\text{ X }(\qquad\qquad)} = \underline{\qquad\qquad}\text{ cu. ft.}$$

REMARKS: ____

Unit Weight of Water Table

Temp °F	lbs/cu. Ft.	Temp °F	lbs/cu. Ft.
68	62.315	77	62.243
69	62.308	78	62.234
70	62.301	79	62.225
71	62.293	80	62.216
72	62.285	81	62.206
73	62.277	82	62.196
74	62.269	83	62.186
75	62.261	84	62.176
76	62.252	85	62.166
		86	62.155

FIGURE 6

MAXIMUM DRY DENSITY AND OPTIMUM MOISTURE OF SOILS BY PROCTOR ALTERNATE METHOD D

(A Modification of AASHTO Designation T 99)

1. SCOPE

1.1 This test method describes the procedure for determining the maximum dry density and optimum moisture content for a soil by the Proctor Alternate Method D.

1.2 Alternate Method D may be used for all maximum dry density and optimum moisture content determinations except for volcanic cinders or light porous material on which the specific gravity cannot be determined with consistency or when the moisture absorption for the coarse aggregate is greater than 4.0%.

1.3 Alternate Method D may be used except when greater than 40% of the material is retained on the 3/4 inch sieve.

1.4 An example is provided in Figure 2 for the calculations and determinations referenced herein.

1.5 This test method may involve hazardous materials, operations, and equipment. This test method does not purport to address all of the safety problems associated with its use. It is the responsibility of whomever uses this test method to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. APPARATUS

2.1 Requirements for the frequency of equipment calibration and verification are found in Appendix A3 of the Materials Testing Manual.

2.2 6 inch proctor mold having a capacity of approximately 1/13.33 cubic foot, with an internal diameter of 6.000 plus 0.039 or minus 0.026 inches and a height of

4.584 plus 0.005 or minus 0.008 inches. The mold shall have a nominal wall thickness of 1/4 inch. It shall be equipped with an extension collar approximately 2-3/8 inches high. A baseplate as shown in Figure 1 shall be provided.

2.3 A hand or mechanical rammer weighing 5.50 ± 0.02 pounds, having a flat face, and equipped with a suitable arrangement to control the height of drop to a free fall of 12 ± 0.06 (1/16) inches above the elevation of the soil. The hand rammer face shall be circular with a diameter of 2.000 plus 0.010 or minus 0.015 inches. The mechanical rammer face shall have the shape of a piece of pie, with a radius of approximately 3 inches, and having an area of 3.134 ± 0.039 square inches. If a mechanical apparatus is used, it must be monitored through the ADOT proficiency sample program and maintain a rating of 3 or better based on the results of testing ADOT and AMRL proficiency samples.

2.4 Hard steel straightedge, at least 10 inches in length. It shall have one beveled edge, and at least one longitudinal surface (used for final trimming) shall be plane within 0.01 inch per 10 inches (0.1 percent) of length with the portion used for trimming the soil.

2.5 Scale or balance capable of measuring the maximum weight to be determined, accurate to at least one gram.

2.6 Scale or balance capable of measuring the maximum weight to be determined, accurate to at least 0.1 gram.

2.7 Oven capable of maintaining a temperature of 230 ± 9 °F.

2.8 3/4 inch and 3 inch sieves conforming to the requirements of ASTM E11.

2.9 Miscellaneous mixing tools and pans.

2.10 Sample Extruder (optional) consisting of a jack, lever, frame, or other device for extruding the compacted sample from the mold.

3. CALIBRATION OF MOLD

3.1 Molds shall be calibrated in accordance with APPENDIX A of Arizona Test Method 225.

4. SAMPLE

4.1 Enough soil material shall be provided from the field to make five compacted specimens. A minimum sample size of 45,000 grams (approximately 100 lbs.) is normally required.

4.2 If the soil sample is damp when received from the field, dry it until it becomes friable under a trowel. Drying may be in air or by use of a slow fan or other drying apparatus such that the temperature of the sample does not exceed 140 °F.

4.3 Thoroughly break up the aggregations in such a manner as to avoid reducing the natural size of individual particles.

4.4 Weigh out an approximate 45,000 gram sample of representative soil. Record the weight of the sample, and sieve the material over a 3/4 inch sieve. If the percentage of coarse aggregate or rock retained on the 3/4 inch sieve is not already known from gradation testing, save any material retained on the 3/4 inch sieve and weigh. Calculate the percent of coarse aggregate or rock particles retained on the 3/4 inch sieve according to the following equation:

$$PR3/4 = \frac{WR3/4}{WT} \times 100$$

Where: PR3/4 = Percentage of coarse aggregate or rock particles retained on the 3/4 inch sieve

WR3/4 = Weight of coarse aggregate or rock particles retained on the 3/4 inch sieve

WT = Total weight of material sieved

4.5 If "PR3/4" is greater than 40%, then too much rock is present to allow for a reasonable maximum dry density determination If "PR3/4" is less than or equal to 40%, blend material passing the 3/4 inch sieve thoroughly and proceed to Section 5 of this test method. If a specific gravity and absorption determination, in accordance with AASHTO T 85, is to be made for the plus 3/4 inch material, save an adequate amount of this material, otherwise, discard it.

5. PROCEDURE

5.1 From the thoroughly blended passing 3/4 inch material from Subsection 4.5, split out 5 representative approximate 5000 gram samples.

5.2 Select one sample and thoroughly mix with sufficient water to dampen it to approximately three percentage points below optimum moisture content.

Note: If desired, an additional three samples may be mixed at this time with approximate moisture contents of 1% below optimum, 1% over optimum, and 3% over optimum. The moisture in each of these samples shall be retained by covering with a damp cloth or being sealed in air tight containers until they are compacted. One of the five samples should be retained for future use since it is necessary to have at least two points defined on each side of the moisture-density curve.

5.3 Heavy clay soils or materials which tend to break down, or those in which it is difficult to incorporate water, shall require approximately 12 hours for uniform moisture absorption to be achieved. This shall be accomplished by preparing separate samples for each increment of water to be added, and then placing and sealing these samples in air tight containers for the 12-hour period.

5.4 Form a specimen by compacting the prepared soil in the six inch mold (with extension collar attached) in three equal layers to give a total compacted depth of about 5 inches. Compact each layer with 56 uniformly distributed blows from the rammer, dropping free from a height of 12 inches. While each layer is being compacted, the remainder of material shall be in a pan covered by a damp cloth. During compaction, the mold shall rest firmly on a dense, uniform, rigid and stable foundation.

Note: Each of the following has been found to be a satisfactory base on which to rest the mold during compaction of the soil: A block of concrete, weighing not less than 200 lbs., supported by a stable foundation; a sound concrete floor; and for field application, such surfaces as found in concrete box culverts, bridges, and pavements.

5.5 When compacting granular, free-draining materials, at moisture contents which are at or above optimum, the mold shall be prepared by first sealing the bottom of the mold with waterproofing grease. All excess grease shall be wiped from the mold and baseplate.

5.6 Following compaction, carefully remove the extension collar. It may be necessary to use a follower to retain the soil in the mold while removing the collar to prevent damage or disturbance of the soil below the top of the mold. Carefully trim the compacted soil even with the top of the mold by means of the straightedge. If any voids are created during trimming, these shall be filled with fine material and smoothed off. Determine the weight of compacted specimen and mold. Determine the wet density, "WD", of the compacted soil by the following:

$$\text{WD} = \frac{\text{M1} - \text{M2}}{\text{VM} \times 453.6\ (\text{grams/lb.})}$$

Where: WD = Wet density of compacted soil, lb./cu. ft.
M1 = Weight of compacted specimen and mold, grams
M2 = Weight of the mold, grams
VM = Volume of the mold, cu. ft. (See Section 3 of this procedure.)

5.7 The estimated dry density, "ED", of the compacted soil may be calculated and recorded to the nearest 0.1 lb./cu. ft. as follows:

$$\text{ED} = \frac{\text{WD}}{(\text{Approx. \% of water added}) + 100} \times 100$$

Where: ED = Estimated dry density of compacted soil, lb./cu. ft.
WD = Wet density of compacted soil, lb./cu. ft.

Note: These estimated densities are approximate only and will be corrected when final moisture results are obtained.

5.8 The estimated dry density is useful in deciding how much water to add in later trial batches, if the procedure described in the note following Subsection 5.2, for initially preparing three additional samples with varying moisture contents is not utilized. By carefully observing the estimated dry density of the compacted samples, the operator should be able to vary the moisture content as the test proceeds so that when the final moisture-density results are plotted, a curve will result that rises to a peak and then falls away.

5.9 Remove the material from the mold and slice vertically through the center. Take a representative minimum 600 gram sample from the full length and width of one of the cut faces. Weigh immediately, and dry to a constant weight in an oven at 230 ± 9 °F to determine the moisture content in accordance with AASHTO T 265. Record the weight of wet soil to the nearest 0.1 gram as "WW", and record the weight of oven dry soil to the nearest 0.1 gram as "DW".

5.10 For granular, free-draining materials, the moisture content shall be determined using the entire compacted proctor specimen. Determine the weight of wet soil, "WW", by subtracting the weight of the mold, "M2", from the weight of compacted specimen and mold, "M1". Record the weight of wet soil, "WW", and the weight of oven dry soil, "DW", to at least the nearest gram. All clinging material shall be removed from the inside of the mold and included with the specimen. To facilitate drying, the specimen may be broken up and spread out in a large pan, being careful to not lose any soil particles.

5.11 Select another of the samples which was split in Subsection 5.1, and if not already done, thoroughly mix with water in sufficient amount to increase the moisture content by approximately two percentage points.

5.12 Repeat the procedure in Subsections 5.3 through 5.10 for the sample at each moisture content, as necessary to establish a moisture-density curve which rises to a peak and then falls away.

6. CALCULATIONS

6.1 Calculate percent moisture and record to the nearest 0.1 percent by the following:

$$\% \text{ Moisture} = \frac{WW - DW}{DW} \times 100$$

Where: WW = weight of wet soil, grams
DW = weight of oven dry soil, grams

6.2 Calculate dry density and record to the nearest 0.1 lb./cu. ft. by the following:

$$DD = \frac{WD}{\% \text{ Moisture} + 100} \times 100$$

Where: DD = Dry density of compacted soil, lb./cu. ft.
WD = Wet density of compacted soil, lb./cu. ft.

7. MOISTURE-DENSITY RELATIONSHIP

7.1 The percent moisture and corresponding dry density for each of the compacted soil specimens shall be plotted on the graph provided on the proctor density test form shown in Figure 3. For a good plot, the majority of the graph is utilized. Normally, three increments on the horizontal axis shall equal one percent of moisture, and three increments on the vertical axis shall equal one lb./cu. ft. of dry density. If another number of increments other than three is utilized, the number of increments for one percent moisture and one lb./cu. ft. dry density shall always be the same.

7.2 On each side of the maximum density curve, at least two points should be utilized to form two straight lines. The intersection point of these two lines defines the peak point of the density-moisture content relationship, or the maximum density and optimum moisture content for the soil. In general it will be found that higher unit mass soils assume steeper slopes with high maximum dry densities at low optimum moisture contents, while the lower unit mass soils assume flatter, more gently sloped lines with high optimum moisture contents and low maximum dry densities. Figure 4 gives examples of moisture-density plots which show the different slopes associated with different maximum dry density ranges.

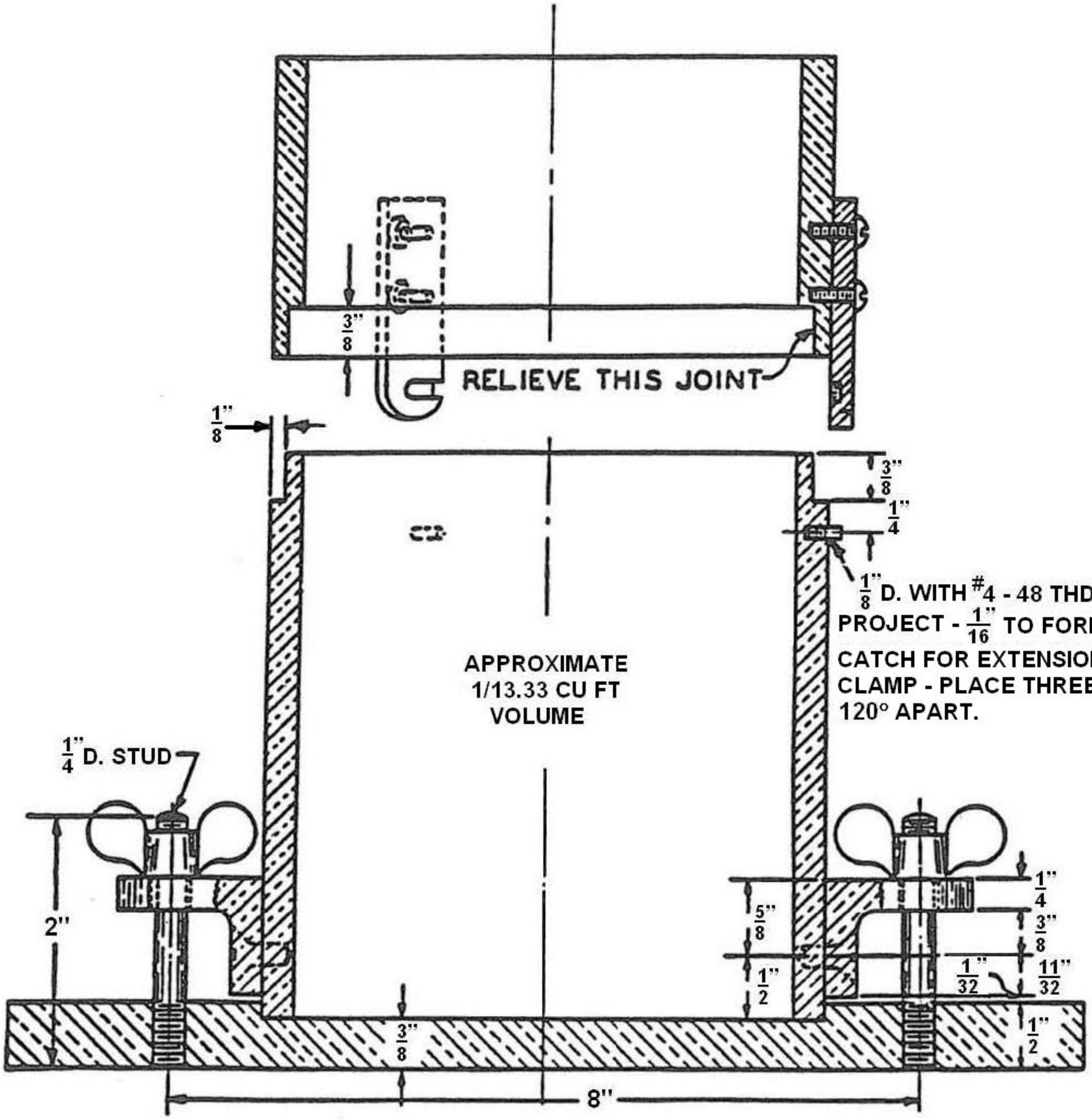
7.3 Optimum moisture content - The percent moisture content corresponding to the peak (intersection point of the two lines) of the moisture-density curve shall be termed the "optimum moisture content", and shall be reported as "OM" to the nearest 0.1 percent.

7.4 Maximum dry density - The dry density at optimum moisture content corresponding to the peak (intersection point of the two lines) of the moisture-density curve shall be termed the "maximum dry density", and shall be reported as "MD" to the nearest 0.1 lb./cu. ft.

Note: The optimum moisture and maximum dry density determinations above are for the material passing the 3/4 inch sieve. When testing field samples for comparison to proctor optimum moisture and maximum dry density, a correction to the proctor optimum moisture and maximum dry density must be made, in accordance with ARIZ 227, for the percent rock which the field sample contains.

8. REPORT

8.1 Record the moisture and density data on the laboratory test form along with the laboratory number, material source and type, and other information required. A blank laboratory test form is provided in Figure 3.



CYLINDERICAL MOLD, COLLAR,
AND BASEPLATE
(6 INCH MOLD)

FIGURE 1

Arizona Department of Transportation

METHOD A or **ALTERNATE METHOD D** PROCTOR DENSITY

(Arizona Test Method 225 or 245)

Project No: ____________ Lab No : ____________ Rec'd Date: ____________

Source and Type of Material : ____________

Proctor Method Used : **Method A** ________ or **Alternate Method D** ✓

Test Operator and Date : ____________ Supervisor and Date: ____________

Weight of Mold = **M2** = **2840** grams | Volume of Mold = **VM** = **0.0744** = cu ft | **a** = VM x 453.6 = **33.7478**

b	M1	c	WD	ED	Moisture Determination				DD
					WW	DW	d	e	
Approx % of water Added	Wt. of Sample and Mold	Wet Wt. of Sample M1 - M2	Wet Density lb/ cu ft $\frac{c}{a}$	Est. Dry Density $\frac{WD \times 100}{b + 100}$	Wet Wt. of Moisture Sample	Dry Wt. of Moisture Sample	Wt. of Water WW - DW	Percent Moisture $\frac{d \times 100}{DW}$	Dry Density lb/cu ft $\frac{WD \times 100}{e + 100}$
7	7180	4340	128.6	120.2	655.5	613.8	41.7	6.8	120.4
9	7376	4536	134.4	123.3	685.3	628.7	56.6	9.0	123.3
11	7474	4634	137.3	123.7	658.4	592.1	66.3	11.2	123.5
13	7457	4617	136.8	121.1	645.9	572.1	73.8	12.9	121.2

METHOD A

WT = ________ WR4 = ________

PR4 = $\frac{WR4}{WT}$ x 100 = ________

ALTERNATE METHOD D

WT = 48780 WR 3/4 = 17951

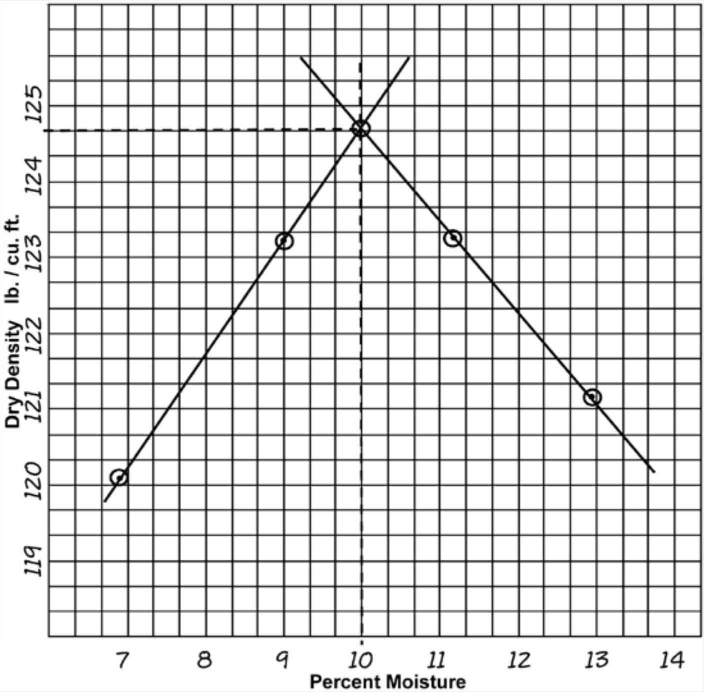
PR 3/4 = $\frac{WR\ 3/4}{WT}$ x 100 = 37 %

Coarse Aggregate Bulk Oven Dry Specific Gravity : 2.631

Coarse Aggregate Absorption : 2.28 %

OPTIMUM MOISTURE CONTENT = OM = 10.0 %

MAXIMUM DRY DENSITY (lb. / cu. ft.) = MD = 124.6



Remarks : ____________

FIGURE 2

Arizona Department of Transportation
METHOD A or **ALTERNATE METHOD D** PROCTOR DENSITY
(Arizona Test Method 225 or 245)

Project No: ______________________ Lab No : ______________ Rec'd Date: ______________

Source and Type of Material : ______________________

Proctor Method Used : **Method A** __________ or **Alternate Method D** ______________

Test Operator and Date : ______________________ Supervisor and Date: ______________

Weight of Mold = **M2** = __________ grams

Volume of Mold = **VM** = __________ = cu ft

a = VM x 453.6 = __________

					Moisture Determination				
b	M1	c	WD	ED	WW	DW	d	e	**DD**
Approx % of water Added	Wt. of Sample and Mold	Wet Wt. of Sample	Wet Density lb/ cu ft	Est. Dry Density	Wet Wt. of Moisture Sample	Dry Wt. of Moisture Sample	Wt. of Water	Percent Moisture	Dry Density lb/cu ft
		M1 - M2	$\frac{c}{a}$	$\frac{WD \times 100}{b + 100}$			WW - DW	$\frac{d \times 100}{DW}$	$\frac{WD \times 100}{e + 100}$

METHOD A

WT = __________ WR4 = __________

PR4 = $\frac{WR4}{WT}$ x 100 = __________

ALTERNATE METHOD D

WT = __________ WR 3/4 = __________

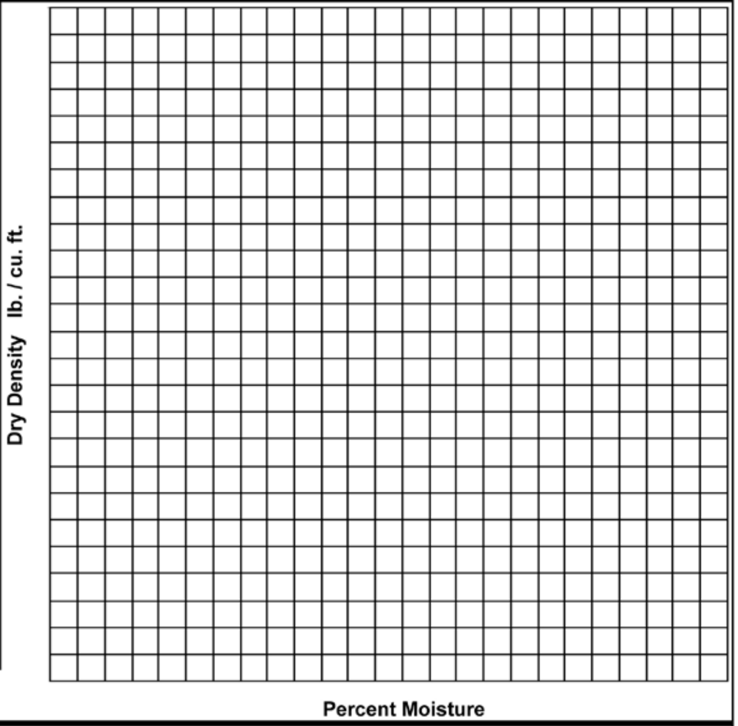
PR 3/4 = $\frac{WR\ 3/4}{WT}$ x 100 = __________ %

Coarse Aggregate
Bulk Oven Dry
Specific Gravity : __________

Coarse Aggregate
Absorption : __________ %

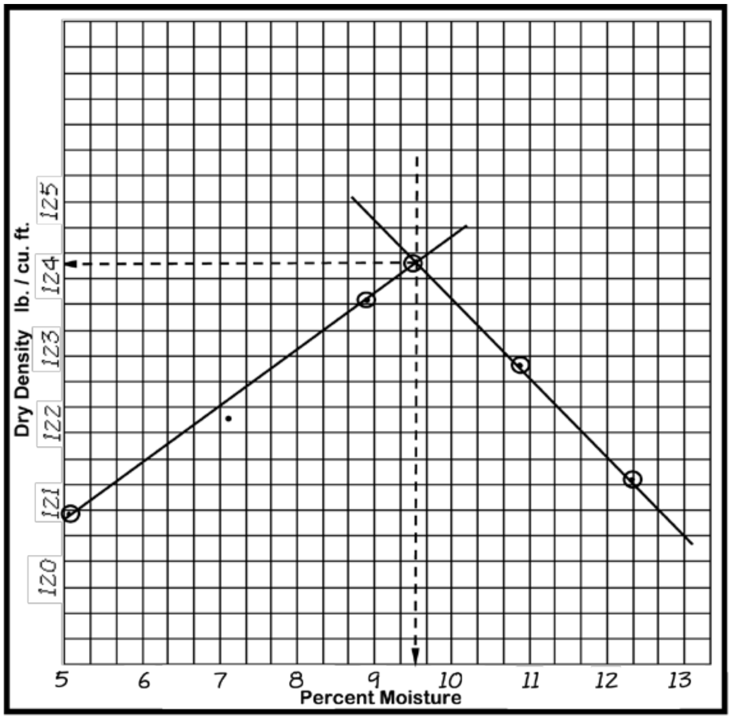
OPTIMUM MOISTURE
CONTENT = OM = __________ %

MAXIMUM DRY DENSITY
(lb. / cu. ft.) = MD = __________



Remarks : ______________________

FIGURE 3



AGGREGATE BASE COURSE

% Moisture	Dry Density
5.1	120.8
7.1	122.1
8.9	123.7
10.8	122.7
12.3	121.3

Moisture Density = 124.1 lb/cu ft
Optimum Moisture = 9.4 %

SILTY SAND AND GRAVEL

% Moisture	Dry Density
7.2	127.0
8.1	129.6
9.4	127.9
10.1	126.6

Moisture Density = 130.0 lb/cu ft
Optimum Moisture = 8.3 %

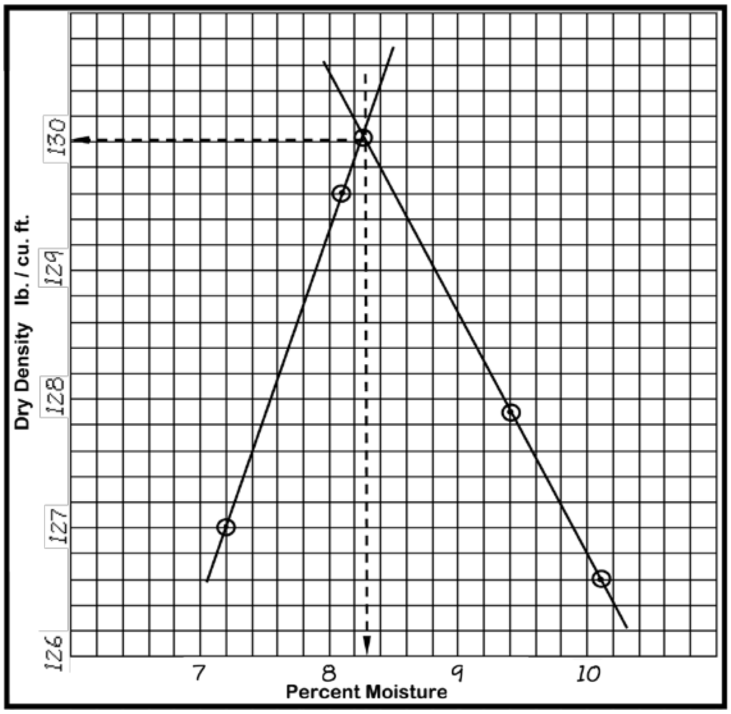
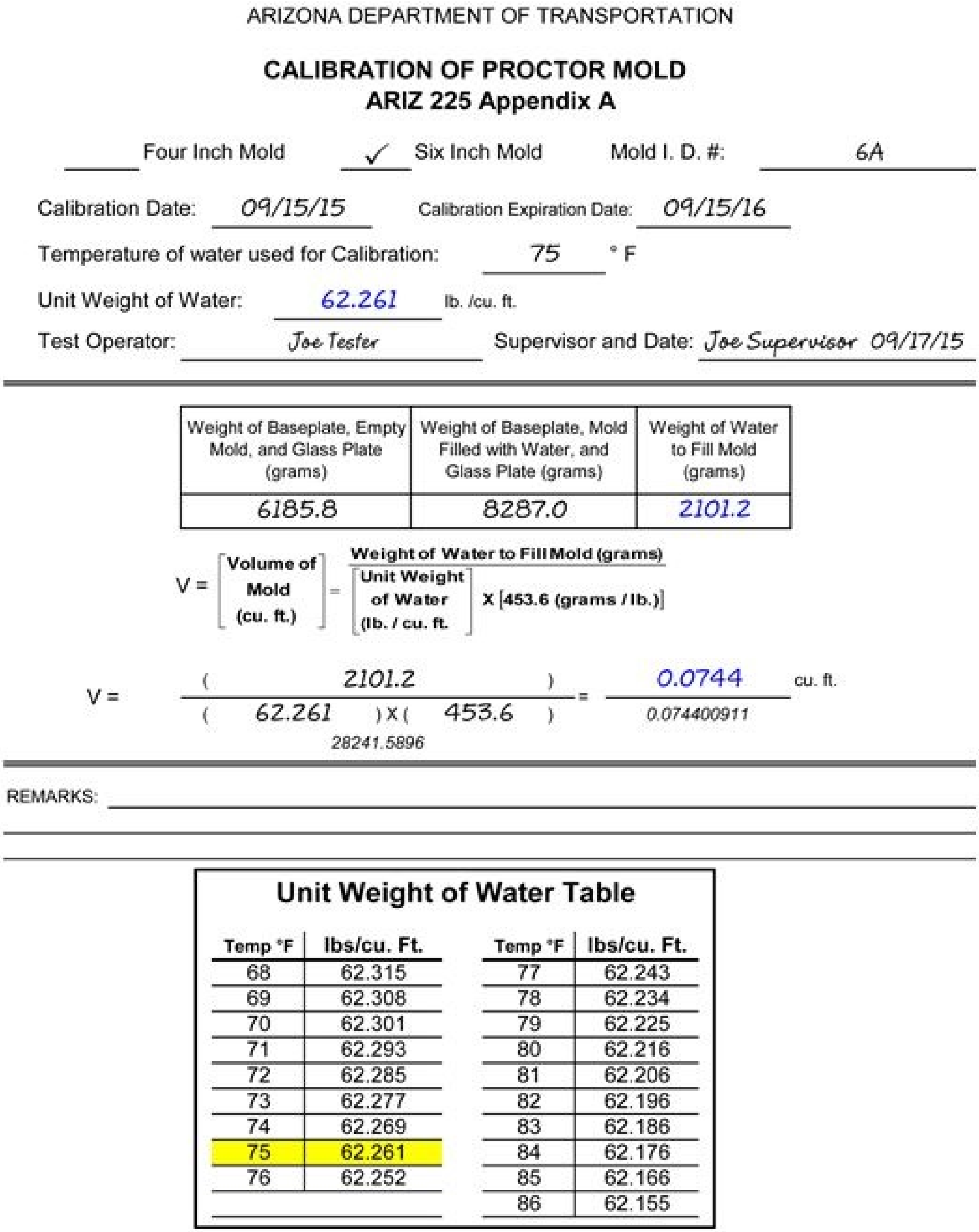


FIGURE 4



ARIZONA DEPARTMENT OF TRANSPORTATION

CALIBRATION OF PROCTOR MOLD
ARIZ 225 Appendix A

____ Four Inch Mold ✓ Six Inch Mold Mold I. D. #: 6A

Calibration Date: 09/15/15 Calibration Expiration Date: 09/15/16

Temperature of water used for Calibration: 75 °F

Unit Weight of Water: 62.261 lb. /cu. ft.

Test Operator: Joe Tester Supervisor and Date: Joe Supervisor 09/17/15

Weight of Baseplate, Empty Mold, and Glass Plate (grams)	Weight of Baseplate, Mold Filled with Water, and Glass Plate (grams)	Weight of Water to Fill Mold (grams)
6185.8	8287.0	2101.2

$$V = \left[\begin{array}{c}\text{Volume of}\\ \text{Mold}\\ \text{(cu. ft.)}\end{array}\right] = \frac{\text{Weight of Water to Fill Mold (grams)}}{\left[\begin{array}{c}\text{Unit Weight}\\ \text{of Water}\\ \text{(lb. / cu. ft.}\end{array}\right] \text{X} \left[453.6 \text{ (grams / lb.)}\right]}$$

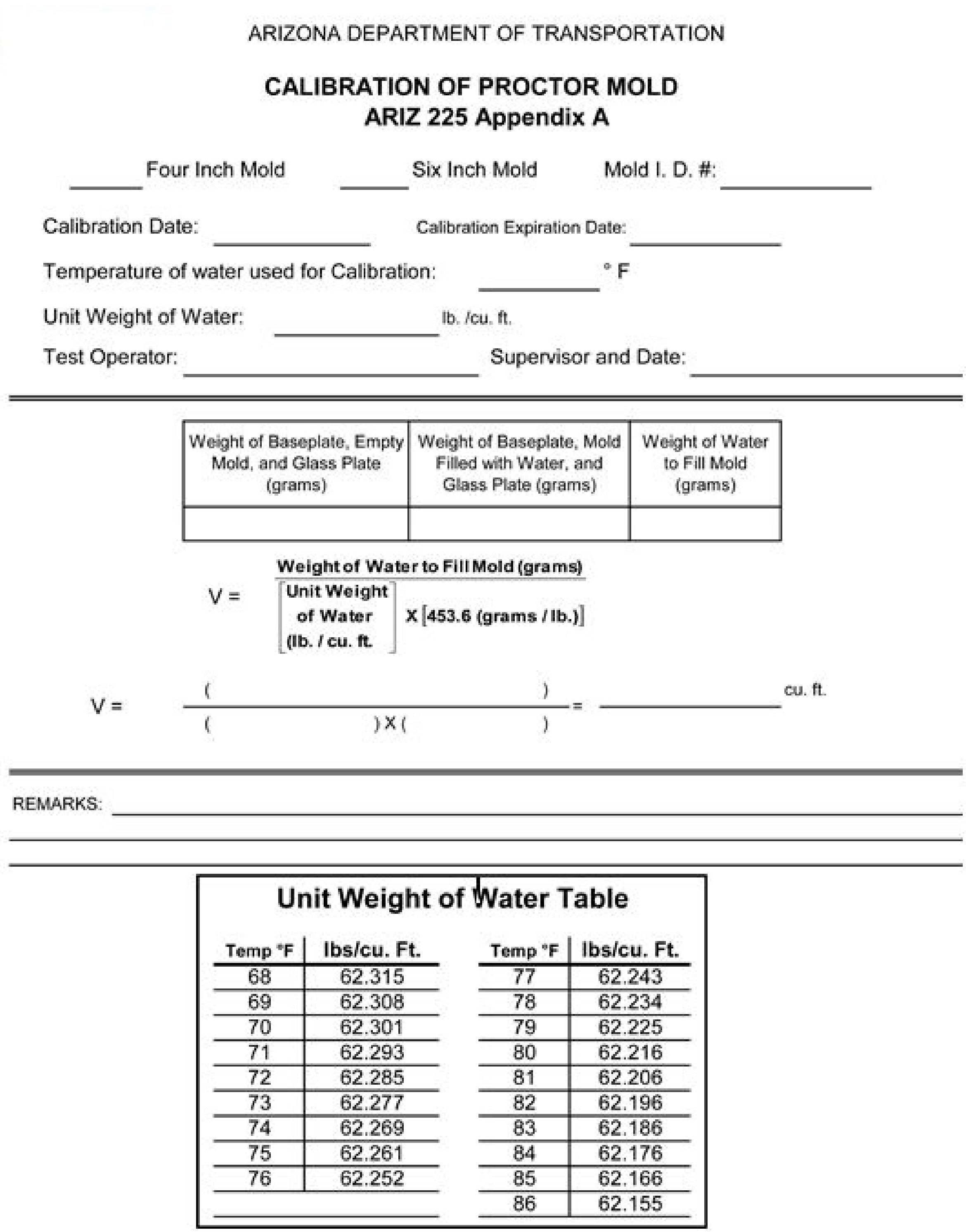
$$V = \frac{(\quad 2101.2 \quad)}{\underset{28241.5896}{(\quad 62.261 \quad) \text{X} (\quad 453.6 \quad)}} = \underset{0.074400911}{0.0744} \text{ cu. ft.}$$

REMARKS: ____

Unit Weight of Water Table

Temp °F	lbs/cu. Ft.	Temp °F	lbs/cu. Ft.
68	62.315	77	62.243
69	62.308	78	62.234
70	62.301	79	62.225
71	62.293	80	62.216
72	62.285	81	62.206
73	62.277	82	62.196
74	62.269	83	62.186
75	62.261	84	62.176
76	62.252	85	62.166
		86	62.155

FIGURE 5



ARIZONA DEPARTMENT OF TRANSPORTATION

CALIBRATION OF PROCTOR MOLD
ARIZ 225 Appendix A

______ Four Inch Mold ______ Six Inch Mold Mold I. D. #: ____________

Calibration Date: ____________ Calibration Expiration Date: ____________

Temperature of water used for Calibration: __________ ° F

Unit Weight of Water: ____________ lb. /cu. ft.

Test Operator: ____________________ Supervisor and Date: ____________________

Weight of Baseplate, Empty Mold, and Glass Plate (grams)	Weight of Baseplate, Mold Filled with Water, and Glass Plate (grams)	Weight of Water to Fill Mold (grams)

$$V = \frac{\textbf{Weight of Water to Fill Mold (grams)}}{\left[\begin{array}{c}\textbf{Unit Weight}\\ \textbf{of Water}\\ \textbf{(lb. / cu. ft.}\end{array}\right] \textbf{ X } [\textbf{453.6 (grams / lb.)}]}$$

$$V = \frac{(\qquad\qquad\qquad\qquad)}{(\qquad\qquad)\text{ X }(\qquad\qquad)} = \underline{\qquad\qquad} \text{ cu. ft.}$$

REMARKS: ____

Unit Weight of Water Table

Temp °F	lbs/cu. Ft.	Temp °F	lbs/cu. Ft.
68	62.315	77	62.243
69	62.308	78	62.234
70	62.301	79	62.225
71	62.293	80	62.216
72	62.285	81	62.206
73	62.277	82	62.196
74	62.269	83	62.186
75	62.261	84	62.176
76	62.252	85	62.166
		86	62.155

FIGURE 6

ADOT
Infrastructure Delivery and Operations

ARIZ 233e
November 2, 2018
(8 Pages)

FLAKINESS INDEX OF COARSE AGGREGATE

(An Arizona Method)

1. SCOPE

1.1 This test method describes the procedure for determining the "Flakiness Index" (flatness) of coarse plus No. 8 aggregate. The Flakiness Index is the percentage of particles having a least dimension smaller than 60 percent of the mean size of each of one or more of the coarse sieve fractions. The lower the index for any sample of aggregate, the more nearly the aggregate particles approximate a cubical shape.

1.2 Once the Flakiness Index is known, the average least dimension of the aggregate can be determined if required, for example as in Arizona Test Method 819, “Design of Exposed Aggregate Seal Coats”. The procedure for determining the average least dimension of the aggregate is described in Section 6 of this test method.

1.3 This test method may involve hazardous material, operations, or equipment. This test method does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user to consult and establish appropriate safety and health practices and determine the applicability of any regulatory limitations prior to use.

1.4 See Appendix A1 of the Materials Testing Manual for information regarding the procedure to be used for rounding numbers to the required degree of accuracy.

2. APPARATUS

2.1 Requirements for the frequency of equipment calibration and verification are found in Appendix A3 of the Materials Testing Manual.

2.2 For each size of material to be tested, a 16 gauge steel plate (1/16 inch nominal thickness) with a slotted opening approximately 4 inches in length and having a width conforming to the applicable requirements given below. If desired, the same plate may contain all or some of the required slots, rather than a separate plate for each.

Size of Material Passing	Size of Material Retained	Slot Width (inches)	Slot Width Tolerance (inches)
1-1/2"	1"	0.738	± 0.023
1"	3/4"	0.520	± 0.016
3/4"	1/2"	0.372	± 0.012
1/2"	3/8"	0.260	± 0.008
3/8"	1/4"	0.187	± 0.006
1/4"	No. 4	0.131	± 0.004
No. 4	No. 8	0.084	± 0.003

2.3 A balance or scale capable of measuring the maximum weight to be determined and conforming to the requirements of AASHTO M 231, except the readability and sensitivity of any balance or scale utilized shall be at least one gram.

2.4 Sieves conforming to the requirements of ASTM E11, of sizes 1-1/2", 1", 3/4", 1/2", 3/8", 1/4", No. 4, and No. 8, as necessary for the material being tested.

3. SAMPLE PREPARATION

3.1 A representative sample of the aggregate for the specified use shall be obtained. The size of sample shall be at least the size required by Arizona Test Method 201, and larger if necessary to provide adequate material for the applicable required individual size fractions indicated below. See Subsection 3.3 below for determination of the individual size fractions to be tested.

Size of Material Passing	Size of Material Retained	Minimum Test Sample (grams)
1-1/2"	1"	3000
1"	3/4"	1500
3/4"	1/2"	1000
1/2"	3/8"	500
3/8"	1/4"	200
1/4"	No. 4	100
No. 4	No. 8	50

3.2 The sample shall be subjected to sieve analysis in accordance with Arizona Test Method 201. If both the coarse and fine sieve analysis of the material are performed, material passing the No. 4 sieve shall be separated into No. 8 and passing No. 8 fractions by sieving over a No. 8 sieve. Reference can also be made to Section 3 of Arizona Test Method 248 for utilizing a No. 8 sieve in the coarse sieving, and a fine sieve analysis not being required. The coarse aggregate size fractions of No. 8 and larger shall be placed in individual containers. The material passing the No. 8 sieve may be discarded.

3.3 From each size fraction that has a percent retained value from sieve analysis which is equal to or greater than 10%, obtain a representative test sample of the weight specified in Subsection 3.1 above.

4. FLAKINESS INDEX TEST PROCEDURE

4.1 Weigh each test sample to the nearest gram and record as the "Weight of Test Sample", for the respective size fraction.

4.2 The particles from the test sample for each size fraction shall be individually tested for their ability to pass through the appropriate slot, as specified in Subsection 2.2. Weigh the material which passes the appropriate slot, and record to the nearest gram as the "Weight Passing Slot", for the respective size fraction.

5. CALCULATIONS FOR FLAKINESS INDEX DETERMINATION

5.1 Figure 1 is an example of the calculations. Figure 2 is a blank Flakiness Index form which contains the required calculations.

5.2 Calculate the "Percent Passing Slot", for each respective size fraction, and record to the nearest percent.

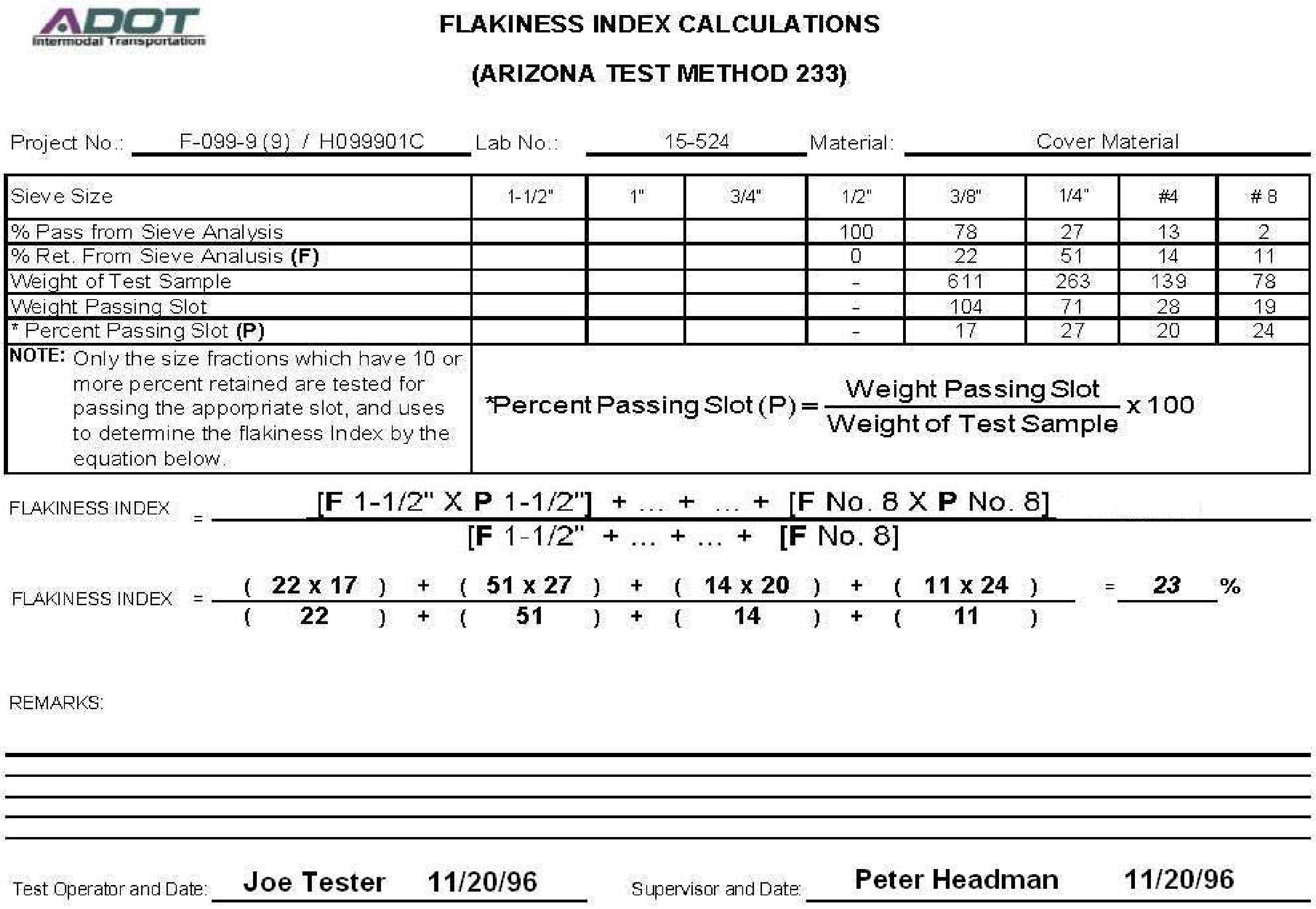
5.3 Calculate the "Flakiness Index", and report the result to the nearest percent.

6. DETERMINATION OF AVERAGE LEAST DIMENSION OF AGGREGATE

6.1 When it is required (such as in Arizona Test Method 819), the average least dimension of the aggregate may be determined by using Figures 3 and 4. (These figures include an example which illustrates the procedure described in the paragraphs below.)

6.2 The median size of the aggregate is determined as shown in the example in Figure 3. Plot the % passing from sieve analysis for the two sieve sizes sufficient to locate the 50% line intercept. Draw a line between the two points. From the 50% passing point on the right side of the chart, proceed horizontally to the left until the line drawn between the two points is intercepted. Draw a line vertically from this point to intercept the "Median Size" scale at the bottom of the chart. Read the resultant median size to the nearest 0.01 inch.

6.3 The average least dimension of the aggregate is determined as shown in the example in Figure 4. Find the point for "Median Size" on the left side of the chart. Proceed horizontally to the right until the corresponding line for Flakiness Index is intercepted. Draw a line vertically from this point to intercept the "AVERAGE LEAST DIMENSION" at the bottom of the chart. Read and record the average least dimension of the aggregate to the nearest 0.01 inch.



FLAKINESS INDEX CALCULATIONS

(ARIZONA TEST METHOD 233)

Project No.: F-099-9 (9) / H099901C Lab No.: 15-524 Material: Cover Material

Sieve Size	1-1/2"	1"	3/4"	1/2"	3/8"	1/4"	#4	# 8
% Pass from Sieve Analysis				100	78	27	13	2
% Ret. From Sieve Analusis **(F)**				0	22	51	14	11
Weight of Test Sample				-	611	263	139	78
Weight Passing Slot				-	104	71	28	19
* Percent Passing Slot **(P)**				-	17	27	20	24

NOTE: Only the size fractions which have 10 or more percent retained are tested for passing the apporpriate slot, and uses to determine the flakiness Index by the equation below.

$$\text{*Percent Passing Slot (P)} = \frac{\text{Weight Passing Slot}}{\text{Weight of Test Sample}} \text{ x 100}$$

$$\text{FLAKINESS INDEX} = \frac{[\mathbf{F}\ 1\text{-}1/2\text{" X } \mathbf{P}\ 1\text{-}1/2\text{"}] + \ldots + \ldots + [\mathbf{F}\text{ No. 8 X }\mathbf{P}\text{ No. 8}]}{[\mathbf{F}\ 1\text{-}1/2\text{"} + \ldots + \ldots + [\mathbf{F}\text{ No. 8}]}$$

$$\text{FLAKINESS INDEX} = \frac{(\ 22 \text{ x } 17\ ) + (\ 51 \text{ x } 27\ ) + (\ 14 \text{ x } 20\ ) + (\ 11 \text{ x } 24\ )}{(\ 22\ ) + (\ 51\ ) + (\ 14\ ) + (\ 11\ )} = \underline{23}\ \%$$

REMARKS:

Test Operator and Date: **Joe Tester 11/20/96** Supervisor and Date: **Peter Headman 11/20/96**

FIGURE 1

FLAKINESS INDEX CALCULATIONS

(ARIZONA TEST METHOD 233)

Project No.: ______________________ Lab No.: ______________ Material: ______________________

Sieve Size	1-1/2"	1"	3/4"	1/2"	3/8"	1/4"	#4	# 8
% Pass from Sieve Analysis								
% Ret. From Sieve Analusis **(F)**								
Weight of Test Sample								
Weight Passing Slot								
* Percent Passing Slot **(P)**								

NOTE: Only the size fractions which have 10 or more percent retained are tested for passing the apporpriate slot, and uses to determine the flakiness Index by the equation below.

$$*\text{Percent Passing Slot (P)} = \frac{\text{Weight Passing Slot}}{\text{Weight of Test Sample}} \times 100$$

$$\text{FLAKINESS INDEX} = \frac{[\mathbf{F}\ 1\text{-}1/2" \times \mathbf{P}\ 1\text{-}1/2"] + \ldots + \ldots + [\mathbf{F}\ \text{No. } 8 \times \mathbf{P}\ \text{No. } 8]}{[\mathbf{F}\ 1\text{-}1/2" + \ldots + \ldots + [\mathbf{F}\ \text{No. } 8]}$$

$$\text{FLAKINESS INDEX} = \frac{(\quad \times \quad) + (\quad \times \quad) + (\quad \times \quad) + (\quad \times \quad)}{(\quad + \quad + \quad + \quad)} = \underline{\qquad}\ \%$$

REMARKS:

Test Operator and Date: ______________________ Supervisor and Date: ______________________

FIGURE 2

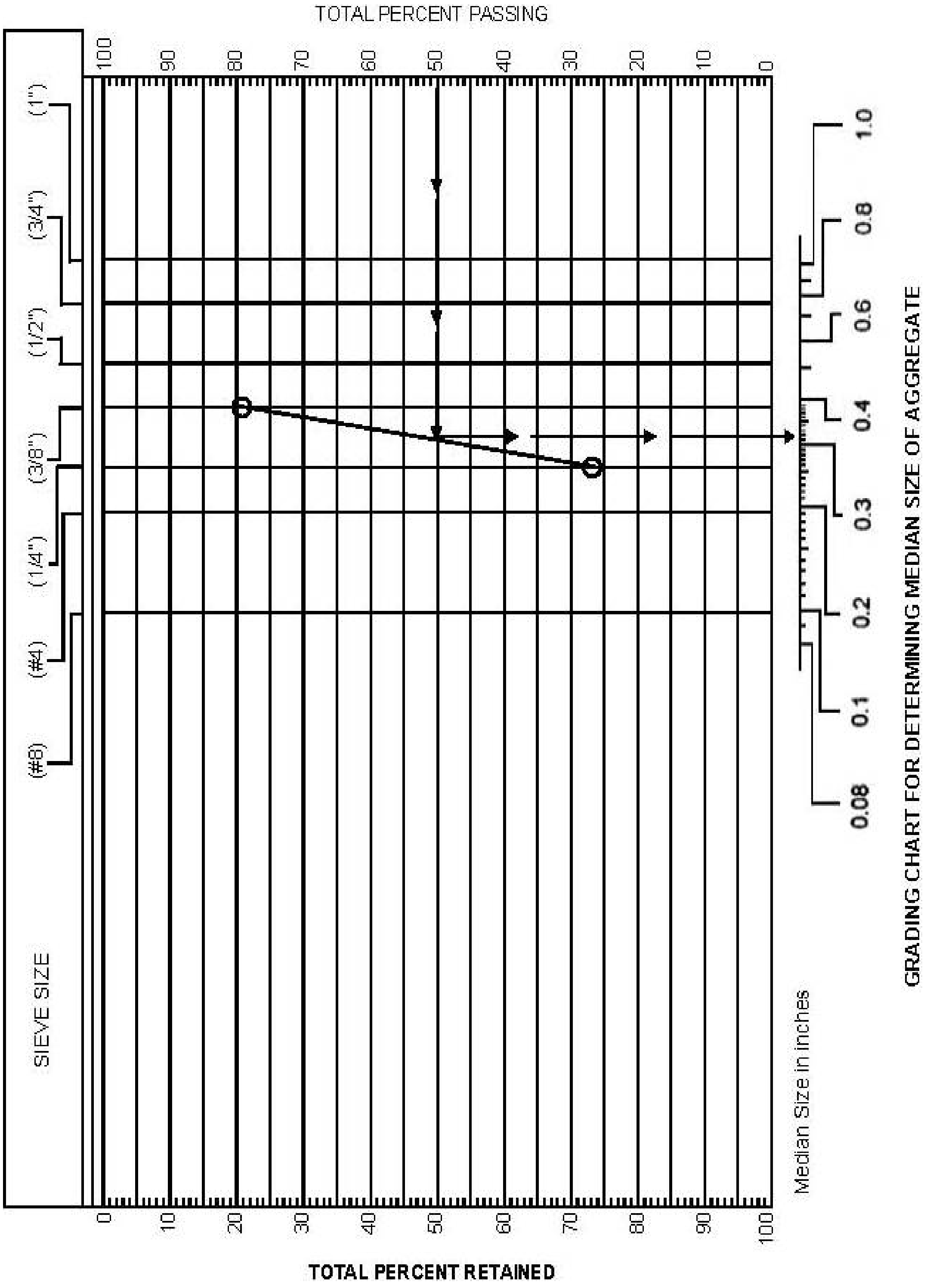

TOTAL PERCENT PASSING
100
90
80
70
60
50
40
30
20
10
0
SIEVE SIZE
(1")
(3/4")
(1/2")
(3/8")
(1/4")
(#4)
(#8)
TOTAL PERCENT RETAINED
0
10
20
30
40
50
60
70
80
90
100
Median Size in inches
1.0
0.8
0.6
0.4
0.3
0.2
0.1
0.08
GRADING CHART FOR DETERMINING MEDIAN SIZE OF AGGREGATE

FIGURE 3

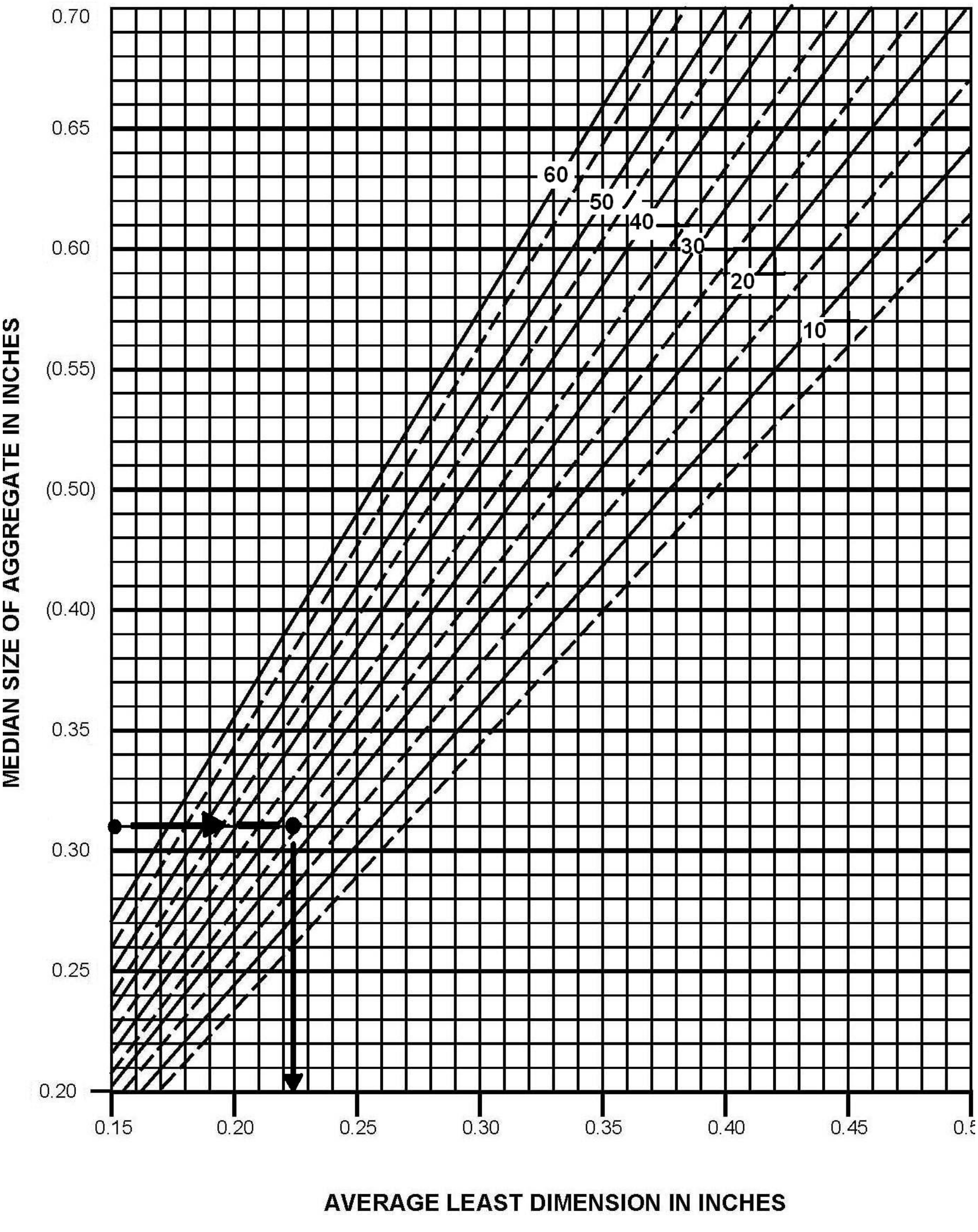

0.70
0.65
0.60
(0.55)
(0.50)
(0.40)
0.35
0.30
0.25
0.20
MEDIAN SIZE OF AGGREGATE IN INCHES
60
50
40
30
20
10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.5
AVERAGE LEAST DIMENSION IN INCHES

FIGURE 4

DETERMINING pH AND MINIMUM RESISTIVITY OF SOILS AND AGGREGATES

(An Arizona Method)

1. SCOPE

1.1 This test method outlines the procedure for determining the pH and minimum resistivity of soil and aggregate materials.

1.2 This test method may involve hazardous material, operations, or equipment. This test method does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user to consult and establish appropriate safety and health practices and determine the applicability of any regulatory limitations prior to use.

1.3 See Appendix A1 of the Materials Testing Manual for information regarding the procedure to be used for rounding numbers to the required degree of accuracy.

2. APPARATUS

2.1 Requirements for the frequency of equipment calibration and verification are found in Appendix A3 of the Materials Testing Manual.

2.2 Drying Apparatus - Any suitable device capable of drying samples at a temperature not exceeding 140 °F.

2.3 100 mL glass beaker or other suitable non-metallic container.

2.4 200 mL minimum capacity cylinder graduated in 1 mL increments.

2.5 Distilled Water.

2.6 pH Meter and combination probe, both having a relative accuracy of ± 0.05 pH units, minimum. The pH meter must be capable of registering a minimum pH range of 4.0 - 10.0, and be equipped with temperature compensation controls.

2.7 Standard Buffer Solutions of pH values 4.0, 7.0, and 10.0. The expiration date of the solution shall be noted on the container. Solution shall not be used past the expiration date.

2.8 Soil Box - Designed for use with the resistance meter. An example of an acceptable soil box is shown in Figure 1. Soil boxes which are commercially available may be used provided they meet the requirements specified herein. Soil boxes may vary in size. A unique soil box factor is determined for each soil box.

2.9 Resistance Meter - Instrument to determine resistance (ohms), readable to at least the nearest 10 ohms.

Note: The accuracy of the meter shall be established at these measurement levels: 50, 100, 200, 500, 900, 1500 ohms. The resistance standard(s) will have a tolerance of ± 1%. Any deviation greater than 5% from the known resistance shall require either calibration to within specified limits or the development of a calibration curve. Calibration results shall be recorded, dated, signed, and maintained on file for review.

2.10 No. 8 sieve conforming to ASTM E11.

2.11 A Balance or Scale capable of measuring the maximum weight to be determined and conforming to the requirements of AASHTO M 231, except the readability and sensitivity of any balance or scale utilized shall be at least 0.1 gram.

2.12 Thermometer - A thermometer accurate to 1 °F.

2.13 Miscellaneous mixing tools and pans.

3. SAMPLE PREPARATION

3.1 The soil sample as received from the field shall be dried thoroughly in air or the drying apparatus at a temperature not exceeding 140 °F.

3.2 A representative test sample of approximately 2000 grams shall then be obtained by splitting or quartering.

3.3 Screen the test sample through a No. 8 sieve.

3.4 From the screened Pass No. 8 Material, split out approximately 1500 grams for the resistivity test and obtain approximately 50 grams for the pH test. Record the weight of the pH material to the nearest 0.1 gram.

3.5 Combine the pH sample with an equal weight of distilled water in the 100 mL beaker. Stir until well mixed into a slurry and then stir at regular intervals of 8 to 10 minutes for an hour.

3.6 The temperature of the standard buffer solutions must be within 2 °F of the pH sample. Also, temperatures of the standard buffer solutions and the pH sample must be within the manufacturer's recommended temperature compensation range of the pH meter.

3.7 Place the resistivity sample in a mixing bowl. Add approximately 200 mL of distilled water to moisten the sample and mix thoroughly.

4. TEST PROCEDURE FOR pH

4.1 Per the manufacturer's instructions, standardize the pH meter using two of the standard buffer solutions: 7.0 and either 4.0 or 10.0, whichever is nearest to the estimated pH of the sample.

4.2 For each standard buffer solution, measure its temperature and adjust the temperature controller of the pH meter before testing for the standard solution pH value. This may not be needed on meters with automatic temperature compensation; follow manufacturer's instructions.

4.3 Stir the slurry mixture in the 100 mL beaker. Measure the temperature of the slurry and adjust the temperature controller of the pH meter before testing for the pH value of the slurry. This may not be needed on meters with automatic temperature compensation; follow manufacturer's instructions.

4.4 Carefully insert the pH probe in the slurry mixture. Do not place the electrode(s) into the soil; place them only into the slurry mixture. Determine the pH reading when the meter reading stabilizes.

4.5 If the pH reading is unstable when the electrode is immersed in the slurry, leave the electrode immersed until the pH reading has stabilized. In some cases, the waiting period for stabilization of the pH reading may take up to 5 minutes.

4.6 Record the pH value of the slurry mixture, to the nearest tenth.

5. TEST PROCEDURE FOR MINIMUM RESISTIVITY

5.1 Place moistened soil in a soil box with a known soil box factor, compact lightly with fingers and level off the top with a straightedge. Connect the resistance meter to the side terminals of the box. Determine resistance as per the manufacturer's instructions and record the resistance to the nearest 10 ohms.

5.2 Empty the soil back into the mixing bowl and add 50 mL of distilled water at room temperature and mix until all the water is dispersed uniformly through the soil.

5.3 Clean the soil box by rinsing with distilled water after each test application.

5.4 Fill the soil box by lightly hand compacting the wet soil, making sure that the soil completely fills the box. Level off the top of the hand compacted sample with a straightedge. Connect the resistance meter to the box. Read and record the resistance.

5.5 Repeat the above procedure, adding distilled water in increments of 50 mL. Ensure that each addition of water is dispersed evenly through the sample. The resistance readings should decrease, with the increase in moisture content, for several readings before an increase is noted. The lowest resistance reading before an increase is used for calculating the minimum resistivity of the soil.

6. CALCULATIONS FOR MINIMUM RESISTIVITY

6.1 Determine the length and width of the electrodes to the nearest 1 mm.

6.2 The soil box factor (SBF) expressed to the nearest 0.01 centimeter, is determined by the following equation:

$$\text{SBF} = \frac{\text{A}}{\text{D}} \text{ x } 0.10$$

Where: A = Area of one electrode, mm^2
D = Distance between electrodes, mm

Example: (For electrodes having a length of 152 mm and a width of 45 mm, and at a distance between electrodes of 102 mm.)

$A = 152 \text{ mm} \times 45 \text{ mm} = 6840 \text{ mm}^2$
$D = 102 \text{ mm}$

$$\text{SBF} = \frac{6840}{102} \text{ x } 0.10 = 6.71 \text{ cm}$$

Note: The soil box factor will depend on the soil box dimensions.

6.3 The minimum resistivity is determined by the following equation:

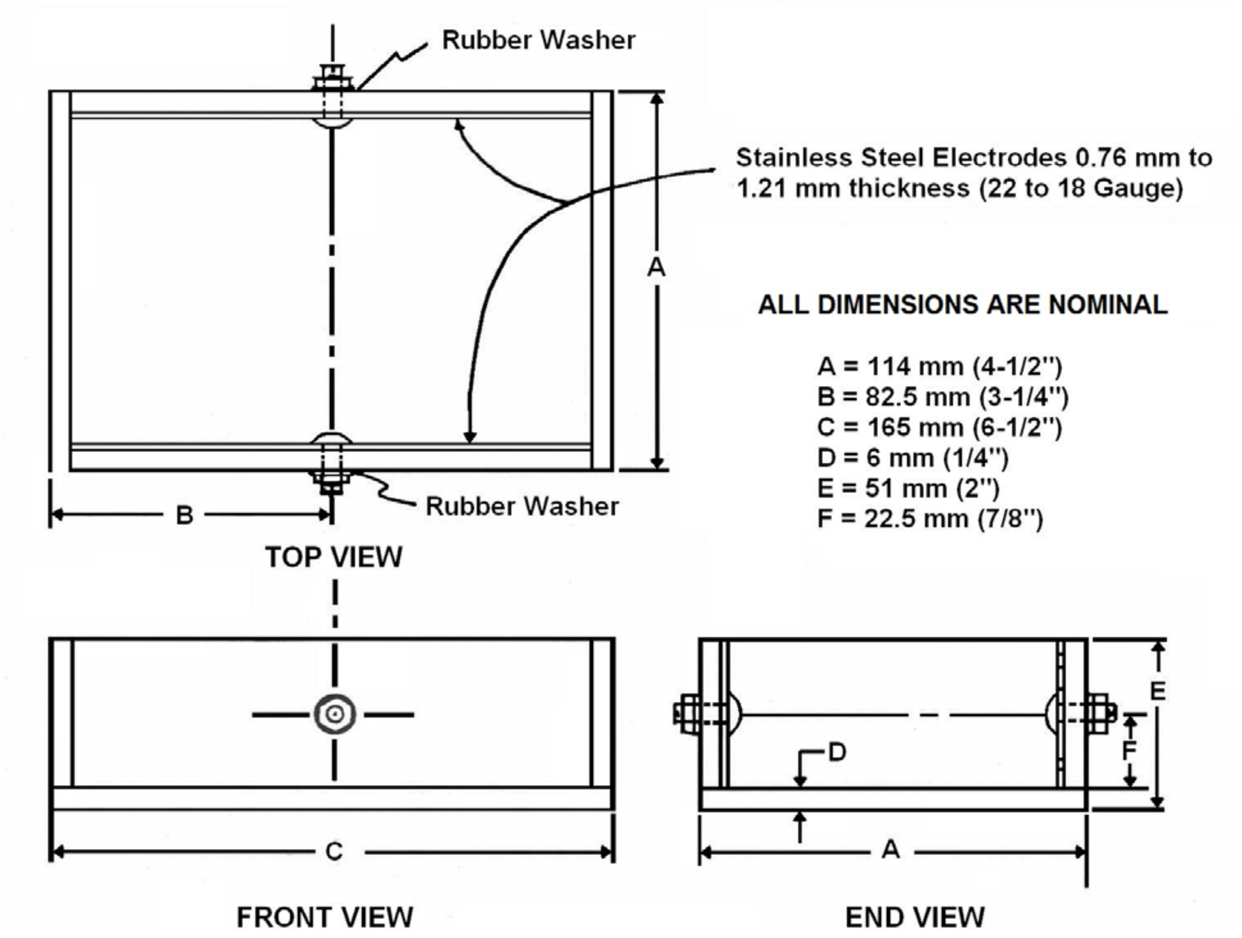
$$\begin{bmatrix} \text{Minimum Resistivity} \\ \text{(ohm - cm)} \end{bmatrix} = \begin{bmatrix} \text{Resistance} \\ \text{(ohms)} \end{bmatrix} \text{ x } \begin{bmatrix} \text{SBF} \\ \text{(cm)} \end{bmatrix}$$

Example: (For a resistance reading of 480 ohms and a soil box factor of 6.71 cm.)

Minimum Resistivity = (480 ohms) x (6.71 cm)
= 3220.8 ohm-cm
= 3221 ohm-cm

6.4 The minimum resistivity value is reported to the nearest whole number.

EXAMPLE OF AN ACCEPTABLE SOIL BOX



Box Material [6 mm (1/4") Plastic]
Bottom - 1 piece: 165 mm x 114 mm x 6mm (6-1/2" x 4-1/2" x 1/4")
Ends - 2 pieces: 114 mm x 45 mm x 6 mm (4-1/2" x 1-3/4" x 1/4")
Sides - 2 pieces: 152 mm x 45 mm x 6 mm (6" x 1-3/4" x 1/4")

Electrodes [0.76 mm to 1.21 mm thickness (22 to 18 Gauge) Stainless Steel]
2 pieces: 152 mm x 45 mm (6" x 1-3/4")

Hardware - 2 each No. 8-32 x ¾" (or longer), or metric equivalent, Stainless Steel or Brass Machine Screw with Washer and Nut

Gasket - Rubber Washer

FIGURE 1

Standard Practice for Reducing Samples of Aggregate to Testing Size

AASHTO Designation: R 76-16[1,2]

Release: Group 3 (August 2016)

ASTM Designation: C702/C702M-11

1. SCOPE

1.1. These methods cover the reduction of large samples of aggregate to the appropriate size for testing, employing techniques that are intended to minimize variations in measured characteristics between the test samples so selected and the large sample.

1.2. The values stated in SI units are to be regarded as the standard.

1.3. *This standard does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user of this procedure to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to its use.*

2. REFERENCED DOCUMENTS

2.1. *AASHTO Standards*:

- T 2, Sampling of Aggregates
- T 84, Specific Gravity and Absorption of Fine Aggregate

2.2. *ASTM Standard*:

- C125, Standard Terminology Relating to Concrete and Concrete Aggregates

3. TERMINOLOGY

3.1. *Definitions*—the terms used in this standard are defined in ASTM C125.

4. SIGNIFICANCE AND USE

4.1. Specifications for aggregates require sampling portions of the material for testing. Other factors being equal, larger samples will tend to be more representative of the total supply. The methods described in this standard provide for reducing the large sample obtained in the field or produced in the laboratory to a convenient size for conducting a number of tests to describe the material and measure its quality. These methods are conducted in such a manner that the smaller test sample portion will be representative of the larger sample and, thus, of the total supply. The individual test methods provide for minimum masses of material to be tested.

4.2. Under certain circumstances, reduction in size of the large sample prior to testing is not recommended. Substantial differences between the selected test samples sometimes cannot be avoided, as, for example, in the case of an aggregate having relatively few large-sized particles in the sample. The laws of chance dictate that these few particles may be unequally distributed among the reduced-size test samples. Similarly, if the test sample is being examined for certain contaminants occurring as a few discrete fragments in only small percentages, caution should be used in interpreting results from the reduced-size test sample. Chance inclusion or exclusion of only one or two particles in the selected test sample may importantly influence interpretation of the characteristics of the original sample. In these cases, the entire original sample should be tested.

4.3. Failure to carefully follow the procedures in these methods could result in providing a nonrepresentative sample to be used in subsequent testing.

---

5. SELECTION OF METHOD

5.1. *Fine Aggregate*—Samples of fine aggregate that are drier than the saturated surface-dry condition (Note 1) shall be reduced in size by a mechanical splitter according to Method A. Samples having free moisture on the particle surfaces may be reduced in size by quartering according to Method B, or by treating as a miniature stockpile as described in Method C.

5.1.1. If the use of Method B or Method C is desired, and the sample does not have free moisture on the particle surfaces, the sample may be moistened to achieve this condition, thoroughly mixed, and then the sample reduction performed.

Note 1—The method of determining the saturated surface-dry condition is described in T 84. As a quick approximation, if the fine aggregate will retain its shape when molded in the hand, it may be considered to be wetter than saturated surface-dry.

5.1.2. If use of Method A is desired and the sample has free moisture on the particle surfaces, the entire sample may be dried to at least the surface-dry condition, using temperatures that do not exceed those specified for any of the tests contemplated, and then the sample reduction performed. Alternatively, if the moist sample is very large, a preliminary split may be made using a mechanical splitter having wide chute openings 38 mm ($1^1/_2$ in.) or more to reduce the sample to not less than 5000 g. The portion so obtained is then dried, and reduction to test sample size is completed using Method A.

5.2. *Coarse Aggregates*—Reduce the sample using a mechanical splitter in accordance with Method A (preferred method) or by quartering in accordance with Method B. The miniature stockpile Method C is not permitted for coarse aggregates or mixtures of coarse and fine aggregates.

5.3. *Combined Coarse and Fine Aggregate*—Samples that are in a dry condition may be reduced in size by either Method A or Method B. Samples having free moisture on the particle surfaces may be reduced in size by quartering according to Method B. When Method A is desired and the sample is damp or shows free water, dry the sample until it appears dry or until clumps can be easily broken by hand (Note 2). Dry the entire sample to this condition, using temperatures that do not exceed those specified for any of the tests contemplated, and then reduce the sample. The miniature stockpile Method C is not permitted for combined aggregates.

Note 2—The dryness of the sample can be tested by tightly squeezing a small portion of the sample in the palm of the hand. If the cast crumbles readily, the correct moisture range has been obtained.

---

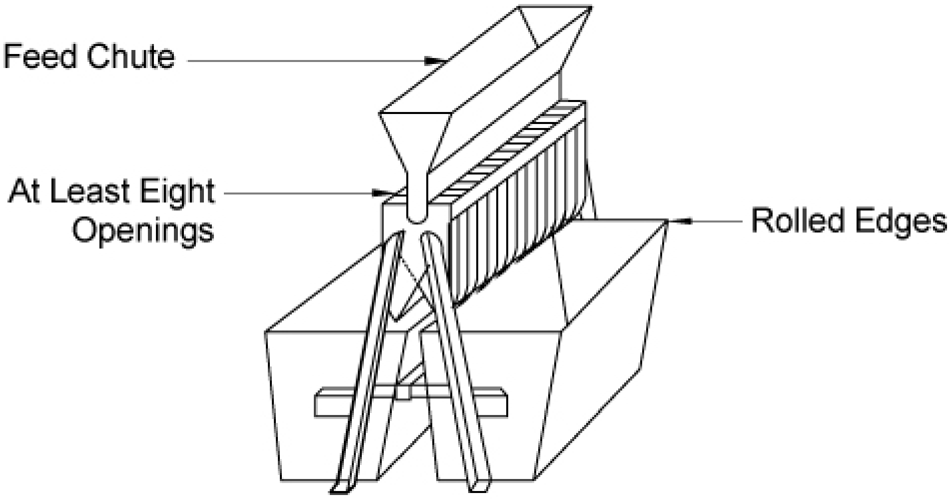
6. SAMPLING

6.1. The samples of aggregate obtained in the field shall be taken in accordance with T 2, or as required by individual test methods. When tests for sieve analysis only are contemplated, the size of field sample listed in T 2 is usually adequate. When additional tests are to be conducted, the user shall determine that the initial size of the field sample is adequate to accomplish all intended tests. Similar procedures shall be used for aggregate produced in the laboratory.

METHOD A—MECHANICAL SPLITTER

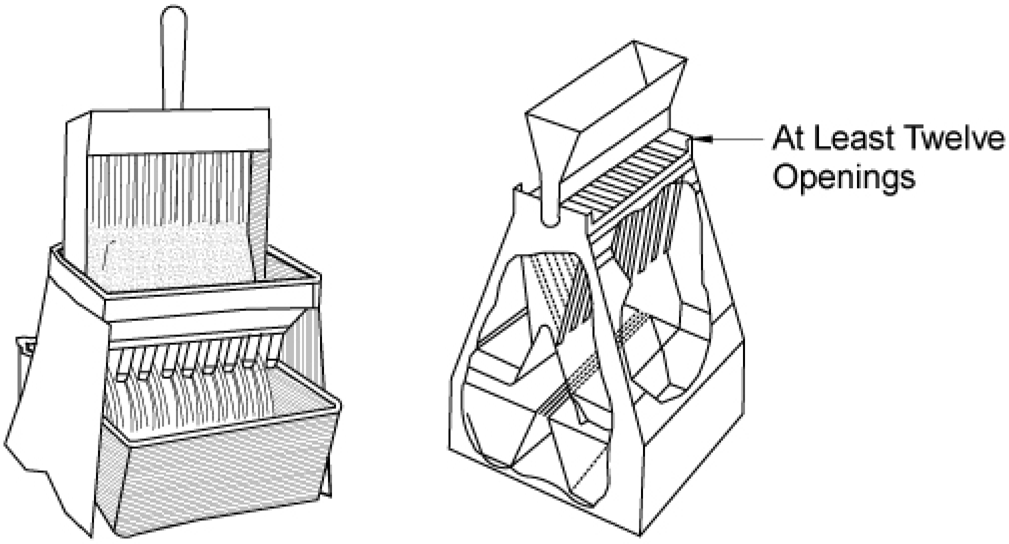
7. APPARATUS

7.1. *Sample Splitter*—Sample splitters shall have an even number of equal-width chutes, but not less than a total of eight for coarse aggregate, or twelve for fine aggregate, which discharge alternatively to each side of the splitter. For coarse aggregate and mixed aggregate, the minimum width of the individual chutes shall be approximately 50 percent larger than the largest particles in the sample to be split (Note 3). For dry fine aggregate in which the entire sample will pass the 9.5-mm ($^3/_8$-in.) sieve, the minimum width of the individual chutes shall be at least 50 percent larger than the largest particles in the sample and the maximum width shall be 19 mm ($^3/_4$ in.). The splitter shall be equipped with two receptacles to hold the two halves of the sample following splitting. It shall also be equipped with a hopper or straightedged pan, which has a width equal to or slightly less than the overall width of the assembly of chutes, by which the sample may be fed at a controlled rate to the chutes. The splitter and accessory equipment shall be so designed that the sample will flow smoothly without restriction or loss of material (see Figure 1).



Riffle Sample Splitter

(a) Large Sample Splitter for Coarse Aggregate



(b) Small Sample Splitters for Fine Aggregate

Note: (a) may be constructed as either closed or open type. Closed type is preferred.

Figure 1—Sample Splitters (Riffles)

Note 3—Mechanical splitters are commonly available in sizes adequate for coarse aggregate having the largest particle not over 37.5 mm ($1^1/_2$ in.).

8. PROCEDURE

8.1. Place the original sample in the hopper or pan and uniformly distribute it from edge to edge, so that when it is introduced into the chutes, approximately equal amounts will flow through each chute. The rate at which the sample is introduced shall be such as to allow free flowing through the chutes into the receptacles below.

8.2. Reintroduce the portion of the sample in one of the receptacles into the splitter as many times as necessary to reduce the sample to the size specified for the intended test. The portion of the material collected in the other receptacle may be reserved for reduction in size for other tests.

METHOD B—QUARTERING

9. APPARATUS

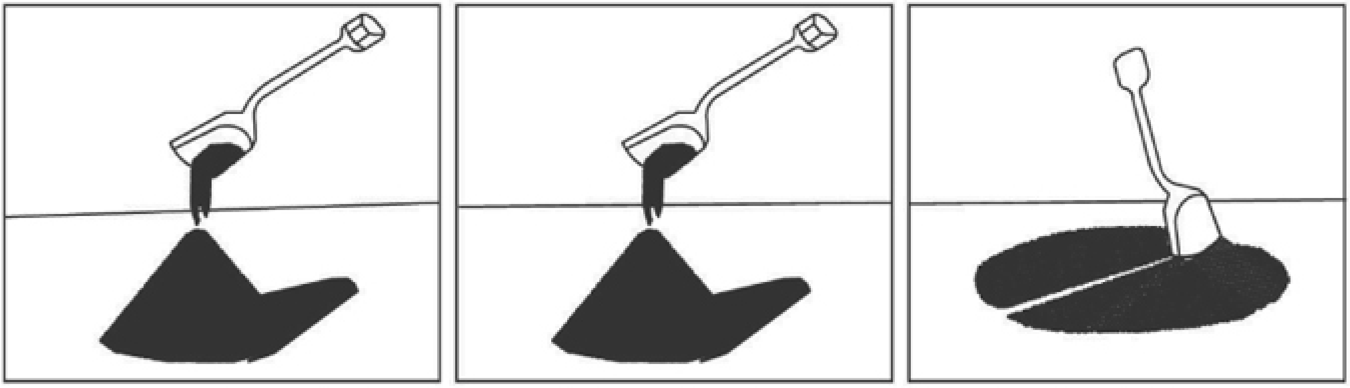
9.1. Apparatus shall consist of a straightedge; straightedged scoop, shovel or trowel; a broom or brush; and a canvas blanket or tear-resistant tarp approximately 2 by 2.5 m (6 by 8 ft).

10. PROCEDURE

10.1. Use either the procedure described in Section 10.1.1 or 10.1.2, or a combination of both.

10.1.1. Place the original sample on a hard, clean, level surface where there will be neither loss of material nor the accidental addition of foreign material. Mix the material by turning the entire sample over at least three times until the material is thoroughly mixed. With the last turning, form the entire sample into a conical pile by depositing individual lifts on top of the preceding lift. Carefully flatten the conical pile to a uniform thickness and diameter by pressing down the apex with a shovel or trowel so that each quarter sector of the resulting pile will contain the material originally in it. The diameter should be approximately four to eight times the thickness. Divide the flattened mass into four equal quarters with a shovel or trowel and remove two diagonally opposite quarters, including all fine material, and brush the cleared spaces clean. The two unused quarters may be set aside for later use or testing, if desired. Successively mix and quarter the remaining material until the sample is reduced to the desired size (see Figure 2).

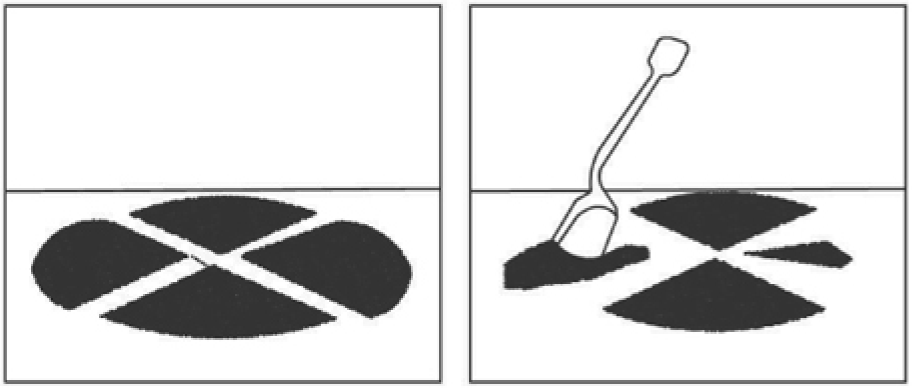
10.1.2. As an alternative to the procedure in Section 10.1.1 or when the floor surface is uneven, the field sample may be placed on a canvas blanket or tear-resistant tarp and mixed with a shovel or trowel as described in Section 10.1.1, leaving the sample in a conical pile. As an alternative to mixing with the shovel or trowel, lift each corner of the blanket or tarp and pull it over the sample toward the diagonally opposite corner, causing the material to be rolled. After the material has been rolled a sufficient number of times (a minimum of four times), so that it is thoroughly mixed, pull each corner of the blanket or tarp toward the center of the pile so the material will be left in a conical pile. Flatten the pile as described in Section 10.1.1. Divide the sample as described in Section 10.1.1, or insert a stick or pipe beneath the blanket or tarp and under the center of the pile, then lift both ends of the stick, dividing the sample into two equal parts. Remove the stick, leaving a fold of the blanket between the divided portions. Insert the stick under the center of the pile at right angles to the first division and again lift both ends of the stick, dividing the sample into four equal parts. Remove two diagonally opposite quarters, being careful to clean the fines from the blanket or tarp. The two unused quarters may be set aside for later use or testing, if desired. Successively mix and quarter the remaining material until the sample is reduced to the desired size (see Figure 3).



Cone Sample on Hard, Clean Surface

Mix by Forming New Cone

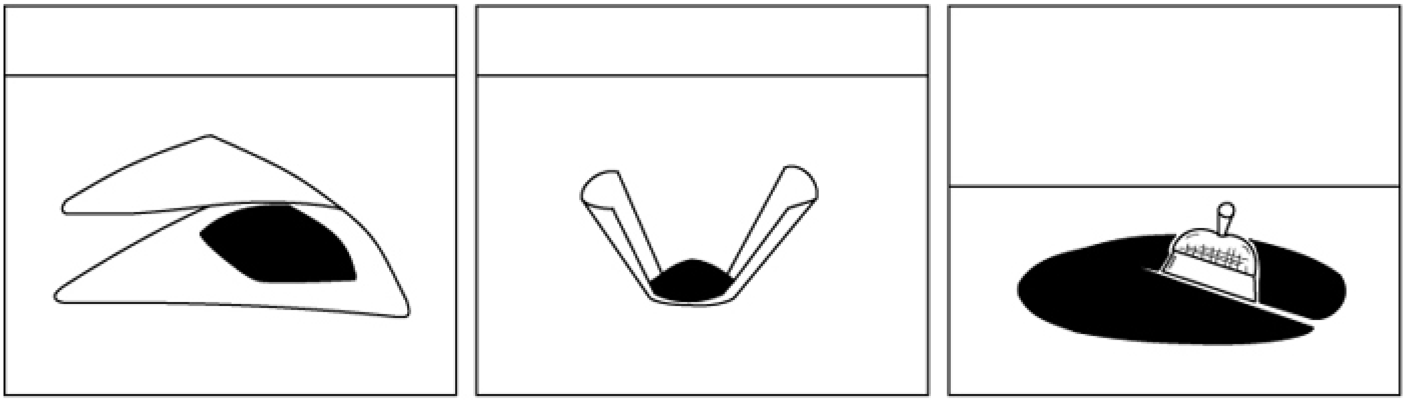
Quarter after Flattening Cone



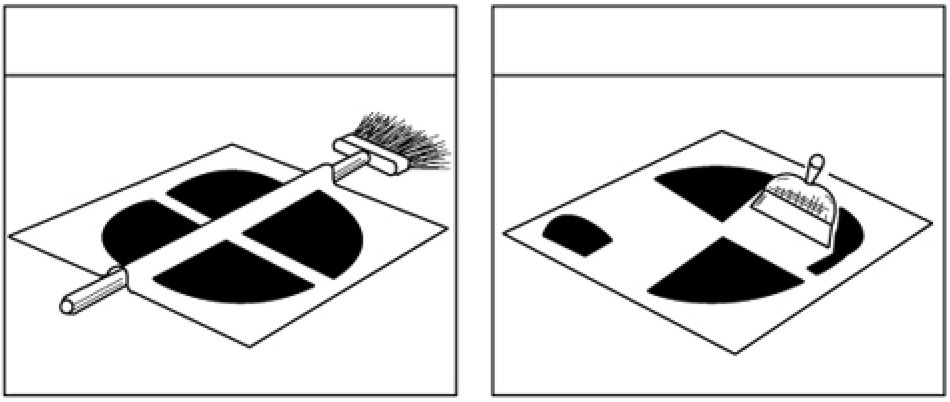
Sample Divided into Quarters

Retain Opposite Quarters Reject the Other Two Quarters

Figure 2—Quartering on a Hard, Clean, Level Surface



Mix by Rolling on Blanket Form Cone after Mixing Quarter after Flattening Cone



Sample Divided into Quarters Retain Opposite Quarters Reject the Other Two Quarters

Figure 3—Quartering on a Canvas Blanket or Tear-Resistant Tarp

METHOD C—MINIATURE STOCKPILE SAMPLING (DAMP FINE AGGREGATE ONLY)

11. APPARATUS

11.1. Apparatus shall consist of a straightedge; straightedged scoop, shovel, or trowel for mixing the aggregate; and either a small sampling thief, small scoop, or spoon for sampling.

12. PROCEDURE

12.1. Place the original sample of damp fine aggregate on a hard, clean, level surface where there will be neither loss of material nor the accidental addition of foreign material. Mix the material by turning the entire sample over at least three times until the material is thoroughly mixed. With the last turning, form the entire sample into a conical pile by depositing individual lifts on top of the preceding lift. If desired, the conical pile may be flattened to a uniform thickness and diameter by pressing the apex with a shovel or trowel so that each quarter sector of the resulting pile will contain the material originally in it. Obtain a sample for each test by selecting at least five increments of material at random locations from the miniature stockpile, using any of the sampling devices described in Section 11.1.

13. KEYWORDS

13.1. Aggregate; aggregate sample; mechanical splitter; quartering.

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[1] Technically equivalent but not identical to ASTM C702/C702M-11.

[2] Formerly T 248. First published as a practice in 2016.

Standard Method of Test for Materials Finer Than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing

AASHTO Designation: T 11-05 (~~2013~~2018)[1]

Technical Section: 1c, Aggregates

Release: Group 3 (August)

ASTM Designation: C117-13

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1. SCOPE

1.1. This test method covers determination of the amount of material finer than a 75-µm (No. 200) sieve in aggregate by washing. Clay particles and other aggregate particles that are dispersed by the wash water, as well as water-soluble materials, will be removed from the aggregate during the test.

1.2. Two procedures are included, one using only water for the washing operation, and the other including a wetting agent to assist the loosening of the material finer than the 75-µm (No. 200) sieve from the coarser material. Unless otherwise specified, Procedure A (water only) shall be used.

1.3. The values stated in SI units are to be regarded as the standard.

1.4. *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user of this procedure to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to its use*.

2. REFERENCED DOCUMENTS

2.1. *AASHTO Standards*:

- M 231, Weighing Devices Used in the Testing of Materials
- R 76, Reducing Samples of Aggregate to Testing Size
- R 90, Sampling Aggregate Products
- T 27, Sieve Analysis of Fine and Coarse Aggregates

2.2. *ASTM Standards*:

- C670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
- E11, Standard Specification for Woven Wire Test Sieve Cloth and Test Sieves

3. SUMMARY OF METHOD

3.1. A sample of the aggregate is washed in a prescribed manner, using either plain water or water containing a wetting agent, as specified. The decanted wash water, containing suspended and dissolved material, is passed through a 75-µm (No. 200) sieve. The loss in mass resulting from the wash treatment is calculated as mass percent of the original sample and is reported as the percentage of material finer than a 75-µm (No. 200) sieve by washing.

4. SIGNIFICANCE AND USE

4.1. Material finer than the 75-µm (No. 200) sieve can be separated from larger particles much more efficiently and completely by wet sieving than through the use of dry sieving. Therefore, when accurate determinations of material finer than 75 µm in fine or coarse aggregate are desired, this test method is used on the sample prior to dry sieving in accordance with T 27. The results of this test method are included in the calculation in T 27, and the total amount of material finer than 75 µm by washing, plus that obtained by dry sieving the same sample, is reported with the results of T 27. Usually the additional amount of material finer than 75 µm obtained in the dry-sieving process is a small amount. If it is large, the efficiency of the washing operation should be checked. A large amount of material could also be an indication of the degradation of the aggregate.

4.2. Plain water is adequate to separate the material finer than 75 µm from the coarser material in most aggregates. In some cases, the finer material is adhered to the larger particles, such as in some clay coatings and coatings on aggregates that have been extracted from bituminous mixtures. In these cases, the fine material will be separated more readily with a wetting agent in the water.

5. APPARATUS AND MATERIALS

5.1. *Balance*—The balance shall have sufficient capacity, be readable to 0.1 percent of the sample mass or better, and conform to the requirements of M 231.

5.2. *Sieves*—A nest of two sieves, the lower being a 75-µm (No. 200) sieve and the upper being a sieve with openings in the range of 2.36 mm (No. 8) to 1.18 mm (No. 16), both conforming to the requirement of ASTM E11.

5.3. *Container*—A pan or vessel of a size sufficient to contain the sample covered with water and to permit vigorous agitation without loss of any part of the sample or water.

5.4. *Oven*—An oven of sufficient size, capable of maintaining a uniform temperature of 110 ± 5°C (230 ± 9°F).

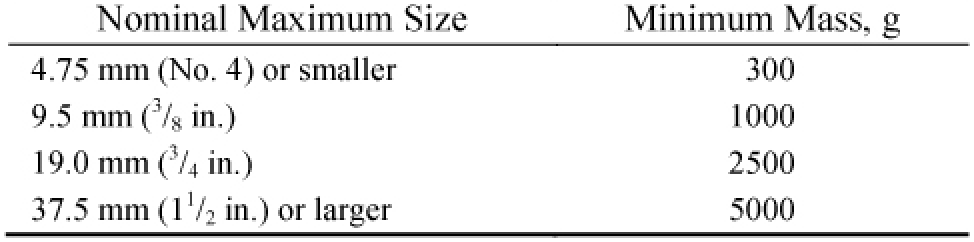
5.5. *Wetting Agent*—Any dispersing agent, such as liquid dishwashing detergents, that will promote separation of the fine materials.

Note 1—The use of a mechanical apparatus to perform the washing operation is not precluded, provided the results are consistent with those obtained using manual operations. The use of some mechanical washing equipment with some samples may cause degradation of the sample.

6. SAMPLING

6.1. Sample the aggregate in accordance with R 90. If the same test sample is to be tested for sieve analysis according to T 27, comply with the applicable requirements of that method.

6.2. Thoroughly mix the sample of aggregate to be tested and reduce the quantity to an amount suitable for testing using the applicable methods described in R 76. If the same test sample is to be tested according to T 27, the minimum mass shall be as described in the applicable sections of that method. Otherwise, the mass of the test sample, after drying, shall conform with the following:



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

The test sample shall be the end result of the reduction. Reduction to an exact predetermined mass shall not be permitted. If the nominal maximum size of the aggregate to be tested is not listed above, the next larger size listed shall be used to determine sample size.

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7. SELECTION OF PROCEDURE

7.1. Procedure A shall be used, unless otherwise specified by the specification with which the test results are to be compared, or when directed by the agency for which the work is performed.

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8. PROCEDURE A—WASHING WITH PLAIN WATER

8.1. Dry the test sample to constant mass at a temperature of 110 ± 5°C (230 ± 9°F). Determine the mass to the nearest 0.1 percent of the mass of the test sample.

8.2. If the applicable specification requires that the amount passing the 75-µm (No. 200) sieve shall be determined on a portion of the sample passing a sieve smaller than the nominal maximum size of the aggregate, separate the sample on the designated sieve and determine the mass of the material passing the designated sieve to 0.1 percent of the mass of this portion of the test sample. Use this mass as the original dry mass of the test sample in Section 10.1.

Note 2—Some specifications for aggregates with a nominal maximum size of 50 mm or greater, for example, provide a limit for material passing the 75-µm (No. 200) sieve determined on that portion of the sample passing the 25.0-mm sieve. Such procedures are necessary because it is impractical to wash samples of the size required when the same test sample is to be used for sieve analysis by T 27.

8.3. After drying and determining the mass, place the test sample in the container and add sufficient water to cover it. No detergent, dispersing agent, or other substance shall be added to the water. Agitate the sample with sufficient vigor to result in complete separation of all particles finer than the 75-µm (No. 200) sieve from the coarser particles, and to bring the fine material into suspension. The use of a large spoon or other similar tool to stir and agitate the aggregate in the wash water has been found satisfactory. Immediately pour the wash water containing the suspended and dissolved solids over the nested sieves, arranged with the coarser sieve on top. Take care to avoid, as much as feasible, the decantation of coarser particles of the sample.

8.4. Add a second charge of water to the sample in the container, agitate, and decant as before. Repeat this operation until the wash water is clear.

Note 3—If mechanical washing equipment is used, the charging of water, agitating, and decanting may be a continuous operation.

Note 4—A spray nozzle or a piece of rubber tubing attached to a water faucet may be used to rinse any of the material that may have fallen onto the sieves. The velocity of water, which may be increased by pinching the tubing or by use of a nozzle, should not be sufficient to cause any splashing of the sample over the sides of the sieve.

8.5. Return all material retained on the nested sieves by flushing into the container containing the washed sample. Dry the washed aggregate to constant mass at a temperature of 110 ± 5°C (230 ± 9°F) and determine the mass to the nearest 0.1 percent of the original mass of the sample.

Note 5—Following the washing of the sample and flushing any materials retained on the 75-µm (No. 200) sieve back into the container, no water should be decanted from the container except through the 75-µm sieve, to avoid loss of material. Excess water from flushing should be evaporated from the sample in the drying process.

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9. PROCEDURE B—WASHING USING A WETTING AGENT

9.1. Prepare the sample in the same manner as for Procedure A.

9.2. After drying and determining the mass, place the test sample in the container. Add sufficient water to cover the sample, and add wetting agent to the water (Note 6). Agitate the sample with sufficient vigor to result in complete separation of all particles finer than the 75-µm (No. 200) sieve from the coarser particles, and to bring the fine material into suspension. The use of a large spoon or other similar tool to stir and agitate the aggregate in the wash water has been found satisfactory. Immediately pour the wash water containing the suspended and dissolved solids over the nested sieves, arranged with the coarser sieve on top. Take care to avoid, as much as feasible, the decantation of coarser particles of the sample.

Note 6—There should be enough wetting agent to produce a small amount of suds when the sample is agitated. The quantity will depend on the hardness of the water and the quality of the detergent. Excessive suds may overflow the sieves and carry some material with them.

9.3. Add a second charge of water (without wetting agent) to the sample in the container, agitate, and decant as before. Repeat this operation until the wash water is clear.

9.4. Complete the test as for Procedure A.

10. CALCULATION

10.1. Calculate the amount of material passing a 75-µm (No. 200) sieve by washing as follows:

$$A = \left[\left(B - C \right) / B \right] \times 100 \qquad (1)$$

where:

A = percentage of material finer than a 75-µm (No. 200) sieve by washing;

B = original dry mass of sample, g; and

C = dry mass of sample after washing, g.

11. REPORT

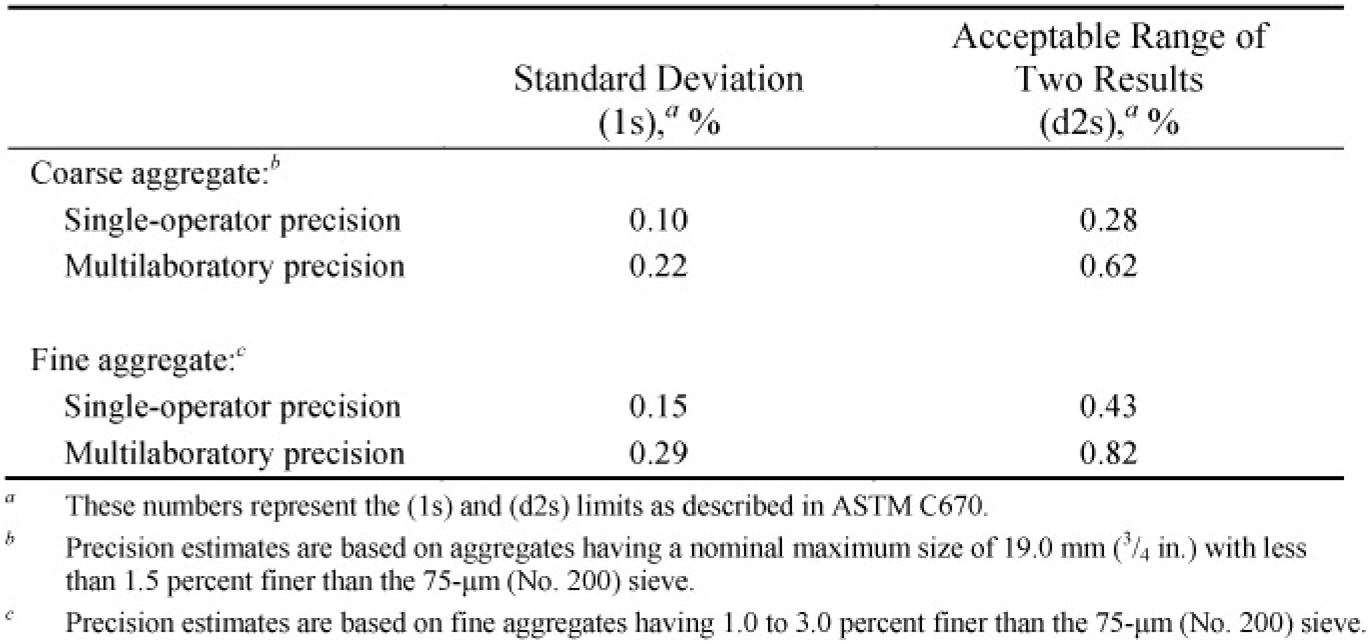
11.1. Report the percentage of material finer than the 75-µm (No. 200) sieve by washing to the nearest 0.1 percent, except if the result is 10 percent or more, report the percentage to the nearest whole number.

11.2. Include a statement as to which procedure was used.

12. PRECISION AND BIAS

12.1. *Precision*—The estimates of precision of this test method listed in Table 1 are based on results from the AASHTO Materials Reference Laboratory Proficiency Sample Program, with testing conducted by this test method and ASTM C117. The significant differences between the methods at the time the data were acquired is that T 11 required, and ASTM C117 prohibited, the use of a wetting agent. The data are based on the analyses of more than 100 paired test results from 40 to 100 laboratories.

Table 1—Precision



	Standard Deviation (1s),[a] %	Acceptable Range of Two Results (d2s),[a] %
Coarse aggregate:[b]		
Single-operator precision	0.10	0.28
Multilaboratory precision	0.22	0.62
Fine aggregate:[c]		
Single-operator precision	0.15	0.43
Multilaboratory precision	0.29	0.82

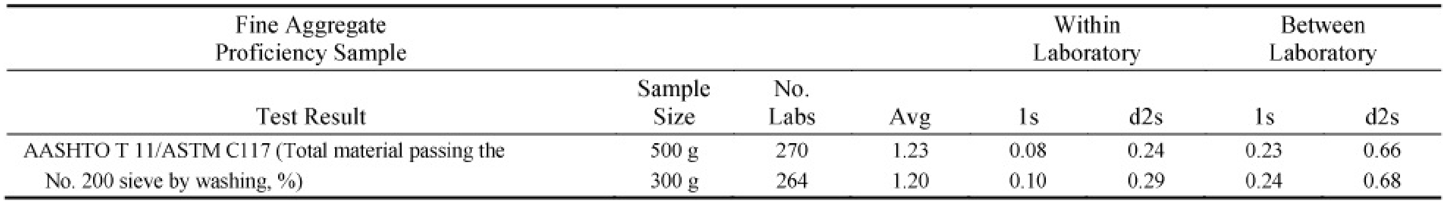
[a] These numbers represent the (1s) and (d2s) limits as described in ASTM C670.

[b] Precision estimates are based on aggregates having a nominal maximum size of 19.0 mm ($^3/_4$ in.) with less than 1.5 percent finer than the 75-µm (No. 200) sieve.

[c] Precision estimates are based on fine aggregates having 1.0 to 3.0 percent finer than the 75-µm (No. 200) sieve.

12.1.1. The precision values for fine aggregate in Table 1 are based on nominal 500-g test samples. Revision of this test method in 1996 permits the fine aggregate test sample size to be 300 g minimum. Analysis of results of testing of 300-g and 500-g test samples from Aggregate Proficiency Test Samples 99 and 100 (Samples 99 and 100 were essentially identical) produced the precision values in Table 2, which indicates only minor differences due to test sample size.

Table 2—Precision Data for 300-g and 500-g Test Samples



Fine Aggregate Proficiency Sample				Within Laboratory		Between Laboratory	
Test Result	Sample Size	No. Labs	Avg	1s	d2s	1s	d2s
AASHTO T 11/ASTM C117 (Total material passing the No. 200 sieve by washing, %)	500 g	270	1.23	0.08	0.24	0.23	0.66
	300 g	264	1.20	0.10	0.29	0.24	0.68

Note 7—The values for fine aggregate in Table 1 will be revised to reflect the 300-g test sample size when a sufficient number of Aggregate Proficiency Tests have been conducted using that sample size to provide reliable data.

12.2. *Bias*—Because there is no accepted reference material suitable for determining the bias for the procedure in this test method, no statement on bias is made.

13. KEYWORDS

13.1. Aggregate; size analysis; wash loss; 75-µm (No. 200) sieve.

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[1] Except for Sections 5.1 and 6.2, and Note 4, this test method is identical to ASTM C117-13.

Standard Method of Test for Bulk Density ("Unit Weight") and Voids in Aggregate

AASHTO Designation: T 19M/T 19-14 (2018)

Technical Section: 1c, Aggregates

Release: Group 3 (August)

ASTM Designation: C29/C29M-09

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1. SCOPE

1.1. This test method covers the determination of bulk density ("unit weight") of aggregate in a compacted or loose condition, and calculated voids between particles in fine, coarse, or mixed aggregates based on the same determination. This test method is applicable to aggregates not exceeding 125 mm [5 in.] in nominal maximum size.

Note 1—Unit weight is the traditional terminology used to describe the property determined by this test method, which is weight per unit volume (more correctly, mass per unit volume, or density).

1.2. The values stated in either inch-pound units or acceptable metric units are to be regarded separately as standard, as appropriate for the specification with which this test method is used. An exception is with regard to sieve sizes and nominal size of aggregate, in which the metric values are the standard as stated in ASTM E11. Within the text, inch-pound units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system must be used independently of the other, without combining values in any way.

1.3. *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user of this procedure to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to its use.*

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2. REFERENCED DOCUMENTS

2.1. *AASHTO Standards*:

- M 231, Weighing Devices Used in the Testing of Materials
- R 76, Reducing Samples of Aggregate to Testing Size
- R 90, Sampling Aggregate Products
- T 84, Specific Gravity and Absorption of Fine Aggregate
- T 85, Specific Gravity and Absorption of Coarse Aggregate
- T 121M/T 121, Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete

2.2. *ASTM Standards*:

- C125, Standard Terminology Relating to Concrete and Concrete Aggregates
- C670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
- D123, Standard Terminology Relating to Textiles
- E11, Standard Specification for Woven Wire Test Sieve Cloth and Test Sieves

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3. TERMINOLOGY

3.1. *Definitions*—definitions are in accordance with ASTM C125 unless otherwise indicated.

3.1.1. *bulk density, n*—of aggregate, the mass of a unit volume of bulk aggregate material, in which the volume includes the volume of the individual particles and the volume of the voids between the particles. Expressed in kg/m^3(lb/ft^3).

3.1.1.1. *Discussion*—units of mass are the kilogram (kg), the pound (lb), or units derived from these. Mass may also be visualized as equivalent to inertia, or the resistance offered by a body to change of motion (acceleration). Masses are compared by weighing the bodies, which amounts to comparing the forces of gravitation acting on them. ASTM D123.

3.1.2. *unit weight, n*—weight (mass) per unit volume. (Deprecated term—use preferred term “bulk density.”)

3.1.2.1. *Discussion*—the term "weight" means the force of gravity acting on the mass.

3.1.3. *weight, n*—the force exerted on a body by gravity. (See also mass.)

3.1.3.1. *Discussion*—weight is equal to the mass of the body multiplied by the acceleration due to gravity. Weight may be expressed in absolute units (newtons, poundals) or in gravitational units (kgf, lbf). For example, on the surface of the earth, a body with a mass of 1 kg has a weight of 1 kgf (approximately 9.81 N), or a body with a mass of 1 lb has a weight of 1 lbf (approximately 4.45 N or 32.2 poundals). Because weight is equal to mass times the acceleration due to gravity, the weight of a body will vary with the location where the weight is determined, while the mass of the body remains constant. On the surface of the earth, the force of gravity imparts to a body that is free to fall an acceleration of approximately $9.81\ m/s^2$ [$32.2\ ft/s^2$] (ASTM D123).

3.2. *Description of Term Specific to This Standard*:

3.2.1. *voids, n*—in unit volume of aggregate, the space between particles in an aggregate mass not occupied by solid mineral matter.

3.2.1.1. *Discussion*—voids within particles, either permeable or impermeable, are not included in voids as determined by T 19M/T 19.

4. SIGNIFICANCE AND USE

4.1. This test method is often used to determine bulk density values that are necessary for use in many methods of selecting proportions for concrete mixtures.

4.2. The bulk density also may be used for determining mass/volume relationships for conversions in purchase agreements. However, the relationship between degree of compaction of aggregates in a hauling unit or stockpile and that achieved in this method is unknown. Further, aggregates in hauling units and stockpiles usually contain absorbed and surface moisture (the latter affecting bulking), while this method determines the bulk density on a dry basis.

4.3. A procedure is included for computing the percentage of voids between the aggregate particles based on the bulk density determined by this method.

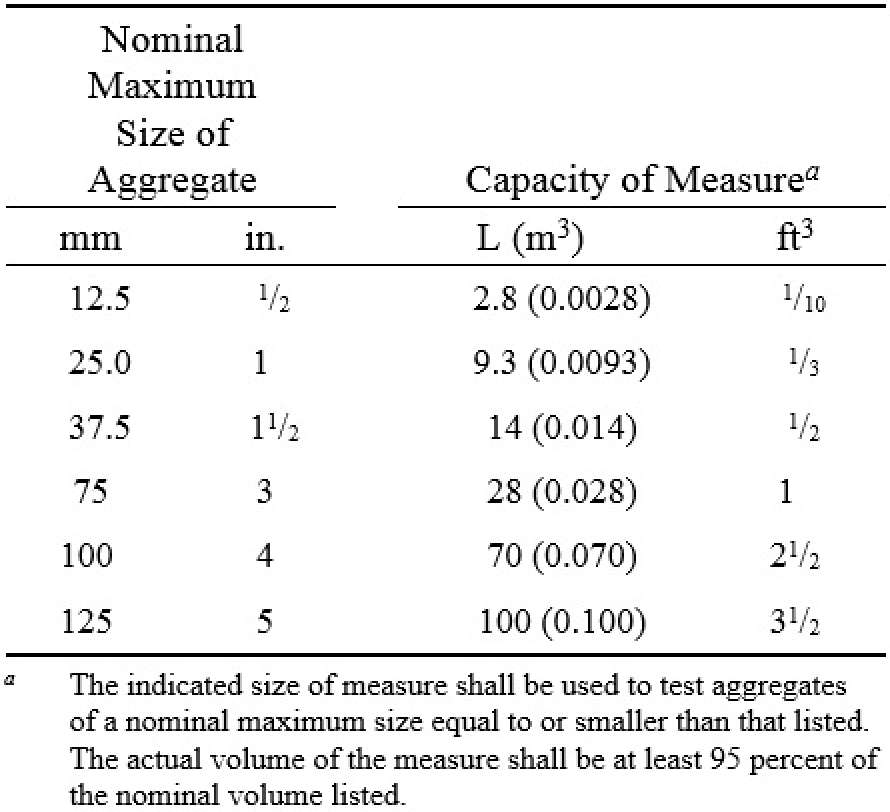
5. APPARATUS

5.1. *Balance*—The balance shall have sufficient capacity, be readable to 0.1 percent of the sample mass or better, and conform to the requirements of M 231.

5.2. *Tamping Rod*—A round, straight steel rod, 16 mm [$^5/_8$ in.] in diameter and approximately 600 mm [24 in.] in length, having one end rounded to a hemispherical tip of the same diameter as the rod.

5.3. *Measure*—A cylindrical metal measure, preferably provided with handles. It shall be watertight, with the top and bottom true and even, and sufficiently rigid to retain its form under rough usage. The measure should have a height approximately equal to the diameter, but in no case shall the height be less than 80 percent nor more than 150 percent of the diameter. The capacity of the measure shall conform to the limits in Table 1 for the aggregate size to be tested. The thickness of metal in the measure shall be as described in Table 2. The top rim shall be smooth and plane within 0.25 mm [0.01 in.] and shall be parallel to the bottom within 0.5 degrees (Note 2). The interior wall of the measure shall be a smooth and continuous surface.

Table 1—Capacity of Measures



Nominal Maximum Size of Aggregate		Capacity of Measure[a]	
mm	in.	L (m^3)	ft^3
12.5	$^1/_2$	2.8 (0.0028)	$^1/_{10}$
25.0	1	9.3 (0.0093)	$^1/_3$
37.5	$1^1/_2$	14 (0.014)	$^1/_2$
75	3	28 (0.028)	1
100	4	70 (0.070)	$2^1/_2$
125	5	100 (0.100)	$3^1/_2$

[a] The indicated size of measure shall be used to test aggregates of a nominal maximum size equal to or smaller than that listed. The actual volume of the measure shall be at least 95 percent of the nominal volume listed.

Note 2—The top rim is satisfactorily plane if a 0.25 mm [0.01 in.] feeler gauge cannot be inserted between the rim and a piece of 6 mm [$^1/_4$ in.] or thicker plate glass laid over the measure. The top and bottom are satisfactorily parallel if the slope between pieces of plate glass in contact with the top and bottom does not exceed 0.87 percent in any direction.

5.3.1. If the measure is also to be used for testing for bulk density of freshly mixed concrete according to T 121M/T 121, the measure shall be made of steel or other suitable metal not readily subject to attack by cement. Reactive materials such as aluminum alloys are permitted, where as a consequence of an initial reaction, a surface film is formed that protects the metal against further corrosion.

5.3.2. Measures larger than nominal 28-L [1-ft^3] capacity shall be made of steel for rigidity, or the minimum thicknesses of metal listed in Table 2 should be suitably increased.

Table 2—Requirements for Measures

	Thickness of Metal, Min		
Capacity of Measure	Bottom	Upper $1^1/_2$ in. or 38 mm of Wall[a]	Remainder of Wall
Less than 11 L	5.0 mm	2.5 mm	2.5 mm
11 to 42 L, incl.	5.0 mm	5.0 mm	3.0 mm
Over 42 to 80 L, incl.	10.0 mm	6.4 mm	3.8 mm
Over 80 to 133 L, incl.	13.0 mm	7.6 mm	5.0 mm
Less than 0.4 ft^3	0.20 in.	0.10 in.	0.10 in.
0.4 ft^3 to 1.5 ft^3, incl.	0.20 in.	0.20 in.	0.12 in.
Over 1.5 to 2.8 ft^3, incl.	0.40 in.	0.25 in.	0.15 in.
Over 2.8 to 4.0 ft^3, incl.	0.50 in.	0.30 in.	0.20 in.

[a] The added thickness in the upper portion of the wall may be obtained by placing a reinforcing band around the top of the measure.

5.4. *Shovel or Scoop*—A shovel or scoop of convenient size for filling the measure with aggregate.

5.5. *Calibration Equipment:*

5.5.1. *Plate Glass*—A piece of plate glass, at least 6 mm [$^1/_4$ in.] thick and at least 25 mm [1 in.] larger than the diameter of the measure to be calibrated.

5.5.2. *Grease*—A supply of water insoluble grease.

Note 3—Petroleum jelly, vacuum grease, water pump grease, or chassis grease are examples of suitable material used to form a seal between the glass plate and measure.

5.5.3. *Thermometer*—A thermometer having a range of at least 10 to 32°C [50 to 90°F] and that is readable to at least 0.5°C [1°F].

5.5.4. *Balance*—A balance as described in Section 5.1.

6. SAMPLING

6.1. Obtain the sample in accordance with T 2, and reduce to test sample size in accordance with R 76.

7. SAMPLE

7.1. The size of sample shall be approximately 125 to 200 percent of the quantity required to fill the measure and shall be handled in a manner to avoid segregation. Dry the sample of aggregate to constant mass, preferably in an oven at 110 ± 5°C [230 ± 9°F].

8. CALIBRATION OF MEASURE

8.1. Measures shall be recalibrated at least once a year or whenever there is reason to question the accuracy of the calibration.

8.2. Place a thin layer of grease on the rim of the measure to prevent leakage of water from the measure.

8.3. Determine the mass of the plate glass and measure to the nearest 0.05 kg [0.1 lb].

8.4. Fill the measure with water that is at room temperature and cover with the plate glass in such a way as to eliminate bubbles and excess water. Remove any water that may have overflowed onto the measure or plate glass.

8.5. Determine the mass of the water, plate glass, and measure to the nearest 0.05 kg [0.1 lb].

8.6. Measure the temperature of the water to the nearest 0.5°C [1°F] and determine its density from Table 3, interpolating if necessary.

Table 3—Density of Water

Temperature			
°C	°F	kg/m³	lb/ft³
15.6	60	999.01	62.366
18.3	65	998.54	62.336
21.1	70	997.97	62.301
(23.0)	(73.4)	(997.54)	(62.274)
23.9	75	997.32	62.261
26.7	80	996.59	62.216
29.4	85	995.83	62.166

8.7. Calculate the volume, *V*, of the measure. Alternatively, calculate the factor, *F*, for the measure.

$$V = (B - C)/D \tag{1}$$

$$F = D/(B - C) \tag{2}$$

where:

V = volume of the measure, m^3 (ft^3);

B = mass of the water, plate glass, and measure, kg (lb);

C = mass of the plate glass and measure, kg (lb);

D = density of the water for the measured kg/m^3 (lb/ft^3); and

F = factor for the measure, 1/m^3 (1/ft^3).

Note 4—For the calculation of bulk density, the volume of the measure in acceptable metric units should be expressed in cubic meters, or the factor as 1/m^3. However, for convenience, the size of the measure may be expressed in liters (equal to m^3/1000).

9. SELECTION OF PROCEDURE

9.1. The shoveling procedure for loose bulk density shall be used only when specifically stipulated. Otherwise, the compact bulk density shall be determined by the rodding procedure for aggregates having a nominal maximum size of 37.5 mm [$1^1/_2$ in.] or less, or by the jigging procedure for aggregates having a nominal maximum size greater than 37.5 mm [$1^1/_2$ in.] and not exceeding 125 mm [5 in.].

10. RODDING PROCEDURE

10.1. Fill the measure one-third full and level the surface with the fingers. Rod the layer of aggregate with 25 strokes of the tamping rod evenly distributed over the surface. Fill the measure two-thirds full and again level and rod as above. Finally, fill the measure to overflowing and rod again in the same manner. Level the surface of the aggregate with the fingers or a straightedge in such a way that any slight projections of the larger pieces of the coarse aggregate approximately balance the larger voids in the surface below the top of the measure.

10.2. In rodding the first layer, do not allow the rod to strike the bottom of the measure forcibly. In rodding the second and third layers, use vigorous effort, but not more force than to cause the tamping rod to penetrate to the previous layer of aggregate.

Note 5—In rodding the larger sizes of coarse aggregate, it may not be possible to penetrate the layer being consolidated, especially with angular aggregates. The intent of the procedure will be accomplished if vigorous effort is used.

10.3. Determine the mass of the measure plus contents, and the mass of the measure alone and record the values to the nearest 0.05 kg [0.1 lb].

11. JIGGING PROCEDURE

11.1. Fill the measure in three approximately equal layers as described in Section 10.1, compacting each layer by placing the measure on a firm base, such as a cement-concrete floor, raising the opposite sides alternately about 50 mm [2 in.], and allowing the measure to drop in such a manner as to hit with a sharp, slapping blow. The aggregate particles, by this procedure, will arrange themselves in a densely compacted condition. Compact each layer by dropping the measure 50 times in the manner described, 25 times on each side. Level the surface of the aggregate with the fingers or a straightedge in such a way that any slight projections of the larger pieces of the coarse aggregate approximately balance the larger voids in the surface below the top of the measure.

11.2. Determine the mass of the measure plus contents, and the mass of the measure alone, and record the values to the nearest 0.05 kg [0.1 lb].

12. SHOVELING PROCEDURE

12.1. Fill the measure to overflowing by means of a shovel or scoop, discharging the aggregate from a height not to exceed 50 mm [2 in.] above the top of the measure. Exercise care to prevent, so far as possible, segregation of the particle sizes of which the sample is composed. Level the surface of the aggregate with the fingers or a straightedge in such a way that any slight projections of the larger pieces of the coarse aggregate approximately balance the larger voids in the surface below the top of the measure.

12.2. Determine the mass of the measure plus contents, and the mass of the measure alone, and record the values to the nearest 0.05 kg [0.1 lb].

13. CALCULATION OF RESULTS

13.1. *Bulk Density*—Calculate the bulk density for the rodding, jigging, or shoveling procedure as follows:

$$M = (G - T)/V \tag{3}$$

or,

$$M = (G - T) \times F \tag{4}$$

where:

M = bulk density of aggregate, kg/m^3 (lb/ft^3);

G = mass of aggregate plus measure, kg (lb);

T = mass of measure, kg (lb);

V = volume of measure, m^3 (ft^3); and

F = factor for measure, m^{-3} (ft^{-3}).

13.1.1. The bulk density determined by this method is for aggregate in an oven-dry condition. If the bulk density in terms of saturated surface-dry (SSD) condition is desired, use the exact procedure in this method, and then calculate the SSD bulk density by the following formula:

$$M_{SSD} = M\left[1 + (A/100)\right] \tag{5}$$

where:

M_{SSD} = bulk density in SSD condition, kg/m^3 (lb/ft^3); and

A = absorption, percent, determined in accordance with T 84 or T 85.

13.2. *Void Content*—Calculate the void content in the aggregate using the bulk density determined by either the rodding, jigging, or shoveling procedure, as follows:

$$\text{voids \%} = \frac{100\left[(S \times W) - M\right]}{S \times W} \tag{6}$$

where:

M = bulk density of aggregate, kg/m^3 (lb/ft^3);

S = bulk specific gravity (dry basis) as determined in accordance with T 84 or T 85; and

W = density of water, 998 kg/m^3 [62.3 lb/ft^3].

14. REPORT

14.1. *Report the results for bulk density to the nearest 10 kg/m^3 [1 lb/ft^3] as follows*:

14.1.1. Bulk density by rodding,

14.1.2. Bulk density by jigging, or

14.1.3. Loose bulk density.

14.2. *Report the results for void content to the nearest one percent as follows*:

14.2.1. Voids in aggregate compacted by rodding, percent,

14.2.2. Voids in aggregate compacted by jigging, percent, or

14.2.3. Voids in loose aggregate, percent.

14.3. Indicate the procedure used.

15. PRECISION AND BIAS

15.1. The following estimates of precision for this method are based on results from the AASHTO Materials Reference Laboratory (AMRL) Proficiency Sample Program, with testing conducted by this method and ASTM C29/C29M. There are no significant differences between the two methods. The data are based on the analyses of more than 100 paired test results from 40 to 100 laboratories.

15.2. *Coarse Aggregate (Bulk Density)*:

15.2.1. *Single-Operator Precision*—The single-operator standard deviation has been found to be 14 kg/m^3 [0.88 lb/ft^3] (1s). Therefore, results of two properly conducted tests by the same operator on similar material should not differ by more than 40 kg/m^3 [2.5 lb/ft^3] (d2s).

15.2.2. *Multilaboratory Precision*—The multilaboratory standard deviation has been found to be 30 kg/m^3 [1.87 lb/ft^3] (1s). Therefore, results of two properly conducted tests from two different laboratories on similar material should not differ by more than 85 kg/m^3 [5.3 lb/ft^3] (d2s).

15.2.3. These numbers represent, respectively, the (1s) and (d2s) limits as described in ASTM C670. The precision estimates were obtained from the analysis of AMRL proficiency sample data for bulk density by rodding of normal-weight aggregates having a nominal maximum aggregate size of 25.0 mm [1 in.], and using a 14-L [$^1/_2$-ft^3] measure.

15.3. *Fine Aggregate (Bulk Density)*:

15.3.1. *Single-Operator Precision*—The single-operator standard deviation has been found to be 14 kg/m^3 [0.88 lb/ft^3] (1s). Therefore, results of two properly conducted tests by the same operator on similar material should not differ by more than 40 kg/m^3 [2.5 lb/ft^3] (d2s).

15.3.2. *Multilaboratory Precision*—The multilaboratory standard deviation has been found to be 44 kg/m^3 [2.76 lb/ft^3] (1s). Therefore, results of two properly conducted tests from two different laboratories on similar material should not differ by more than 125 kg/m^3 [7.8 lb/ft^3] (d2s).

15.3.3. These numbers represent, respectively, the (1s) and (d2s) limits as described in ASTM C670. The precision estimates were obtained from the analysis of AMRL proficiency sample data for loose bulk density from laboratories using a 2.8-L [$^1/_{10}$-ft^3] measure.

15.4. No precision data on void content are available. However, as the void content in aggregate is calculated from bulk density and bulk specific gravity, the precision of the voids content reflects the precision of these measured parameters given in Sections 15.2 and 15.3 of this method and in T 84 and T 85.

15.5. *Bias*—The procedure in this test method for measuring bulk density and void content has no bias because the values for bulk density and void content can be defined only in terms of a test method.

16. KEYWORDS

16.1. Bulk density; unit weight; voids in aggregate.

Standard Method of Test for Organic Impurities in Fine Aggregates for Concrete

AASHTO Designation: T 21M/T 21-15[1],[2]

ASTM Designation: C40/C40M-11

1. SCOPE

1.1. This test method covers two procedures for an approximate determination of the presence of injurious organic compounds in fine aggregates that are to be used in hydraulic cement mortar or concrete. One procedure uses a glass color standard and the other uses a standard color solution.

1.2. The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.3. This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user of this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. REFERENCED DOCUMENTS

2.1. AASHTO Standards:

- M 6, Fine Aggregate for Hydraulic Cement Concrete
- R 16, Regulatory Information for Chemicals Used in AASHTO Tests
- T 2, Sampling of Aggregates
- T 71, Effect of Organic Impurities in Fine Aggregate on Strength of Mortar
- T 248, Reducing Samples of Aggregate to Testing Size

2.2. ASTM Standard:

- D1544, Standard Test Method for Color of Transparent Liquids (Gardner Color Scale)

3. SIGNIFICANCE AND USE

3.1. This test method is of significance in making a preliminary determination of the acceptability of fine aggregates with respect to the requirements of M 6.

3.2. The principal value of this test method is to furnish a warning that organic impurities may be present. When a sample subjected to this test produces a color darker than the standard color, it is advisable to perform the test for the effect of organic impurities on the strength of mortar in accordance with T 71.

4. APPARATUS

4.1. Glass Bottles—Colorless glass graduated bottles, approximately 240 to 470-mL (8 to 16-oz) nominal capacity, equipped with watertight stoppers or caps, not soluble in the specified reagents. In no case shall the maximum outside dimension of the bottles, measured along the line of sight used for the color comparison, be greater than 60 mm (2.5 in.) or less than 40 mm (1.5 in.). The graduations on the bottles shall be in milliliters or ounces (U.S. fluid), except that unmarked bottles may be calibrated and scribed with graduations by the user. In such case, graduation marks are required at only three points as follows:

4.1.1. Standard Color Solution Level—75 mL, ($2^1/_2$ oz) (U.S. fluid);

4.1.2. Fine Aggregate Level—130 mL, ($4^1/_2$ oz) (U.S. fluid); and

4.1.3. NaOH Solution Level—200 mL, (7 oz) (U.S. fluid).

4.2. Glass Color Standard:

4.2.1. Glass color standard shall be used as described in Table 1 of ASTM D 1544.

Note 1—A suitable instrument consists of five glass color standards mounted in a plastic holder. Only the glass identified as Gardner Color Standard No. 11, corresponding to organic plate number three, is to be used as the glass color standard in Section 9.1.1..

5. REAGENT AND STANDARD COLOR SOLUTION

5.1. Reagent Sodium Hydroxide Solution (3 percent)—Dissolve 3 parts by mass of sodium hydroxide (NaOH) in 97 parts of water.

5.2. Standard Color Solution—Dissolve reagent grade potassium dichromate ($K_2Cr_2O_7$) in concentrated sulfuric acid (sp gr 1.84) at the rate of 0.250 g/100 mL of acid. The solution must be freshly made for the color comparison, using gentle heat if necessary to effect solution. Preparation of the reference standard color solution is unnecessary when the Glass Color Standard Procedure is used to determine the color value.

6. SAMPLING

6.1. The sample shall be selected in general accordance with T 2.

7. TEST SAMPLE

7.1. Obtain a test sample of fine aggregate of about 450 g (approximately 1 lb) in accordance with T 248. Sample drying prior to testing, if necessary, shall be done by air drying only.

8. PROCEDURE

8.1. Fill a glass bottle to the 130-mL (approximately $4^1/_2$-fluid oz) level with the sample of the fine aggregate to be tested.

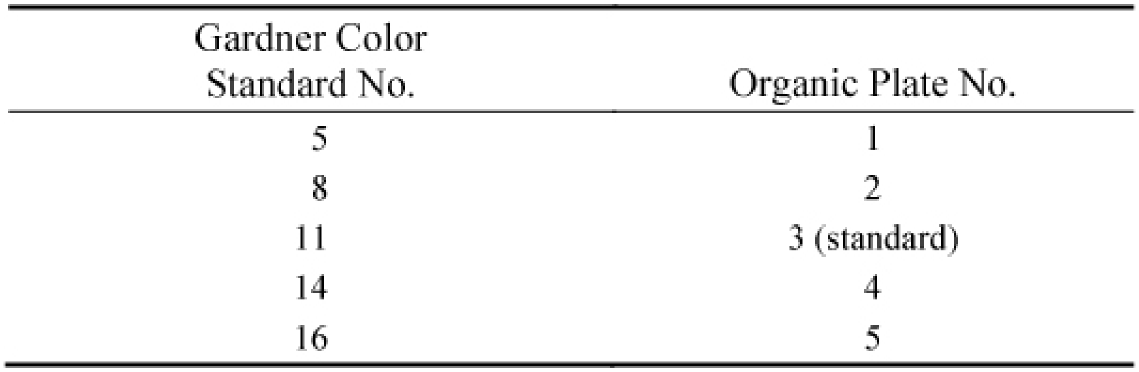
8.2. Add a 3-percent NaOH solution in water until the volume of the fine aggregate and liquid, indicated after shaking, is 200 mL (approximately 7 fluid oz).

8.3. Stopper the bottle, shake vigorously, and then allow to stand for 24 h.

9. DETERMINATION OF COLOR VALUE

9.1. Glass Color Standard Procedure—At the end of the 24-h standing period, visually compare the color standards to the color of the supernatant liquid above the test specimen. Report the organic plate number corresponding to the Gardner Color Standard number that is nearest the color of the supernatant liquid. When using this procedure, it is not necessary to prepare the standard color solution.

9.1.1. To define the color of the liquid of the test sample, use five glass standard colors as described in Table 1 of ASTM D1544, using the following colors:



Gardner Color Standard No.	Organic Plate No.
5	1
8	2
11	3 (standard)
14	4
16	5

9.2. Standard Color Solution Procedure—At the end of the 24-h standing period, fill a glass bottle to the 75-mL level (approximately 2½ fluid oz.) with the fresh standard color solution, prepared not longer than 2 h previously, as prescribed in Section 5.2. Hold the bottle with the test solution and the bottle with the standard color solution side by side and compare the color of light transmitted through the supernatant liquid above the test sample with the color of light transmitted through the standard color solution. Record whether it is lighter, darker, or of equal color to that of the reference standard.

10. INTERPRETATION OF RESULTS

10.1. If the color of the supernatant liquid is darker than that of the glass color standard organic plate No. 3 (Gardner Color Standard No. 11) or the standard color solution, the fine aggregate under test shall be considered to possibly contain injurious organic compounds, and further tests should be made before approving the fine aggregate for use in concrete.

11. PRECISION AND BIAS

11.1. Because this test produces no numerical values, determination of the precision and bias is not necessary.

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[1] First published in dual units in 2015.

[2] This method agrees with ASTM C40/C40M-11, except for shifting of text between Sections 5.2 and 9.2.

Standard Method of Test for Determining the Liquid Limit of Soils

AASHTO Designation: T 89-13 (2017)

Technical Section: 1a, Soil and Unbound Recycled Materials

Release: Group 3 (August)

1. SCOPE

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

1.2. The following applies to all specified limits in this standard: For the purposes of determining conformance with these specifications, an observed value or a calculated value shall be rounded off "to the nearest unit" in the last right-hand place of figures used in expressing the limiting value, in accordance with ASTM E29.

2. REFERENCED DOCUMENTS

2.1. *AASHTO Standards*:

- M 231, Weighing Devices Used in the Testing of Materials
- R 58, Dry Preparation of Disturbed Soil and Soil–Aggregate Samples for Test
- R 74, Wet Preparation of Disturbed Soil Samples for Test
- T 265, Laboratory Determination of Moisture Content of Soils

2.2. *ASTM Standards*:

- D4318, Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils
- E29, Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

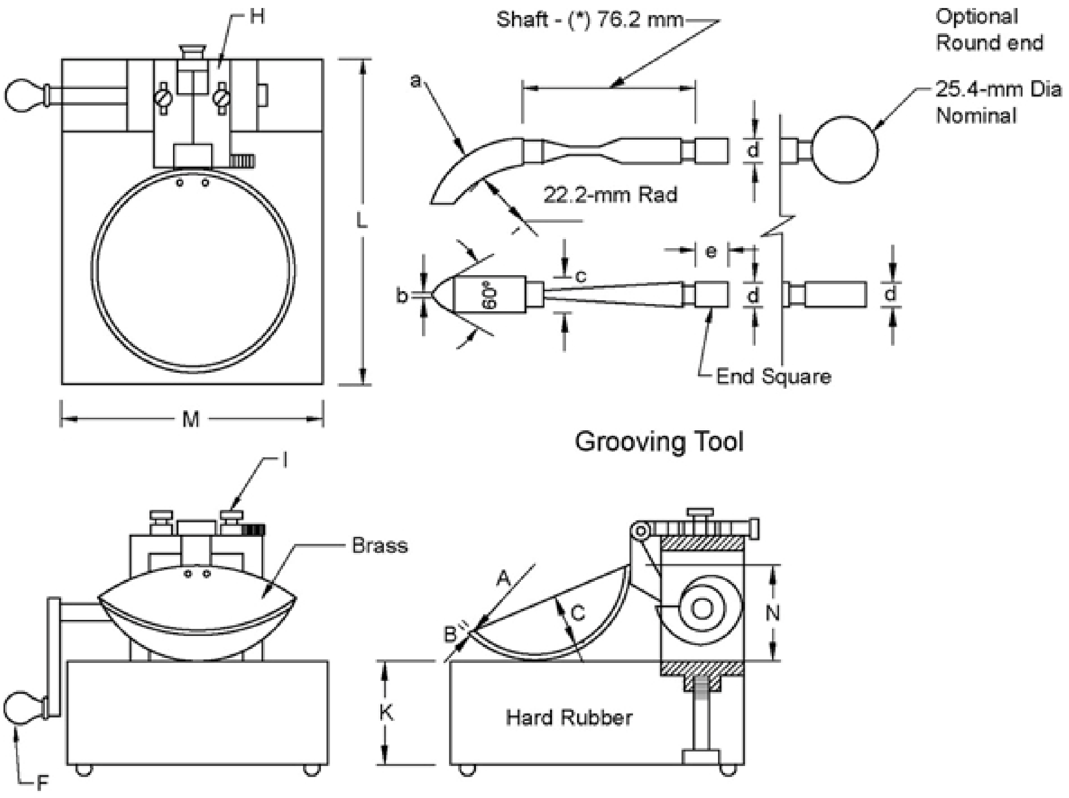
3. APPARATUS

3.1. *Dish*—A porcelain dish, preferably unglazed, or similar mixing dish, about 115 mm in diameter.

3.2. *Spatula*—A spatula or pill knife having a blade about 75 to 100 mm in length and about 20 mm in width.

3.3. *Liquid Limit Device*:

3.3.1. *Manually Operated*—A device consisting of a brass dish and carriage, constructed according to the plan and dimensions shown in Figure 1 (see Note 1).



	Liquid Limit Device							Grooving Tool				
	Cup Assembly				Base			Curved End			Gauge	
Dimension	A	B	C	N	K	L	M	a	b	c	d	e*
Description	Radius of Cup	Thickness of Cup	Depth of Cup	Cup at Cam Follower to Base	Thickness	Length	Width	Thickness	Cutting Edge	Width	Depth	Length
Metric, mm	54	2.0	27	47	50	150	125	10.0	2.0	13.5	10.0	15.9
Tolerance, mm	2	0.1	1	1.5	5	5	5	0.1	0.1	0.1	0.2	—

Note: Plate "H" may be designed for using one (1) securing screw (I).
An additional wear tolerance of 0.1 mm shall be allowed for dimension "b" for used grooving tools.
Feet for base shall be of resilient material.
(*) Nominal dimensions.
All tolerances specified are plus or minus (±) except as noted above.

Figure 1—Manual Liquid Limit Device

3.3.2. *Mechanically Operated*—A motorized device equipped to produce the rise and rate of shocks to a brass cup as described in Sections 5.2 and 6.3 of this procedure, respectively. The cup and the critical dimensions of the device shall conform to those shown in Figure 1 of this procedure. The device shall give the same liquid limit values as obtained with the manually operated device (Note 1).

Note 1—The base of the liquid limit device should have a resilience of at least 80 percent and not more than 90 percent when determined in accordance with the procedure given in the Appendix.

3.4. *Grooving Tool*:

3.4.1. *Curved Grooving Tool*—A grooving tool conforming to the critical dimensions shown in Figure 1. The gauge need not be part of the tool.

3.4.2. *Flat Grooving Tool (Alternate)*—A grooving tool made of plastic or noncorroding metal conforming to the critical dimensions shown in ASTM D4318, Figure 3. The gauge need not be part of the tool (Note 2).

Note 2—The flat grooving tool should not be used interchangeably with the curved grooving tool. There are some data that indicate that the liquid limit is slightly increased when the flat tool is used instead of the curved tool.

3.5. *Gauge*—A gauge, whether attached to the grooving tool or separate, conforming to the critical dimension "d" shown in Figure 1 of this test method or "K" in Figure 3 of ASTM D4318, and may be, if separate, a metal bar 10.0 ± 0.2 mm thick and approximately 50 mm long.

3.6. *Containers*—Suitable containers made of material resistant to corrosion and not subject to change in mass or disintegration on repeated heating and cooling. Containers shall have close-fitting lids to prevent loss of moisture from samples before initial mass determination and to prevent absorption of moisture from the atmosphere following drying and before final mass determination. One container is needed for each moisture content determination.

3.7. *Balance*—The balance shall have sufficient capacity and conform to M 231, Class G 1.

3.8. *Oven*—A thermostatically controlled drying oven capable of maintaining temperatures of 110 ± 5°C for drying moisture samples.

METHOD A

4. SAMPLE

4.1. A sample with a mass of about 100 g shall be taken from the thoroughly mixed portion of the material passing the 0.425-mm sieve that has been obtained in accordance with R 58 or R 74; for structural analysis use R 74, Method B.

5. ADJUSTMENT OF LIQUID LIMIT DEVICE

5.1. The Liquid Limit Device shall be inspected to determine that the device is in good working order; that the pin connecting the cup is not worn sufficiently to permit side play; that the screws connecting the cup to the hanger arm are tight; that the points of contact on the cup and base are not excessively worn; that the lip of the cup is not excessively worn; and that a groove has not been worn in the cup through long usage. The grooving tool shall be inspected to determine that the critical dimensions are as shown in Figure 1 of this test method or ASTM D4318, Figure 3.

Note 3—Wear is considered excessive when the point of contact on the cup or base exceeds approximately 13 mm in diameter, or when any point on the rim of the cup is worn to approximately one half of the original thickness. Although a slight groove in the center of the cup is noticeable, it is not objectionable. If the groove becomes pronounced before other signs of wear appear, the cup should be considered excessively worn. Excessively worn cups shall be replaced. A base that is excessively worn may be refinished as long as the thickness does not exceed the tolerance shown in Figure 1 of this test method by more than –2.5 mm and the distance between the cup at the cam follower and the base is maintained within the tolerances specified in Figure 1.

5.2. Adjust the height of drop of the cup so that the point on the cup that comes in contact with the base rises to a height of 10.0 ± 0.2 mm. See Figure 2 for proper location of the gauge relative to the cup during adjustment. Check the height of drop of the cup prior to each day's testing.

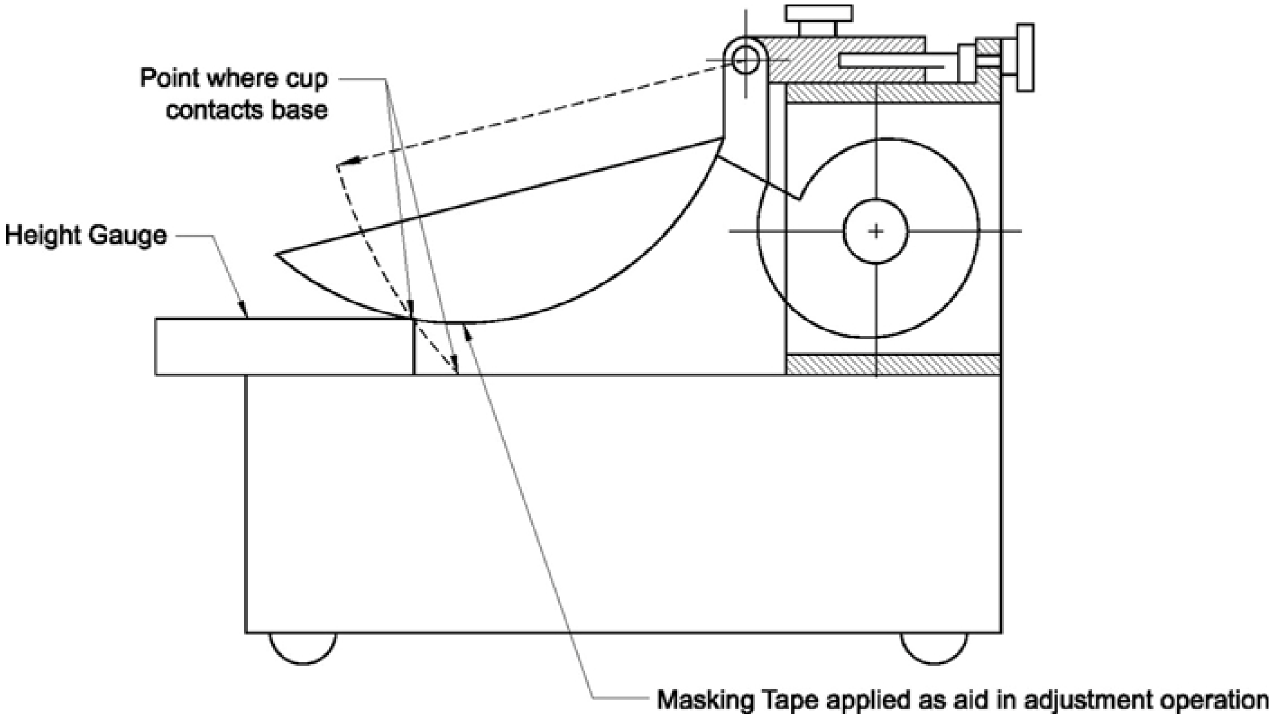


Figure 2—Calibration for Height of Drop

Note 4—A convenient procedure for adjusting the height of drop is as follows: place a piece of masking tape across the outside bottom of the cup parallel with the axis of the cup hanger pivot. The edge of the tape away from the cup hanger should bisect the spot on the cup that contacts the base. For new cups, placing a piece of carbon paper on the base and allowing the cup to drop several times will mark the contact spot. Attach the cup to the device and turn the crank until the cup is raised to its maximum height. Slide the height gauge under the cup from the front, and observe whether the gauge contacts the cup or the tape (see Figure 2). If the tape and cup are both contacted, the height of drop is approximately correct. If not, adjust the cup until simultaneous contact is made. Check adjustment by turning the crank at two revolutions per second while holding the gauge in position against the tape and cup. If a ringing or clicking sound is heard without the cup rising from the gauge, the adjustment is correct. If no ringing is heard or if the cup rises from the gauge, readjust the height of drop. If the cup rocks on the gauge during this checking operation, the cam follower pivot is excessively worn and the worn parts should be replaced. Always remove tape after completion of adjustment operation.

6. PROCEDURE USING THE CURVED GROOVING TOOL

6.1. The soil sample shall be placed in the mixing dish and thoroughly mixed with 15 to 20 mL of distilled or demineralized water by alternately and repeatedly stirring, kneading, and chopping with a spatula. Further additions of water shall be made in increments of 1 to 3 mL. Each increment of water shall be thoroughly mixed with the soil as previously described before another increment of water is added. Once testing has begun, no additional dry soil should be added to the moistened soil. The cup of the Liquid Limit Device shall not be used for mixing soil and water. If too much moisture has been added to the sample, the sample shall either be discarded, or mixed and kneaded until natural evaporation lowers the closure point into an acceptable range.

Note 5—Some soils are slow to absorb water; therefore, it is possible to add the increments of water so fast that a false liquid limit value is obtained. This can be avoided if more mixing and/or time is allowed. Tap water may be used for routine testing if comparative tests indicate no differences in results between using tap water and distilled or demineralized water. However, referee or disputed tests shall be performed using distilled or demineralized water.

6.2. When sufficient water has been thoroughly mixed with the soil to form a uniform mass of stiff consistency, a sufficient quantity of this mixture shall be placed in the cup above the spot where the cup rests on the base and shall be squeezed and spread with the spatula to level and at the same time trimmed to a depth of 10 mm at the point of maximum thickness. As few strokes of the spatula as possible shall be used, care being taken to prevent the entrapment of air bubbles within the mass. The excess soil shall be returned to the mixing dish and covered to retain the moisture in the sample. The soil in the cup of the device shall be divided by a firm stroke of the grooving tool along the diameter through the centerline of the cam follower so that a clean sharp groove of the proper dimensions will be formed as shown in Figure 3. To avoid tearing of the sides of the groove or slipping of the soil cake on the cup, up to six strokes from front to back or from back to front counting as one stroke, shall be permitted. The depth of the groove should be increased with each stroke and only the last stroke should scrape the bottom of the cup.

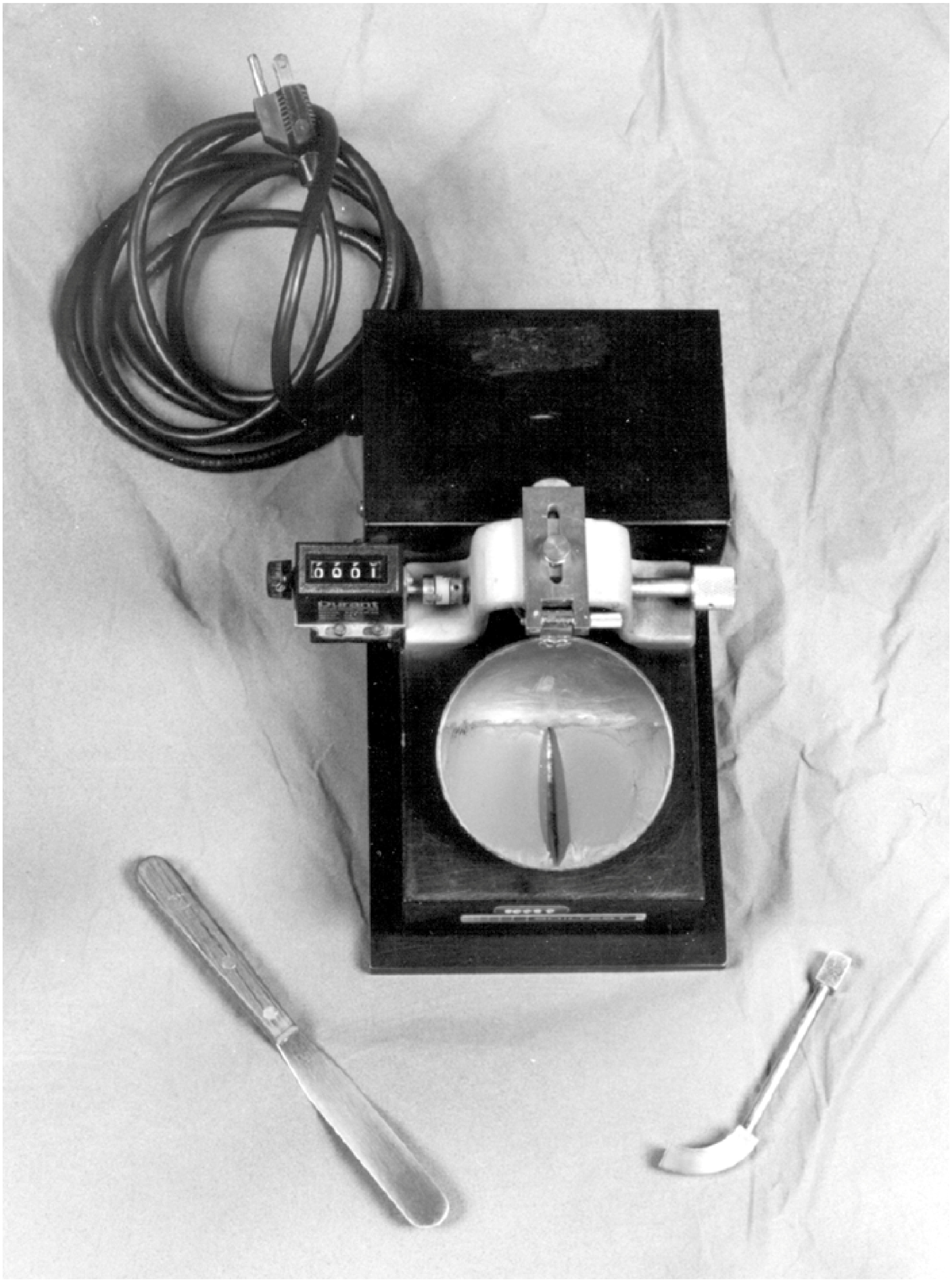


Figure 3—Liquid Limit Device with Soil Sample in Place

6.3. The cup containing the sample prepared as described in Section 6.2 shall be lifted and dropped by turning the crank F at the rate of approximately two revolutions per second until the two sides of the sample come in contact at the bottom of the groove along a distance of about 13 mm. The number of shocks required to close the groove this distance shall be recorded. The base of the machine shall not be held with the free hand while the crank F is turned.

Note 6—Some soils tend to slide on the surface of the cup instead of flowing. If this occurs, more water should be added to the sample and remixed, then the soil–water mixture placed in the cup, a groove cut with the grooving tool and Section 6.2 repeated. If the soil continues to slide on the cup at a lesser number of blows than 25, the test is not applicable and a note should be made that the liquid limit could not be determined.

6.4. A slice of soil approximately the width of the spatula, extending from edge to edge of the soil cake at right angles to the groove and including that portion of the groove in which the soil flowed together, shall be removed and placed in a suitable container. The soil in the container shall be dried in accordance with T 265 to determine the moisture content, and the results recorded.

6.5. The soil remaining in the cup shall be transferred to the mixing dish. The cup and grooving tool shall then be washed and dried in preparation for the next trial.

6.6. Repeat the foregoing operations, adding sufficient water to bring the soil to a more fluid condition. Obtain the first sample in the range of 25 to 35 shocks, the second sample in the range of 20 to 30 shocks, and the third sample in the range of 15 to 25 shocks. The range of the three determinations shall be at least 10 shocks.

7. ALTERNATE PROCEDURE USING THE FLAT GROOVING TOOL

7.1. The procedure shall be the same as prescribed in Sections 6.1 through 6.6, except for the procedure in Section 6.2 for forming the groove. Form a groove in the soil pat in accordance with Section 11.2 of ASTM D4318.

8. CALCULATION

8.1. The water content of the soil shall be expressed as the moisture content in percentage of the mass of the oven-dried soil and shall be calculated as follows:

$$\text{percentage moisture} = \frac{\text{mass of water}}{\text{mass of oven-dried soil}} \times 100 \tag{1}$$

8.1.1. Calculate the percentage of moisture to the nearest whole percent.

9. PREPARATION OF FLOW CURVE

9.1. A "flow curve" representing the relation between moisture content and corresponding number of shocks shall be plotted on a semilogarithmic graph with the moisture contents as abscissae on the arithmetical scale, and the number of shocks as ordinates on the logarithmic scale. The flow curve shall be a straight line drawn as nearly as possible through the three or more plotted points.

10. LIQUID LIMIT

10.1. The moisture content corresponding to the intersection of the flow curve with the 25-shock ordinate shall be taken as the liquid limit of the soil. Report this value to the nearest whole number.

METHOD B

11. SAMPLE

11.1. A sample with a mass of about 50 g shall be taken as described in Section 4.1.

12. PROCEDURE

12.1. Using the curved grooving tool (Section 6) or the flat grooving tool (Section 7) the procedure shall be the same as prescribed in Sections 6.1 through 6.5 except that the initial amount of water to be added in accordance with Section 6.1 shall be approximately 8 to 10 mL and the moisture sample taken in accordance with Section 6.4 shall be taken only for the accepted trial.

12.2. For accuracy equal to that obtained by the standard three-point method, the accepted number of blows for groove closure shall be restricted to between 22 and 28 blows. After obtaining a preliminary closure in the acceptable blow range, immediately return the soil remaining in the cup to the mixing dish and, without adding any additional water, repeat as directed in Sections 6.2 and 6.3. If the second closure occurs in the acceptable range (22 to 28, inclusive) and the second closure is within two (2) blows of the first closure, secure a water content specimen as directed in Section 6.4.

12.3. Groove closures between 15 and 40 blows may be accepted if variations of ±5 percent of the true liquid limit are tolerable.

13. CALCULATION

13.1. The water content of the soil at the time of the accepted closure shall be calculated in accordance with Section 8.1.

14. LIQUID LIMIT

14.1. The liquid limit shall be determined by one of the following methods: the nomograph, Figure 4; the correction factor method, Table 1; or by any other method of calculation that produces equally accurate liquid limit values. The standard three-point method shall be used as a referee test to settle all controversies.

14.2. The key in Figure 4 illustrates the use of the nomograph (mean slope).

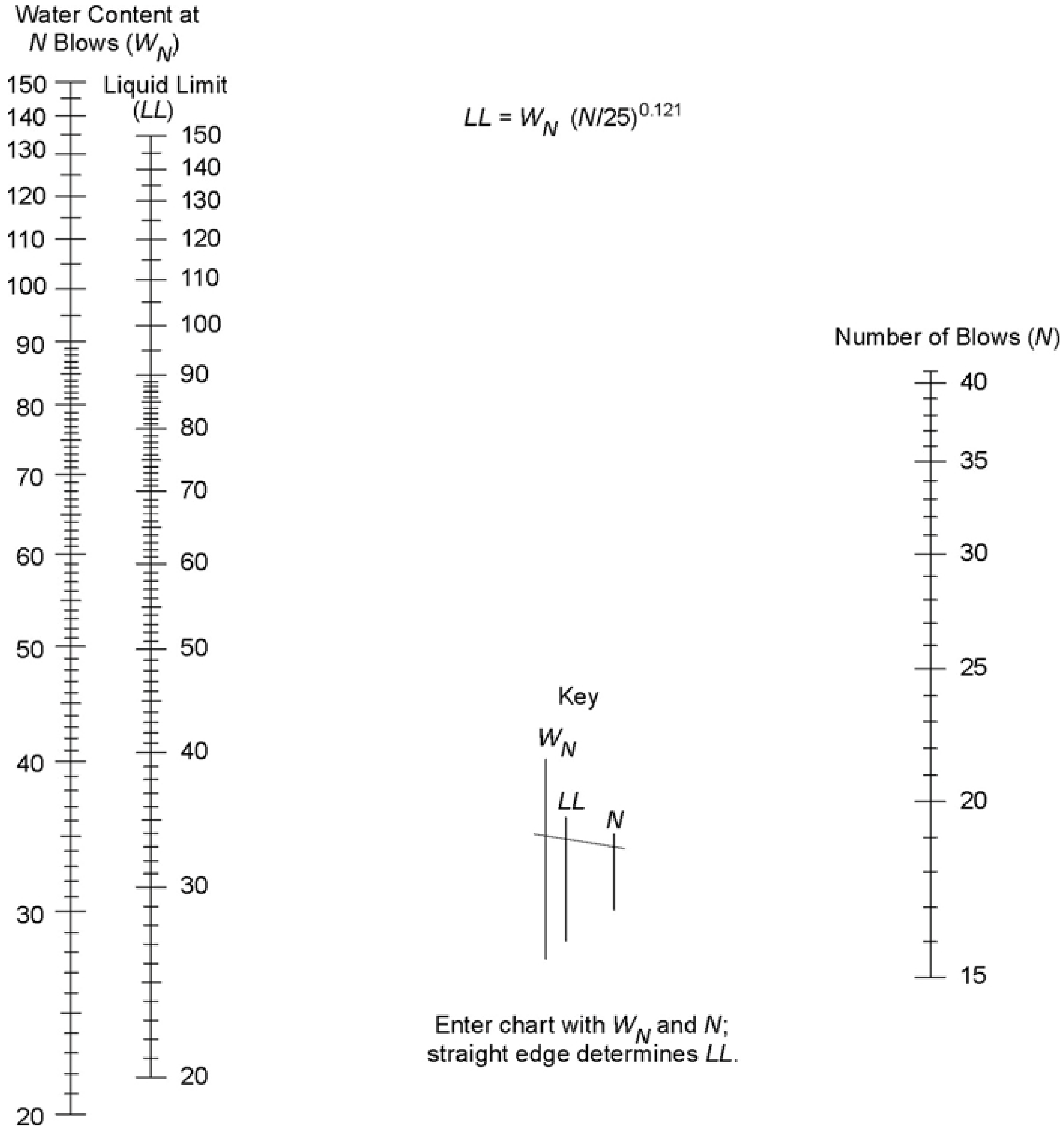


Figure 4—Nomographic Chart Developed by the Waterways Experiment Station, Corps of Engineers, U.S. Army, to Determine Liquid Limit Using Mean Slope Method

14.3. The correction factor method, Table 1, uses the moisture content of the liquid limit sample multiplied by a factor (k) of the second closure blow count. Figure 5 was developed for the Calculation of the Liquid Limit.

$$LL = W_N(N/25)^{0.121} \tag{2}$$

or

$$LL = kW_N \tag{3}$$

where:

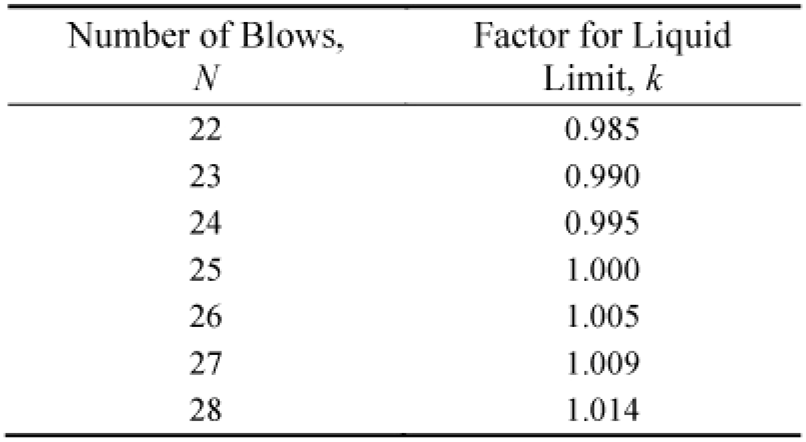
N = number of blows causing closure of the groove at water content,

LL = liquid limit corrected for closure at 25 blows,

W_N = water content, and

k = factor given in Table 1.

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



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

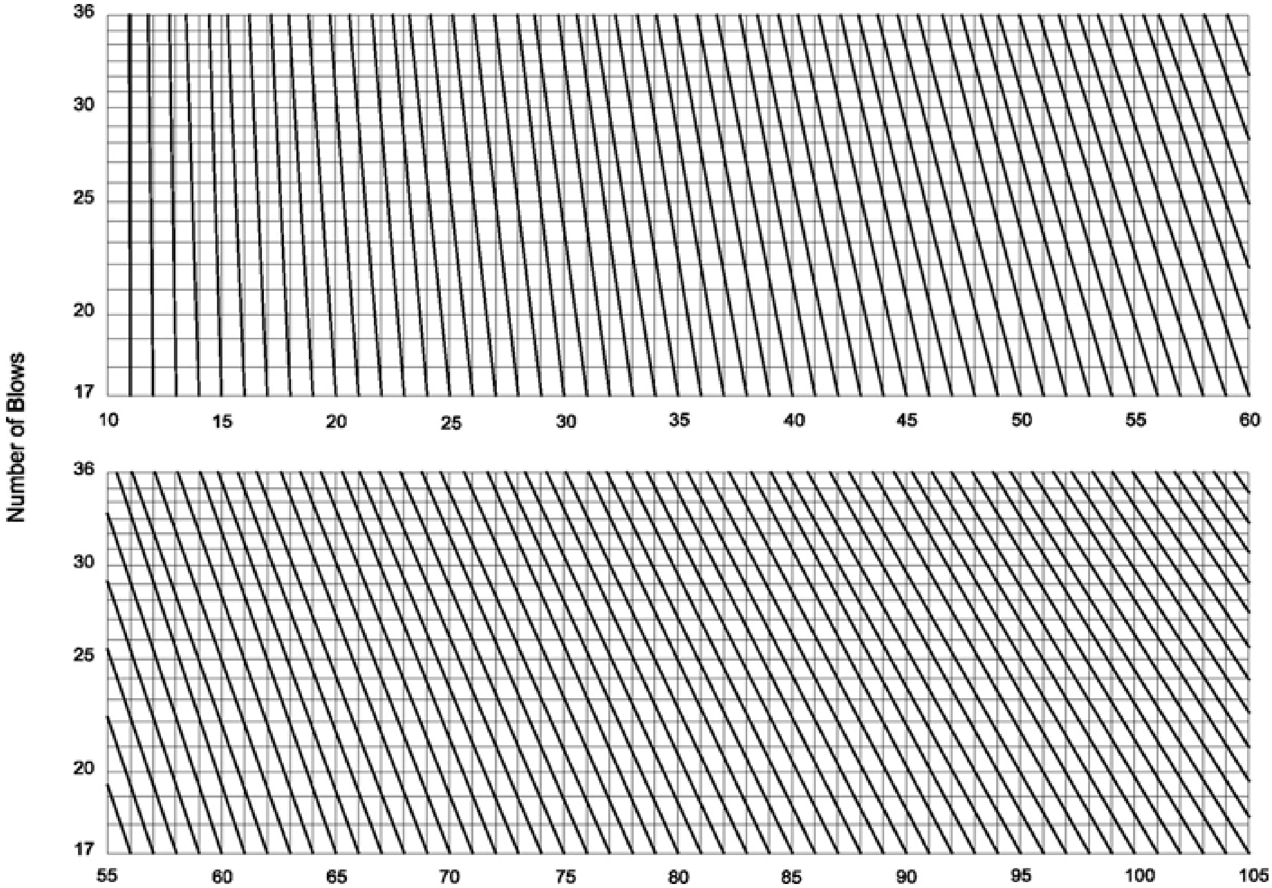


Figure 5—Chart Developed by Washington State Highway Department for the Calculation of the Liquid Limit

CHECK OR REFEREE TESTS

15. METHOD TO BE USED

15.1. Method A, using the curved grooving tool procedure (Section 6), shall be used in making check or referee tests. The results of liquid limit tests are influenced by:

15.1.1. The time required to make the test;

15.1.2. The moisture content at which the test is begun; and

15.1.3. The addition of dry soil to the seasoned sample.

16. PROCEDURE

16.1. Therefore, in making the liquid limit test for check or referee purposes, the following time schedule shall be used:

16.1.1. *Mixing of soil with water*—5 to 10 min, the longer period being used for the more plastic soils;

16.1.2. *Seasoning in the humidifier*—30 min;

16.1.3. *Remixing before placing in the brass cup*—add 1 mL of water and mix for 1 min;

16.1.4. *Placing in the brass cup and testing*—3 min; and

16.1.5. *Adding water and remixing*—3 min.

16.2. No trial requiring more than 35 blows or fewer than 15 blows shall be recorded. In no case shall dried soil be added to the seasoned soil being tested.

17. PRECISION STATEMENT

17.1. This precision statement applies to soils having a liquid limit range from 21 to 67.

17.2. *Repeatability (Single Operator)*—Two results obtained by the same operator on the same sample in the same laboratory using the same apparatus, and on different days, should be considered suspect if they differ by more than 7 percent of their mean.

17.3. *Reproducibility (Multilaboratory)*—Two results obtained by different operators in different laboratories should be considered suspect if they differ from each other by more than 13 percent of their mean.

18. KEYWORDS

18.1. Atterberg; clay soil; liquid limit; plasticity index.

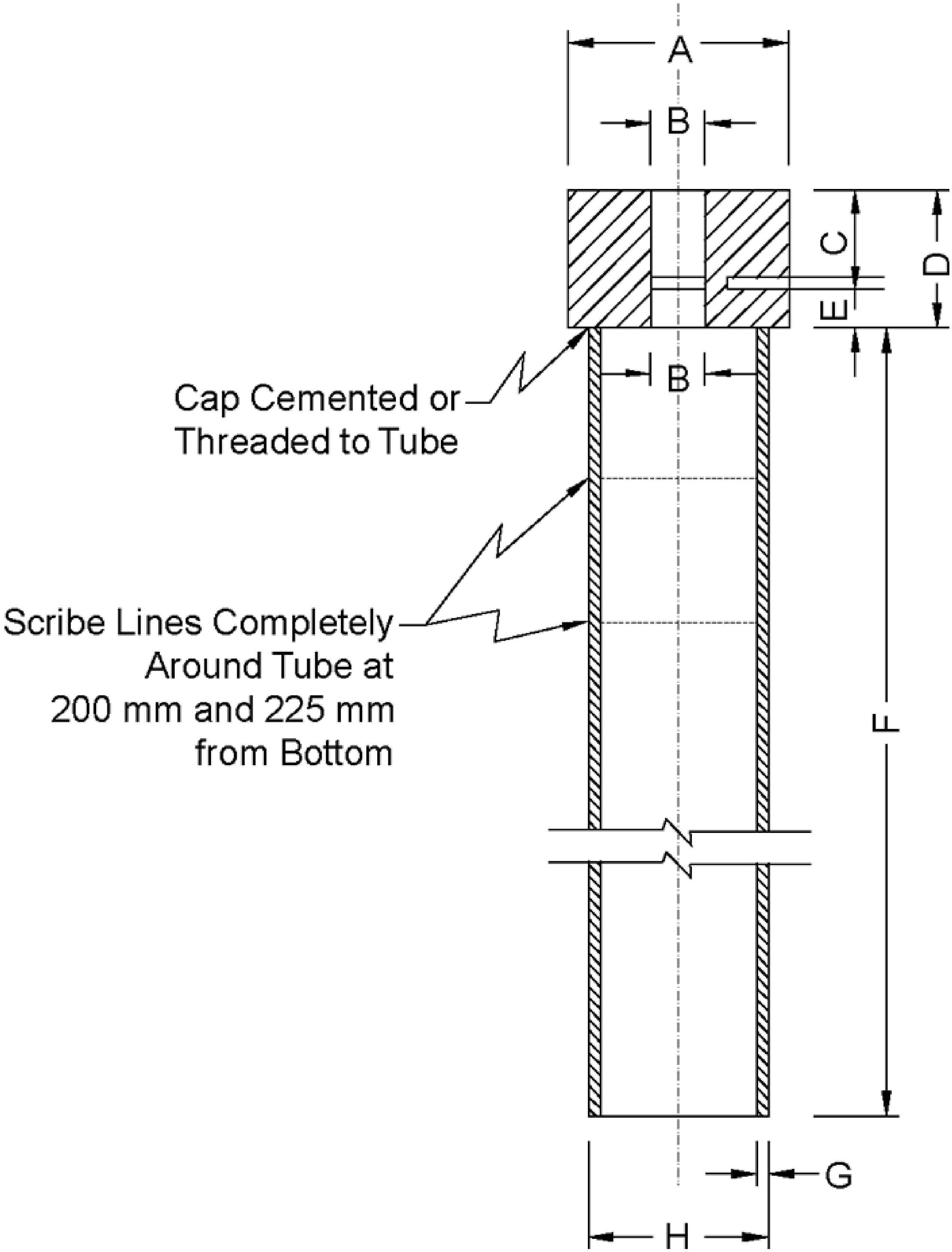
APPENDIX

(Nonmandatory Information)

X1. MEASURING THE RESILIENCE OF LIQUID LIMIT DEVICE BASES

X1.1. A device for measuring the resilience of liquid limit device bases is shown in Figure X1.1 and Table X1.1. The device consists of a clear acrylic plastic tube and cap, an 8-mm diameter polished steel ball, and a small bar magnet. The cylinder may be cemented to the cap or threaded as shown. The small bar magnet is held in the recess of the cap, and the steel ball is fixed into the recess in the underside of the cap with the bar magnet. The cylinder is then turned upright and placed on the top surface of the base to be tested. Hold the tube lightly against the liquid limit device base with one hand, and release the ball by pulling the magnet out of the cap. Use the scale markings on the outside of the cylinder to determine the highest point reached by the bottom of the ball. Repeat the drop at least three times, placing the tester in a different location for each drop. The average rebound of the steel ball, expressed as a percent of the total drop, equals the resilience of the liquid limit device base. Tests should be conducted at room temperature.

Clear Plastic (such as Acrylic)
Cap and Tube

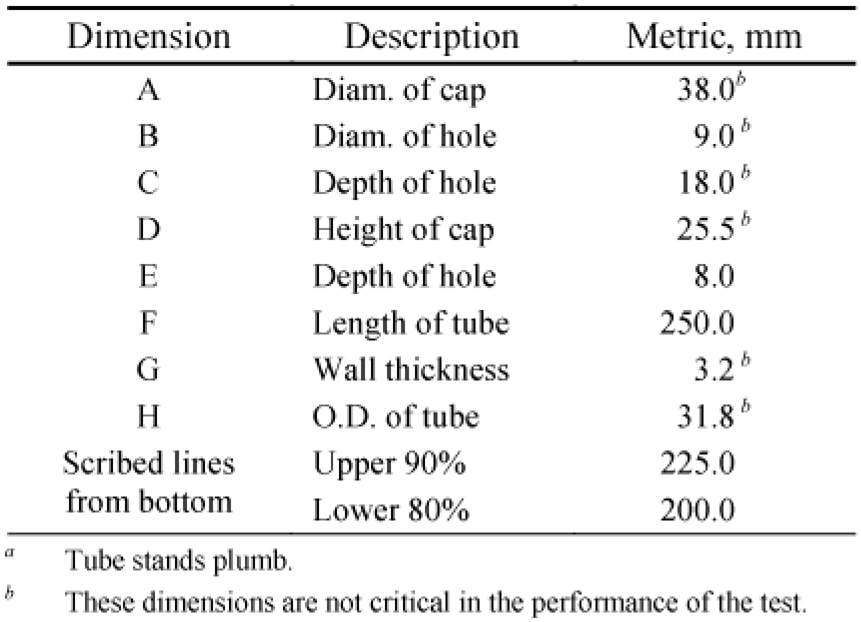


Cap Cemented or Threaded to Tube

Scribe Lines Completely Around Tube at 200 mm and 225 mm from Bottom

Figure X1.1—Resilience Tester

Table X1.1—Table of Measurements for Resilience Tester[a]



Dimension	Description	Metric, mm
A	Diam. of cap	38.0[b]
B	Diam. of hole	9.0[b]
C	Depth of hole	18.0[b]
D	Height of cap	25.5[b]
E	Depth of hole	8.0
F	Length of tube	250.0
G	Wall thickness	3.2[b]
H	O.D. of tube	31.8[b]
Scribed lines from bottom	Upper 90%	225.0
	Lower 80%	200.0

[a] Tube stands plumb.

[b] These dimensions are not critical in the performance of the test.

Standard Method of Test for Determining the Plastic Limit and Plasticity Index of Soils

AASHTO Designation: T 90-16

Technical Section: 1a, Soil and Unbound Recycled Materials

Release: Group 3 (August)

1. SCOPE

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

1.2. The following applies to all specified limits in this standard: For the purpose of determining conformance with these specifications, an observed value or a calculated value shall be rounded off "to the nearest unit" in the last right-hand place of figures used in expressing the limiting value, in accordance with ASTM E29.

1.3. Two procedures for rolling out soil samples are provided in this method: the Hand Rolling Method and the Plastic Limit Device Method. The Hand Rolling Method shall be used as the referee procedure.

1.4. This test method is often conducted in conjunction with T 89, which is used to determine the liquid limit of soils.

2. REFERENCED DOCUMENTS

2.1. *AASHTO Standards*:

- M 231, Weighing Devices Used in the Testing of Materials
- R 18, Establishing and Implementing a Quality Management System for Construction Materials Testing Laboratories
- R 58, Dry Preparation of Disturbed Soil and Soil–Aggregate Samples for Test
- R 61, Establishing Requirements for Equipment Calibrations, Standardizations, and Checks
- R 74, Wet Preparation of Disturbed Soil Samples for Test
- T 89, Determining the Liquid Limit of Soils
- T 265, Laboratory Determination of Moisture Content of Soils

2.2. *ASTM Standard*:

- E29, Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

3. APPARATUS

3.1. *Dish*—A porcelain evaporating dish or similar mixing dish about 115 mm in diameter.

3.2. *Spatula*—A spatula or pill knife having a blade about 75 mm in length and about 20 mm in width.

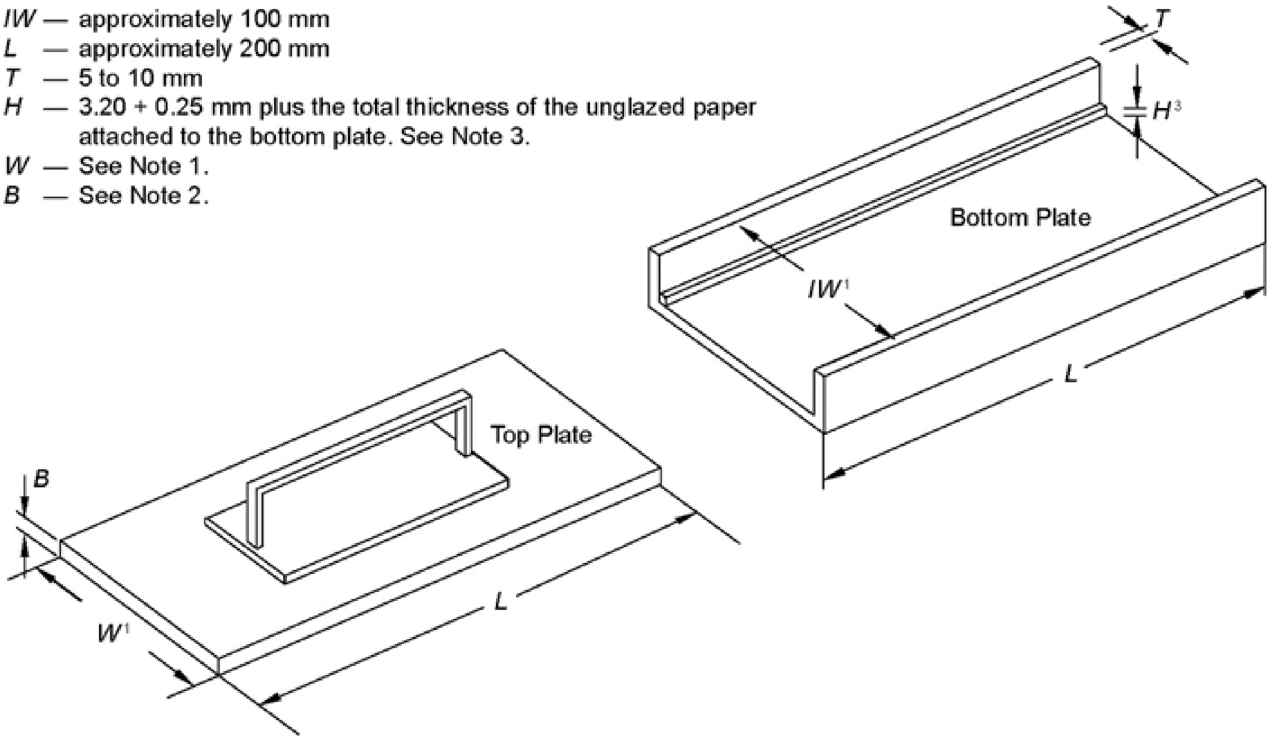
3.3. *Surface for Rolling*—Shall consist of one of the following:

3.3.1. A ground glass plate or piece of smooth, unglazed paper on which to roll the sample. Paper, if used, shall not add foreign matter (fibers, paper fragments, etc.) to the soil during the rolling process and shall lay flat on a smooth horizontal surface.

3.3.2. *Plastic Limit Rolling Device*[1,2]—A device made of acrylic conforming to the dimensions shown in Figure 1.

Dimensions:

IW — approximately 100 mm
L — approximately 200 mm
T — 5 to 10 mm
H — 3.20 + 0.25 mm plus the total thickness of the unglazed paper attached to the bottom plate. See Note 3.
W — See Note 1.
B — See Note 2.



Notes:

1. The tolerance between the width of the top plate (*W*) and the inside width of the bottom plate (*IW*) shall be such that the top plate slides freely on the rails without wobbling.
2. The top plate shall be rigid enough so that the thickness of the soil threads is not influenced by flexure of the top plate.
3. The width of the side rails shall be between 3 and 6 mm.

Figure 1—Plastic Limit Rolling Device

3.3.2.1. *Paper for Rolling Device*—Unglazed paper that does not add foreign matter (fibers, paper fragments, etc.) to the soil during the rolling process. Attach the unglazed paper to the top and bottom plates of the device either by a spray-on adhesive or by use of a self-adhesive backing.

Note 1—Take special care to remove the adhesive that remains on the plastic limit rolling device after testing. Repeated tests without such removal will result in a buildup of the residual adhesive and a decreased soil thread diameter.

3.4. *Moisture Content Container*—Made of material resistant to corrosion and not subject to change in mass or disintegration on repeated heating and cooling. The container shall have a close-fitting lid to prevent loss of moisture from samples before initial mass determination and to prevent absorption of moisture from the atmosphere following drying and before final mass determination. One container is needed for each moisture content determination.

3.5. *Balance*—A class G1 balance meeting the accuracy requirements of M 231.

3.6. *Oven*—Thermostatically controlled and capable of maintaining temperatures of 110 ± 5°C for drying samples.

4. CALIBRATIONS, STANDARDIZATIONS, AND CHECKS

4.1. Unless otherwise specified, follow the requirements and intervals for equipment calibrations, standardizations, and checks in R 18.

4.2. Follow the procedures for performing equipment calibrations, standardizations, and checks found in R 61.

5. SAMPLE

5.1. *If only the plastic limit is to be determined*—Take a quantity of soil with a mass of about 20 g from the thoroughly mixed portion of the material passing the 0.425-mm (No. 40) sieve, obtained in accordance with R 58 or R 74. Place the air-dried soil in a mixing dish and thoroughly mix with distilled, demineralized, or de-ionized water until the mass becomes plastic enough to be easily shaped into a ball (Notes 2 and 3). Take a portion of this ball with a mass of about 10 g for the test sample.

Note 2—Tap water may be used for routine testing if comparative tests indicate no differences in results between using tap water and distilled, demineralized, or de-ionized water. However, use distilled, demineralized, or de-ionized water for referee or disputed tests.

Note 3—The objective is to add enough moisture to a plastic soil sample so that the 3-mm thread described in Section 6 does not crumble on the first roll. For a nonplastic soil, this will not be possible.

5.2. *If the plasticity index (both liquid and plastic limit) is to be determined*—Take a test sample with a mass of about 10 g from the thoroughly wet and mixed portion of the soil prepared in accordance with T 89. Take the sample at any stage of the mixing process at which the mass becomes plastic enough to be easily shaped into a ball without sticking to the fingers excessively when squeezed. If the sample is taken before completion of the liquid limit test, set it aside and allow to season in air until the liquid limit test has been completed. If the sample taken during the liquid limit test is too dry to permit rolling to a 3-mm thread as described in Section 6, add more water and remix (Note 3).

6. PROCEDURE

6.1. Determine and record the mass of the moisture content container.

6.2. Select a 1.5- to 2.0-g portion from the 10-g mass of soil prepared in accordance with Section 5. Form the selected portion into an ellipsoidal mass.

6.3. Use one of the following methods to roll the soil mass into a 3-mm-diameter thread at a rate of 80 to 90 strokes per minute, counting a stroke as one complete motion of the hand forward and back to the starting position again.

6.3.1. *Hand Rolling Method*—Roll the mass between the palm or fingers and the ground-glass plate or unglazed paper with just sufficient pressure to roll the mass into a thread of uniform diameter throughout its length. Deform the thread further on each stroke until its diameter reaches 3 mm. Take no more than 2 min to roll the soil mass to the 3-mm diameter.

Note 4—The amount of hand or finger pressure required will vary greatly, according to the soil. Fragile soils of low plasticity are best rolled under the outer edge of the palm or at the base of the thumb.

6.3.2. *Alternate Procedure, Plastic Limit Device Method*—Place the soil mass on the bottom plate. Place the top plate in contact with the soil mass. Simultaneously apply a slight downward force and back and forth motion to the top plate so the plate comes in contact with the side rails within 2 min. During this rolling process, do not allow the soil thread to contact the side rails.

Note 5—In most cases, more than one soil mass (thread) can be rolled simultaneously in the plastic limit rolling device.

6.4. When the diameter of the thread reaches 3 mm, squeeze the thread between the thumbs and fingers and form the mass back into a roughly ellipsoidal shape. Repeat the rolling process described in Section 6.3.1 or 6.3.2 until the soil can no longer be rolled into a thread and begins to crumble. Reform the soil into an ellipsoidal mass after each rolling of the thread to a 3-mm diameter. The crumbling may occur when the thread has a diameter greater than 3 mm. This is considered a satisfactory end point, provided the solid has been previously rolled into a thread 3 mm in diameter (Note 6). Do not attempt to produce failure at an exact 3-mm diameter by allowing the thread to reach 3 mm, then reducing the rate of rolling or the hand pressure, or both, and continuing the rolling without further deformation until the thread falls apart (Note 7).

Note 6—The crumbling will manifest itself differently with various types of soil. Some soils fall apart in numerous small aggregations of particles; others may form an outside tubular layer that starts splitting at both ends. The splitting may progress toward the middle, and the thread may finally fall apart in many small platy particles. Heavy clay soils require much pressure to deform the thread, particularly as they approach the plastic limit. These types of soils may break into a series of barrel-shaped segments each about 6 to 9 mm in length.

Note 7—For feebly plastic soils, it may be necessary to reduce the total amount of deformation by making the initial diameter of the ellipsoidal-shaped mass nearer to the required 3-mm final diameter.

6.5. Gather the portions of the crumbled soil together and place in the moisture content container. Immediately cover the container with a close-fitting lid to prevent additional loss of moisture.

6.6. Repeat the operations described in Sections 6.3 through 6.5 until the entire 10-g specimen is tested. Place all of the crumbled portions into the same moisture content container.

6.7. Determine the moisture content of the soil in the container in accordance with T 265, and record the results.

7. CALCULATIONS

7.1.

The plastic limit of the soil is the moisture content determined in Section 6.7, expressed as a percentage of the oven-dry mass, and determined in accordance with T 265. Report the plastic limit to the nearest whole number.

7.2. If applicable, calculate the plasticity index of a soil as the difference between its liquid limit and its plastic limit, as follows:

$$\text{plasticity index} = \text{liquid limit} - \text{plastic limit} \tag{1}$$

7.3. Report the results as calculated in Section 7.2 as the plasticity index, except under the following conditions:

7.3.1. When the liquid limit or plastic limit cannot be determined, report the plasticity index as NP (nonplastic).

7.3.2. When the plastic limit is equal to, or greater than, the liquid limit, report the plasticity index as NP.

8. PRECISION STATEMENT

8.1. This precision statement applies to soils with a plastic limit range between 15 and 32, tested using the hand rolling method.

8.2. *Repeatability (Single Operator)*—Two results obtained by the same operator on the same sample in the same laboratory using the same apparatus should be considered suspect if they differ by more than 10 percent of their mean.

8.3. *Reproducibility (Multilaboratory)*—Two results obtained by different operators in different laboratories should be considered suspect if they differ from each other by more than 18 percent of their mean.

9. KEYWORDS

9.1. Atterberg; clay soil; plastic limit; plasticity index.

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[1] The plastic limit rolling device is covered by a patent (U.S. Patent No. 5,027,660). Interested parties are invited to submit information regarding the identification of an alternative(s) to this patent to AASHTO Headquarters. Your comments will receive careful consideration at a meeting of AASHTO Technical Section 1a on Soil Materials Tests.

[2] Bobrowski, L. J., Jr. and D. M. Griekspoor, "Determination of the Plastic Limit of a Soil by Means of a Rolling Device," Geotechnical Testing Journal, GTJODJ, Vol. 15, No. 3, September 1992, pp. 284–287.

Standard Practice for

Dry Preparation of Disturbed Soil and Soil–Aggregate Samples for Test

AASHTO Designation: R 58-11 (2019)[1]

Technical Subcommittee: 1a, Soil and Unbound Recycled Materials

Release: Group 3 (July)

American Association of State Highway and Transportation Officials
444 North Capitol Street N.W., Suite 249
Washington, D.C. 20001

Standard Practice for

Dry Preparation of Disturbed Soil and Soil–Aggregate Samples for Test

AASHTO Designation: R 58-11 (2019)[1]

Technical Subcommittee: 1a, Soil and Unbound Recycled Materials

Release: Group 3 (July)

1. SCOPE

1.1. This method describes the dry preparation of soil and soil–aggregate samples, as received from the field, for mechanical analysis, physical tests, and other tests as may be desired.

1.2. The values stated in SI units are to be regarded as the standard.

2. REFERENCED DOCUMENTS

2.1. *AASHTO Standards*:
- M 231, Weighing Devices Used in the Testing of Materials
- R 76, Reducing Samples of Aggregate to Testing Size
- T 88, Particle Size Analysis of Soils
- T 89, Determining the Liquid Limit of Soils
- T 90, Determining the Plastic Limit and Plasticity Index of Soils
- T 100, Specific Gravity of Soils

2.2. *ASTM Standard*:
- E11, Standard Specification for Woven Wire Test Sieve Cloth and Test Sieves

3. APPARATUS

3.1. The balance shall conform to the requirements of M 231, for the class of general purpose balance required for the principal sample mass of the sample being tested.

3.2. *Drying Apparatus*—Any suitable device capable of drying samples at a temperature not exceeding 60°C [140°F].

3.3. *Sieves*—A series of sieves of the following sizes: 4.75 mm (No. 4), 2.00 mm (No. 10), 0.425 mm (No. 40), and others as required for preparing the sample for a specific test. The sieves shall conform to ASTM E11.

3.4. *Pulverizing Apparatus*—Either a mortar and rubber-covered pestle or a mechanical device consisting of a power-driven, rubber-covered muller suitable for breaking up the aggregations of soil particles without reducing the size of the individual grains.

Note 1—Other types of apparatus, such as a revolving drum into which the soil sample and rubber-covered rollers are placed and tumbled until soil aggregations are pulverized, are satisfactory if the aggregations of soil particles are broken up without reducing the size of the individual grains.

3.5. *Sample Splitter*—A suitable riffle sampler or sample splitter for proportional splitting of the sample and capable of obtaining representative portions of the sample without appreciable loss of fines. The width of the container used to feed the riffle sample splitter should be equal to the total combined width of the riffle chutes. Proportional splitting of the sample on a canvas cloth is also permitted.

Note 2—The procedure for proportional splitting is described in R 76.

4. SAMPLE SIZE

4.1. *The amounts of soil material required to perform the individual tests are as follows:*

4.1.1. *Particle Size Analysis of Soils (T 88)*—For the particle size analysis, material passing a 2.00-mm (No. 10) sieve is required in amounts equal to approximately 110 g for sandy soils and approximately 60 g for silty or clayey soils. A sufficient amount of material retained on either the 4.75-mm (No. 4) sieve or 2.00-mm (No. 10) sieve is required (Note 3) to obtain a representative gradation, and, depending on the maximum particle size, shall not be less than the amount shown in the following table:

Diameter of Largest Particle, mm (in.)	Approximate Minimum Mass of Portion, kg
9.5 ($^3/_8$)	0.5
25 (1)	2.0
50 (2)	4.0
75 (3)	5.0

Note 3—The material for coarse sieve analysis may be separated by either of two alternate methods, Section 5.2.1 (2.00-mm sieve) or Section 5.2.2 (4.75-mm sieve). When only a small percentage of the material will be retained on the 4.75-mm or 2.00-mm sieve, a considerable total mass of sample will be required to provide the minimum quantity shown in the above table; consequently, adherence to the minimum mass requirements in the above table may not be necessary if the material represented by the sample is not to be used in a base or subbase course, select borrow, or other item having a requirement for coarse aggregate.

4.1.2. *Specific Gravity (T 100)*—For the specific gravity test performed in conjunction with T 88, material passing the 2.00-mm (No. 10) sieve is required in the amounts (oven-dry) of at least 25 g when the volumetric flask is used and at least 10 g when the stoppered bottle is used.

4.1.3. *Physical Tests*—For the physical tests, material passing the 0.425-mm (No. 40) sieve is required in the total amount of at least 300 g, allocated approximately as follows:

Test (and AASHTO Designation)	Approximate Mass, g
Liquid limit (T 89)	100
Plastic limit (T 90)	20
Shrinkage factors	30
Field moisture equivalent	50
Check and referee tests	100

5. INITIAL PREPARATION OF TEST SAMPLES

5.1. Dry the soil sample as received from the field thoroughly in air or in the drying apparatus at a temperature not exceeding 60°C [140°F]. Obtain a representative test sample of the amount required to perform the desired tests (Section 4) with the sampler, or by splitting or quartering. Break up the aggregations of soil particles in the pulverizing apparatus in such a way as to avoid reducing the natural size of individual particles.

Note 4—Samples dried in an oven or other drying apparatus at a temperature not exceeding 60°C [140°F] are considered to be air dried.

5.2. Weigh the portion of the dried sample selected for particle-sized analysis and physical tests (including specific gravity), and record that mass as the mass of total sample uncorrected for hygroscopic moisture. Separate this portion into fractions by one of the following methods:

5.2.1. *Alternate Methods Using 2.00-mm (No. 10) Sieve*—Separate the dried sample into two fractions using a 2.00-mm sieve. Grind the fraction retained on the sieve with the pulverizing apparatus until the aggregations of soil particles are broken into separate grains. Separate the ground soil into two fractions using the 2.00-mm sieve.

5.2.2. *Alternate Method Using 4.75-mm and 2.00-mm (Nos. 4 and 10) Sieves*—Separate the dried sample into two fractions using a 4.75-mm sieve. Grind the fraction retained on this sieve with the pulverizing apparatus until the aggregation of soil particles is broken into separate grains, and then separate these grains on the 4.75-mm sieve. Thoroughly mix the fractions passing the 4.75-mm sieve and, by the use of the sampler or by splitting and quartering, obtain a representative portion adequate for the desired tests. Separate this portion on the 2.00-mm sieve and process it as described in Section 5.2.1. Record the mass of the material from this split-off fraction that is retained on the 2.00-mm sieve for later use in coarse sieve analysis computations.

6. TEST SAMPLE FOR PARTICLE SIZE ANALYSIS AND SPECIFIC GRAVITY

6.1. Set aside the fraction retained on the 2.00-mm (No. 10) sieve in Section 5.2.1, or that retained on the 4.75-mm (No. 4) sieve in Section 5.2.2 after the second sieving, for use in sieve analysis of the coarse material.

6.2. Thoroughly mix the fractions passing the 2.00-mm (No. 10) sieve in both sieving operations in Sections 5.2.1 or 5.2.2 and, by the use of the sampler or by splitting or quartering, obtain representative portions having approximate masses as follows: (1) for the hydrometer analysis and sieve analysis of the fraction passing the 2.00-mm sieve, 110 g for sandy soil and 60 g for silty or clayey soils; and (2) for specific gravity, 25 g when the volumetric flask is to be used and 10 g when the stoppered bottle is to be used.

7. TEST SAMPLE FOR PHYSICAL TESTS

7.1. Separate the remaining portion of the material passing the 2.00-mm (No. 10) sieve into two parts by means of a 0.425-mm (No. 40) sieve. Grind the fraction retained on the 0.425-mm (No. 40) sieve with the pulverizing apparatus in such a manner as to break up the aggregations without fracturing the individual grains. If the sample contains brittle particles, such as flakes of mica, fragments of sea shells, etc., carefully perform the pulverizing operation with just enough pressure to free the finer material that adheres to the coarser particles. Separate the ground soil into two fractions by means of the 0.425-mm (No. 40) sieve, and regrind the material retained on the sieve. When repeated grinding produces only a small quantity of soil passing the 0.425-mm sieve, discard the material retained on the 0.425-mm sieve. Thoroughly mix the several fractions passing the 0.425-mm sieve obtained from the grinding and sieving operations and set aside for use in performing the physical tests.

8. KEYWORDS

8.1. Sample preparation; soil sample; soil–aggregate sample; test sample.

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[1] Formerly T 87. Reclassified as a standard practice in 2011.

Standard Method of Test for Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test

AASHTO Designation: T 176-17

Technical Section: 1a, Soil and Unbound Recycled Materials

Release: Group 3 (August)

1. SCOPE

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

1.2. The following applies to all specified limits in this standard: For the purpose of determining conformance with these specifications, an observed value or a calculated value shall be rounded off "to the nearest unit" in the last right-hand place of figures used in expressing the limiting value, in accordance with ASTM E29, Using Significant Digits in Test Data to Determine Conformance with Specifications.

1.3. The values stated in SI units are to be regarded as the standard.

1.4. *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. REFERENCED DOCUMENTS

2.1. *AASHTO Standards*:

- M 231, Weighing Devices Used in the Testing of Materials
- R 76, Reducing Samples of Aggregate to Testing Size
- R 90, Sampling Aggregate products

2.2. *ASTM Standards*:

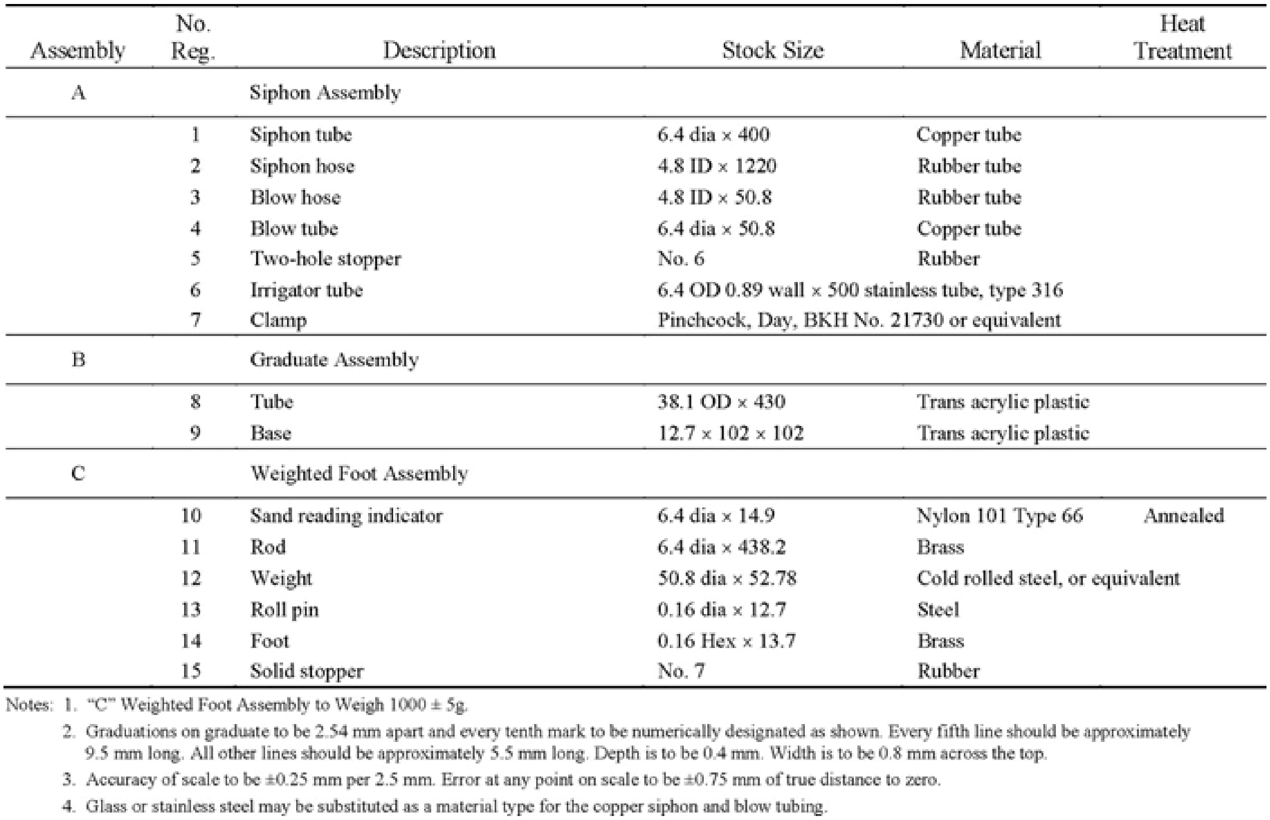
- E11, Standard Specification for Woven Wire Test Sieve Cloth and Test Sieves
- E29, Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

3. SIGNIFICANCE AND USE

3.1. This test method is used to determine the proportion of detrimental fines in the portion passing the 4.75-mm (No. 4) sieve of soils or graded aggregates.

4. APPARATUS

4.1. *Sand Equivalent Apparatus*—A graduated plastic cylinder, rubber stopper, irrigator tube, weighted foot assembly, and siphon assembly, all conforming to their respective specifications and dimensions shown in Figure 1. Fit the siphon assembly to a 4-L (1-gal) bottle of working calcium chloride solution (see Section 2.8) placed on a shelf 915 ± 25 mm (36 ± 1 in.) above the work surface. In lieu of the specified 4-L (1-gal) bottle, a glass or plastic vat having a larger capacity may be used provided the liquid level of the working solution is maintained between 915 and 1170 mm (36 and 46 in.) above the work surface (see Figure 2).



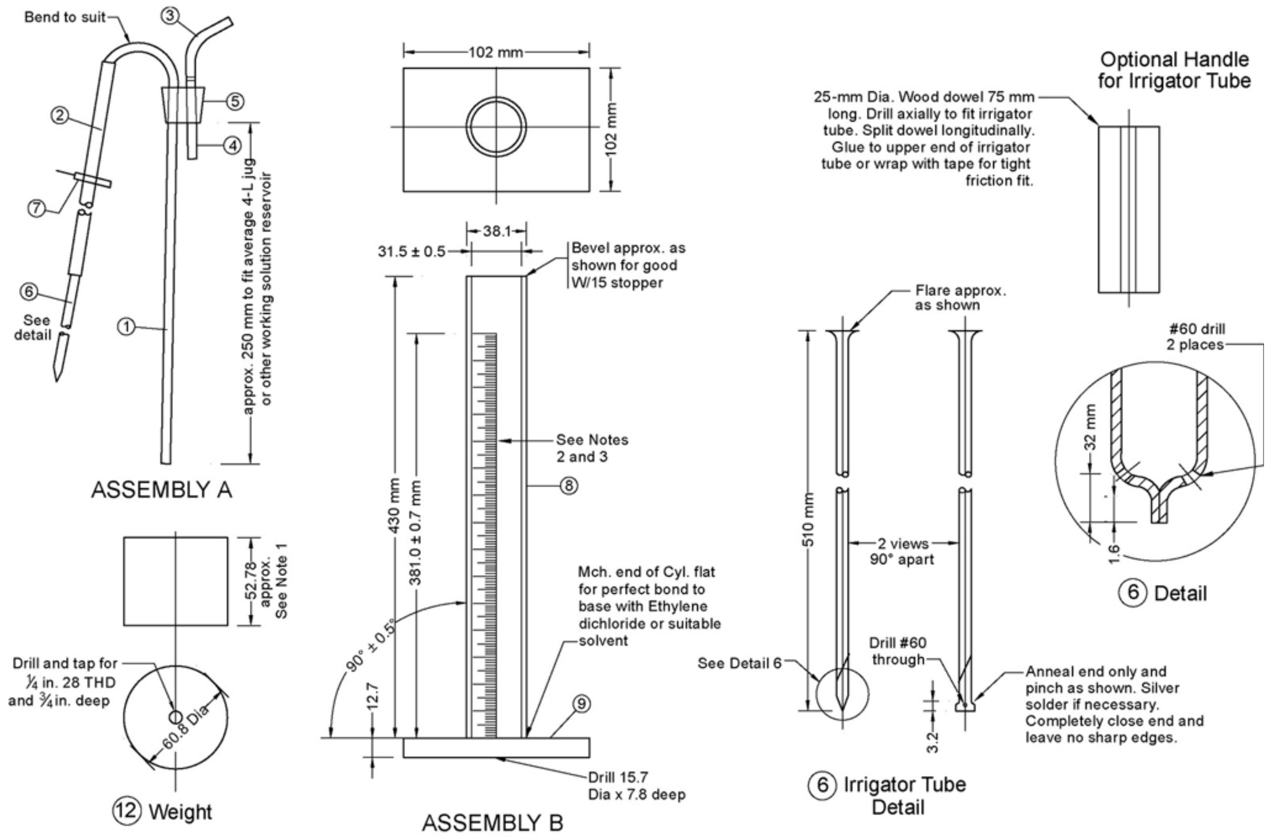
Assembly	No. Reg.	Description	Stock Size	Material	Heat Treatment
A		Siphon Assembly			
	1	Siphon tube	6.4 dia × 400	Copper tube	
	2	Siphon hose	4.8 ID × 1220	Rubber tube	
	3	Blow hose	4.8 ID × 50.8	Rubber tube	
	4	Blow tube	6.4 dia × 50.8	Copper tube	
	5	Two-hole stopper	No. 6	Rubber	
	6	Irrigator tube	6.4 OD 0.89 wall × 500 stainless tube, type 316		
	7	Clamp	Pinchcock, Day, BKH No. 21730 or equivalent		
B		Graduate Assembly			
	8	Tube	38.1 OD × 430	Trans acrylic plastic	
	9	Base	12.7 × 102 × 102	Trans acrylic plastic	
C		Weighted Foot Assembly			
	10	Sand reading indicator	6.4 dia × 14.9	Nylon 101 Type 66	Annealed
	11	Rod	6.4 dia × 438.2	Brass	
	12	Weight	50.8 dia × 52.78	Cold rolled steel, or equivalent	
	13	Roll pin	0.16 dia × 12.7	Steel	
	14	Foot	0.16 Hex × 13.7	Brass	
	15	Solid stopper	No. 7	Rubber	

Notes: 1. "C" Weighted Foot Assembly to Weigh 1000 ± 5g.

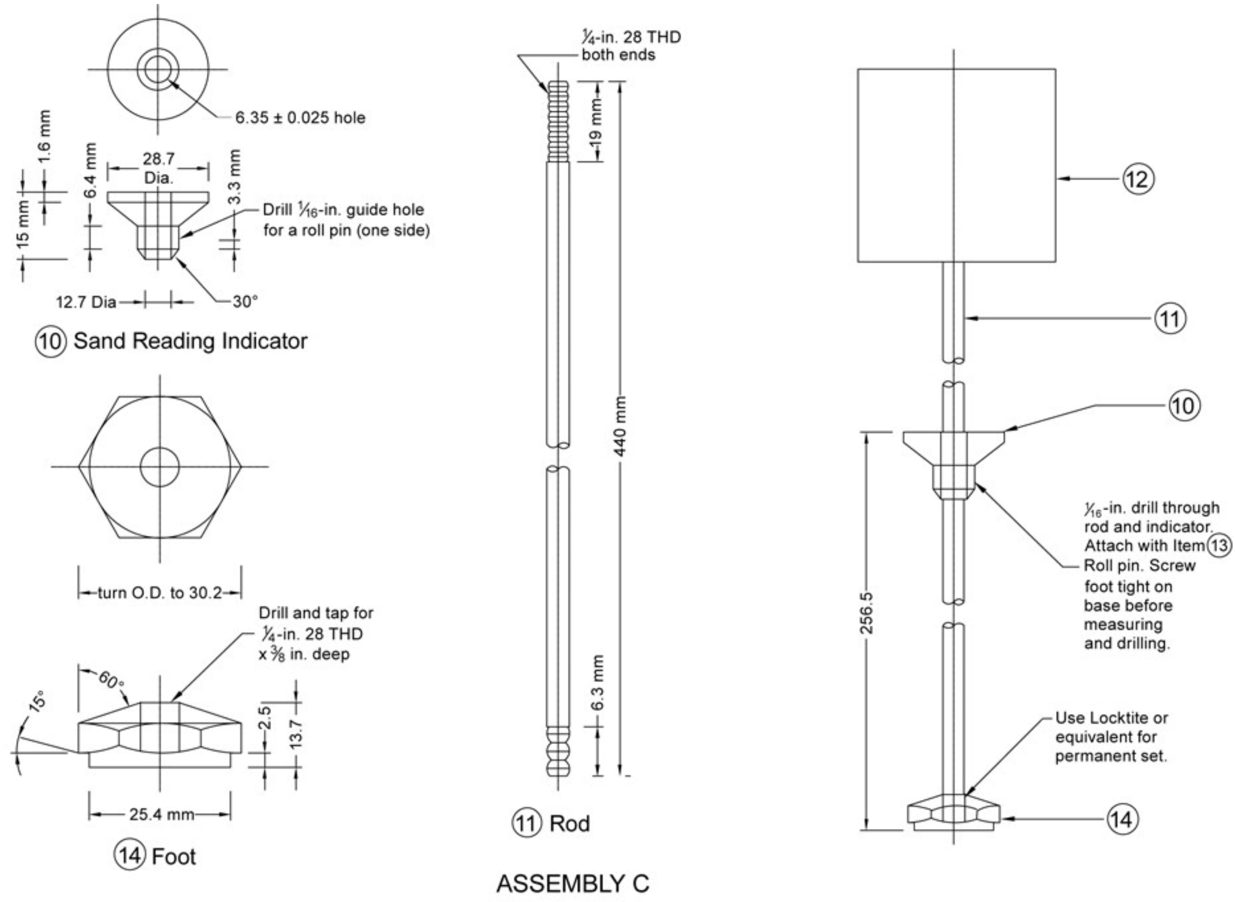
2. Graduations on graduate to be 2.54 mm apart and every tenth mark to be numerically designated as shown. Every fifth line should be approximately 9.5 mm long. All other lines should be approximately 5.5 mm long. Depth is to be 0.4 mm. Width is to be 0.8 mm across the top.

3. Accuracy of scale to be ±0.25 mm per 2.5 mm. Error at any point on scale to be ±0.75 mm of true distance to zero.

4. Glass or stainless steel may be substituted as a material type for the copper siphon and blow tubing.



Note: All dimensions are shown in millimeters unless otherwise indicated.



Note: All dimensions are shown in millimeters unless otherwise indicated.

Figure 1—Sand Equivalent Apparatus

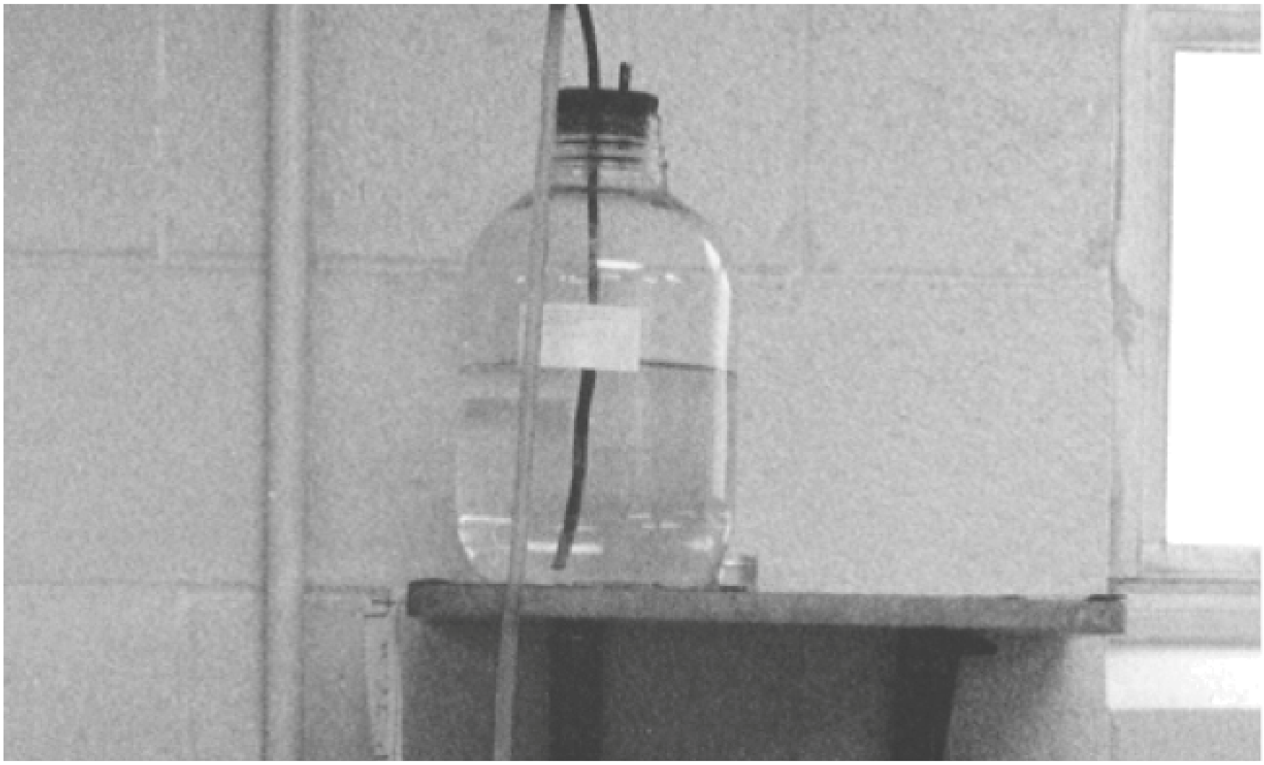


Figure 2—Graduated Cylinder, Irrigator Tube, Weighted Foot Assembly, and Siphon

Note 1—An older model of a weighted foot assembly has a guide cap that fits over the upper end of the graduated cylinder and centers the rod in the cylinder; the foot of the assembly has a conical upper surface and three centering screws to center it loosely in the cylinder. The older model does not have the sand reading indicator affixed to the rod (Figure 1), but a slot in the centering screws of the weighted foot is used to indicate the sand reading. Apparatus with the sand reading indicator (Figure 1) is preferred for testing clayey materials.

4.2. *Measure*—A tinned measure, having a capacity of 85 ± 5 mL (3 oz), approximately 57 mm (2.25 in.) in diameter.

4.3. *Balance*—The balance shall have sufficient capacity, be readable to not more than 0.1 percent of the sample mass, and conform to the requirements of M 231.

4.4. *Funnel*—A wide-mouth funnel approximately 100 mm (4 in.) in diameter at the mouth.

4.5. *Timer*—A clock or watch reading in minutes and seconds.

4.6. *Mechanical Shaker*—A mechanical shaker having a throw of 203.2 ± 1.0 mm (8.00 ± 0.04 in.) and operating at 175 ± 2 cpm (2.92 ± 0.03 Hz) (Note 2). Prior to use, fasten the mechanical sand equivalent shaker securely to a firm and level mount.

4.7. *Manual Shaker*—A manually operated shaker, capable of producing an oscillating motion at the rate of 100 complete cycles in 45 ± 5 s, with a hand-assisted half stroke length of 127 ± 5 mm (5.0 ± 0.2 in.). The shaker shall be fastened securely to a firm and level mount by bolts or clamps if a large number of determinations are to be made.

Note 2—The mechanical shaker shall be used when performing reference sand equivalent determinations. Either the mechanical or manually operated shaker should be used in lieu of the hand method whenever possible.

4.8. *Stock Solution*—The materials listed in Sections 4.8.1, 4.8.2, or 4.8.3 may be used to prepare the stock solution. A fourth alternative is not to use any biocide, provided the time of storage of stock solution is not sufficient to promote the growth of fungi.

4.8.1. Stock solution with formaldehyde.

4.8.1.1. Anhydrous calcium chloride, 454 g (1.0 lb) of technical grade.

4.8.1.2. USP glycerin, 2050 g (4.515 lb).

4.8.1.3. Formaldehyde, (40 volume percent solution) 47 g (0.10 lb).

4.8.1.4. Dissolve the 454 g (1.0 lb) of calcium chloride in 1.89 L ($^1/_2$ gal) of distilled water. Cool and filter it through ready pleated rapid filtering paper. Add the 2050 g (4.515 lb) of glycerin and the 47 g (0.10 lb) of formaldehyde to the filtered solution, mix well, and dilute to 3.78 L (1 gal).

4.8.2. Stock solution with glutaraldehyde.

4.8.2.1. Calcium chloride dihydrate, 577 g (1.27 lb) of A.C.S. grade.

Note 3—A.C.S.-grade calcium chloride dihydrate is specified for the stock solution prepared with glutaraldehyde because tests indicate that impurities in the technical grade anhydrous calcium chloride may react with the glutaraldehyde resulting in an unknown precipitate.

4.8.2.2. USP glycerin, 2050 g (4.515 lb).

4.8.2.3. 1.5-pentanedial (glutaraldehyde), 50 percent solution in water 59 g (0.13 lb).

4.8.2.4. Dissolve the 577 g (1.27 lb) of calcium chloride dihydrate in 1.89 L ($^1/_2$ gal) of distilled water. Cool and add the 2050 g (4.515 lb) of glycerin and the 59 g (0.13 lb) of glutaraldehyde to the solution, mix well, and dilute to 3.78 L (1 gal).

Note 4—1.5-pentanedial, also known as glutaraldehyde, glutaric dialdehyde, and trade name UCARCIDE 250, may be obtained as glutaraldehyde solution 50 percent.[1]

4.8.3. Stock solution with Kathon CG/ICP.

4.8.3.1. Calcium chloride dihydrate, 577 g (1.27 lb) of A.C.S. Grade.

4.8.3.2. USP glycerin, 2050 g (4.515 lb).

4.8.3.3. Kathon CG/ICP, 63 g (0.14 lb).

4.8.3.4. Dissolve the 577 g (1.27 lb) of calcium chloride dihydrate in 1.89 L ($^1/_2$ gal) of distilled water. Cool and add the 2050 g (4.515 lb) of glycerin and the 63 g (0.14 lb) of Kathon CG/ICP to the solution, mix well, and dilute to 3.78 L (1 gal).[2]

4.9. *Working Solution*—Working calcium chloride solution: Prepare the working calcium chloride solution by diluting one measuring tin full (85 ± 5 mL) of the stock calcium chloride solution with water until it reaches a total volume of 3.8 L (1 gal). Thoroughly mix solution by filling the bottle with approximately 2 L ($^1/_2$ gal) of water. Add the stock solution and agitate vigorously for 1 to 2 min. Add the remainder of the water and repeat the agitation process. Use distilled or demineralized water for the normal preparation of the working solution. However, if it is determined that the local tap water is of such purity that it does not affect the test results, it is permissible to use in lieu of distilled or demineralized water except in the event of dispute. Discard working solutions more than 30 days old.

4.10. *Straightedge*—A straightedge or spatula, suitable for striking off the excess soil from the tin measure.

4.11. *Oven*—A thermostatically controlled drying oven capable of maintaining a temperature of 110 ± 5°C (230 ± 9°F).

4.12. *Quartering Cloth*—Quartering or splitting cloth, approximately 600 mm (2 ft) square, nonabsorbent material such as plastic or oil cloth.

4.13. *Sieve*—A 4.75-mm (No. 4) sieve conforming to the requirements of ASTM E11.

4.14. *Optional Handle for Irrigation Tube*—A 25-mm diameter wooden dowel to aid in pushing the irrigation tube into firm materials. See Figure 1, Assembly B.

5. TEMPERATURE CONTROL

5.1. The temperature of the working solution should be maintained at 22 ± 3°C (72 ± 5°F) during the performance of this test. If field conditions preclude the maintenance of the temperature range, frequent reference samples should be submitted to a laboratory where proper temperature control is possible. It is also possible to establish temperature correction curves for each material being tested where proper temperature control is not possible. However, no general correction curve should be utilized for several materials even within a narrow range of sand equivalent values. Samples that meet the minimums and equivalent requirement at a working solution temperature below the recommended range need not be subject to reference testing.

6. SAMPLING

6.1. Obtain a sample of the material to be tested in accordance with R 90.

6.2. Reduce the sample according to R 76. The sample shall be of sufficient size to yield 1000 to 1500 g of material passing the 4.75-mm (No. 4) sieve.

6.3. Sieve the sample over a 4.75-mm (No. 4) sieve. All aggregations of fine-grained soil material shall be pulverized to pass the 4.75-mm (No. 4) sieve, and all fines shall be cleaned from the particles retained on the 4.75-mm (No. 4) sieve and included with the material passing the 4.75-mm (No. 4) sieve.

6.4. Split or quarter the material passing the 4.75-mm (No. 4) sieve to yield 500 to 750 g (1.1 to 1.6 lb) of material. Use extreme care to obtain a truly representative portion of the original sample (Note 5).

Note 5—Experiments show that as the amount of material being reduced by splitting or quartering is decreased, the accuracy of providing representative portions is reduced. It is imperative that the sample be split or quartered carefully. When it appears necessary, dampen the material before splitting or quartering, to avoid segregation or loss of fines.

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7. SAMPLE PREPARATION

7.1. Prepare the desired number of test samples by one of the following methods:

7.1.1. *Alternate Method No. 1*—Air Dry.

7.1.1.1. Split or quarter enough material from the portion passing the 4.75-mm (No. 4) sieve to fill the 85-mL (3-oz) tin measure so it is slightly rounded above the brim. While filling the measure, tap the bottom edge of the tin on the work table or other hard surface to cause consolidation of the material and allow the maximum amount to be placed in the tin. Strike off the tin with the spatula or straightedge so the material is level with the top of the measuring tin.

7.1.2. *Alternate Method No. 2*—Pre-Wet.

7.1.2.1. The sample must be in the proper moisture condition to achieve reliable results. This condition is determined by tightly squeezing a small portion of the thoroughly mixed sample in the palm of the hand. If the cast that is formed permits careful handling without breaking, the correct moisture range has been obtained. If the material is too dry, the cast will crumble and it will be necessary to add water, remix, and retest until the material forms a cast. If the material shows any free water it is too wet to test and must be drained and air dried, mixing it frequently to ensure uniformity. This overly wet material will form a good cast when checked initially, so the drying process should continue until a squeeze check on the drying material gives a cast that is more fragile and delicate to handle than the original. If the moisture content of the original sample prepared in Section 6.2 is within the limits described above, the test sample may be obtained immediately. If the moisture content is altered to meet these limits, the altered sample should be placed in a pan, covered with a lid or with a damp cloth that does not touch the material, and allowed to stand for a minimum of 15 minutes.

7.1.2.2. After the minimum 15-minute tempering period, place the sample on the splitting cloth and mix by alternately lifting each corner of the cloth and pulling it over the sample toward the diagonally opposite corner, causing the material to be rolled. When the material appears homogeneous, finish the mixing with the sample in a pile near the center of the cloth.

7.1.2.3. Fill the 85-mL (3-oz) tin measure by pushing it through the base of the pile while exerting pressure with the hand against the pile on the side opposite the measure. As the tin is moved through the pile, hold enough pressure with the hand to cause the material to fill the tin to overflowing. Press firmly with the palm of the hand, compacting the material and allowing the maximum amount to be placed in the tin. Strike off the tin with the spatula or straightedge so the material is level with the top of the measuring tin.

Note 6—Moist test specimens produce lower sand equivalent values than the corresponding over-dry specimens with almost no exceptions; therefore, if a dual specification encompassing both the wet and dry methods of sample preparation is utilized, it will be necessary to determine the appropriate correction for each material because a standard correction does not appear possible. Either method can be employed with equal confidence, however.

7.1.3. *Reference Method (Mechanical Shaker)*—Obtain the 85-mL (3-oz) tin measure of material by one of the alternate methods, Section 7.1.1 or 7.1.2, above; then dry the test sample to constant mass at 110 ± 5°C (230 ± 9°F) and cool to room temperature before testing.

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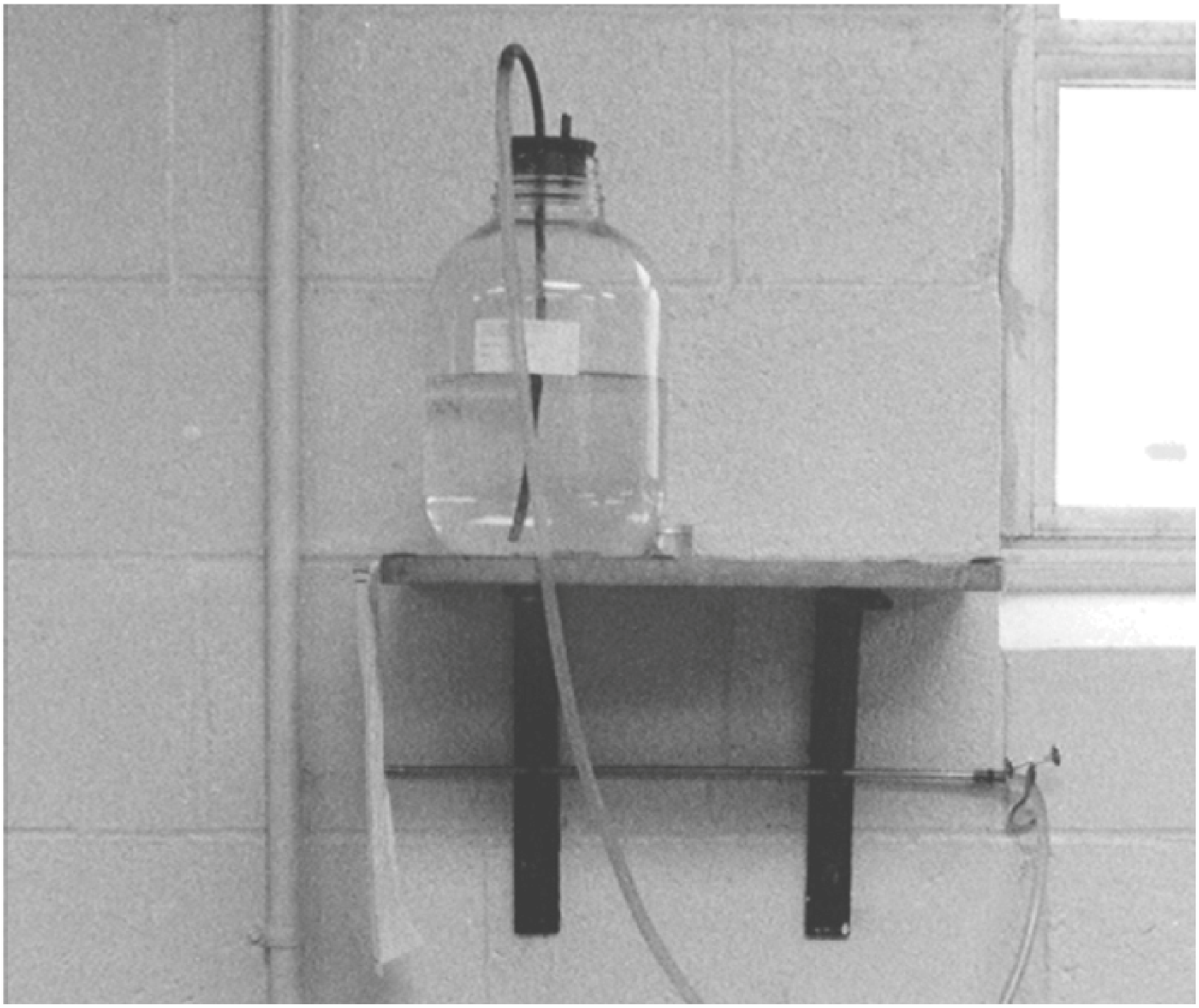
8. PROCEDURE

8.1. Start the siphon by forcing air into the top of the solution bottle through the bent copper, glass, or stainless steel blow tube while the pinch clamp is open. The apparatus is now ready for use.

8.2. Siphon 101.6 ± 2.5 mm (4.0 ± 0.1 in.) of working calcium chloride solution into the plastic cylinder. Pour the prepared test sample from the measuring tin into the plastic cylinder using the funnel to avoid spillage (see Figure 3). Tap the bottom of the cylinder sharply on the heel of the hand several times to release air bubbles and to promote thorough wetting of the sample.



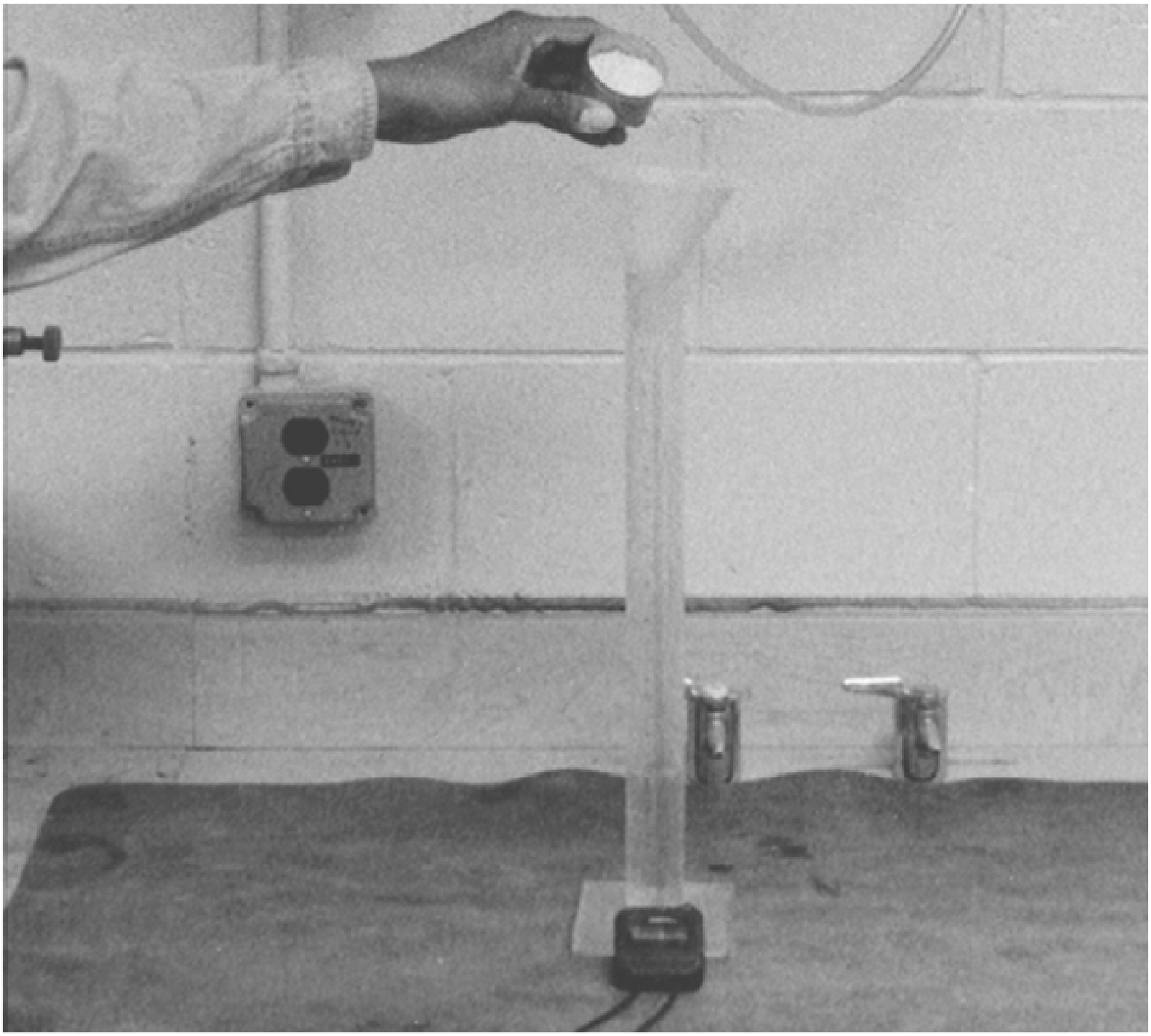


Figure 3—Transfer of Sample from Measuring Tin to Cylinder

8.3. Allow the wetted sample to stand undisturbed for 10 ± 1 min. At the end of the 10-min soaking period, stopper the cylinder, then loosen the material from the bottom by partially inverting the cylinder and shaking it simultaneously.

8.4. After loosening the material from the bottom of the cylinder, shake the cylinder and contents by any one of the following methods:

8.4.1. *Mechanical Shaker Method (Reference Method)*—Place the stoppered cylinder in the mechanical sand equivalent shaker, set the timer, and allow the machine to shake the cylinder and contents for 45 ± 1 s.

8.4.2. *Manual Shaker Method*—Secure the stoppered cylinder in the three spring clamps on the carriage of the hand-operated sand equivalent shaker and reset the stroke counter to zero. Stand directly in front of the shaker and force the pointer to the stroke limit marker painted on the backboard by applying an abrupt horizontal thrust to the upper portion of the right-hand spring steel strap. Then remove the hand from the strap and allow the spring action of the straps to move the carriage and cylinder in the opposite direction without assistance or hindrance. Apply enough force to the right-hand spring steel strap during the thrust portion of each stroke to move the pointer to the stroke limit marker by pushing against the strap with the ends of the fingers to maintain a smooth oscillating motion. The center of the stroke limit marker is positioned to provide the proper stroke length and its width provides the maximum allowable limits of variation. The proper shaking action is accomplished only when the tip of the pointer reverses direction within the marker limits. Proper shaking action can best be maintained by using only the forearm and wrist action to propel the shaker. Continue the shaking action for 100 strokes.

8.4.3. *Hand Method*—Hold the cylinder in a horizontal position as illustrated in Figure 4 and shake it vigorously in a horizontal linear motion from end to end. Shake the cylinder 90 cycles in approximately 30 s using a throw of 229 ± 25 mm (9 ± 1 in.). A cycle is defined as a complete back and forth motion. To properly shake the cylinder at this speed, it will be necessary for the operator to shake with the forearms only, relaxing the body and shoulders.

Figure 4—Using Hand Method of Shaking

8.5. Following the shaking operation, set the cylinder upright on the work table and remove the stopper.

8.6. *Irrigation Procedure*—Insert the irrigator tube in the cylinder and rinse material from the cylinder walls as the irrigator is lowered. Force the irrigator through the material to the bottom of the cylinder by applying a gentle stabbing and twisting action while the working solution flows from the irrigator tip. This flushes the fine material into suspension above the coarser sand particles. Continue to apply the stabbing and twisting action while flushing the fines upward until the cylinder is filled to the 381-mm (15-in.) mark. Then raise the irrigator slowly without shutting off the flow so the liquid level is maintained at about 381 mm (15 in.) while the irrigator is being withdrawn. Regulate the flow just before the irrigator is entirely withdrawn and adjust the final level to 381 mm (15 in.). The final level of the liquid shall be between the top two graduations on the tube but shall not be above the 381-mm (15-in.) mark when the liquid is read at the bottom of the meniscus.

Note 7—For certain soils, particularly on crushed materials, the stabbing action may not be possible. For these materials, the irrigation technique is as follows: Continue to apply a twisting action as the irrigation tube is slowly withdrawn. As the tube is withdrawn, it is essential that as many fines be flushed upward until the cylinder is filled to the 381-mm mark.

8.7. Allow the cylinder and contents to stand undisturbed for 20 min ± 15 s. Start the timing immediately after withdrawing the irrigator tube.

8.8. At the end of the 20-min sedimentation period, read and record the level of the top of the clay suspension. This is referred to as the "clay reading." If no clear line of demarcation has formed at the end of the specified 20-min sedimentation period, allow the sample to stand undisturbed until a clay reading can be obtained, then immediately read and record the level of the top of the clay suspension and the total sedimentation time. If the total sedimentation time exceeds 30 min, rerun the test using three individual samples of the same material. Read and record the clay column height of that sample requiring the shortest sedimentation period only.

8.9. After the clay reading has been taken, the "sand reading" shall be obtained by one of the following methods:

8.9.1. When using the weighted foot assembly having the sand indicator on the rod of the assembly, place the assembly over the cylinder and gently lower the assembly toward the sand. Do not allow the indicator to hit the mouth of the cylinder as the assembly is being lowered. As the weighted foot comes to rest on the sand, tip the assembly toward the graduations on the cylinder until the indicator touches the inside of the cylinder. Subtract 254 mm (10 in.) from the level indicated by the extreme top edge of the indicator and record this value as the "sand reading" (see Figure 5).

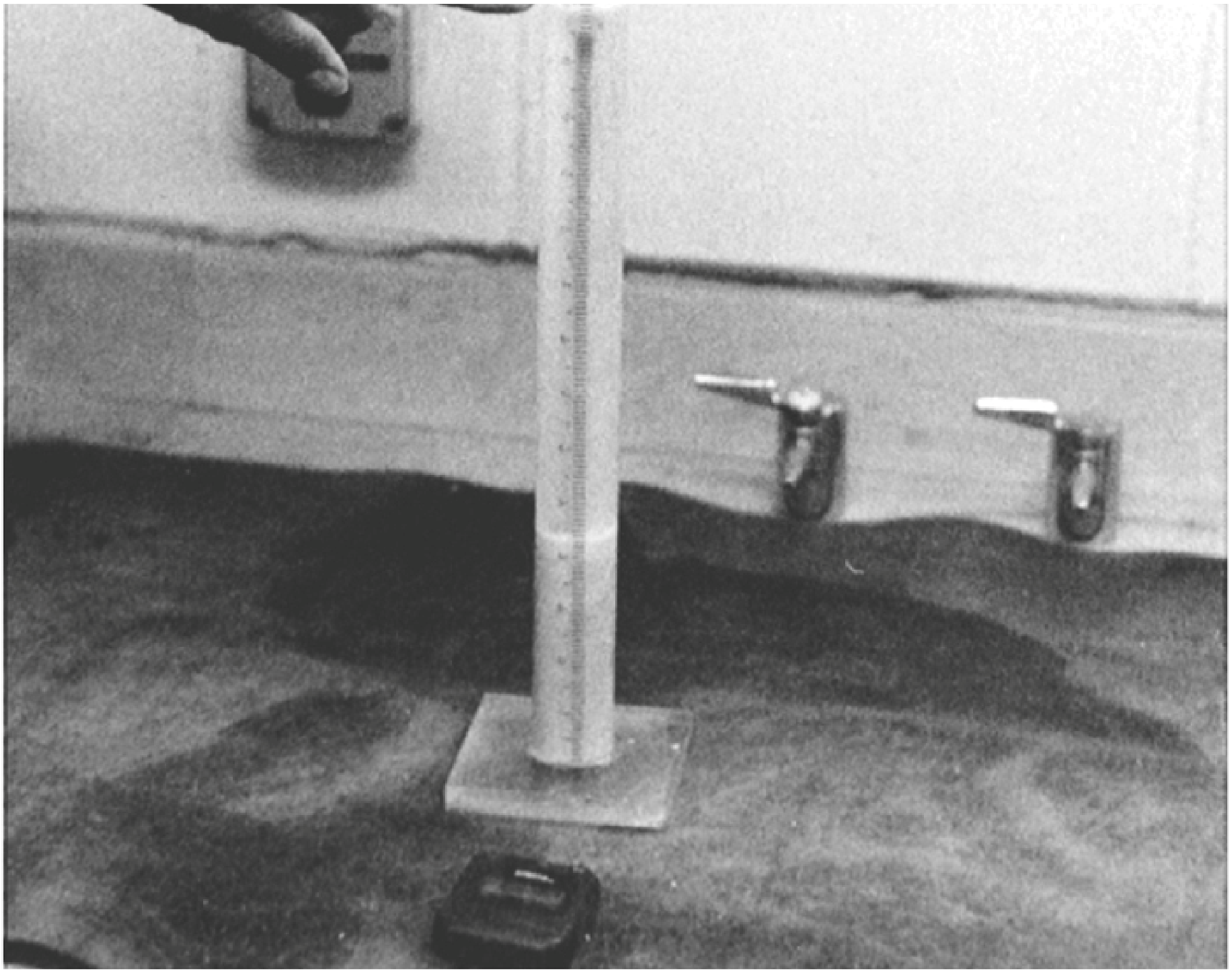


Figure 5—Sand Reading

8.9.2. If an older model weighted foot assembly having centering screws is used, keep one of the centering screws in contact with the cylinder wall near the graduations so it can be seen at all times while the assembly is being lowered. When the weighted foot has come to rest on the sand, read the level of the centering screw and record this value as the "sand reading."

8.10. If clay or sand readings fall between 2.5-mm (0.1-in.) graduations, record the level of the higher graduation as the reading. For example, a clay reading of 7.95 would be recorded as 8.0, and a sand reading of 3.22 would be recorded as 3.3.

Note 8—Samples obtained from aggregate proposed for use in hot-asphalt paving mixtures shall be prepared by oven-drying if acceptance of the material is based on tests on material that has passed through a hot-plant drier.

9. CALCULATIONS

9.1. Calculate the sand equivalent (*SE*) to the nearest 0.1 using the following formula:

$$SE = \frac{\text{sand reading}}{\text{clay reading}} \times 100 \qquad (1)$$

9.2. If the calculated sand equivalent is not a whole number, report it as the next higher whole number, as in the following example:

$$SE = \frac{3.3}{8} \times 100 = 41.3 \tag{2}$$

which is reported as 42.

9.3. If it is desired to average a series of sand equivalent values, average the whole number values determined as described above. If the average of these values is not a whole number, raise it to the next higher whole number, as in the following example: Calculated *SE* values: 41.2, 43.8, 40.9.

After raising each to the next higher whole number, they become: 42, 44, and 41.

The average of these values is then determined:

$$\frac{42 + 44 + 41}{3} = 42.3 \tag{3}$$

9.3.1. Since the average value is not a whole number, it is raised to the next higher whole number and the reported averages and equivalent value is reported as 43.

10. PRECAUTIONS

10.1. Perform the test in a location free of vibrations; vibrations may cause the suspended material to settle at a rate greater than normal.

10.2. Do not expose the plastic cylinders to direct sunlight any more than is necessary.

10.3. *Removal of Organic Growth*—Occasionally it may be necessary to remove an organic growth from the working calcium chloride solution container and from the inside of the flexible tubing and irrigator tube. This organic material can easily be seen as a slimy substance in the solution. To remove this growth, prepare a cleaning solvent by diluting sodium hypochlorite[3] with an equal quantity of water. Fill the solution container with the prepared cleaning solvent, allow about a liter of the cleaning solvent to flow through the siphon assembly and irrigator tube, then place the pinch clamp on the end of the tubing to cut off the flow of solvent and to hold the solvent in the tube. Refill the container and allow it to stand overnight. After soaking, allow the cleaning solvent to flow out through the siphon assembly and irrigator tube. Remove the siphon assembly from the solution container and rinse both with clear water. The irrigator tube and siphon assembly can be rinsed easily by attaching a hose between the tip of the irrigator tube and water faucet and backwashing fresh water through the tube.

10.4. Occasionally the holes in the tip of the irrigator tube may become clogged by a particle of sand. If the obstruction cannot be freed by any other method, use a pin or other sharp object to force it out, using extreme care not to enlarge the size of the opening.

11. KEYWORDS

11.1. Clay soil; plastic fines; plasticity; sand equivalent.

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[1] Available from Aldrich Chemical Company, P.O. Box 2060, Milwaukee, WI 53201 or Fisher Scientific, 711 Forbes Ave., Pittsburgh, PA 15219.

[2] Kathon CG/ICP may be obtained from Rohm and Hass Chemical Company, Independence Mall West, Philadelphia, PA 19105. Kathon CG/ICP contains the following components: 5-chloro-2-methyl-4-isothiazolin-3-one; 2-methyl-4 isothiazolin-3-one; magnesium chloride; and magnesium nitrate.

[3] Household strength liquid bleach or its equivalent has been found satisfactory for this purpose.

Standard Method of Test for Total Evaporable Moisture Content of Aggregate by Drying

AASHTO Designation: T 255-00 (2017)1

Technical Section: 1c, Aggregates

Release: Group 3 (August)

ASTM Designation: C566-13

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1. SCOPE

1.1. This test method covers the determination of the percentage of evaporable moisture in a sample of aggregate by drying both surface moisture and moisture in the pores of the aggregate. Some aggregate may contain water that is chemically combined with the minerals in the aggregate. Such water is not evaporable and is not included in the percentage determined by this test method.

1.2. The values stated in SI units are to be regarded as the standard. The values stated in parentheses are provided for information only.

1.3. *This standard does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user of this procedure to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to its use*. For specific precautionary statements, see Sections 5.3.1, 7.2.1, and 7.3.1.

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2. REFERENCED DOCUMENTS

2.1. *AASHTO Standards*:

- M 231, Weighing Devices Used in the Testing of Materials
- R 90, Sampling Aggregate Products
- T 19M/T 19, Bulk Density (“Unit Weight”) and Voids in Aggregate
- T 84, Specific Gravity and Absorption of Fine Aggregate
- T 85, Specific Gravity and Absorption of Coarse Aggregate

2.2. *ASTM Standards*:

- C125, Standard Terminology Relating to Concrete and Concrete Aggregates
- C670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
- E11, Standard Specification for Woven Wire Test Sieve Cloth and Test Sieves

2.3. *Other Document*:

- National Research Council Report SHRP-P-619

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3. TERMINOLOGY

3.1. *Definitions*—For definitions of terms used in this test method, refer to ASTM C125.

4. SIGNIFICANCE AND USE

4.1. This test method is sufficiently accurate for usual purposes such as adjusting batch quantities of ingredients for concrete. It will generally measure the moisture in the test sample more reliably than the sample can be made to represent the aggregate supply. In rare cases where aggregate itself is altered by heat, or where more refined measurement is required, the test should be conducted using a ventilated, controlled-temperature oven.

4.2. Large particles of coarse aggregate, especially those larger than 50 mm (2 in.), will require greater time for the moisture to travel from the interior of the particle to the surface. The user of this test method should determine by trial if rapid drying methods provide sufficient accuracy for the intended use when drying large-size particles.

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5. APPARATUS

5.1. *Balance*—The balance shall have sufficient capacity, be readable to 0.1 percent of the sample mass, or better, and conform to the requirements of M 231.

5.2. *Source of Heat*—A ventilated oven capable of maintaining the temperature surrounding the sample at 110 ± 5°C (230 ± 9°F). Where close control of the temperature is not required (see Section 4.1), other suitable sources of heat may be used, such as an electric or gas hot plate, electric heat lamps, or a ventilated microwave oven.

5.3. *Sample Container*—A container not affected by the heat, and of sufficient volume to contain the sample without danger of spilling, and of such shape that the depth of sample will not exceed one-fifth of the least lateral dimension.

5.3.1. **Precaution**—When a microwave oven is used, the container shall be nonmetallic.

Note 1—Except for testing large samples, an ordinary frying pan is suitable for use with a hot plate, or any shallow flat-bottomed metal pan with heat lamps or oven. Note precaution in Section 5.3.1.

5.4. *Stirrer*—A metal spoon or spatula of convenient size.

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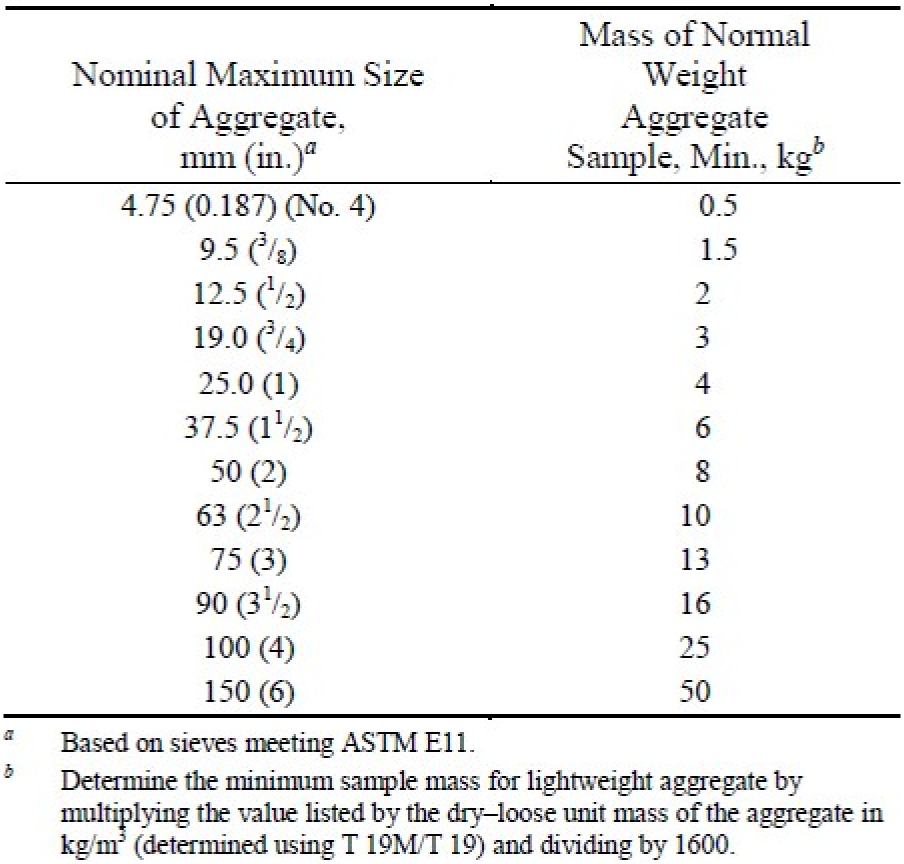
6. SAMPLE

6.1. Sampling shall generally be accomplished in accordance with R 90, except the sample size may be as stated in Table 1.

Table 1—Sample Size for Aggregate



Nominal Maximum Size of Aggregate, mm (in.)[a]	Mass of Normal Weight Aggregate Sample, Min., kg[b]
4.75 (0.187) (No. 4)	0.5
9.5 ($^3/_8$)	1.5
12.5 ($^1/_2$)	2
19.0 ($^3/_4$)	3
25.0 (1)	4
37.5 ($1^1/_2$)	6
50 (2)	8
63 ($2^1/_2$)	10
75 (3)	13
90 ($3^1/_2$)	16
100 (4)	25
150 (6)	50

[a] Based on sieves meeting ASTM E11.

[b] Determine the minimum sample mass for lightweight aggregate by multiplying the value listed by the dry–loose unit mass of the aggregate in kg/m^3 (determined using T 19M/T 19) and dividing by 1600.

6.2. Secure a sample of the aggregate representative of the moisture content in the supply being tested and having a mass not less than the amount listed in Table 1. Protect the sample against loss of moisture prior to determining the mass.

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7. PROCEDURE

7.1. Determine the mass of the sample to the nearest 0.1 percent.

7.2. Dry the sample thoroughly in the sample container by means of the selected source of heat, exercising care to avoid loss of any particles. Very rapid heating may cause some particles to explode, resulting in loss of particles. Use a controlled temperature oven when excessive heat may alter the character of the aggregate, or where more precise measurement is required. If a source of heat other than the controlled temperature oven is used, stir the sample during drying to accelerate the operation and avoid localized overheating. When using a microwave oven, stirring of the sample is optional.

7.2.1. **Caution**: When using a microwave oven, occasionally minerals are present in aggregates that may cause the material to overheat and explode. If this occurs, it can damage the microwave oven.

7.3. When a hot plate is used, drying can be expedited by the following procedure. Add sufficient anhydrous denatured alcohol to cover the moist sample. Stir and allow suspended material to settle. Decant as much of the alcohol as possible without losing any of the sample. Ignite the remaining alcohol and allow it to burn off during drying over the hot plate.

7.3.1. **Warning**: Exercise care to control the ignition operation to prevent injury or damage from the burning alcohol.

7.4. The sample is thoroughly dry when further heating causes, or would cause, less than 0.1 percent additional loss in mass.

7.5. Determine the mass of the dried sample to the nearest 0.1 percent after it has cooled sufficiently not to damage the balance.

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8. CALCULATION

8.1. Calculate total evaporable moisture content as follows:

$$p = 100(W - D)/D \tag{1}$$

where:

p = total evaporable moisture content of sample, percent;

W = mass of original sample, g; and

D = mass of dried sample, g.

8.2. Surface moisture content is equal to the difference between the total evaporable moisture content and the absorption, with all values based on the mass of a dry sample. Absorption may be determined in accordance with T 85, Test for Specific Gravity and Absorption of Coarse Aggregate, or T 84, Test for Specific Gravity and Absorption of Fine Aggregate.

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9. PRECISION AND BIAS

9.1. *Precision*:

9.1.1. The within-laboratory single-operator standard deviation for moisture content of aggregates has been found to be 0.28 percent (Note 2). Therefore, results of two properly conducted tests by the same operator in the same laboratory on the same type of aggregate sample should not differ by more than 0.79 percent (Note 2) from each other.

9.1.2. The between-laboratory standard deviation for moisture content of aggregates has been found to be 0.28 percent (Note 2). Therefore, results of properly conducted tests from two laboratories on the same aggregate sample should not differ by more than 0.79 percent (Note 2) from each other.

9.1.3. Test data used to derive the above precision indices were obtained from samples dried to a constant mass in a drying oven maintained at 110 ± 5°C. When other drying procedures are used, the precision of the results may be significantly different than that indicated above.

Note 2—These numbers represent, respectively, the 1s and d2s limits as described in ASTM C670.

9.2. *Bias*:

9.2.1. When experimental results are compared with known values from accurately compounded specimens, the following has been derived.

9.2.1.1. The bias of moisture tests on one aggregate material has been found to have a mean of +0.06 percent. The bias of individual test values from the same aggregate material has been found with 95 percent confidence to lie between –0.07 percent and +0.20 percent.

9.2.1.2. The bias of moisture tests on a second aggregate material has been found to have a mean of less than +0.01 percent. The bias of individual test values from the same aggregate material has been found with 95 percent confidence to lie between –0.14 percent and +0.14 percent.

9.2.1.3. The bias of moisture tests overall on both aggregate materials has been found to have a mean of +0.03 percent. The bias of individual test values overall from both aggregate materials has been found with 95 percent confidence to lie between –0.12 percent and +0.18 percent.

9.2.2. Test data used to derive the above bias statement were obtained from samples dried to a constant mass in a drying oven maintained at 110 ± 5°C. When other drying procedures are used, the bias of the results may be significantly different than that indicated above.

Note 3—These precision and bias statements were derived from aggregate moisture data provided by 17 laboratories participating in the SHRP Soil Moisture Proficiency Sample Program, which is fully described in the National Research Council Report SHRP-P-619. The samples tested that relate to these statements were well-graded mixtures of fine and coarse aggregate with moisture contents ranging from air dry to saturated surface-dry.

10. KEYWORDS

10.1. Aggregate; drying; moisture content.

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[1] This method is technically equivalent to ASTM C566-13, except for the balance statement in Section 5.1.

Standard Method of Test for Laboratory Determination of Moisture Content of Soils

AASHTO Designation: T 265-15

Technical Section: 1a, Soil and Unbound Recycled Materials

Release: Group 3 (August)

1. SCOPE

1.1. This method covers the laboratory determination of the moisture content of soils.

1.2. The following applies to all specified limits in this standard: For the purposes of determining conformance with these specifications, an observed value or a calculated value shall be rounded off "to the nearest unit" in the last right-hand place of figures used in expressing the limiting value, in accordance with ASTM E29.

2. REFERENCED DOCUMENTS

2.1. *AASHTO Standard*:

- M 231, Weighing Devices Used in the Testing of Materials

2.2. *ASTM Standards*:

- C670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
- E29, Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

2.3. *Other Document*:

- NCHRP Web-Only Document 164: Precision Estimates of AASHTO T 265: Laboratory Determination of Moisture Content of Soils

3. TERMINOLOGY

3.1. *moisture or water content of a soil*—the ratio, expressed as a percentage, of the mass of water in a given mass of soil to the mass of the solid particles. Practical application is to determine the mass of water removed by drying the moist soil to a constant mass in a drying oven controlled at 110 ± 5°C (230 ± 9°F) and to use this value as the mass of water in the given soil mass. The mass of soil remaining after oven-drying is used as the mass of the solid particles.

4. APPARATUS

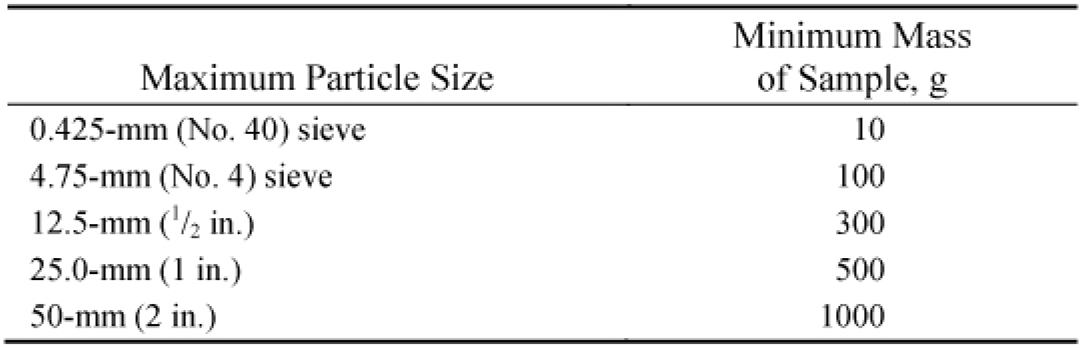
4.1. *Drying Oven*—Thermostatically controlled, preferably of the forced-draft type, capable of being heated continuously at a temperature of 110 ± 5°C (230 ± 9°F).

4.2. *Balance*—The balance shall have sufficient capacity, be readable to 0.1 percent of the sample mass, or better, and conform to the requirements of M 231.

4.3. *Containers*—Suitable containers made of material resistant to corrosion and not subject to change in mass or disintegration on repeated heating and cooling. Containers shall have close-fitting lids to prevent loss of moisture from samples before initial weighing and to prevent absorption of moisture from the atmosphere following drying and before final weighing. One container is needed for each moisture content determination.

5. TEST SAMPLE

5.1. Select a representative quantity of moist soil in the amount indicated in the method of test. If no amount is indicated, the minimum mass of the sample shall be in accordance with the following table:



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

6. PROCEDURE

6.1. Weigh a clean, dry container with its lid and place the moisture content sample in the container. Replace the lid immediately and weigh the container, including the lid and the moist sample. Remove the lid and place the container with the moist sample in the drying oven maintained at a temperature of 110 ± 5°C (230 ± 9°F) and dry overnight (15 h minimum) or dry until the mass loss of the sample after 1 h of additional drying is less than 0.1 percent (constant mass) (Notes 1 and 2). Immediately upon removal from the oven, place the lid and allow the sample to cool to room temperature. Weigh the container including the lid and the dried sample (Notes 3 and 4).

Note 1—In cases where there is doubt concerning the adequacy of overnight drying, drying should continue until constant mass is achieved. Samples of sand may often be dried to constant mass in a period of several hours. Since dry soil may absorb moisture from wet samples, dried samples should be removed before placing wet samples in the oven.

Note 2—Oven-drying at 110 ± 5°C (230 ± 9°F) does not result in reliable moisture content values for soil containing gypsum or other minerals having loosely bound water from hydration or for soil containing significant amounts of organic material. Reliable moisture content values for these soils can be obtained by drying in an oven at approximately 60°C (140°F), or by vacuum desiccation at a pressure of approximately 10 mmHg and at a temperature not lower than 23°C (73°F).

Note 3—A container without a lid may be used provided the moist sample is weighed immediately after being taken, and provided the dried sample is weighed immediately after being removed from the oven or after cooling in a desiccator.

Note 4—Moisture content samples should be discarded and should not be used in any other tests.

7. CALCULATION

7.1. Calculate the moisture content of the soil as follows:

$$w=\left[\frac{(\text{mass of moisture})}{(\text{mass of oven-dry soil})}\right]\times 100=\left[\frac{(W_1-W_2)}{(W_2-W_c)}\right]\times 100 \qquad (1)$$

where:

w = moisture content, percent;

W_1 = mass of container and moist soil, g;

W_2 = mass of container and oven-dried soil, g; and

W_c = mass of container, g.

7.2. Calculate the percent of moisture content to the nearest 0.1 percent.

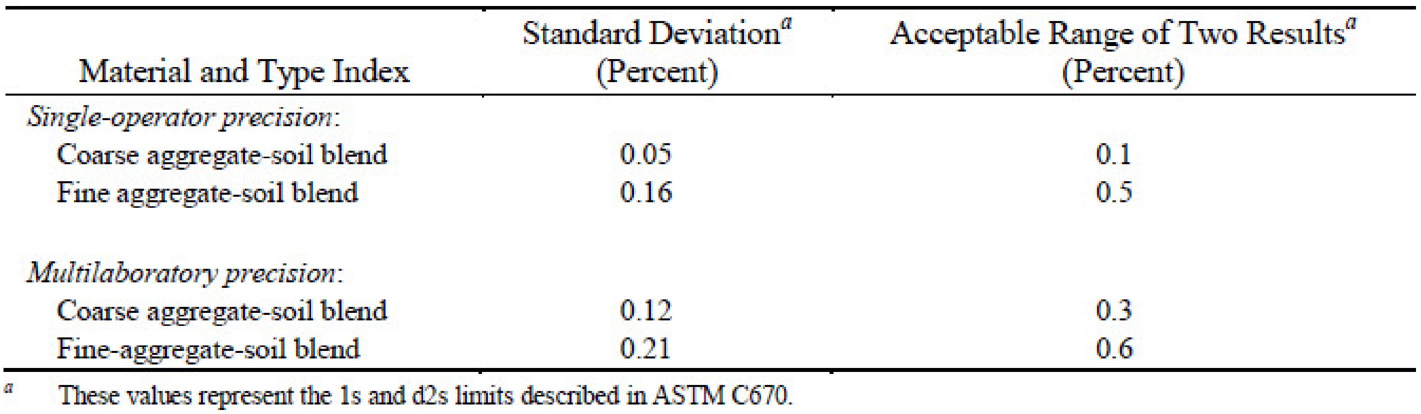
8. PRECISION AND BIAS

8.1. *Precision*—Criteria for judging the acceptability of determining percentage of moisture content of soil using T 265 are given in Table 1:

8.1.1. *Single-Operator Precision (Repeatability)*—The figures in Column 2 of Table 1 are the standard deviations that have been found to be appropriate for percent moisture content of the materials in Column 1. Two results obtained in the same laboratory, by the same operator using the same equipment, in the shortest practical period of time, should not be considered suspect unless the difference in the two results exceed the single-operator limits given in Table 1, Column 3.

8.1.2. *Multilaboratory Precision (Reproducibility)*—The figures in Column 2 of Table 1 are the standard deviations that have been found to be appropriate for the percent moisture content of the materials in Column 1. Two results submitted by two different operators testing the same material in different laboratories shall not be considered suspect unless the difference in the two results exceeds the multilaboratory limits given in Table 1, Column 3.

Table 1—Precision Estimates for T 265



Material and Type Index	Standard Deviation[a] (Percent)	Acceptable Range of Two Results[a] (Percent)
Single-operator precision:		
Coarse aggregate-soil blend	0.05	0.1
Fine aggregate-soil blend	0.16	0.5
Multilaboratory precision:		
Coarse aggregate-soil blend	0.12	0.3
Fine-aggregate-soil blend	0.21	0.6

[a] These values represent the 1s and d2s limits described in ASTM C670.

Note 5—The precision estimates given in Table 1 are based on the analysis of test results from an AMRL interlaboratory study (ILS). The ILS data consisted of results from 26 to 29 laboratories that tested three replicates of four different aggregate-soil blends each having about 7 percent passing a No. 200 sieve. The average moisture contents of the test specimens ranged from 3 to 6 percent. The details of this analysis are in NCHRP Web-Only Document 164.

8.2. *Bias*—No information can be presented on the bias of the procedure because no comparison with the material having an accepted reference value was conducted.

9. KEYWORDS

9.1. Moisture content; pore water; soil moisture.

APPENDIX A1
December 4, 2015
(2 Pages)

ROUNDING PROCEDURE

The following describes the rounding procedure which is to be used for rounding numbers to the required degree of accuracy:

1. Except as specified in Section 2 below, the following procedure will apply. This procedure correlates with the "built-in" rounding method normally utilized by calculators and computers.

1.1 When the figure next beyond the last figure or place to be retained is less than 5, the figure in the last place retained is left unchanged.

Examples:
Rounding 2.6324 to the nearest thousandth is 2.632
Rounding 7843.343 to the nearest hundredth is 7843.34
Rounding 4928.22 to the nearest tenth is 4928.2
Rounding 7293.1 to the nearest whole number is 7293
Rounding 2042 to the nearest units of 10 is 2040
Rounding 3548 to the nearest units of 100 is 3500
Rounding 8436 to the nearest units of 1000 is 8000

1.2 When the figure next beyond the last figure or place to be retained is 5 or larger, the figure in the last place retained is increased by 1.

Examples:
Rounding 4839.4575 to the nearest thousandth is 4839.458
Rounding 9347.215 to the nearest hundredth is 9347.22
Rounding 8420.35 to the nearest tenth is 8420.4
Rounding 1728.5 to the nearest whole number is 1729
Rounding 3685 to the nearest units of 10 is 3690
Rounding 6650 to the nearest units of 100 is 6700
Rounding 2500 to the nearest units of 1000 is 3000

Rounding 2.6326 to the nearest thousandth is 2.633
Rounding 7843.347 to the nearest hundredth is 7843.35
Rounding 4928.28 to the nearest tenth is 4928.3
Rounding 7293.9 to the nearest whole number is 7294
Rounding 2046 to the nearest units of 10 is 2050
Rounding 3572 to the nearest units of 100 is 3600
Rounding 8634 to the nearest units of 1000 is 9000

1.3 No result shall be rounded more than once.

Example: 3024.5 rounded to the nearest units of 10 will be 3020;

<u>not</u>

3024.5 rounded to 3025, and then rounded again to 3030.

2. The rounding procedure specified in Section 1 above shall be used for all calculations and recording of data in performing materials testing, except when a specific test method cites a method of rounding which differs from this procedure, for example, the sand equivalent test (AASHTO T 176 or Arizona Test Method 242).

3. Compliance will be based upon interpreting the reported results as though they are rounded to the terms (whole numbers, decimals, or fractions reduced to decimals) of the specifications. For example, a value reported as 8.4% shall be considered as having no deviation from specifications that require 4 – 8%. It would however be a deviation for specifications requiring 4.0 – 8.0%.

4. Computers and most electronic calculators automatically carry several decimal places beyond the point of desired accuracy. At times, results of calculations utilizing these values are different than that achieved when calculations are performed utilizing values that have been rounded to the desired degree of accuracy by the above rules. The user is cautioned that the use of a computer or electronic calculator without re-entry of values after rounding, and discarding any figures beyond those needed, may cause unacceptable variations in final results.

APPENDIX A2
November 2, 2018
(8 Pages)

METRIC GUIDE

The following information is provided as a guide for utilizing the International System of Units (SI), generally referenced as "metric units". Related information can be found in AASHTO R1 "Metric Practice Guide", and ASTM E380, "Use of the International System of Units (SI)(The Modernized Metric System)".

Included herein are commonly used equivalents and conversions for U.S. Customary Units and Metric Units. It is not the intention of this guide to provide a detailed compilation of such equivalents and conversions. Such lists are available in many publications, including those referenced above.

One common conversion, which is found in many test procedures, is to determine an equivalent temperature in units of either degrees Celsius or degrees Fahrenheit.

Convert degrees Fahrenheit to degrees Celsius by:

$$^{\circ}C = \frac{5}{9} \times \left(^{\circ}F - 32\right)$$

Convert degrees Celsius to degrees Fahrenheit by:

$$^{\circ}F = \left[\frac{9}{5} \times {}^{\circ}C\right] + 32$$

Under the SI (Metric) system, the base unit for mass is the "kilogram". (Although not technically correct, "weight" is often used in common practice to mean "mass".) The base unit for length is the "meter". The base unit for time is the "second". Primary metric units for area and volume are the "square meter" and the "cubic meter", respectively.

In addition to expressing values in the base or primary metric units, other associated metric units are identified and determined by varying the magnitude of the base metric unit by powers of 10. Metric values are commonly shown in scientific notation form, (for example, $1 \times 10^{4} = 10{,}000$; $1 \times 10^{-4} = 0.0001$).

Table 1 below gives a listing of prefixes used in the metric system, with their associated powers of ten, and their symbol.

TABLE 1

Prefix	Power of ten	Symbol
*deci	10^{-1}	d
*centi	10^{-2}	c
milli	10^{-3}	m
micro	10^{-6}	μ
nano	10^{-9}	n
pico	10^{-12}	p
femto	10^{-15}	f
atto	10^{-18}	a
*deka	10^{1}	da
*hecto	10^{2}	h
kilo	10^{3}	k
mega	10^{6}	M
giga	10^{9}	G
tera	10^{12}	T
peta	10^{15}	P
exa	10^{18}	E

* Use is to be avoided where practical. When expressing a quantity by a numerical value and a unit, a prefix should preferably be chosen so that the numerical value lies between 0.1 and 1000. In expressing area and volume, the prefixes hecto, deka, deci, and centi may be required, for example, square hectometer, cubic centimeter.

Table 2 below gives the symbols commonly used for various metric units.

TABLE 2

kg = kilogram
g = gram
mg = milligram
m = meter
km = kilometer
cm = centimeter
mm = millimeter
μm = micrometer (micron)
s = second
m^2 = square meter
cm^2 = square centimeter
mm^2 = square millimeter
m^3 = cubic meter
cm^3 or cc = cubic centimeter
mm^3 = cubic millimeter
L = liter
mL = milliliter
Pa = pascal
N = newton
kPa = kilopascal
MPa = megapascal

Table 3 below includes common conversions from the base and primary metric units (kilogram, meter, square meter, and cubic meter) to other associated metric units. Also listed are some common derived metric units.

TABLE 3

1 gram = 0.001 kilogram
1 milligram = 1 x 10^{-6} kilogram
1 milligram = 0.001 gram
1 kilogram = 1000 grams
1 metric ton = 1000 kilograms
1 kilometer = 1000 meters
1 centimeter = 0.01 meter
1 millimeter = 0.001 meter
1 micron (micrometer) = 1 x 10^{-6} meter
1 square kilometer = 1 x 10^{6} square meters
1 square centimeter = 1 x 10^{-4} square meter
1 square millimeter = 1 x 10^{-6} square meter
1 cubic centimeter = 1 x 10^{-6} cubic meter
1 cubic millimeter = 1 x 10^{-9} cubic meter
1 liter = 0.001 cubic meter
1 milliliter = 1 x 10^{-6} cubic meter
1 milliliter = 1 cubic centimeter
1 newton = 1 $kg \cdot m/s^2$
1 pascal = 1 N/m^2
1 kilopascal = 1000 pascals
1 megapascal = 1 x 10^{6} pascals
1 poise (absolute viscosity) = 0.10 $Pa \cdot s$
1 centistoke (kinematic viscosity) = 1 mm^2/s or 1 x 10^{-6} m^2/s

Some common U.S Customary units, with their corresponding base and primary metric unit equivalents, are given below in Table 4.

TABLE 4

1 pound (avoirdupois) = 0.453 5924 kilogram
1 ton (2000 lbs.) = 907.1847 kilograms
* 1 inch = 0.0254 meter
* 1 foot = 0.3048 meter
* 1 yard = 0.9144 meter
* 1 mile (5280 feet) = 1609.344 meters
* 1 square inch = 6.4516 x 10^{-4} square meter
* 1 square foot = 0.092 903 04 square meter
1 square yard = 0.836 1274 square meter
1 cubic inch = 1.638 706 x 10^{-5} cubic meter
1 cubic foot = 0.028 316 85 cubic meter
1 cubic yard = 0.764 5549 cubic meter
1 pint (U.S. liquid) = 4.731 765 x 10^{-4} cubic meter
1 quart (U.S. liquid) = 9.463 529 x 10^{-4} cubic meter
1 gallon (U.S. liquid) = 0.003 785 412 cubic meter

(Exact equivalents are noted with an asterisk.)

Table 5 below lists commonly used conversions for U.S. Customary Units and metric units. Values are shown to the degree of accuracy which generally may be used to achieve satisfactory results. If more accuracy is desired, the values may be derived by using Tables 3 and 4.

TABLE 5

1 kilogram = 2.205 pounds
1 pound = 453.6 grams
1 ounce (avoirdupois) = 28.35 grams
1 ton (2000 lbs) = 0.9072 metric ton
1 meter = 39.37 inches or 3.281 feet
1 kilometer = 0.62 miles
* 1 mil = 0.0254 millimeters or 25.4 micrometers
* 1 inch = 2.54 centimeters or 25.4 millimeters
* 1 foot = 0.3048 meters
* 1 yard = 0.9144 meters
1 mile = 1.61 kilometers
1 square inch = 6.452 cm^2 or 645.16 mm^2
1 square foot = 0.0929 square meters
1 square yard = 0.836 square meters
1 cubic inch = 16.39 cm^3 or 16386 mm^3
1 cubic foot = 0.028 m^3 or 28317 cm^3
1 cubic yard = 0.765 cubic meters
1 liter = 1.06 quarts (U.S. liquid)
1 ounce (U.S. fluid) = 29.574 milliliter
1 pint (U.S. liquid) = 0.47 liter
1 quart (U.S. liquid) = 0.95 liter
1 gallon (U.S. liquid) = 3.79 liters
1 lb/ft^3 = 16.02 kg/m^3
1 kilometer/hour = 0.62 mile/hour
1 mile/hour = 1.61 km/hour
1 pound/square inch = 6.895 kPa
1 pound force = 4.448 newton
1 gallon/square yard = 4.527 liters/m^2
1 gallon/ton (2000 lbs.) = 4.173 liters/metric ton
1 gallon/cubic yard = 4.951 liters/m^3
1 pound/square yard = 0.542 kg/m^2
1 pound/cubic yard = 0.593 kg/m^3
1 pound/gallon = 0.120 kg/liter
1 cubic yard/square yard = 0.914 m^3/m^2
1 inch/mile = 0.0158 meter/kilometer

(Exact equivalents are noted with an asterisk.)

Table 6 below is from information contained in ASTM E11 "Standard Specification for Woven Wire Test Sieve Cloth and Test Sieves", and shows Standard (Metric) and Alternative (U.S. Customary) sieve size designations. As shown, metric size designations are given in mm or µm. (1,000 µm = 1 millimeter)

8 inch diameter sieve = 203.2 mm diameter sieve
12 inch diameter sieve = 304.8 mm diameter sieve

TABLE 6

Sieve Designation		Sieve Designation	
Standard	Alternate	Standard	Alternate
125 mm	5 in.	2.36 mm	No. 8
106 mm	4.24 in.	2.00 mm	No. 10
100 mm	4 in.	1.70 mm	No. 12
90 mm	3-1/2 in.	1.40 mm	No. 14
75 mm	3 in.	1.18 mm	No. 16
63 mm	2-1/2 in.	1.00 mm	No. 18
53 mm	2.12 in.	850 µm	No. 20
50 mm	2 in.	710 µm	No. 25
45 mm	1-3/4 in.	600 µm	No. 30
37.5 mm	1-1/2 in.	500 µm	No. 35
31.5 mm	1-1/4 in.	425 µm	No. 40
26.5 mm	1.06 in.	355 µm	No. 45
25.0 mm	1 in.	300 µm	No. 50
22.4 mm	7/8 in.	250 µm	No. 60
19.0 mm	3/4 in.	212 µm	No. 70
16.0 mm	5/8 in.	180 µm	No. 80
13.2 mm	0.530 in.	150 µm	No. 100
12.5 mm	1/2 in.	125 µm	No. 120
11.2 mm	7/16 in.	106 µm	No. 140
9.5 mm	3/8 in.	90 µm	No. 170
8.0 mm	5/16 in.	75 µm	No. 200
6.7 mm	0.265 in.	63 µm	No. 230
6.3 mm	1/4 in.	53 µm	No. 270
5.6 mm	No. 3-1/2	45 µm	No. 325
4.75 mm	No. 4	38 µm	No. 400
4.00 mm	No. 5	32 µm	No. 450
3.35 mm	No. 6	25 µm	No. 500
2.80 mm	No. 7	20 µm	No. 635

TABLE 7

SI* (METRIC) CONVERSION FACTORS

(Approximate equivalents, except as noted**)

CONVERSIONS TO SI UNITS					CONVERSIONS FROM SI UNITS				
Abbrev./Symbol	*When you know*	*Multiply by*	*To find*	*Symbol*	*Symbol*	*When you know*	*Multiply by*	*To find*	*Abbrev./Symbol*
		LENGTH					**LENGTH**		
in.	inches	25.4**	millimeters	mm	mm	millimeters	0.03937	inches	in.
ft.	feet	0.3048**	meters	m	m	meters	3.28	feet	ft.
yd.	yards	0.9144**	meters	m	m	meters	1.09	yards	yd.
mi.	miles	1.61	kilometers	km	km	kilometers	0.621	miles	mi.
		AREA					**AREA**		
sq. in. or in^2	square inches	645.2	square millimeters	mm^2	mm^2	square millimeters	0.0016	square inches	sq. in. or in^2
sq. ft. or ft^2	square feet	0.093	square meters	m^2	m^2	square meters	10.764	square feet	sq. ft. or ft^2
sq. yd. or yd^2	square yards	0.836	square meters	m^2	m^2	square meters	1.19	square yards	sq. yd. or yd^2
	acres	0.405	hectares	ha	ha	hectares	2.47	acres	
sq. mi. or mi^2	square miles	2.59	square kilometers	km^2	km^2	square kilometers	0.386	square miles	sq. mi. or mi^2
		VOLUME					**VOLUME**		
fl. oz.	fluid ounces	29.57	milliliters	mL	mL	millimeters	0.034	fluid ounces	fl. oz.
gal.	gallons (liquid)	3.7854	liters***	L	L	liters***	0.264	gallons (liquid)	gal.
cu. ft. or ft^3	cubic feet	0.028	cubic meters	m^3	m^3	cubic meters	35.315	cubic feet	cu. ft. or ft^3
cu. yd. or yd^3	cubic yards	0.765	cubic meters	m^3	m^3	cubic meters	1.31	cubic yards	cu. yd. or yd^3
		MASS					**MASS**		
oz.	ounces	28.35	grams	g	g	grams	0.035	ounces	oz.
lb.	pounds	0.454	kilograms	kg	kg	kilograms	2.205	pounds	lb.
T	short tons (2000 lb)	0.907	metric tons****	t	t	metric tons****	1.102	short tons (2000 lb)	T
T	short tons (2000 lb)	0.907	megagrams****	Mg	Mg	megagrams****	1.102	short tons (2000 lb)	T

* SI is the symbol for the International System of Units.

** Exact equivalent.

*** Metric volumes greater than 1000 liters should be shown in m^3. The following conversion factors are helpful in making necessary conversions:
1 liter = 0.001 cubic meter; 1 cubic meter = 264.17 gallons (liquid).

**** 1 metric ton = 1000 kilograms = 1,000,000 grams = 1 Mg.