

NOTICE

UDOT-TTQP

UDOT "TTQP" manual included; Long Form Versions listed.

- "WAQTC/TTQP" Certifications are listed as a 5 day course.
- 3 min. days of "Training" (completed outside of certification days).
- 2 days of "Certification" (completed at UDOT Central unless otherwise specified).

3 training + 2 certifying = 5 days!

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GUIDANCE FOR COURSE EVALUATION FORM

The Course Evaluation Form on the following page is very important to the continuing improvement and success of this course. The form is included in each Participant Workbook. During the course introduction, the Instructor will call the participants' attention to the form, its content, and the importance of its thoughtful completion at the end of the course. Participants will be encouraged to keep notes, or write down comments as the class progresses, in order to provide the best possible evaluation. The Instructor will direct participants to write down comments at the end of each day and to make use of the back of the form if more room is needed for comments.

On the last day of the course, just prior to the written examination, the Instructor will again refer to the form and instruct participants that completion of the form after their last examination is a requirement prior to leaving. Should the course have more than one Instructor, participants should be directed to list them as A, B, etc., with the Instructor's name beside the letter, and direct their answers in the Instructor Evaluation portion of the form accordingly.

UTAH DEPARTMENT OF TRANSPORTATION TTQP COURSE EVALUATION FORM

The UDOT Transportation Technician Qualification Program would appreciate your thoughtful completion of all items on this evaluation form. Your comments and constructive suggestions will be an asset in our continuing efforts to improve our course content and presentations.

Course Title: _____

Location: _____

Dates: _____

Employer: _____

Instructor(s) _____

Please circle your responses to the following questions, where 1 is the lowest and 5 is the highest rating. If you wish to make comments, do so in the space provided at the end of the form.

COURSE MATERIALS

1. Were the manuals written so that instructional material was clearly presented?

1 2 3 4 5

2. Did the review questions at the ends of the Field Operating Procedures help you understand the information presented in the manuals?

1 2 3 4 5

3. How effective were the PowerPoint review presentations in helping you understand the study materials?

1 2 3 4 5

4. How effective was the sample test in helping you prepare for the written examinations?

1 2 3 4 5

CLASSROOM INSTRUCTION

5. Were the instructors knowledgeable, and did they clearly communicate the information?

Instructor #1 Name: _____ 1 2 3 4 5

Instructor #2 Name: _____ 1 2 3 4 5

6. Did the instructors create an open atmosphere in which to ask questions, and give adequate attention in answering them?

Instructor #1 Name: _____ 1 2 3 4 5

COURSE OBJECTIVES AND SCHEDULE

Learning Objectives

Instructional objectives for this course include:

- Becoming proficient in the following test procedures:
 - AASHTO T 19
Bulk Density (“Unit Weight”) and Voids in Aggregate
 - AASHTO T 21
Organic Impurities in Concrete Sand
 - AASHTO T 84
Specific Gravity and Absorption of Fine Aggregate
 - AASHTO T 85
Specific Gravity and Absorption of Coarse Aggregate
 - AASHTO T 96 & ASTM C 535
Resistance to Abrasion of Small-Size and Large-size Coarse Aggregate
 - AASHTO T 104
Soundness of Aggregate Using Magnesium or Sodium Sulfate
 - AASHTO T 112
Clay Lumps and Friable Particles in Aggregates
 - AASHTO T 113
Lightweight Pieces in Aggregate
 - AASHTO T 193
California Bearing Ratio of Soils
 - AASHTO T 304
Uncompacted Void Content of Fine Aggregate

The overall goals of this course are to understand the basics of laboratory tests and to be competent with specific quality control test procedures identified for the Utah Department of Transportation (UDOT) Transportation Technician Qualification Program (TTQP).

It is assumed that the student has previously obtained a copy of the manual, and has adequately prepared for the qualification by studying and receiving training from a senior trainer.

Course Outline and Suggested Schedule**Day One**

0900	Welcome Introduction of Instructors
0915	Presentations
1200	Lunch
1300	Presentations. Distribute copies of Sample Exams

Day Two

0800	Review Sample Exam and answer questions from the Previous Day
0900	Start of Written Exams
Varies	Practical Exams (After successful completion of written exam)

**BULK DENSITY (“UNIT WEIGHT”) AND VOIDS IN AGGREGATE
FOP FOR AASHTO T 19**

02

Scope

This FOP describes methods for determining bulk density and void content of aggregates not exceeding five inches in nominal maximum size. Aggregates are tested in a compacted state unless loose bulk density is required by the specifying agency. The procedure yields values based on aggregates in a dry condition.

A representative aggregate sample is placed in a calibrated measure and the mass determined. The bulk density is calculated by dividing the aggregate mass by the volume of the measure. Bulk density for this FOP is expressed as pounds per cubic foot (lb/ft³). Void content is expressed as a percentage and will require knowledge of the $G_{sb}(OD)$ (oven-dry bulk specific gravity) of the aggregate.

03

Significance

Results of this test method are frequently used when materials are proportioned on a volume basis or where a minimum density is specified by the governing agency. The test is also useful in determining mass/volume relationships for purchase agreements.

04

Apparatus

- **Balance:** Of sufficient capacity and readable to 0.1% of sample mass or better. Must meet the requirements of AASHTO M 231.
- **Tamping Rod:** A round steel rod of $\frac{5}{8}$ inch diameter, approximately 24 inches in length, with one end rounded to a hemispherical tip of the same diameter as the rod.

05

- **Measure:** A cylindrical metal measure with the top and bottom parallel to each other. The height should be 80 to 150 percent of the diameter. The volume of the measure shall conform to the requirements of Table 1. The top rim shall be plane and smooth within 0.01 inch and the interior wall of the measure shall be smooth and seamless. The metal thickness of the measure shall conform to the requirements of Table 2.

06

- **Shovel or Scoop:** Of convenient size and shape for filling the measure.
- **Calibration Equipment:** A piece of plate glass at least 1/4 inch thick, and at least 1 inch larger than the diameter of the measure.
- **Thermometer (for Calibration):** Range of 50 – 90° F, readable to 1° F.

Table 1 – Capacities of Measures

07

Nominal Maximum Aggregate Size	Capacity of Measure *
1/2"	1/10 ft ³
1"	1/3 ft ³
1 1/2"	1/2 ft ³
3"	1 ft ³
4"	2.5 ft ³
5"	3.5 ft ³

* The actual volume of the measure shall be at least 95% of the nominal volume indicated in this table.

Table 2 – Requirements for Measures

08

Capacity of Measure	Thickness of Metal		
	Bottom	Upper 1 1/2" of Wall *	Remainder of Wall
Less than 0.4 ft ³	0.20 in.	0.10 inch	0.10 inch
0.4 through 1.5 ft ³	0.20 in.	0.20 inch	0.12 inch
Over 1.5 through 2.8 ft ³	0.4 in.	0.25 inch	0.15 inch
Over 2.8 through 4.0 ft ³	0.5 in.	0.3 inch	0.20 inch

* The additional upper wall thickness may be achieved by attaching a reinforcing band at the top of the measure.



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Calibration of Measure

Measures shall be calibrated annually, or whenever there is a question of accuracy, according to the following steps:

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1. Determine mass to the nearest 0.1 lb (50 g). (This does not preclude making mass determinations of greater accuracy).
2. Determine the mass of the clean dry measure and glass plate.
3. Fill the measure with water at room temperature and cover with the glass plate in such a way as to eliminate air bubbles.
4. Leaving the glass plate in place, remove water from the exposed surfaces of the glass plate and measure and determine the mass of the measure, water and glass plate.
5. Subtract the mass of the empty measure and glass plate.
6. Remove the glass plate and determine the temperature of the water in the measure (nearest 1°F). Find the density of water corresponding to the measured temperature in Table 3, interpolating if needed.
7. Divide the mass of water in the measure by the density determined in the previous step. Express the volume of the measure to the nearest 0.001 ft³.

Table – 3 Density of Water

14

Temperature (° F)	Density (lb/ft ³)
60	62.366
65	62.336
70	62.301
(73.4)	(62.274)
75	62.261
80	62.216
85	62.166

15

Sampling

- Obtain the sample according to AASHTO T 2. Reduce to appropriate testing size according to AASHTO T 248.

Note 1: For this FOP, Nominal Maximum Size is one specification sieve size larger than the first sieve to cumulatively retain more than 10 percent.



Sample Preparation

- 16 • The test sample shall represent a volume approximately 125 to 200 percent of that required to fill the measure.
- The sample shall be handled in such a way as to prevent segregation.
- Dry the sample to constant mass in an oven regulated at 230 ±9°F according to the FOP for AASHTO T 255. Cool to room temperature prior to conducting the test.

Selection of Procedure

17 The shoveling procedure for loose bulk density shall only be permitted when the governing agency requires it. Otherwise, compaction of the aggregate in the measure shall be by rodding or jiggling depending on nominal maximum aggregate size.

Rodding: Compact the aggregate in the measure by rodding when the nominal maximum aggregate size is less than or equal to 1½ inch.

Jiggling: Compact the aggregate in the measure by jiggling for nominal maximum aggregate sizes larger than 1½ inch.

Procedure, General

- 19 • Record all masses to the nearest 0.1 lb (50 g). (This does not preclude mass determinations of greater accuracy).
- Determine the mass of the clean, empty measure.
- Select the appropriate procedure from the following.

Rodding Procedure

- 20 1. Fill the measure approximately 1/3 full and level the layer with the fingers. Compact the layer with 25 strokes of the tamping rod taking care to not forcibly strike the bottom of the measure.
- 21



22

2. Fill the measure approximately 2/3 full and level that layer with the fingers. Compact the layer with 25 strokes of the tamping rod, penetrating to the underlying layer if possible.

23

Note 2: When rodding large or angular aggregate pieces it may not be possible to completely penetrate the layer being compacted. Vigorous effort used in rodding the material is considered sufficient to achieve the proper degree of compaction.



24

3. Fill the measure to overflowing and rod again as in step 2 above. After rodding, level the surface with the fingers or with a straightedge such that slight projections above the top of the measure compensate for the depressions in the surface below the top of the measure.

25

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4. Determine the mass of the measure and aggregate. Subtract the mass of the empty measure. Record mass in pounds.

Jigging Procedure



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1. Fill the measure in three approximately equal layers, compacting each layer by alternately lifting opposite sides of the measure approximately 2 inches and allowing it to fall in a manner that results in a sharp slapping blow. Each layer shall be compacted by applying 50 blows (25 per side).
2. When full, the measure shall be leveled with the fingers or a straightedge such that slight projections above the top of the measure compensate for the depressions in the surface below the top of the measure.
3. Determine the mass of the measure and aggregate. Subtract the mass of the empty measure. Record mass in pounds.

Shoveling Procedure

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1. Using a shovel or scoop, carefully fill the measure to overflowing. Do not allow aggregate particles to fall from a height more than 2 inches above the top of the measure. Do not allow vibration or any movement of the measure that will compact the aggregate beyond the loose state. Prevent segregation of the aggregate as the measure is filled.

- 31 2. When full, the measure shall be leveled with the fingers or a straightedge such that slight projections above the top of the measure compensate for the depressions in the surface below the top of the measure.
3. Determine the mass of the measure and aggregate. Subtract the mass of the empty measure. Record mass in pounds.

Calculations

32 Calculate values for bulk density and voids to the nearest 0.1, but round to the whole number for reporting.

33 **Bulk Density:** Calculate the bulk density for the rodding, jigging, or shoveling method according to the following formula:

$$M = \frac{(G - T)}{V}$$

where:

M = bulk density of aggregate (lb/ft³)

G = mass of aggregate plus measure (lb)

T = mass of measure (lb)

V = volume of measure (ft³)

34 **Void Content:** Calculate the percentage of voids according to the following formula:

$$\text{Voids, \%} = \frac{100((S \times W) - M)}{S \times W}$$

where:

M = bulk density of aggregate (lb/ft³)

S = dry bulk specific gravity (G_{sb}) as determined by AASHTO T 84 or AASHTO T 85

W = density of water (62.3 lb/ft³)

Sample Worksheet for Test Method AASHTO T 19

Date: _____ Project: _____

Material: 1½ inch Nominal Maximum Size Coarse Aggregate

Source: _____ Tested By: _____

I – Calibration of Measure

Line	Description	Data Source or Formula	No. 1	No. 2	Average
A	Measure + Plate + Water (lb)	Balance	48.10	48.09	
B	Dry Measure + Plate (lb)	Balance	16.87	16.87	
C	Water (lb)	A – B	31.23	31.22	
D	Water Temperature (° F)	Thermometer	75	73	
E	Water Density (lb/ft ³)	Table No. 3	62.261	62.277	
F	Volume of Measure (ft ³)	C/E	0.5016	0.5013	0.501

II – Aggregate Bulk Density and Void Content

35

Procedure Used: **RODDING** Jigging Shoveling

Line	Description	Data Source or Formula	No. 1	No. 2	Average
G	Measure + Aggregate (lb)	Balance	74.07	74.68	
H	Empty Measure (lb)	Balance	14.83	14.83	
J	Aggregate (lb)	G – H	59.24	59.85	
K	Volume of Measure (ft ³)	Avg. from “F”	0.501	0.501	
L	Aggregate Bulk Density (lb/ft ³)	J/K	118.2	119.5	118.8 *
M	Oven-Dry Bulk Specific Gravity, G _{sb} (OD)	T 84 or T 85			2.628
N	Density of Water	Constant			62.3 lb/ft ³
O	Voids, %	See Below			27.4 *

* Note: These values are calculated to the nearest 0.1 but must be rounded to the whole number for reporting purposes. 36

Voids in Aggregate

Formula:

$$\text{Voids, \%} = \frac{100((M \times N) - L)}{M \times N}$$

Example:

$$\frac{100((2.628 \times 62.3) - 118.8)}{2.628 \times 62.3} = 27.4, \text{ say } 27\%$$

37

38

Report

- Report on standard agency forms
- Project description and location
- Material source and description, including nominal maximum size
- Method used: rodding, jiggling, or shoveling
- Bulk density by rodding, jiggling, or loose bulk density to the nearest 1 lb/ft³
- Void content of aggregate compacted by rodding, jiggling, or loose bulk density to the nearest 1 percent
- Procedure used (Rodding, Jiggling, or Shoveling)

Tips

39

- Make sure the aggregate is dry
- Calibrate the volume of the measure at least annually or whenever there is a question of accuracy
- Use rodding or jiggling method based on nominal maximum aggregate size, unless the governing agency specifically calls for the shoveling method.

40

- Obtain $G_{sb}(OD)$ (oven-dry bulk specific gravity) according to AASHTO T 84 or AASHTO T 85 for void content calculation.
- Calculate values for bulk density and voids to the nearest 0.1 but round to the whole number for reporting.

REVIEW QUESTIONS

1. According to this FOP, aggregate up to _____ in Nominal Maximum Size may be tested.
2. Summarize requirements for volume of the measure.
3. The _____ method should be used to fill the measure when nominal maximum size of aggregate is 1 inch.
4. What approximate volume of aggregate is used for conducting this test?
5. To what degree of accuracy is the volume of the measure determined?
6. When is the shoveling method allowed?
7. Given the following, the bulk density of the aggregate as reported is _____.

Mass of Measure and Aggregate: 36.24 lb.

Mass of Measure: 8.47 lb.

Volume of Measure: 0.248 ft³

Dry Bulk Specific Gravity (G_{sb}): 2.649

Density of Water: 62.3 lb/ft³

8. Given the data from question 7, the void content as reported is _____.

PERFORMANCE EXAM CHECKLIST

BULK DENSITY (“UNIT WEIGHT”) AND VOIDS IN AGGREGATE FOP FOR AASHTO T 19

Participant Name: _____ Exam Date: _____

Procedure

Calibration of Measure

- 1. All masses determined to 0.1% of sample mass or better? _____
- 2. Clean dry mass of measure and glass plate determined? _____
- 3. Measure filled with water at room temperature and glass plate placed to eliminate air bubbles? _____
- 4. Exterior of measure and glass plate dried and mass determined? _____
- 5. Mass of water determined? _____
- 6. Temperature of water measured and density of water determined? _____
- 7. Volume of measure correctly determined to 0.001 ft³? _____

Sample Preparation

- 1. Sample obtained by AASHTO T 2 and reduced by AASHTO T 248? _____
- 2. Aggregate dried to constant mass at 230 ±9° F? _____
- 3. Aggregate quantity 125 to 200 percent of that needed to fill measure? _____
- 4. Sample handled so as to avoid segregation? _____

Procedure

- 1. All masses determined to 0.1 lb or 50 g or better? _____
- 2. Mass of clean, empty measure determined? _____
- 3. Correct method of filling measure selected based on agency requirements and nominal maximum aggregate size? (1½ inch or less by rodding; greater than 1½ inch by jiggling; shoveling only when required by agency) _____
- 4. Rodding performed in 3 layers, leveling first two layers with fingers; 25 rods per layer but not forcibly striking bottom of measure on first layer; penetrating depth of layer if possible; third layer filled to overflowing? _____
- 5. Jiggling performed in 3 layers; 50 drops per layer (25 per opposite side); last layer filled to overflowing? _____

- 6. Shoveling performed by carefully filling in loose state; not dropping aggregate more than 2 inches; avoiding vibration or movement of measure? _____
- 7. For all procedures, final layer leveled with fingers or straightedge such that projections above top of measure compensate for depressions? _____
- 8. Mass of aggregate and measure determined properly? _____
- 9. Mass of aggregate determined by subtracting empty measure from total? _____
- 10. Bulk density correctly calculated? _____
- 11. Dry bulk specific gravity of aggregate obtained? _____
- 12. Void content correctly determined? _____

Comments: First attempt: (Pass/Fail) ____ Second attempt: (Pass/Fail) ____

Signature of Examiner _____.

ORGANIC IMPURITIES IN FINE AGGREGATE FOR CONCRETE FOP FOR AASHTO T 21

02 **Scope**

This method of test covers a procedure for an approximate determination of the presence of injurious organic compounds in natural sands, which are to be used in cement mortar or concrete.

In this procedure a sample of fine aggregate is placed in a sodium hydroxide solution and shaken. The following day the color of the supernatant solution is compared with a standard color. If the color is darker than the standard, the fine aggregate should not be used without further investigation.

03 **Significance**

Aggregates are potentially harmful if they contain compounds known to react chemically with portland cement and other constituents of the portland-cement concrete, and produce undesirable properties such as expansion of the paste or aggregates, reduction in strength, etc.

Organic impurities may delay setting and hardening of concrete, may reduce strength gain, and in unusual cases may cause deterioration.

04 **Apparatus**

- 05 • **Balance or Scale:** Capacity of 1000 g and sensitive to 0.1 g
- **Bottles:** Clear (colorless), graduated glass bottles having a capacity of 8 to 16 fl. oz. with water tight stoppers or caps. Outside diameter (measured along the line of sight used for color comparison) 1.5 in to 2.5 in.
- **Glass Color Standard:** Glass color plate with organic plate numbers 1-5. (Organic plate No. 3 to be equal to Gardener Color Standard No. 11)



06

Reagent and Standard Color Solution

- **Reagent Sodium Hydroxide Solution:** 3 parts NaOH to 97 parts water by mass.
- **Standard Color Solution:** Solution of reagent grade Potassium Dichromate dissolved in sulfuric acid. Solution to be freshly made (within 2 hours), equal to Organic Color No. 3.

07

Sampling

Obtain a representative sample of fine aggregate according to the FOP for AASHTO T 2.

08

Test Sample

Using the FOP for AASHTO T 248, obtain a test sample weighing approximately 450 g. from the sand to be tested. If sample drying prior to testing is necessary, only air-drying shall be allowed.

09

Procedure

1. Fill a bottle to the 130 mL (4½ ounce) mark with the sand to be tested.
2. Add a sufficient amount of the 3 per cent sodium hydroxide solution to bring the level of the liquid, after shaking, to the 200 mL (7 ounce) mark.
3. Stopper the bottle and shake vigorously to eliminate air bubbles.
4. Allow the bottle to stand undisturbed for 24 hours. (Do not place bottle in direct sunlight).
5. At the end of the 24-hour standing period compare the color of the supernatant liquid against one of the reference color standards.

10

11



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Report

- Report on standard agency forms.
- Standard solution method: Record whether the supernatant liquid is lighter, darker, or equal in color to that of the reference standard.
- Glass color plate method: Record the organic plate number that is nearest the color of the supernatant liquid.

13

Tips!

- Be cautious handling reagents. They are caustic and may cause serious skin or eye injury.
- Be careful handling sample bottle when color comparison is made. Disturbance of the contents may cause the liquid to become clouded, making color comparison difficult.

REVIEW QUESTIONS

1. From the sample that was obtained according to AASHTO T 2, how much material is generally required to perform this test?
2. According to this FOP, how may the sample be dried?
3. After addition of the NaOH solution, what must be done?
4. Describe the color comparison procedure.

PERFORMANCE EXAM CHECKLIST

**ORGANIC IMPURITIES IN FINE AGGREGATES FOR CONCRETE
FOP FOR AASHTO T 21**

Participant Name: _____ Exam Date: _____

Procedure

Sample Preparation

- 1. A representative sample of appropriate mass obtained by T 2 and T 248? _____
- 2. If sample is dried prior to testing, is it dried only by air-drying? _____
- 3. Sample weighs approximately 450 g? _____

Procedure

- 1. Sand added to the 4½ oz. (130 ml) level in the bottle? _____
- 2. NaOH solution added to the 7 oz. (200 mL) level? (7 oz. after shaking)? _____
- 3. Bottle stoppered and shaken vigorously? _____
- 4. Bottle, containing sample, allowed to stand for 24 hours? _____
- 5. Color comparison made against color standards? _____

Report

- 1. Standard agency forms? _____
- 2. Standard Color Solution Method
 - a. Solution freshly made (within two hours)? _____
 - b. Supernatant solution color lighter or darker than standard? _____
- 3. Glass Color Standard Procedure
 - a. Proper Gardener Color Standards? _____
 - b. Glass color standard closest to supernatant liquid color recorded? _____

Comments: First attempt: (Pass/Fail) ____ Second attempt: (Pass/Fail) ____

Signature of Examiner _____

SPECIFIC GRAVITY AND ABSORPTION OF FINE AGGREGATE FOP FOR AASHTO T 84



Scope

02 This field operating procedure (FOP) covers the
03 determination of bulk, bulk (SSD), and apparent
04 specific gravity, as well as absorption of fine
05 aggregate after a prescribed soaking period in water.

Apparatus

- 06 • **Balance:** A balance of sufficient capacity,
sensitive to 0.1 g. (M 231, class G 2)
- **Pycnometer:** A flask or other suitable
container into which the fine aggregate sample
can be introduced, and in which the volume can
be reproduced within ± 0.1 ml. The volume of
the flask shall be at least 50 percent greater than
required for the test sample.
- 07 • **Mold:** A metal mold in the form of a frustum
of a cone 40 ± 3 mm in diameter at the top,
 90 ± 3 mm in diameter at the bottom, and
 75 ± 3 mm in height.
- **Tamper:** A metal tamper weighing 340 ± 15 g
and having a flat circular tamping face 25 ± 3
mm in diameter

Sample

08 Obtain the sample and reduce to testing size
according to AASHTO T 2 and T 248.

Sample Preparation

- 09 1. Obtain approximately 1000 g. of fine aggregate
passing the No. 4 sieve from the sample by use
of a sample splitter or by quartering. Dry it in a
suitable pan or vessel to constant mass at a
temperature of $230 \pm 9^\circ$ F.
2. After the sample has been allowed to cool to
comfortable handling temperature, cover with
water, and allow to stand for 15 to 19 hours.
- 10 3. Carefully decant the water without losing fines,
and spread the sample on a flat smooth surface
exposed to a gently moving current of warm air.
Stir frequently to secure uniform drying.
Continue this operation until the test sample
approaches a free flowing condition.
4. With the mold held firmly on a smooth non-

Note 1: If the fine aggregate slumps on the first trial, it has already dried past the saturated surface-dry condition. Thoroughly mix a few milliliters of water with the aggregate and permit the sample to stand in a covered container for 30 minutes. The process of drying and testing for the free-flowing condition shall then be resumed.

11 absorbent surface (large diameter down) fill the mold to overflowing with a portion of the partially dried fine aggregate. Lightly tamp the surface 25 times with the tamper, clean excess from around the base, and lift the mold vertically. (Allow the tamper to fall freely from approximately 0.2" above the top of the sample)

12 5. Continue drying with constant stirring, and test at frequent intervals until the tamped fine aggregate slumps slightly upon removal of the mold. This indicates that it has reached a saturated surface-dry (SSD) condition.

Procedure

13 1. Record all masses to the nearest 0.1 g.
 2. Partially fill the pycnometer with water. Immediately introduce into the pycnometer 500 ±10 g of fine aggregate and fill with water to approximately 90% capacity.
 3. Roll, invert, and agitate the pycnometer to eliminate all air bubbles. Adjust its temperature to 73.4 ±3°F if necessary, by immersion in circulating water, and bring the water level to its calibrated capacity.

14 4. Dispel any foam, and record the total mass of the pycnometer, sample, and water to the nearest 0.1 g.
 5. The sample shall then be dried to a condition of constant mass such that it will not lose more than 0.1% of moisture after drying at the specified temperature for 2 hours (more than one successive 2 hour drying period shall be required to achieve the constant mass).
 6. Cool the sample to room temperature for 1.0 ±0.5 hours and determine final mass to the nearest 0.1 g.

Note 2: In lieu of weighing the sample that has been removed from the pycnometer, a second sample taken at the same time, within 0.2 g of the sample placed in the pycnometer, may be used to determine the oven-dry mass.

Calculation

15

Calculate specific gravities and absorption of the sample according to the following formulas:

Bulk Specific Gravity Oven Dry, $G_{sb}(OD)$

$$G_{sb}(OD) = \frac{A}{B + S - C}$$

Bulk Specific Gravity Saturated Surface-Dry, $G_{sb}(SSD)$

$$G_{sb}(SSD) = \frac{S}{B + S - C}$$

Apparent Specific Gravity, G_{sa}

$$G_{sa} = \frac{A}{B + A - C}$$

16

Absorption, Percent

$$\text{Absorption, percent} = \frac{S - A}{A} \times 100$$

where:

A = mass of oven-dry specimen in air, g

B = mass of pycnometer filled with water, g

C = mass of pycnometer with specimen and water to calibration mark, g

S = mass of saturated surface-dry specimen, g

Calculation Examples

Using the following data, specific gravity and absorption calculations may be completed as in the following examples (Formulas are also shown for clarity):

A	B	C	S
499.0 g.	666.1 g.	979.1 g.	502.3 g.

Bulk Specific Gravity, G_{sb} :

$$G_{sb} \text{ (OD)} = \frac{A}{B + S - C}$$

17

$$G_{sb} \text{ (OD)} = \frac{499.0}{666.1 + 502.3 - 979.1} = 2.636$$

Bulk Specific Gravity Saturated Surface-Dry, G_{sb} (SSD):

$$G_{sb} \text{ (SSD)} = \frac{S}{B + S - C}$$

$$G_{sb} \text{ (SSD)} = \frac{502.3}{666.1 + 502.3 - 979.1} = 2.653$$

Apparent Specific Gravity, G_{sa} :

$$G_{sa} = \frac{A}{B + A - C}$$

$$G_{sa} = \frac{499.0}{666.1 + 499.0 - 979.1} = 2.683$$

Absorption, Percent:

$$\text{Absorption, (\%)} = \frac{S - A}{A} \times 100$$

18

$$\text{Absorption, (\%)} = \frac{502.3 - 499.0}{499.0} \times 100 = 0.661, \text{ say } 0.7\%$$

19

Note 3: AASHTO 2010 - If material meets M6 requirements, specific gravity may be reported to the nearest 0.01

20

Report

- Report on standard agency forms.
- Report specific gravity to nearest 0.001
- Report percent absorption to nearest 0.1.

Tips!

- To assure uniform drying of the sample, frequent stirring or rolling of the fine aggregate is required during the process of drying from the wet to saturated surface-dry condition.
- Weigh the test sample immediately when it reaches the saturated surface-dry condition to avoid undue evaporation loss from the sample.
- Exercise care to eliminate all air bubbles from the test sample in the pycnometer before making the final volume determination.

REVIEW QUESTIONS

1. From the sample that was obtained according to the FOP for AASHTO T 2, how much material is generally required to perform this test?
2. According to this FOP, when is soaking required? For how long must material be soaked?
3. Describe the SSD condition and how it is determined.

PERFORMANCE EXAM CHECKLIST

**SPECIFIC GRAVITY AND ABSORPTION OF FINE AGGREGATE
FOP FOR AASHTO T 84**

Participant Name _____ Exam Date _____

Record the symbols “P” for passing or “F” for failing on each step of the checklist.

Sample Preparation	Trial 1	Trial 2
1. Sampled according to AASHTO T 2?	_____	_____
2. Sample reduced according to AASHTO T 248 to approximately 1000 g?	_____	_____
3. Dried to a constant mass at 230 ±9° F, cooled to a comfortable handling temp?	_____	_____
4. Covered with water?	_____	_____
5. Allowed to stand 15 – 19 hours?	_____	_____
6. Excess water decanted without loss of fines?	_____	_____
7. Sample spread on flat, non-absorbent surface?	_____	_____
8. Uniformly dried by a current of warm air, with frequent stirring?	_____	_____
9. Mold placed on flat, non-absorbent surface and filled to over-flowing?	_____	_____
10. Sample compacted with 25 light drops of tamper from 0.2” above top of sample?	_____	_____
11. Tamper allowed to fall freely under gravitational attraction?	_____	_____
12. Loose sand removed from around bases and mold lifted vertically?	_____	_____
13. Sample fails to slump on the first test?	_____	_____
14. If it does slump, is water added, sample covered and allowed to stand 30 minutes?	_____	_____
15. Drying continued, and test repeated at frequent intervals until sample slumps slightly?	_____	_____
Testing Procedure		
1. Pycnometer partially filled with water and 500 ±10 g sample added?	_____	_____
2. Pycnometer filled to 90 % of calibrated capacity and agitated to eliminate air bubbles?	_____	_____
3. Temperature adjusted to 73.4 ±3° F.?	_____	_____
4. Water level brought to calibrated capacity and agitated to eliminate air bubbles?	_____	_____

- 5. Sample removed and dried to constant mass at 230 ±9° F? _____
- 6. Sample cooled in air at room temperature for 1.0 ±0.5 hr. and weighed? _____
- 7. Pycnometer calibrated mass determined? _____
- 8. All masses determined to nearest 0.1 g? _____
- 9. Calculations performed and values rounded correctly? _____

Formulas for Specific Gravities and Absorption

Bulk Specific Gravity $\frac{A}{B+S-C}$

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

Apparent Specific Gravity $\frac{A}{B+A-C}$

Absorption, percent $\frac{(S-A)}{A} \times 100$

where:

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

Comments: First attempt: Pass Fail Second attempt: Pass Fail

Signature of Examiner _____

**RESISTANCE TO ABRASION OF SMALL-SIZE AND LARGE-SIZE COARSE AGGREGATE BY USE OF THE LOS ANGELES MACHINE
FOP FOR AASHTO T 96 AND ASTM C 535**

02 **Scope**

This FOP describes methods for testing coarse aggregate using the Los Angeles machine. Two procedures are presented: AASHTO T 96 for small-size coarse aggregate (smaller than 1½ inch), and ASTM C 535 for large-size coarse aggregate (smaller than 3 inch).

A graded aggregate sample is placed in a hollow steel cylinder along with a charge consisting of steel spheres and rotated for a specified number of revolutions (500 or 1000 depending on test method). The interior of the cylinder has a shelf that picks up the sample and charge during each rotation and drops them on the opposite side of the cylinder, subjecting the sample to abrasion or attrition.

03 **Significance**

The L.A. Abrasion test determines the relative competence or resistance to abrasion of the aggregate. Aggregates with distinctly different origins should be expected to perform differently in the Los Angeles machine.

Apparatus

- 04
- **Los Angeles machine:** An abrasion machine consisting of a hollow steel cylinder, closed at both ends, with an inside diameter of 28 ± 0.2 inch. The machine should be mounted and counterbalanced to provide a uniform peripheral speed, and shall rotate at 30 to 33 rpm. *See Figure 1 AASHTO T 96 for a more complete description of the apparatus.*
- 05
- **Shelf:** A removable steel shelf extending the full length of the cylinder and projecting inward 3.5 ± 0.1 in. shall be mounted on the interior cylindrical surface of the drum or on the inside surface of the cover.
- 06
- **Sieves:** Woven wire-cloth sieves with square openings, conforming to the requirements of AASHTO M 92.
 - **Balance:** Accurate to 0.1% for the range required by this procedure.



07

- **Oven:** An oven capable of maintaining a uniform temperature of 230 ±9°F.
- **Charge:** Steel spheres averaging approximately 1²⁷/₃₂ inches in diameter, with a mass of 390 to 445 g. (See Table 1 for charge requirements).

Table 1 – Charge for Selected Methods and Gradings

08

Test Method -- Grading	Number of Spheres	Mass of Charge, g
T 96 -- A	12	5000 ±25
T 96 -- B	11	4584 ±25
T 96 -- C	8	3330 ±20
T 96 -- D	6	2500 ±15
C 535 -- All Gradings	12	5000 ±25

09

Sampling

Obtain the sample according to AASHTO T 2. Reduce to appropriate testing size according to AASHTO T 248.

Sample Preparation

10

- The test sample shall consist of clean washed aggregate that has been oven-dried to constant mass at a temperature of 230 ±9° F.
- Separate the sample into individual size fractions by sieving, and recombine to the grading of Table 2 or Table 3 that most nearly corresponds to the range of sizes in the aggregate as furnished for testing. The sample mass shall be recorded to the nearest 1 g.

Note: Constant mass is that condition where the moisture loss does not exceed 0.1% after an additional 2 hours of drying.



11

12

Table – 2 AASHTO T 96 Sample Grading

Sieve Size		Mass of Indicated Sizes, g.			
<i>Passing</i>	<i>Retained on</i>	<i>Grading</i>			
		A	B	C	D
1½"	1"	1250 ±25	-----	-----	-----
1"	¾"	1250 ±25	-----	-----	-----
¾"	½"	1250 ±10	2500 ±10	-----	-----
½"	⅜"	1250 ±10	2500 ±10	-----	-----
⅜"	¼"	-----	-----	2500 ±10	-----
¼"	No. 4	-----	-----	2500 ±10	-----
No. 4	No. 8	-----	-----	-----	5000 ±10
Total		5000 ±10	5000 ±10	5000 ±10	5000 ±10

13

Table – 3 ASTM C 535 Sample Grading

Sieve Size		Mass of Indicated Sizes, g.		
<i>Passing</i>	<i>Retained on</i>	<i>Grading</i>		
		1	2	3
3"	2½"	2500 ±50	-----	-----
2½"	2"	2500 ±50	-----	-----
2"	1½"	5000 ±50	5000 ±50	-----
1½"	1"	-----	5000 ±25	5000 ±25
1"	¾"	-----	-----	5000 ±25
Total		10000 ±100	10000 ±75	10000 ±50

Procedure

- 14 1. Inspect the inside of the cylinder to be sure that no residue from previous samples is present.
2. Place the test sample and charge in the cylinder and close the opening with the dust-tight cover.
3. Rotate the cylinder at 30 to 33 rpm for the required number of revolutions: 500 revolutions for test method AASHTO T 96; 1000 revolutions for test method ASTM C 535.
- 15 4. Carefully remove all material from the cylinder and make a preliminary separation of the sample on a sieve coarser than the No. 12.
- 16 5. Sieve the finer portion of the material on a No. 12 sieve in a manner conforming to AASHTO T 27. Discard the portion passing the No. 12 sieve.

6. Wash the material coarser than the No. 12 sieve, dry to constant mass at $230 \pm 9^\circ\text{F}$, and record mass to the nearest 1 g.

Calculation

17

Express the loss as a percentage of the original mass of the test sample according to the following formula:

$$P = \frac{a - b}{a} \times 100$$

where:

P = percent loss

a = original sample mass, g.

b = final sample mass, g.

(See the sample worksheet on page 5 for examples)

Sample Worksheet for Test Method AASHTO T 96

Date: _____ Project: _____

Material: _____

Source: _____ Tested By: _____

L.A. ABRASION TEST DATA (AASHTO T 96)

Grading	Charge		Sample Mass Before Test, g.	Sample Mass After Test, g	Percent Loss
	Number	Mass, g	a	b	
A, B, C, or D					P
A	12	5012	5008	3778	25
Sample Mass Used for Test, g					
Passing	Retained on	A	B	C	D
1½"	1"	1262	-----	-----	-----
1"	¾"	1241	-----	-----	-----
¾"	½"	1253		-----	-----
½"	⅜"	1252		-----	-----
⅜"	¼"	-----	-----		-----
¼"	No. 4	-----	-----		-----
No. 4	No. 8	-----	-----	-----	
Total		5008			

Calculation: $P = \frac{a - b}{a} \times 100$

$P = \frac{5008 - 3778}{5008} \times 100 = 24.6$, say 25%

18

REQUIREMENTS FOR SAMPLE MASS AND CHARGE

Sample Mass, g					
Passing	Retained on	A	B	C	D
1½"	1"	1250 ±25	-----	-----	-----
1"	¾"	1250 ±25	-----	-----	-----
¾"	½"	1250 ±10	2500 ±10	-----	-----
½"	⅜"	1250 ±10	2500 ±10	-----	-----
⅜"	¼"	-----	-----	2500 ±10	-----
¼"	No. 4	-----	-----	2500 ±10	-----
No. 4	No. 8	-----	-----	-----	5000 ±10
Total		5000 ±10	5000 ±10	5000 ±10	5000 ±10

Charge		
Grading	Number of Spheres	Mass of Charge, g
A	12	5000 ±25
B	11	4584 ±25
C	8	3330 ±20
D	6	2500 ±15

19

Report

- Report on standard agency forms
- Project description and location
- Material source and description, including nominal maximum size
- Test method used (T 96 or C 535)
- Grading used for test (A, B, C, D, 1, 2, or 3)
- Percent loss to the nearest 1%

20

Tips

- Make sure the aggregate is dry and clean
- Periodically check the mass of the steel spheres, and discard those that do not meet specifications
- Prior to each test, check the cylinder of the testing machine to insure that no material is left from the previous test
- When selecting the grading to be used for the test sample, use the one that most closely represents the aggregate gradation supplied for testing. Do not combine two or more gradings. Doing so will result in a nonstandard, invalid test.

21

REVIEW QUESTIONS

1. What is the purpose of the shelf used in the Los Angeles Machine?
2. Describe the “charge.” What does it consist of for grading 3?
3. What is the difference between gradings B and C?
4. How does one know which sample grading to use for this test?
5. Describe the difference in aggregate grading between AASHTO T 96 grading A and ASTM C 535 grading 3.
6. Excluding the answer to question 5, name at least two differences between ASTM C 535 and AASHTO T 96.

PERFORMANCE EXAM CHECKLIST

**RESISTANCE TO ABRASION OF SMALL-SIZE AND LARGE-SIZE COARSE AGGREGATE BY USE OF THE LOS ANGELES MACHINE
FOP FOR AASHTO T 96 AND ASTM C 535**

Participant Name: _____ Exam Date: _____

Procedure

Sample Preparation

- 1. Sample obtained by T 2 and reduced by T 248? _____
- 2. Aggregate washed to ensure that it is clean? _____
- 3. Clean aggregate dried to constant mass at 230 ±9° F? _____
- 4. Mass determined to nearest 1 g? _____
- 5. Specimen masses conform to those defined in FOP tables 2 or 3? _____
- 6. Number of spheres and mass of charge conform to table 1? _____

Procedure

- 1. Sample and spheres put in machine and tumbled for the required number of revolutions (500 or 1000) at the proper rate (30 to 33 rpm)? _____
- 2. Sample after testing initially separated on sieve coarser than a No. 12? _____
- 3. Finer material separated on a No. 12 sieve per T 27, and minus No. 12 discarded? _____
- 4. Material coarser than No. 12 washed and dried to constant mass at 230 ±9° F? _____
- 5. Mass of material coarser than No. 12 determined to nearest 1 g? _____
- 6. Percentage of loss calculated by dividing original mass into the difference between the original and final mass? _____

Comments: First attempt: (Pass/Fail) _____ Second attempt: (Pass/Fail) _____

Signature of Examiner _____

SOUNDNESS OF AGGREGATE BY USE OF SODIUM SULFATE OR MAGNESIUM SULFATE FOP FOR AASHTO T 104

02

Scope

Aggregate samples are subjected to alternate cycles of immersion in soundness solution (sodium or magnesium sulfate) and drying in an oven at a regulated temperature of $230 \pm 9^\circ \text{F}$.

03

Significance

- During the 16 to 18-hour immersion phase, salts penetrate the permeable void spaces of the aggregates.
- During the drying phase, the salt solution on the surface and within the permeable pores of the aggregate particles dehydrates resulting in an expansive pressure. This pressure simulates the expansion of water when frozen.

04

Apparatus

- **Balance:** Sufficient capacity for the principal sample masses to be determined, sensitive to 0.1 g
- **Sieves:** Woven wire-cloth sieves with square openings, conforming to the requirements of AASHTO M 92.
- **Sample Containers:** 8-inch diameter sieves for each individual size fraction of aggregate being tested (No. 8 size for coarse aggregate, No. 60 size for fine aggregate). Sieves out of tolerance with AASHTO M 92, in an acceptable condition, may also be used as sample containers. Other types of sample containers may be used provided that they permit free access of the solution to the samples and draining of the solution from the samples without loss of aggregate. (See Note 1)
- **Apparatus for immersing samples in solution:** Optional, for permitting free access of solution to sample and to provide for free drainage of solutions.
- **Temperature regulation:** Suitable means for providing temperature regulation of the samples (68.5 to 71.5°F) during immersion in solution.

05

06



Note 1: AASHTO T 104 requires the use of 8-inch diameter sieves as sample containers for referee testing, comparison testing, or for testing of aggregates to be used in critical applications.

07

- 08 • **Temperature Recorder:** Capable of recording solution temperature a minimum of once every 10 minutes throughout the test with an accuracy of 0.5° F.
- **Drying Oven:** Capable of maintaining heat level of 230 ±9° F for drying phase. Oven must also be capable of maintaining an evaporation rate of 25 grams per hour over a four-hour period (see “Determining Evaporation Rate”).
- 09 • **Hydrometers:** Conforming to ASTM E 100. Used to check the specific gravity of the solution. Hydrometers should be capable of measuring the solution specific gravity within ±0.001. In lieu of hydrometers, AASHTO T 104 allows the use of graduated glassware and a scale to determine the specific gravity of the solutions.
- 10 • **Prepared Soundness Solution:** Magnesium sulfate or sodium sulfate, depending upon the procedure being used.
- **Barium Chloride Solution:** 0.2 molar solution of barium chloride to test for presence of magnesium or sodium sulfate in the final wash water.

Determining Evaporation Rate

- 11 1. Prepare five 1-liter Griffin Low-form beakers for each shelf of the oven. Beakers will be placed in the center and at each corner of oven shelves.
2. Place 500 g water in each beaker at 70 ±3° F. Place beakers on shelves in oven regulated at 230 ±9° F for 4 hours. Do not open the oven door during the evaporation test. Oven vents must be open to allow for venting of evaporated moisture.
- 12 3. At the end of the four-hour period, remove beakers and record weight of water remaining in them. The water weight in each beaker must be no more than 400 grams as per the 25-gram per hour required evaporation rate. That is, each beaker must lose at least 100 grams of water after 4 hours in an oven regulated at 230 ±9° F.

Note 2: For the sodium sulfate solution, 225 g per liter of solution is recommended to achieve the saturated state. For magnesium sulfate solution, 350 g of anhydrous salt per liter of solution is recommended to achieve the saturated state.

Note 3: Discolored solution shall be discarded or filtered and checked for specific gravity.

Table 1

Passing Sieve	Retained on Sieve
3/8"	No. 4
No. 4	No. 8
No. 8	No. 16
No. 16	No. 30
No. 30	No. 50

Solution Preparation

- 13 1. Solutions need to be prepared well in advance of the test procedure. Enough solution should be prepared to be at least 5 times the solid volume of all the samples to be tested.
2. Prepare a saturated solution of either sodium sulfate (Na₂SO₄) or magnesium sulfate (MgSO₄) using a reagent grade of salt added to water. Distilled water is not required but shall be used in referee or comparison testing.
3. Add enough salt to the water to ensure not only saturation but also the presence of excess crystals when the solution is ready for use in the tests. This can be accomplished by continually adding salts to the water and stirring. Add salts in increments allowing it to dissolve to determine crystallization potential.
- 14 4. Cover solution containers while not in use to prevent evaporation and contamination. Allow the solution to cool to 68.5 to 71.5° F.
5. Stir the solution and allow it to stand at least 48 hours, prior to use. Break up salt cakes, if any, prior to submerging the samples in the solution.
6. Check and record specific gravity and temperature of the solution each day the test is run. The temperature required for both solutions is 68.5 to 71.5° F. The specific gravity of the sodium sulfate solution must be between 1.154 and 1.171; that of the magnesium sulfate solution must be between 1.297 and 1.306.

Sample Sizes

Fine Aggregate

15 The sample should be passed through a 3/8 inch sieve. Sample should be of sufficient size to yield not less than 100 grams for each of the sizes shown in Table 1.

16 If the sample being tested contains less than 5% of any of the specified sizes, that size shall not be tested.

Table 2

Sieve Size	Mass, g
2 1/2" to 1 1/2"	5000 ± 300
consisting of: 2" to 1 1/2"	2000 ± 200
2 1/2" to 2"	3000 ± 300
1 1/2" to 3/4"	1500 ± 50
consisting of: 1" to 3/4"	500 ± 30
1 1/2" to 1"	1000 ± 50
3/4" to 3/8"	1000 ± 10
consisting of: 1/2" to 3/8"	330 ± 5
3/4" to 1/2"	670 ± 10
3/8" to No. 4	300 ± 5

Coarse Aggregate

1. Remove all particles passing the No. 4 sieve prior to test.
2. The sample should be of sufficient size to yield portions conforming to the mass requirements shown in Table 2.

Special consideration for coarse aggregate sample preparation

- a. If the sample contains less than 5% of any of the prescribed sieve sizes, that size should not be tested. When a combination of sizes is specified and one of the sizes specified is less than 5%, reduce the test portion by the applicable mass listed in the table.
- b. When testing large rock (broken stone, ledge rock, cobbles, and boulders for use as riprap, channel lining, etc.), obtain the test portion by crushing, splitting, or sawing. Test only those particles in the 2 1/2 to 1 1/2 inch and 1 1/2 to 3/4 inch size fractions when reduction is by crushing or splitting. Test 2 1/2 to 1 1/2 inch size fractions when reduction is by sawing.
- c. When testing large rock that will be crushed, obtain the test portion by crushing the aggregate. Test pieces only in those sizes that will be included in the test aggregate, but ignore any material finer than the No. 4 or larger than the 2 1/2 inch sieve.
- d. When the finished aggregate will contain pieces larger than 2 1/2 inch, crush those larger pieces and distribute the crushed material among the range of 2 1/2 inch to No. 4 sieves.
- e. When an aggregate being tested contains appreciable amounts of both fine and coarse material (more than 10% coarser than 3/8 inch, and more than 10% finer than the No. 4 sieves), test separate samples of the coarse and fine particles in accordance with the applicable procedures, giving the percentages of fine and coarse aggregates in the original grading.

Note 4: After sieving to refusal, when removing the material retained on the sieves, exclude those particles stuck in the sieve mesh from the sample.



Sample Preparation

Fine Aggregate

- 24 1. Thoroughly wash the sample of fine aggregate on a No. 50 sieve, and dry to a constant mass at $230 \pm 9^\circ \text{F}$.
- 25 2. Separate the dried sample into the different sizes by sieving as required. Make a rough separation of the sample using the appropriate sieves. Obtain enough material to yield at least 100 g of material on each sieve.
- 26 3. Sieve the rough-cut sample to refusal. Sieving to refusal means that no more material will pass through the sieves after additional agitation.
- 26 4. Weigh out the samples consisting of $100.0 \pm 0.1 \text{ g}$ from each of the separate fractions after final sieving. Record the mass of the test samples and place in separate containers for the test.

Coarse Aggregate

- 27 1. Thoroughly wash and dry the samples of coarse aggregate to a constant mass at $230 \pm 9^\circ \text{F}$.
- 28 2. Separate the sample into the different sizes according to Table 2 by sieving to refusal. Record the mass of the test samples to the nearest 1 g.
- 29 3. In the case of particles larger than $\frac{3}{4}$ -inch, record the number of particles in each test fraction.

Procedure

- 30 1. Immerse the samples in the prepared solution for 16 to 18 hours. The solution should cover the samples to a depth of at least $\frac{1}{2}$ inch. Cover the soundness tanks to reduce evaporation and contamination. Maintain sample temperature between 68.5 and 71.5°F .
- 31 2. After the soaking period, remove samples from the solution and allow them to drain for 15 ± 5 minutes.
- 32 3. After draining, place samples in an oven regulated at $230 \pm 9^\circ \text{F}$. Dry the samples until a constant mass has been obtained.

33



34

Determination of Constant Mass

- a. With the oven containing the maximum sample load expected, check the mass loss of test samples by removing them and weighing without cooling at intervals of 2 to 4 hours.
- b. Make enough measurements to determine the drying time for the least favorable oven location and sample condition. Constant mass is achieved when mass loss is less than 0.1% in four hours of drying.

35

4. After achieving constant mass, allow the samples to cool to 68 to 77° F. Cooling may be aided by the use of an air conditioner or fan. Check the temperature of the material with a thermometer or other acceptable means. After cooling, immerse the samples in the solution.

Note 5: Begin qualitative examination of the particles larger than 3/4 inch at this time, it may not be possible to categorize the types of distress after the particles have been disturbed.

36

5. Repeat the process of immersing, drying, and cooling until the required number of cycles has been completed. The test should be performed continuously until all cycles are completed. If the test must be interrupted, leave the samples in the oven at 230 ±9° F until testing can be resumed.

37

6. Once all cycles have been completed, and the sample is cooled, wash the salt solution from the sample by circulating 110 ±10° F water through the samples and their containers. Introduce the warm water near the bottom and allow it to pass through the samples and overflow.

Note 6: A 0.2 molar solution is equivalent to 41.6 grams of BaCl₂ per liter of solution.

In areas where the water gives a reaction with barium chloride, other analytical means shall be used to assure thoroughness of washing. One possible solution is to use distilled water for the final wash cycle.

38

7. Check washing thoroughness by obtaining a sample of the rinse water after it has overflowed the samples and check with a 0.2 molar barium chloride solution. Further washing is needed if the barium chloride causes the water to become cloudy.

Note 7: When performing final sieving of the fine aggregate particles, stack the sieves in "reverse" order with the smallest sieve on top and the largest sieve on bottom. Clean the sieves completely after performing final sieving.

39

8. After the solution has been completely removed from the aggregate samples, dry each fraction of the sample to constant mass at 230 ±9° F.

9. Sieve the fine aggregate over the same sieve on which it was retained before the test. Use the same mechanism and duration of sieving as for

Table 3

Size of Aggregate Fraction	Sieve Used to Determine Loss
2 1/2" to 1 1/2"	1 1/4"
1 1/2" to 3/4"	5/8"
3/4" to 3/8"	5/16"
3/8" to No. 4	No. 5

40

the original sample preparation.

41

10. Sieve the coarse aggregate particles in the fractions over the appropriate sieves shown in Table 3. Sieve particles by hand, with agitation sufficient only to assure that all undersized material passes the designated sieve. No extra manipulation should be employed to break up particles.

42

11. Determine and record the mass of the particles retained on each sieve. Calculate percent loss and weighted percent loss for each size fraction.

43

12. Perform the qualitative examination of aggregate particles larger than 3/4 inch and record the number and percent of particles showing each of the following types of distress: disintegration, splitting, crumbling, cracking, and flaking.

Calculations

- Perform calculations according to the formulas on the following page.
- To calculate the weighted average, use the average loss of the next larger and next smaller size for any size fraction with less than 5% of the total sample, if one of these sizes is not present use the loss of the next larger or next smaller.
- Calculate values for Percent Loss and Weighted Percent Loss of individual size fractions to the nearest 0.1%, but report total weighted percent loss of the entire sample to the nearest whole percent (See sample worksheet and report on pages 10 and 11 respectively).

Calculation Formulas and Examples (See sample worksheet on page 10 for data)

Quantitative Examination (Examples are for the No. 8 to No. 16 Size Fraction)

Percent Loss for Size Fraction:

$$D = \frac{B - C}{B} \times 100 \quad 44$$

$$D = \frac{99.9 - 91.9}{99.9} \times 100 = 8.01, \text{ say } 8.0\% \quad 45$$

Weighted Percent Loss for Size Fraction:

$$E = D \times \frac{A}{100} \quad 46$$

$$E = 8.0 \times \frac{17}{100} = 1.36, \text{ say } 1.4\% \quad 47$$

where:

A = individual percent retained in sample grading

B = mass of test fraction before test

C = mass of test fraction after test

D = percent loss for size fraction

E = weighted percent loss for size fraction

Qualitative Examination (Example is for Cracking in the 2½ to 1½ inch Fraction)

Percent Distressed Particles (P) in Each Category for Each Fraction Larger than ¾ inch:

$$P = \frac{\text{Number of Distressed Particles}}{\text{Number of Particles in Fraction}} \times 100 \quad 48$$

$$P = \frac{2}{29} \times 100 = 6.8, \text{ say } 7\% \quad 49$$

Report

- 50 • Report on standard agency forms (See sample report on page 11)
- Date and Project
- Material source and description
- Type of solution and number of cycles
- Grading of original sample
- Mass of test fractions before test
- Percent passing the designated sieve after test
- 51 • Weighted percent loss for each fraction, based on the original sample gradation
- Total weighted percent loss for the entire sample, based on original gradation
- Qualitative examination results of coarse aggregate particles larger than the $\frac{3}{4}$ inch sieve

Tips!

- Determine aggregate gradation first 52
- Check solution specific gravities daily
- Record number of particles in each size fractions larger than $\frac{3}{4}$ inch prior to test
- Be sure samples have achieved constant mass during drying
- Use barium chloride to check wash water during removal of salt solution
- For coarse aggregate, check sieve size used to determine loss 53
- To determine loss for fine aggregate, use same sieve sizes, shaker, and sieving duration as for sample preparation
- Remember that the reported weighted losses are calculated according to the original sample gradation

Sample Worksheet

54, 55, 56

Date: _____ Project: _____

Material: _____ Solution: _____ No. of Cycles: _____

Source: _____ Tested By: _____

Quantitative Examination					
Sieve Size	Grading of Sample, %	Fraction Mass, g		Percent Loss	Weighted % Loss
		Before	After		
	A	B	C	D	E
Minus No. 100	6	---	---	---	---
No. 50 to No. 100	11	---	---	---	---
No. 30 to No. 50	26	100.0	95.8	4.2	1.1
No. 16 to No. 30	25	100.0	95.2	4.8	1.2
No. 8 to No. 16	17	99.9	91.9	8.0	1.4
No. 4 to No. 8	11	100.0	88.8	11.2	1.2
3/8" to No. 4	4	---	---	11.2	0.4
Totals	100	---	---	---	5
2 1/2" to 1 1/2" 2 1/2" - 2" (2825 g) 2" - 1 1/2" (1958 g) Total:	20	4783	4554	4.8	1.0
1 1/2" to 3/4" 1 1/2" - 1" (1012 g) 1" - 3/4" (513 g) Total:	45	1525	1402	8.1	3.6
3/4" to 3/8" 3/4" - 1/2" (675 g) 1/2" - 3/8" (333 g) Total:	23	1008	912	9.5	2.2
3/8" to No. 4 298 g	12	298	265	11.1	1.3
Totals	100	---	---	---	8

Qualitative Examination of Coarse Particles											
Sieve Size	Disinteg		Splitting		Crumbling		Cracking		Flaking		No. of Particles in Fraction
	No.	%	No.	%	No.	%	No.	%	No.	%	
2 1/2" - 1 1/2"	---	---	2	7	---	---	2	7	---	---	29
1 1/2" - 3/4"	---	---	5	10	1	2	4	8	---	---	50

Please note that the calculated values in columns "D" and "E" for "Percent Loss" and "Weighted Percent Loss" are expressed to the nearest 0.1%. The total weighted loss for the entire sample is expressed to the nearest 1%.

Sample Report – – Soundness of Fine and Coarse Aggregates

Date: _____ Project: _____

Material: _____ Solution: _____ No. of Cycles: _____

Source: _____ Tested By: _____

Sieve Size	Grading of Original Sample, %	Weight of Test Fractions Before Test, g	Percent Passing Designated Sieve After Test	Weighted Percent Loss
Soundness Test of Fine Aggregate				
Minus No. 100	6	---	---	---
No. 50 to No. 100	11	---	---	---
No. 30 to No. 50	26	100	4.2	1.1
No. 16 to No. 30	25	99.9	4.8	1.2
No. 8 to No. 16	17	100	8.0	1.4
No. 4 to No. 8	11	100	11.2	1.2
3/8" to No. 4	4 ^A	---	11.2 ^A	0.4
Totals	100	---	---	5

Soundness Test of Coarse Aggregate				
2½" to 2"	2825 g			
2" to 1½"	1958 g			
2½" to 1½" Fraction:		20	4783	4.8
1½" to 1"	1012 g			
1" to ¾"	513 g			
1½" to ¾" Fraction:		45	1525	8.1
¾" to ½"	675 g			
½" to ⅜"	333 g			
¾" to ⅜" Fraction:		23	1008	9.5
⅜" to No. 4	298 g	12	298	11.1
Totals		100	---	8

Qualitative Examination of Coarse Sizes												
Particles Exhibiting Distress												
Sieve Size	Disinteg.		Splitting		Crumblin g		Cracking		Flaking		Total No. of Particles Before Test	
	No.	%	No.	%	No.	%	No.	%	No.	%		
2½" to 1½"	---	---	2	7	---	---	2	7	---	---	29	
1½" to ¾"	---	---	5	10	1	2	4	8	---	---	50	

Note ^A Since less than 5% of this size was present in the sample gradation, no testing of this fraction was performed. The percentage loss of the next size was used to calculate weighted loss.

REVIEW QUESTIONS

1. Describe the sample containers that may be used according to this FOP.
2. According to this FOP, what is the acceptable temperature range for the samples while they are immersed in the soundness solutions?
3. If less than 5% of one of the specified sizes is present in the material to be tested, what should be done? How is the weighted percent loss calculated for this size?
4. How much material is required for testing of the 2½ to 1½ inch size fraction? What should be done if the material being tested has less than 5% in the 2 to 1½ inch size?
5. What should be done if the aggregate being tested has both 10% coarser than the ¾ inch and finer than the No. 4 sieves?
6. For how long are the samples immersed in the soundness solution during each cycle?
7. Describe determination of the evaporation rate.
8. For the ¾ to ½ inch size fraction, what sieve is used to determine loss?
9. Given that the ¾ inch to No. 4 size constitutes 13% of the material under test, what is the weighted percent loss for this size fraction if the masses before and after testing are 303 g and 286 g respectively?

PERFORMANCE EXAM CHECKLIST

**SOUNDNESS OF AGGREGATE BY USE OF SODIUM SULFATE OR
MAGNESIUM SULFATE
FOP FOR AASHTO T 104**

Participant Name: _____ Exam Date: _____

Procedure

Sample Preparation

Sample obtained by T 2 and reduced by T 248? _____

Fine Aggregate:

- 1. Passed through a 3/8 inch sieve? _____
- 2. Washed on a No. 50 sieve? _____
- 3. Dried to constant mass at 230 ±9° F? _____
- 4. Sample rough graded to obtain approximately 110 g of each of the following sizes, if required:
 - 3/8 inch to No. 4? _____
 - No. 4 to No. 8? _____
 - No. 8 to No. 16? _____
 - No. 16 to No. 30? _____
 - No. 30 to No. 50? _____
- 5. If sample contains less than 5% of any specified size, that size not tested? _____
- 6. Each size sieved a second time to refusal? _____
- 7. Aggregates sticking in sieve opening discarded? _____
- 8. 100 ±0.1 g of each size weighed out and put in separated containers? _____

Coarse Aggregate:

- 1. Material finer than No. 4 removed? _____
- 2. Aggregate thoroughly washed? _____
- 3. Dried to constant mass at 230 ±9° F? _____
- 4. By sieving to refusal, sample separated into the following sizes with masses as indicated:
 - 2½ to 1½ inch 5000 ±500g, consisting of:** _____
 - 2½ to 2 inch 3000 ±300g _____
 - 2 to 1½ inch 2000 ±200g _____
 - 1½ to ¾ inch 1500 ±50g, consisting of:** _____
 - 1½ to 1 inch 1000 ±50g _____
 - 1 to ¾ inch 500 ±30g _____
 - ¾ to ⅜ inch 1000 ±10g, consisting of:** _____
 - ¾ to ½ inch 670 ±10g _____
 - ½ to ⅜ inch 330 ±5g _____
 - ⅜ inch to No. 4: 300 ±5g** _____
- 5. If sample contains less than 5% of any specified size, that size not tested? _____

Procedure

- 1. Salt cake in bottom of solution container broken up and stirred? _____
- 2. Specific gravity of solution checked? _____
- 3. Each sample immersed to a depth at least 1/2 inch above its top? _____
- 4. Kept immersed for 16 to 18 hours? _____
- 5. After removal from solution, each sample drained 10 to 20 minutes? _____
- 6. Dried to constant mass at 230 ±9° F? _____
- 7. Cooled to room temperature: 68 to 77° F? _____
- 8. Temperature of aggregate checked by thermometer or other acceptable means before placing in sulfate solution? _____
- 9. Re-immersed and process continued until required number of cycles is completed? _____
- 10. After final cooling, sample washed by circulating water at 110 ±10° F through the samples in their containers? _____
- 11. Hot water introduced near bottom and allowed to pass through samples and overflow? _____
- 12. Impact or abrasion of samples avoided during washing operation? _____
- 13. Barium chloride used to check completeness of washing? _____
Note: If barium chloride reacts with lab water, completeness of washing must be determined by other means.
- 14. Each fraction dried to constant mass at 230 ±9° F? _____
- 15. Fine Aggregate: Sieved over same sieves used before test and in the same manner? _____
- 16. Coarse Aggregate: Hand sieved with minimum effort needed, over:
 - 1 1/4 inch sieve for 2 1/2 to 1 1/2 inch? _____
 - 5/8 inch sieve for 1 1/2 to 3/4 inch? _____
 - 5/16 inch sieve for 3/4 to 3/8 inch? _____
 - No. 5 sieve for 3/8 inch to No. 4? _____
- 17. Material retained on each sieve weighed? _____
- 18. Calculations for individual loss and weighted loss performed correctly? _____

Comments: First attempt: (Pass/Fail) _____ Second attempt: (Pass/Fail) _____

Signature of Examiner _____

**CLAY LUMPS AND FRIABLE PARTICLES IN AGGREGATES
FOP FOR AASHTO T 112**02 **Scope**

This Method of test describes a procedure for determining the percentage of clay lumps and friable particles in natural aggregates.

For Fine Aggregate, the percentage of clay lumps and friable particles is reported based on testing a single fraction of the material coarser than the No. 16 sieve. For Coarse Aggregate, the percentage of clay lumps and friable particles is reported as the weighted average of individual size fractions based on the overall grading of the material under test.

03 **Significance**

The results of this test may be used in determining compliance with specifications for aggregates used in Portland Cement Concrete and Hot Mix Asphalt.

Specifications, such as AASHTO M 6 and M 80 for Portland Cement Concrete, typically state the maximum acceptable percentage of clay lumps and friable particles.

For Superpave Hot Mix Asphalt, this test is considered to be source specific rather than a consensus property. The individual governing agency is responsible for setting maximum allowable limits for deleterious materials described as clay lumps and friable particles.

04 **Apparatus**

- **Balance:** Conforming to requirements of M 231, of sufficient capacity and readable to 0.1% of the sample mass.
- **Containers:** Rust-resistant containers of sufficient shape and size to allow spreading the sample in a thin layer.
- **Sieves:** Conforming to AASHTO M 92.
- **Oven:** Capable of maintaining $230 \pm 9^\circ$ F, providing free circulation of air.

05 **Sampling**

The samples used for this test shall be obtained and reduced to testing size according to AASHTO T 2 and T 248 respectively.

Table 1

Size of Test Fraction	Minimum Mass of Fraction, g
No. 4 to 3/8"	1000
3/8" to 3/4"	2000
3/4" to 1½"	3000
Over 1½"	5000



06

Sample Preparation

Aggregates for testing shall consist of the material remaining after completion of the AASHTO T 11 procedure, "Materials Finer than No. 200 Sieve in Mineral Aggregate by Washing."

07

After the T 11 (washing) procedure, the sample shall be dried to constant mass at a temperature of 230 ±9° F.

For Coarse Aggregate, the sample shall be separated into sizes with minimum mass of each size fraction conforming to Table 1.

Samples of Fine Aggregate (-#4) shall consist of that portion coarser than a No. 16 sieve and shall have a mass of at least 25 g.

Procedure

08

1. Determine the mass of the test fraction(s) to 0.1% of sample mass.

09

2. Spread sample fractions in pans in a thin layer and cover with distilled water. Soak the material for 24 ±4 hours.

10

3. Roll and squeeze the particles between thumb and forefinger to try to break the particles into smaller sizes; but do not use the fingernail or press particles against a hard surface.

11

Table 2

Size of Particles in Test Fraction	Sieve Size for Wet Sieving of Particles
Fine Aggregate (Plus No. 16)	No. 20
No. 4 to 3/8"	No 8
3/8" to 3/4"	No. 4
3/4" to 1½"	No. 4
Over 1½"	No. 4

Tips!

- Don't forget to perform the AASHTO T 11 procedure prior to testing.
- In breaking up clay lumps and friable particles, don't use fingernail or press particles against hard surfaces
- Consult Table 2 for correct sieve size for wet sieving after breaking up clay lumps

12

4. After all clay lumps and friable particles have been broken up, select the appropriate sieve specified in Table 2 for wet sieving. Wet sieve by passing water over the sample while manually agitating the sieve until all undersize material is removed.

13

14

5. Carefully remove the retained samples from the sieve and dry to substantially constant mass at a temperature of $230 \pm 9^\circ \text{F}$.

6. Allow sample to cool, and determine mass of each fraction to the nearest 0.1% of sample mass.

15

Calculation

Calculate the percentage of clay lumps and friable particles in each size fraction to the nearest 0.1% according to the following formula:

$$P = \frac{M - R}{M} \times 100$$

where:

P = percent of clay lumps and friable particles

M = mass of test fraction before test

R = mass of particles retained on designated sieve after wet sieving

16

Report

- Report on standard agency forms to the nearest 1%.
- For Coarse Aggregate, the percent of clay lumps and friable particles shall be a weighted average according to the grading of the original sample prior to separation.

REVIEW QUESTIONS

1. Before conducting the clay lumps and friable particles test, what procedure must first be performed?

2. According to this FOP, what is the minimum amount of fine aggregate actually tested?

3. How are the clay lumps and friable particles broken up?

4. After breaking up the particles, what is the next step in the procedure? How is it performed?

5. How is the percent clay lumps and friable particles reported for coarse aggregate?

PERFORMANCE EXAM CHECKLIST

**CLAY LUMPS AND FRIABLE PARTICLES IN AGGREGATES
FOP FOR AASHTO T 112**

Participant Name: _____ Exam Date: _____

Procedure

Sampling and Sample Preparation

- 1. A representative sample of appropriate mass obtained by T 2 and T 248? _____
- 2. Sample washed by T 11, then dried to constant mass at 230 ±9° F? _____
- 3. Fine aggregate sample mass at least 25 g? _____
- 4. Coarse aggregate separated into fractions, masses according to Table 1? _____

Procedure and Calculation

- 1. Mass of test fractions determined to 0.1% of sample mass? _____
- 2. Samples spread in thin layer, covered with distilled water for 24 ±4 hours? _____
- 3. Particles tested by rolling and squeezing between thumb and forefinger, but without use of fingernail or pressing against hard surface? _____
- 4. Correct sieve selected for wet sieving according to Table 2? _____
- 5. Wet sieved by passing water over samples while manually shaking sieve? _____
- 6. Fractions dried to constant mass at 230 ±9° F? _____
- 7. Fractions cooled and masses determined to 0.1% of sample mass? _____
- 8. Percent clay lumps and friable particles correctly calculated for each fraction? _____
- 9. Weighted percent clay lumps and friable particles correctly calculated for coarse aggregate sample based on aggregate grading? _____

Report

- 1. Standard agency forms? _____
- 2. Clay lumps and friable particles reported to nearest 1% _____
- 3. For coarse aggregate, weighted percentage according to sample grading? _____

Comments: First attempt: (Pass/Fail) ____ Second attempt: (Pass/Fail) ____

Signature of Examiner _____

**LIGHTWEIGHT PIECES IN AGGREGATE
FOP FOR AASHTO T 113**

02

Scope

This FOP describes methods of determining the percentage of lightweight pieces in coarse and fine aggregates.

Aggregates are tested in a saturated-surface-dry (SSD) condition in a heavy solution of the required specific gravity. Floating particles are removed from the sample with a skimming device, and the percentage of lightweight pieces is calculated as the proportion by mass of floating particles to that of the original sample tested.

03

Significance

This method is used to determine conformance with AASHTO M 6 and M 80 regarding the permissible amounts of lightweight pieces in fine and coarse aggregates. For this FOP, coal and lignite particles are defined as those having a specific gravity less than 2.00; chert particles are those having a specific gravity less than 2.40.

04

Apparatus

- **Balance:** Meeting requirements of AASHTO M 231, of sufficient capacity and readable to 0.1% of sample mass or better.
- **Containers:** Suitable for drying the aggregate samples and suitable for containing the heavy liquids during test.
- **Skimmer:** A suitably shaped piece of No. 50 screen cloth conforming to AASHTO M 92 for removing floating pieces during the sink-float separation portion of the test.
- **Oven or Hotplate:** Capable of maintaining a uniform temperature of $230 \pm 9^\circ \text{F}$.
- **Sieves:** No. 50 and No. 4 sieves conforming to AASHTO M 92.
- **Specific Gravity Measurement:** Hydrometers conforming to ASTM E 100 for the desired ranges of heavy liquid specific gravity, or suitable balance and glassware capable of measuring specific gravity within ± 0.01 .

05

06

Heavy Liquid

The heavy liquid shall be one of the following:

- A solution of zinc chloride in water for materials having specific gravities less than 2.00.
- A solution of zinc bromide in water for materials having a specific gravity of less than 2.60.
- A mixture of kerosene and 1,1,2,2 tetrabromoethane, proportioned to produce solutions of the desired specific gravity.
- Heavy liquid specific gravities shall be maintained within ± 0.01 at all times during the testing procedure.

07

08

Safety

The chemicals used to make the heavy liquids are toxic, both by inhalation and absorption through the skin.

Suitable personal protective equipment such as face shields, goggles, and gloves must be worn to prevent inhalation or skin contact. Solutions must be used only in vent hoods or out of doors.

09

Sampling

Obtain the sample according to AASHTO T 2. Reduce to appropriate testing size according to AASHTO T 248.

The sample used for testing shall conform to the requirements of Table 1.

Table 1 – Test Sample Size

10

Nominal Maximum Aggregate Size	Minimum Sample Mass (g)
No. 4	200
3/8"	1500
3/4"	3000
1½"	5000
3"	10000

Absolute Volume Calculation

$$A_s = \frac{W_s}{(SPG)(997)}$$

Where:

A_s = Absolute Volume of aggregate in kilograms (kg)

SPG = Specific Gravity of aggregate
997 = mass of 1 cubic meter of water

Note 1: As an alternative to the full soaking period stated in AASHTO T 84, if the aggregate absorption is known for the material being tested, the mass of water required to achieve the SSD state may be added to the dry sample, thoroughly mixed and covered for at least 30 minutes. Remix the sample at the end of the saturation period and test for the SSD condition according to AASHTO T 84.

Note 2: Water is a suitable solvent for solutions made with zinc bromide or zinc chloride. Alcohol is a suitable solvent for solutions made with 1,1,2,2, tetrabromoethane

Sample Preparation

Dry the sample to constant mass and cool to room temperature prior to conducting the test. Constant mass is defined as that moisture condition where there is no more than 0.1% loss in mass after an additional 2 hours of drying in an oven regulated at 230 ±9° F.

Procedure

Fine Aggregate

1. Sieve the dried material over a No. 50 screen until less than 1% of the retained material passes the screen after an additional 1 minute of continuous sieving.
2. Determine the mass of the material coarser than the No. 50 screen to the nearest 0.1 g and bring to a saturated-surface-dry (SSD) state as described in AASHTO T 84 (See Note 1).
3. Introduce the sample into the heavy liquid in a container of suitable size such that the volume of the liquid is at least three times the absolute volume of the fine aggregate. Agitate the sample in the liquid to permit lightweight pieces to float.
4. Pour the heavy liquid and floating pieces over the skimmer into a second container, taking care to not decant any of the particles that sank.
5. Return to the first container the liquid from the second container, agitate, and repeat step 4 until the sample has no more floating pieces.
6. Wash the decanted pieces in the skimmer with a suitable solvent to remove the heavy liquid, and allow them to become at least surface dry (See Note 2).
7. Further dry the washed sample to constant mass as noted under sample preparation.

If a heavy liquid was made using kerosene and tetrabromoethane, drying shall take place either out of doors or under a vent hood. If an oven is used, it must be forced air ventilated. In no case may the sample temperature exceed 239° F.

- 17 8. Allow the sample to cool to room temperature and determine the mass of the lightweight pieces to the nearest 0.1 g.

Coarse Aggregate

- 18 1. Sieve the dried material over a No. 4 screen until less than 1% of the retained material passes the screen after an additional 1 minute of continuous sieving.
- 2. Determine the mass of the material coarser than the No. 4 screen to the nearest 1 g and bring material to a saturated-surface-dry (SSD) state as described in AASHTO T 85.
- 19 3. Introduce the sample into the heavy liquid in a container of suitable size such that the volume of the liquid is at least three times the absolute volume of the coarse aggregate. Agitate the sample in the liquid to permit lightweight pieces to float.
- 4. Using the skimmer, remove the floating pieces and save them. Repeatedly agitate the material in the heavy liquid and remove the lightweight pieces until no more pieces float to the surface.
- 20 5. Wash the lightweight pieces with a suitable solvent to remove the heavy liquid (See Note 2). After washing allow the pieces to become at least surface dry prior to drying to constant mass.
- 6. Further dry the washed sample to constant mass as noted under sample preparation.

Absolute Volume Calculation

$$A_s = \frac{W_s}{(SPG)(997)}$$

Where:

A_s = Absolute Volume of aggregate in kilograms (kg)
 SPG = Specific Gravity of aggregate
 997 = mass of 1 cubic meter of water

21 **If a heavy liquid was made using kerosene and tetrabromoethane, drying shall take place either out of doors or under a vent hood. If an oven is used, it must be forced air ventilated. In no case may the sample temperature exceed 239° F.**

- 22 7. Allow the sample to cool to room temperature and determine the mass of the lightweight pieces to the nearest 1 g.

Calculations

Calculate the percentage of lightweight pieces according to the following formulas:

23

Fine Aggregate

$$L = 100 \frac{W_1}{W_2}$$

24

Coarse Aggregate

$$L = 100 \frac{W_1}{W_3}$$

where:

L = percentage of lightweight pieces

W₁ = dry mass of pieces that float

W₂ = dry mass of portion of specimen coarser than the No. 50 screen

W₃ = dry mass of portion of specimen coarser than the No. 4 screen

Tips

- Follow all required safety precautions during testing and when drying samples to constant mass after the sink-float procedure.
- Use the appropriate heavy liquids. (specific gravity of 2.40 for chert; 2.00 for coal & lignite).

Check heavy liquid specific gravity frequently to assure that variation does not exceed ± 0.01 at any time during testing.

25

Report

- Report on standard agency forms
- Project identification and location
- Material source and description, including nominal maximum size
- Type(s) and specific gravity of solution(s)
- Percentage of Lightweight pieces categorized as coal & lignite (specific gravity less than 2.00), calculated to the nearest 0.1%
- Percentage of lightweight pieces categorized as chert (specific gravity less than 2.40), calculated to the nearest 0.1%

REVIEW QUESTIONS

1. According to this FOP, what is the minimum required test sample mass when nominal maximum size is $\frac{3}{4}$ inch; when nominal maximum size is 1 inch?

2. Summarize specific gravity requirements for the heavy liquid(s).

3. Describe the safety precautions when handling the chemicals and heavy liquids.

4. In what moisture condition are aggregates when the sink-float procedure is performed?

5. What is the minimum volume of heavy solution needed for a coarse aggregate sample of 3812 grams having a specific gravity of 2.653?

6. Describe the skimming process for coarse aggregate testing.

7. Describe the remaining procedures after the skimming process but prior to calculation.

8. Given the following, the percentage of chert particles as reported is _____.

Dry Mass of Sample Before Test: 3812 g
Dry Mass of Lightweight Pieces (Chert): 13 g
Dry Bulk Specific Gravity (Gsb): 2.649

PERFORMANCE EXAM CHECKLIST

**LIGHTWEIGHT PIECES IN AGGREGATE
FOP FOR AASHTO T 113**

Participant Name: _____ Exam Date: _____

Procedure

Heavy Liquid Preparation and Safety

- 1. Solution(s) correctly prepared using all required safety procedures? _____
- 2. Specific gravity of solution checked with hydrometers or suitable glassware and is ± 0.01 of that specified (2.00 for coal and lignite; 2.40 for chert)? _____
- 3. Sufficient heavy liquid placed in a suitable container that will permit use of the skimming device (volume of solution at least 3 times that of the solid volume of the aggregate being tested)? _____
- 4. All required safety precautions adequately described (PPE, ventilated hood, temperature control, etc)? _____

Sampling and Sample Preparation

- 1. Sample obtained by AASHTO T 2 and reduced by T 248? _____
- 2. Sample of suitable size? (Table 1) _____
- 3. Aggregate dried to constant mass at $230 \pm 9^\circ$ F? _____

Procedure (Fine Aggregate)

- 1. All masses determined to 0.1 g? _____
- 2. Sample sieved over No. 50 screen until less than 1% of material passes after 1 minute of continuous sieving? _____
- 3. Mass correctly determined and sample brought to SSD condition? _____
- 4. Material placed in heavy liquid and agitated? _____
- 5. Liquid poured off over skimmer into second container without decanting pieces that sank? _____
- 6. Liquid returned to first container and the agitation and skimming process continued until no more floating particles appear? _____
- 7. Lightweight pieces cleaned of heavy solution in an appropriate solvent and allowed to surface dry? _____
- 8. Lightweight pieces further dried to constant mass and allowed to cool? _____
- 9. Final dry mass of lightweight pieces determined? _____
- 10. Specific gravity of solution after testing within ± 0.01 of the value before test? _____
- 11. Calculations properly performed and reported to 0.1%? _____

Procedure (Coarse Aggregate)

- 1. All masses determined to 1 g? _____
- 2. Sample sieved over No. 4 screen until less than 1% of material passes after 1 minute of continuous sieving? _____
- 3. Mass correctly determined and sample brought to SSD condition? _____
- 4. Material placed in heavy liquid and agitated? _____
- 5. Floating particles removed using skimmer and saved? _____
- 6. Agitation and skimming process continued until no more floating particles appear? _____
- 7. Lightweight pieces cleaned of heavy solution in an appropriate solvent and allowed to surface dry? _____
- 8. Lightweight pieces further dried to constant mass and allowed to cool? _____
- 9. Final dry mass of lightweight pieces determined? _____
- 10. Specific gravity of solution after testing within ± 0.01 of the value before test? _____
- 11. Calculations properly performed and reported to 0.1%? _____

Comments: First attempt: (Pass/Fail) ____ Second attempt: (Pass/Fail) ____

Signature of Examiner _____

CALIFORNIA BEARING RATIO OF SOILS FOP FOR AASHTO T 193

02 **Scope**

This method of test covers the determination of the California Bearing Ratio (CBR) of soils at optimum moisture content.

03 **Significance**

This test method is used to evaluate the potential strength of soils, including recycled materials, for use in roadway and airfield pavements. The CBR is an integral part of several flexible pavement design methods.

Where the effect of compaction water content on CBR is small, such as cohesionless, coarse-grained materials the CBR may be determined at the optimum water content of a specified compactive effort.

Where the effect of compaction water content on CBR is unknown or when its effect is to be accounted for, the CBR is determined for a range of water contents. See AASHTO T 193 for this procedure.

04 **Apparatus**

- 04 • **Mold(s):** Cylindrical-shaped steel mold(s), 7.0 ±0.018 in. in height, inside diameter of 6.0 ±0.026 in. The mold shall be provided with a collar extension, approximately 2.0 in. in height. The mold and collar assembly shall be so constructed that it can be fastened firmly to a perforated metal base plate. Perforations in the base plate shall have a diameter not exceeding 1/16 in.
- 05 • **Spacer-disc:** A metal disc, 2.416 ±0.01 in. in height with a diameter of $5\frac{15}{16} \pm \frac{1}{32}$ in., to be used as a false bottom in the mold during compaction.
- 06 • **Compaction equipment:** Mechanical equipment suitable to compact a solid specimen in a 6-in. diameter mold according to AASHTO T 99 or T 180.
- **Scale or Balance:** Capacity of at least 11 kg. (25 lb.), sensitive to 5 g. (0.01 lb.).





- 07
- **Apparatus for measuring expansion:** A perforated metal swell plate with an adjustable stem, a tripod dial mount, and a dial gauge with divisions of 0.001 in. The swell plate shall have a diameter of $5\frac{7}{8} \pm \frac{1}{16}$ in. Perforations in the swell plate shall have a diameter not exceeding $\frac{1}{16}$ in.
- 08
- **Weights:** One annular metal weight with a center hole $2\frac{1}{8}$ in. in diameter and several slotted metal weights, all $5\frac{7}{8}$ in. in diameter and weighing 5 ± 0.10 lb. The weights shall be suitable for applying a surcharge load on the surface of the soil specimen during soaking and penetration.
- 09
- **Penetration piston:** A metal piston of circular cross-section, at least 4 in. in length and with a diameter of 1.954 ± 0.005 in. (area of 3 in^2). The piston shall be long enough to penetrate the specimen with the surcharge weights in place.
- 10
- **Soaking tank:** A soaking tank suitable for maintaining the water level 1 in. above the top of the sample.
- 11
- **Loading device:** A laboratory testing machine or screw jacks and frame arrangement capable of applying a uniformly increasing load up to 10,000 lb., suitable to force the penetration piston into the specimen at a uniform rate of 0.05 in. per minute.

The loading device shall be fitted with a proving ring or other load indicating equipment, suitable for reading loads in 10 lb. increments.
- 12
- **Drying oven:** A thermostatically controlled oven capable of maintaining a temperature of $230 \pm 9^\circ \text{ F}$.
 - **Miscellaneous:** Tools such as mixing pan, spoon, spatula, straightedge, etc.
- 13
- Sampling and Sample Reduction**
- Obtain a sample of sufficient size for the specified procedure according to AASHTO T 2.
 - Reduce to a test sample size of at least 35 kg. (75 lb.) according to AASHTO T 248.

Sample

- 14
- Prepare the sample according to AASHTO T 99 or T 180 except that if material larger than 3/4 in. is present, that material shall be removed and replaced with an equal amount of material passing the 3/4 in. but retained on the No. 4 sieve. Material for replacement shall be obtained from the original representative sample. Recombine the material thus prepared and mix thoroughly.

Moisture Density Relations

- 15
- From the prepared sample, select a representative portion of approximately 11 kg. (25 lb.).
 - Determine the maximum dry density and optimum moisture content of the material according to AASHTO T 99 or T 180. (Consult agency specifications for determining which method is applicable).

CBR Specimen Preparation

- 16
1. From the prepared material, select three or more samples of approximately 6.8 kg. (15 lb.) each, and mix with sufficient water to obtain the optimum moisture content. If the soil is clay with hard dry lumps, the moistened material shall be placed in air tight containers and allowed to cure for approximately 24 hours.
- 17
2. These specimens will be used for compaction at separate compactive efforts. Consult agency specifications for the required range of compactive effort. Follow the remaining procedures for each of the specimens.
- 18
3. Clamp the 6-in. diameter mold to the base plate, and determine the mass of the assembly including two filter papers.
- 19
4. Insert the spacer disc. Place one filter paper on top of the disc and install the removable collar.
 5. Compact the soil into the mold using the applicable rammer, number of layers, and number of blows required to achieve the desired level of compactive effort.

Note 1: Some laboratories may prefer to test only one specimen which would be compacted to maximum dry density at optimum moisture content as determined by the FOP for AASHTO T 99/T 180.

20

- 6. Obtain samples at the beginning and end of the compaction procedure to determine the moisture content according to T 265.
- 7. Following compaction, remove the extension collar and carefully trim the compacted soil even with the top of the mold. Release the mold from the base and remove the spacer disc. Place the second filter paper on the perforated base plate, invert the mold and specimen, and clamp the perforated base plate to the mold with the filter paper in contact with the compacted specimen.

21

- 8. Determine the mass of the specimen, filter papers, and mold with base plate. Subtract the mass of the mold, base plate, and filter papers, and record.

22

- 9. Attach the extension collar to the mold and place the perforated swell plate with adjustable stem on the surface of the specimen. Apply annular weights to produce a surcharge within 5 lb. of the anticipated mass of the base course and pavement (at least 10 lb. must be applied). Take initial measurements for swell by placing the tripod on the mold and adjustable stem and reading the dial gage.

23



24

$$\% \text{ swell} = \frac{\text{height change (in.)}}{4.584 \text{ in.}} \times 100$$

25

Note 2: A shorter soaking period is permissible for A-1-a and A-3 soils if tests show that a shorter period does not affect the test results, but in no case shall the soaking period be less than 24 hours.

26

- 10. Immerse the assembled mold, swell plate, and annular weights in water allowing free access of water to the top and bottom of the specimen. Allow the specimen to soak for 96 hours. (See Note 2). Be sure the water level is maintained approximately 1 in. above the top of the specimen during this period. At the end of the soaking period, take final swell measurements and determine the swell as a percentage of the initial height of the specimen (4.584 in.).
- 11. Remove the free water from the top of the specimen and allow draining downward for 15 minutes. Care shall be taken not to disturb the surface of the specimen during removal of water and draining.
- 12. Remove the extension collar, annular weights, and perforated plate. Determine the mass of the specimen and mold with base plate.
- 13. Immediately conduct the penetration procedure.



Penetration Procedure

- 27 1. Place annular weights on the surface of the specimen equal to the surcharge maintained during the soaking period. To prevent displacement of soft materials, seat the penetration piston with a 10 lb. load after one surcharge weight has been placed on the specimen. After seating the penetration piston, place the remainder of the surcharge weights around the piston.
- 28 2. Seat the penetration piston with a 10 lb. load, and set both the stress and strain gages to zero. This initial load is required to insure satisfactory seating of the piston and shall be considered as zero load when determining the stress-strain relationship. (The mass of the penetration piston is considered negligible).
- 29 3. Apply the load on the penetration piston so that the rate of penetration is 0.05 in. per minute. Take load readings to the nearest 10 lb. at penetrations of 0.025, 0.050, 0.075, 0.100, 0.125, 0.150, 0.175, 0.200, and 0.300 in. (Load readings at 0.400 and 0.500 in. may also be taken if desired). Note the maximum load and penetration if it occurs before 0.300 in.
- 30 4. Remove the soil from the mold. If required, determine the moisture content of the upper 1 in. soil layer according to AASHTO T 265.

Calculation

- 31 The California Bearing Ratio shall be calculated as follows (See examples on pages 6-7 through 6-9):
- Using the load data, plot a stress-strain curve for each specimen with the resistance to penetration (lb.) as the ordinate and the inches of penetration as the abscissa. (If the load-penetration curve is concave upward initially, the zero point shall be adjusted by extending the straight-line portion of the curve downward to the point at which it intercepts the abscissa. All penetration values shall also be adjusted accordingly).
 - 32 • The corrected load values for each specimen will be noted at penetrations of 0.100 and 0.200 in.

33

- Convert the corrected load values to pounds per square inch (psi) by dividing the load (lb.) by the cross-sectional area (in²) of the penetration piston.
- Divide the calculated strength values for 0.100 and 0.200 in. penetration by the standard loads of 1000 and 1500 psi respectively, multiplying the ratios by 100 to convert to whole percentages.
- Generally, the CBR value at 0.100 in. penetration is selected. If the value at 0.200 in. penetration is greater than that at 0.100 in., the test must be re-run. If the retest gives similar results, the value at 0.200 in. penetration shall be reported.

34

Report

- Report on standard agency forms.
- CBR percent at 0.100 or 0.200 in. penetration.
- Compactive effort (blows per layer).
- Compaction method used (AASHTO T 99 or T 180).
- Moisture content as molded.
- Swell (percent of original height).
- Soil description.
- Sample and project identification.

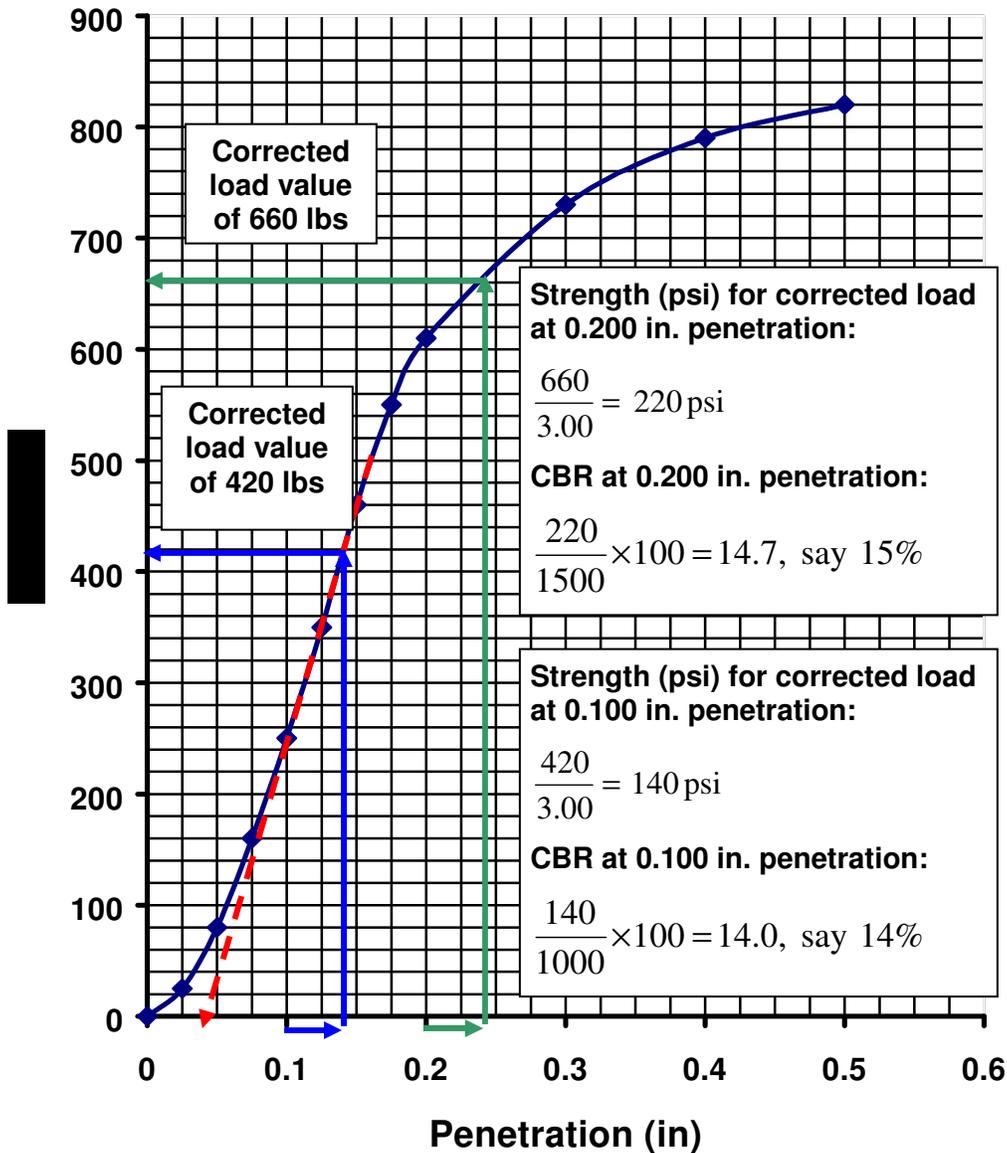
35

Tips!

- At all times, except during processing, keep the test sample in covered containers to avoid moisture loss due to evaporation.
- Frequently change the water in the soaking tank to minimize contamination of test specimens during the soaking period.

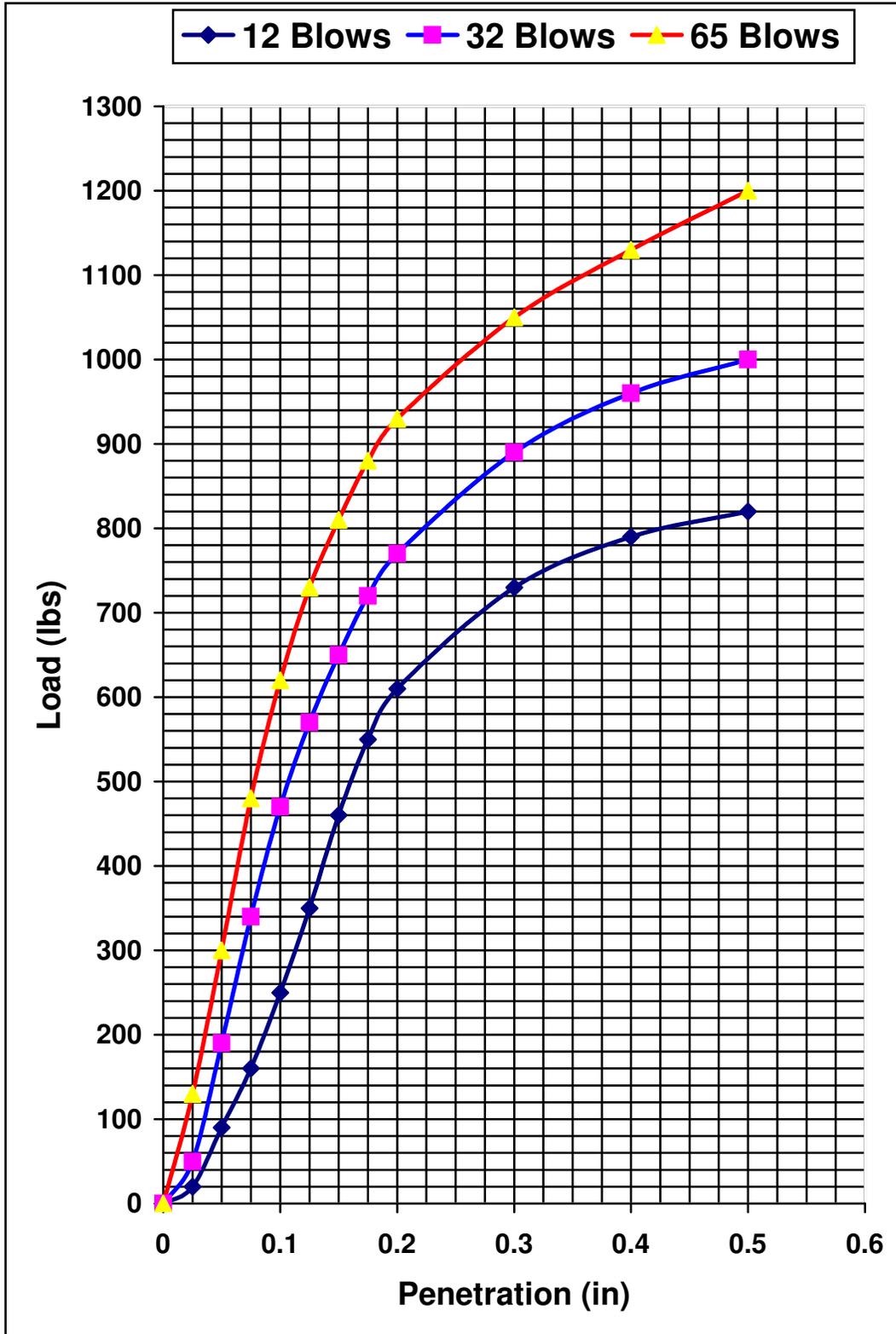
Correction of stress-strain curve

If there is an initial concave upward portion of the curve, correction is made by extending the straight-line portion downward to where it intercepts the abscissa. The load values for 0.100 and 0.200 in. penetration are corrected accordingly.



Penetration Piston Diameter = 1.953 inches	
Remember:	$A = \pi r^2$
$\pi = 3.1416$	$A = \pi (.9765^2)$
$r = \text{radius}$	$A = 2.9957$
	$A = 3.00 \text{ in}^2$

Load Penetration Values for 3 Compactive Efforts



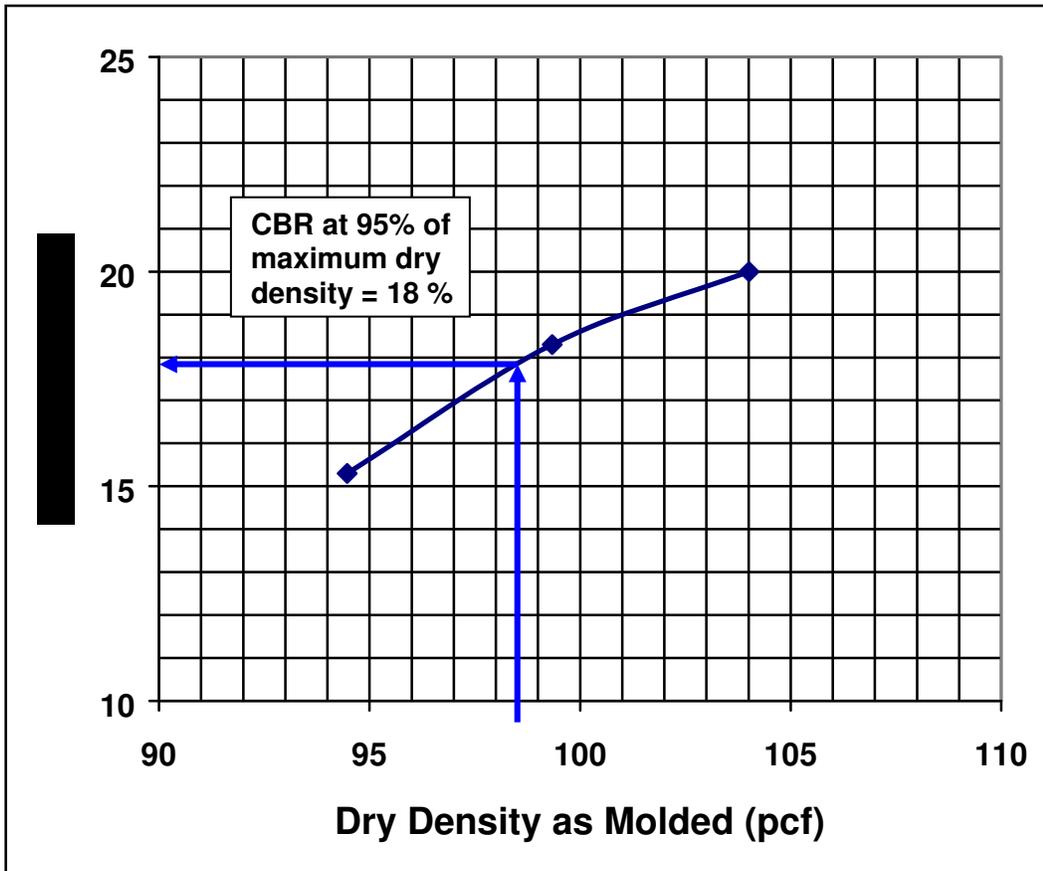
Dry Density vs. CBR for 3 Compactive Efforts

Moisture Density Relations:

Maximum Dry Density: 103.5 pcf
 Optimum Moisture Content: 18.6 %

Compactive Effort

12 Blows per Layer – 94.5 pcf (91.3 % of max)
 32 Blows per Layer – 99.3 pcf (95.9 % of max)
 65 Blows per Layer – 104.0 pcf (100.5 % of max)



REVIEW QUESTIONS

1. If material larger than $\frac{3}{4}$ inch is present in the sample obtained for performing the CBR, what must be done?
2. According to this FOP, how many different compactive efforts are evaluated?
3. How much surcharge is applied to the sample? What does it represent?
4. For how long are samples usually soaked? Is a shorter soaking period allowed? Explain.
5. Describe the penetration procedure.
6. At what penetration is the CBR usually reported? Are there any exceptions? Explain.

PERFORMANCE EXAM CHECKLIST

**CALIFORNIA BEARING RATIO OF SOILS
FOP FOR AASHTO T 193**

Participant Name: _____ Exam Date: _____

Procedure

Sampling

- 1. Sample of sufficient size obtained according to FOP for AASHTO T 2? _____
- 2. Sample reduced to testing size of approximately 35 kg according to FOP for AASHTO T 248? _____

Sample Preparation

- 1. If all material passes ¾ inch sieve, entire sample used? _____
- 2. If materials larger than ¾ inch present, oversize replaced with equal mass of ¾ inch to No. 4 material from the original representative sample? _____
- 3. Representative portion of initial sample, weighting approximately 11 kg (25 lb), selected for moisture-density test? _____
- 4. Sample tested according to AASHTO T 99 or T 180 using 6 in mold? _____
- 5. Remainder of sample divided to obtain at least 3 representative portions weighing approx. 6.8 kg (15 lb) each? _____
- 6. Compactive effort(s) selected (frequently 10, 30, and 65 blows per layer) according to agency standards? _____

Procedure

- 1. Mold clamped to base plate and extension collar attached? _____
- 2. Mold, base, 2 filter papers weighed to nearest 5 g (0.01 lb)? _____
- 3. Spacer disc placed in mold and filter paper placed on disc? _____
- 4. Each sample mixed with water to obtain optimum water content, and compacted in mold according to desired method? _____
- 5. Moisture samples obtained at beginning and end of compaction according to AASHTO T 265? _____
- 6. Extension collar removed, and compacted soil trimmed even with top of mold using straightedge. _____
- 7. Mold loosened from base and spacer disk removed? _____
- 8. Filter paper placed on perforated base plate? _____
- 9. Mold inverted and placed on filter paper (compacted soil contacts paper)? _____
- 10. Base plate clamped to mold? _____
- 11. Mass determined to nearest 5 g (0.01 lb)? _____

Soaking

- 1. Swell plate placed on sample in mold? _____
- 2. Sufficient annular weights, at least 10 lb, placed on swell plate load? _____
- 3. Tripod and dial indicator placed on top of mold and initial reading taken? _____

- 4. Mold immersed in water, allowing free access of water to top and bottom of specimen? _____
- 5. Water level in mold and tank maintained approximately 1 in above the top of specimen during soaking? _____
- 6. Specimen soaked for 96 hours (4 days)? _____
Note: A shorter immersion period (not less than 24 hours) may be used for materials that drain readily, if tests show that shorter period doesn't affect test results. Soaking period greater than 4 days may be required for some clays.
- 7. Final dial reading taken and percent swell calculated? _____
- 8. Specimen removed from tank, water poured off top, and allowed to drain downward for 15 minutes? _____
- 9. Surcharge weights, perforated plate removed after draining? _____
- 10. Mass of specimen determined (optional)? _____

Penetration Test

- 1. Penetration test conducted immediately after draining down? _____
- 2. Same number of surcharge weights placed on specimen as during soaking period (weight with circular hole at bottom)? _____
- 2. Soaked sample placed in testing apparatus with piston installed? _____
- 3. Piston seated with 10 lb load? _____
- 4. Penetration dial indicator and load indicators set to zero? _____
- 5. Loads applied to piston so penetration rate is uniform at 0.05 in per minute? _____
- 6. Loads recorded at penetrations of 0.025, 0.050, 0.075, 0.100, 0.150, 0.200, and 0.300 inch (0.400 and 0.500, if desired)? _____
- 7. Water content of upper 1 inch of sample determined (optional)? _____
- 8. Stress-strain curve prepared, correction made if necessary? _____
- 9. CBR values obtained correctly? _____

Comments: First attempt: (Pass/Fail) _____ Second attempt: (Pass/Fail) _____

Signature of Examiner _____

**UNCOMPACTED VOID CONTENT OF FINE AGGREGATE
FOP FOR AASHTO T 304**

02

Scope

This Field Operating Procedure (FOP) covers a method for determining the loose uncompact void content of a sample of fine aggregate

Three procedures are included for the measurement of void content:

- **Standard Graded Sample (Method A)**
- **Individual Size Fractions (Method B)**
- **As-Received Grading (Method C)**

For Method A or C, the percent void content is determined directly, and the average value of two test runs is reported.

For Method B, the mean percent void content is calculated using results from the three individual size fractions (average of two test runs for each size).

03

Significance

Methods A and B provide percent void content determined under standardized conditions which depend on the particle shape and texture of a fine aggregate. An increase in void content by these procedures indicates greater angularity, less sphericity, rougher surface texture, or some combination of these three factors.

04

Method C measures the uncompact void content of the minus No. 4 portion of the as-received material. This void content depends on both grading as well as particle shape and texture.

The standard graded sample (Method A) is most useful as a quick test that indicates the particle shape properties of a graded fine aggregate. Typically, the material used to make up the standard graded sample can be obtained from the remaining size fractions after performing a single sieve analysis of the fine aggregate.

Obtaining and testing individual size fractions (Method B) is more time-consuming and requires a larger initial sample than using the graded sample. However, Method B provides additional information concerning the shape and texture characteristics of individual size fractions.

Testing samples in the as-received grading (Method C) may be useful in selecting proportions of the components used in a variety of mixtures. In general, high void content suggests that the material could be improved by providing additional fine aggregate or more binder may be needed to fill the voids between particles.

05 The $G_{sb}(OD)$, oven-dry bulk specific gravity of the fine aggregate, is used to calculate the void content. The effectiveness of these methods of determining void content and its relationship to particle shape and texture depend on the $G_{sb}(OD)$ of the various size fractions being equal (or nearly so).

Void content information from Methods A, B, and C may be a useful indicator of properties such as:

- Mixing water demand of hydraulic cement concrete.
- Flowability, pumpability, or workability of grouts and mortars.
- The effect of fine aggregate on stability, strength and VMA in bituminous concrete.
- Stability and strength of base course material.



06 **Apparatus**

- 07
- **Cylindrical Measure:** A right cylinder of approximately 100 mL capacity having an inside diameter of approximately 1.5 in. and an inside height of approximately 3.4 in. made of drawn copper water tube. The bottom of the measure shall be at least 0.25 in. thick, shall be firmly sealed to the tubing, and shall be provided with the means for aligning the axis of the cylinder with that of the funnel. Determine the volume of the measure to the nearest 0.1 mL.
 - **Funnel:** A funnel such that the lateral surface of the right frustrum of the cone is sloped $60 \pm 4^\circ$ from the horizontal with an opening of 0.5 ± 0.02 in. diameter. The funnel section shall be a piece of metal, smooth on the inside, and at least 1.5 in. high. It shall have a volume of at least 200 mL, or shall be provided with a supplemental container to provide the required volume.

08

- **Funnel stand:** A three or four-legged support capable of holding the funnel firmly in position with the axis of the funnel collinear (within 4° angle and a displacement of 0.07 inches) with the axis of the cylinder measure. The funnel opening shall be 4.5 in. above the top of the cylinder.

- **Glass Plate:** A square glass plate approximately 2.3 by 2.3 in. with a minimum 0.15 in. thickness.

09

Note 1: 2011 AASHTO – the pan shall not be warped, so as to prevent rocking of the apparatus during testing.

- **Pan:** A metal or plastic pan of sufficient size to contain the funnel stand and prevent loss of material.

- **Spatula:** A metal spatula with a blade approximately 4 in. long and at least 0.75 in. wide, with straight edges. The end shall be cut at a right angle to the edges.

- **Balance:** A balance with a capacity of 1000 g and sensitive to ±0.1 g.

Sample

10

- The samples used for this test shall be obtained using AASHTO T 2 and AASHTO T 248, or from sieve analysis samples used for AASHTO T 27, or from an extracted bituminous concrete sample.

11

- For Methods A and B, the sample is washed over a No. 100 or No. 200 sieve in accordance with AASHTO T 11 and then dried and sieved into separate size fractions according to AASHTO T 27. Maintain the necessary size fractions obtained from one or more sieve analyses in a dry condition in separate containers for each size.

- For Method C, dry a split of the as-received sample in accordance with the drying provisions of AASHTO T 27.

Sample Preparation

12 • **Method A – Standard Graded Sample**

Weigh out and combine the following quantities of fine aggregate that has been dried and sieved in accordance with AASHTO T 27.

<u>Individual Size Fraction</u>	<u>Mass, g</u>
No. 8 to No. 16	44 ±0.2
No. 16 to No. 30	57 ±0.2
No. 30 to No. 50	72 ±0.2
No. 50 to No. 100	<u>17 ±0.2</u>
	190 ±0.2

13 • **Method B – Individual Size Fractions**

Prepare a separate 190 g sample of fine aggregate, dried and sieved in accordance with AASHTO T 27 for each of the following size fractions:

<u>Individual Size Fraction</u>	<u>Mass, g</u>
No. 8 to No. 16	190 ±1
No. 16 to No. 30	190 ±1
No. 30 to No. 50	190 ±1

Do not mix fractions together. Each size is tested separately.

14 • **Method C – As-received Grading**

Pass the sample (dried in accordance with AASHTO T 27) through a No. 4 sieve. Obtain a 190 ±1 g sample of this material for the test.

Specific Gravity of Fine Aggregate

15 If the $G_{sb}(OD)$ of the fine aggregate from the source is unknown, determine it according to AASHTO T 84. Use this value in subsequent calculations unless some size fractions differ by more than 0.05 from the specific gravity typical of the sample, in which case the specific gravity of the fraction(s) must be determined.

Procedure

- 16 1. Record all masses to the nearest 0.1 g.
2. Record the mass of the empty measure
3. Mix each test sample with the spatula until it appears to be homogeneous.
4. Position the jar and funnel section in the stand and center the cylindrical measure with the axis of the funnel. Use a finger to block the opening of the funnel.
5. Pour the test sample into the funnel. Level the material in the funnel with the spatula.
- 17 6. Remove the finger and allow the sample to freely flow into the cylindrical measure.
7. After the funnel empties, strike off excess from the top of the cylindrical measure by a single pass of the spatula with the width of the blade vertical, using the straight part of its edge in light contact with the top of the measure. Until this operation is complete, avoid vibration or disturbance that could cause compaction of the fine aggregate in the measure (see Note 1).
- 18 8. Brush adhering grains from the outside of the cylindrical measure. Determine the mass of the measure and its contents to the nearest 0.1 g.
9. Recombine the sample from the retaining pan and cylindrical measure, repeat the procedure, and average the results of the two test runs.

Note 2: After strike-off, the cylindrical measure may be tapped lightly to compact the sample for easier transport of the container to the scale or balance without loss of any sample.

Calculation

- 19 Calculate the uncompacted voids for each determination according to the following formula:

$$U = \frac{V - \left(\frac{F}{G}\right)}{V} \times 100$$

where:

U = uncompacted voids, percent, in the material;
 V = volume of cylindrical measure, mL;
 F = net mass of fine aggregate in measure, g; and,
 G = $G_{sb}(OD)$ of aggregate

20

For Methods A and C: Calculate the average uncompacted voids for the two determinations.

For Method B: First determine the uncompacted void content for each of the individual size fractions (two determinations each); then calculate the mean uncompacted void content as follows:

$$U_m = \frac{U_1 + U_2 + U_3}{3}$$

where:

U_m = Mean uncompacted void content, %

U_1, U_2, U_3 = Uncompacted void content of individual size fractions

Calculation Examples

$$U = \frac{99.8 - \left(\frac{146.2}{2.636} \right)}{99.8} \times 100 = 44.43, \text{ say } 44.4\%$$

21

where:

U = Uncompacted void content, %;

V = 99.8 mL

F = 146.2 g.

G = 2.636

$$U_m = \frac{48.7 + 49.9 + 47.0}{3} = 48.53, \text{ say } 48.5\%$$

22

where:

U_m = Mean uncompacted void content, %

U_1 = 48.7%

U_2 = 49.9%

U_3 = 47.0%

23

Report

- Results shall be reported on standard agency forms to the nearest 0.1 percent.
- Method used
- Material source and description
- Sample mass
- Bulk specific gravity used

Tips!

- Check agency specifications for method to be used, “A,” “B,” or “C” 24
- Level the material in the funnel
- Strike-off the measure with a single pass of the spatula
- Tapping the cylindrical measure after striking off will help prevent loss while handling

REVIEW QUESTIONS

1. Describe the sample used for Method A.
2. Describe the difference(s) between Method C and Method A?
3. What information is required to perform the Method A uncompacted void calculation?
4. After material is placed in the funnel, what is the next step?
5. After the first test run, how many times is the test repeated to calculate the average uncompacted void content?
6. Describe how the strike-off of the cylindrical measure is performed.

PERFORMANCE EXAM CHECKLIST

**UNCOMPACTED VOID CONTENT OF FINE AGGREGATE
FOP FOR AASHTO T 304**

Participant Name: _____ Exam Date: _____

Record the symbols “P” for passing or “F” for failing on each step of the checklist.

Procedure Element

Trial 1

Trial 2

Sampling

1. Sample obtained by one of the following:

(a) T 2 & T 248 (sampling, splitting and quartering)? _____

or (b) From sieve analysis samples used for T 27? _____

or (c) From aggregate extracted from a bituminous concrete specimen (T 308)? _____

2. Methods A and B:

(a) Sample washed over No. 100 or No. 200 sieve in accordance with T 11? _____

(b) Sample dried and sieved into separate size fractions in accordance with T 27? _____

(c) Necessary size fractions obtained from sieve analysis maintained in a dry condition in separate containers for each size? _____

Method C:

(a) A split of the as-received sample dried in accordance with the drying procedure of T 27? _____

Sample Preparation

Method A- Standard Graded Sample

1. Following quantities of aggregate that has been dried and sieved in accordance with T 27 weighed out and combined? _____

Individual Size Fractions	Mass, g	OK?
No. 8 to No. 16	44 ± 0.2	
No. 16 to No. 30	57 ± 0.2	
No. 30 to No. 50	72 ± 0.2	
No. 50 to No. 100	17 ± 0.2	
Total:	190 ± 0.2	

Method B- Individual Size Fractions

1. Separate 190 g sample of aggregate prepared for each of the following size fractions?

Individual Size Fractions	Mass, g	OK?
No. 8 to No. 16	190 ± 1	
No. 16 to No. 30	190 ± 1	
No. 30 to No. 50	190 ± 1	

2. Samples not mixed together, but each size saved for separate testing?

Trial 1
Trial 2

Method C- As Received Grading

1. Sample passed through No. 4 sieve? _____

2. Representative sample of 190 ± 1 g. obtained from minus No. 4 sieve? _____

Specific Gravity of Fine Aggregate

1. If bulk dry specific gravity of aggregate from the source is unknown, specific gravity determined on material passing No. 4 sieve in accordance with T 84? _____

2. This value used in subsequent calculations unless some size fractions(s) being tested must be determined? _____

3. If specific gravity differences between size fractions exceed 0.05:
 - (a) Specific gravity of the individual No. 8 to No. 100 sizes determined for use with Method A or the individual size fractions for use with Method B? _____

 - (b) Specific gravity determined by direct measurement or by calculation using specific gravity data on gradings with and without the size fraction of interest? _____

Procedure

1. Each test sample mixed with spatula until it appears to be homogeneous? _____

2. Funnel stand apparatus with cylindrical measure, positioned in retaining pan? _____

3. Finger used to block opening of funnel? _____

4. Test sample poured into funnel? _____

5. Material in funnel leveled with spatula? _____

6. After funnel empties, excess heaped aggregate struck off from cylindrical measure by single pass of spatula, with blade width vertical and using straight part of its edge in _____

- light contact with top of measure? _____

7. Care exercised to avoid vibration or any disturbance that could cause compaction aggregate into cylindrical measure? _____ of

- Note: After strike-off, measure may be tapped lightly to compact sample to make it easier to transfer container to scale or balance without spilling any of the sample.*
8. Adhering grains brushed from outside of container? _____

9. Mass of cylindrical measure and contents determined to nearest 0.1 g? _____

10. All aggregate particles retained for second test run? _____

11. Sample from retaining pan and cylindrical measure recombined and procedure repeated? _____

12. Mass of empty measure recorded? _____

13. Calculations performed properly? _____

Formula for Calculation of Uncompacted Voids, percent

$$U = \frac{V - \left(\frac{F}{G}\right)}{V} \times 100$$

where:

- U = uncompacted voids, percent;
- V = volume of cylindrical measure to nearest 0.1 mL;
- F = net mass, g, of fine aggregate in measure; and,
- G = bulk dry specific gravity of fine aggregate (G_{sb})

