Manual of Aggregate Quality Test Procedures

State of Illinois
Illinois Department of Transportation

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Manual of Aggregate Quality Test Procedures

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Revision History and Document Control

The Manual of Aggregate Quality Test Procedures will be reviewed by the Aggregate Technology Coordinator for adequacy and updated as necessary to reflect the current policies and technology changes. Updates are made to the electronic file as needed and hard copies are uncontrolled.

Revision Date	Description	Approval
1/1/18	Changes to Manual dated January 1, 2017. Illinois Test Procedures 87 and 88 were added. All Illinois Test Procedures were updated with an effective date of January 1, 2018.	Julie Beran
4/16/19	Revised Table 1 in Illinois Test Procedure 96.	Andrew Stolba

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ILLINOIS TEST PROCEDURE 21

ORGANIC IMPURITIES IN FINE AGGREGATES FOR CONCRETE (COLOR)

Effective Date: January 1, 2018

1. SCOPE

1.1 This test method covers two procedures for an approximate determination of the presence of injurious organic compounds in fine aggregates that are to be used in hydraulic cement mortar or concrete. One procedure uses a standard color solution and the other uses a glass color standard.

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

2. REFERENCED DOCUMENTS

2.1 Illinois Test Procedure (ITP):

- ITP 2, Sampling of Aggregates
- ITP 71, Effect of Organic Impurities in Fine Aggregate on Strength of Mortar
- ITP 248, Reducing Samples of Aggregate to Testing Size

2.2 AASHTO Standards:

- M 6, Fine Aggregate for Hydraulic Cement Concrete
- R 16, Regulatory Information for Chemicals Used in AASHTO Tests

2.3 ASTM Standards:

- D 1544, Test for Color of Transparent Liquids (Gardner Color Scale)

3. SIGNIFICANCE AND USE

3.1 This test method is of significance in making a preliminary determination of the acceptability of fine aggregates with respect to the requirements of AASHTO M 6.

3.2 The principal value of this test method is to furnish a warning that organic impurities may be present. When a sample subjected to this test produces a color darker than the standard color, it is advisable to perform the test for the effect of organic impurities on the strength of mortar in accordance with ITP 71.

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ORGANIC IMPURITIES IN FINE AGGREGATES FOR CONCRETE (COLOR)

Effective Date: January 1, 2018

4. APPARATUS

4.1 *Glass Bottles* – Colorless glass graduated bottles, approximately 8 to 14fl.oz (236.6 to 414mL) nominal capacity, equipped with watertight stoppers or caps, not soluble in the specified reagents. In no case shall the maximum outside dimension of the bottles, measured along the line of sight used for the color comparison, be greater than 3.0 inch (76.2 mm) or less than 1.5 inch (38.1 mm). The graduations on the bottles shall be milliliters or ounces (U.S. fluid), except that unmarked bottles may be calibrated and scribed with graduations by the user. In such case, graduation marks are required at only three points as follows:

4.1.1 *Standard Color Solution Level* – 2 ½fl.oz (73.9mL);

4.1.2 *Fine Aggregate Level* – 4 ½fl.oz (133.1mL);

4.1.3 *NaOH Solution Level* – 7fl.oz (207mL).

4.2 *Glass Color Standard:*

4.2.1 Glass standard colors shall be used as described in Table 1 of ASTM D 1544.

Note 1 – A suitable instrument consists of five glass color standards mounted in a plastic holder. Only the glass identified as Gardner color Standard No. 11 is to be used as the Glass color Standard in Section 9.1.

5. REAGENT AND STANDARD COLOR SOLUTION

5.1 *Reagent Sodium Hydroxide Solution (3 percent)* – Dissolve 3 parts by mass of sodium hydroxide (NaOH) in 97 parts of water.

5.2 *Standard Color Solution* – Dissolve reagent grade potassium dichromate ($K_2Cr_2O_7$) in concentrated sulfuric acid (SPG 1.84) at the rate of 0.250g/100mL of acid. The solution must be freshly made for the color comparison using gentle heat if necessary to effect solution. Preparation of the reference standard color solution is unnecessary when the Glass Color Standard procedure is used to determine the color value.

6. SAMPLING

6.1 The sample shall be selected in general accordance with ITP 2.

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ORGANIC IMPURITIES IN FINE AGGREGATES FOR CONCRETE (COLOR)

Effective Date: January 1, 2018

7. TEST SAMPLE

7.1 Reduce field sample by use of a sample splitter or by quartering according to ITP 248, to obtain approximately 2500g of fine aggregate. Place sample in a suitable pan or vessel and allow to air dry prior to testing.

Using a fine aggregate sample splitter, separate out approximately 450g for test sample; retain remaining material for Section 10.1.

8. PROCEDURE

8.1 Fill a glass bottle to approximately 4 ½fl.oz (133.1mL) level with the sample of the fine aggregate to be tested.

8.2 Add a 3-percent NaOH solution in water until the volume of the fine aggregate and liquid, indicated after shaking, is approximately 7fl.oz (207mL).

8.3 Stopper the bottle, shake vigorously, and then allow to stand for 24 hours.

9. DETERMINATION OF COLOR VALUE

9.1 *Standard Procedure* – At the end of the 24-hour standing period, fill a glass bottle to the 2.5fl.oz (73.9mL) level with the fresh reference color solution, prepared not longer than 2 hours previously, as prescribed in Section 5.2. Then compare the color of the liquid of the test sample with the Hellige Comparator using all 16 color standards of the Gardner Color Scale. The color that most closely matches the test specimen shall be reported.

10. INTERPRETATION OF RESULTS

10.1 If the color of the supernatant liquid is darker than that of the standard color solution or the glass color standard organic plate No. 8 (Gardner Color Standard No. 11), the fine aggregate under test shall be considered to possibly contain injurious organic compounds, and further testing shall be done in accordance with ITP 71 before approving the fine aggregate for use in concrete.

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ILLINOIS TEST PROCEDURE 71

EFFECT OF ORGANIC IMPURITIES IN FINE AGGREGATE ON STRENGTH OF MORTAR (MORTAR STRENGTH)

Effective Date: January 1, 2018

1. SCOPE

1.1 This test method covers the determination of the effect on mortar strength of the organic impurities in fine aggregate, whose presence is indicated by tests with ITP 21. Comparison is made between compressive strengths of mortar made with washed and unwashed fine aggregate.

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

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

2. REFERENCED DOCUMENTS

2.1 Illinois Test Procedure (ITP):

- ITP 2, Sampling of Aggregates
- ITP 21, Organic Impurities in Fine Aggregates for Concrete
- ITP 84, Specific Gravity and Absorption of Fine Aggregates
- ITP 248, Reducing Samples of Aggregate to Testing Size

2.2 AASHTO Standards:

- M 6, Fine Aggregate for Hydraulic Cement Concrete
- M 85 (Illinois Modified), Portland Cement
- M 152M/M 152 (Illinois Modified), Flow Table for Use in Tests of Hydraulic Cement
- M 231, Weighing Devices Used in the Testing of Materials
- R 16, Regulatory Information for Chemicals Used in AASHTO Tests
- T 106M/T 106, Compressive Strength of Hydraulic Cement Mortar (Using 50 mm or 2 in. Cube Specimens)
- T 162, Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency

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EFFECT OF ORGANIC IMPURITIES IN FINE AGGREGATE ON STRENGTH OF MORTAR (MORTAR STRENGTH)

Effective Date: January 1, 2018

2.3 ASTM Standard:

- C 670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
- C 778, Standard Specification for Standard Sand

3. SIGNIFICANCE AND USE

3.1 This test method is of significance in making a final determination of the acceptability of fine aggregates with respect to the requirements of AASHTO M 6 concerning organic impurities.

3.2 This test method is only applicable to those samples which, when tested in accordance with ITP 21, have produced a supernatant liquid with a color darker than that of the reference standard color Plate No. 3 or color solution.

4. SAMPLING AND SAMPLE PREPARATION

4.1 The fine aggregate shall be compared in mortar with a standard sample. The standard sample shall be made of silica sand consisting of equal parts of a 20/30 blend sand and a graded sand, both meeting ASTM C 778.

4.2 Strength comparisons shall be made at 14 days in accordance with the following conditions:

4.2.1 Mix one batch of mortar for the fine aggregate test sample and one batch of mortar for the standard sample. All batches shall have the same quantity of fine aggregate. Mix the batches for the two conditions alternately.

4.2.2 Mold three 2 inch (50 mm) cubes from each batch.

4.2.3 Test the three cubes for compressive strength at 14 days.

5. SAMPLING AND SAMPLE PREPARATION

5.1 Sample portions of fine aggregate for this test shall be obtained from the same sample used for ITP 21. Needed reduction of samples to obtain test portions shall be in accordance with ITP 248.

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Effective Date: January 1, 2018

5.2 Secure an additional field sample if needed from the aggregate supply in accordance with ITP 2.

5.3 In the event that the fine aggregate being used includes particles so large that the adjustment bracket (as described in AASHTO T 162) cannot provide adequate clearance, the oversized particles shall be removed by sieving on the No. 4 (4.75 mm) or No. 8 (2.36 mm) sieve. If this procedure is employed, the report shall so state and shall indicate the percentage of material so removed.

Note 1 – *Caution*: The clearances between the paddle and the bowl specified in T 162 are suitable when using the standard mortar made with graded sand. To permit the mixer to operate freely and to avoid serious damage to the paddle and bowl when coarser aggregates are used, it may be necessary to set the clearance adjustment bracket to provide greater clearances than specified. A clearance of approximately 0.16 inch (4.0 mm) is required in AASHTO T 162; a clearance of approximately 0.2 inch (5.0 mm) has been found to be satisfactory for this method when used with fine aggregate from which the material retained on the No. 4 (4.75 mm) sieve has been removed.

5.4 Split the fine aggregate to be used for these tests into two approximately equal portions, using ITP 248. Set one portion aside to be used in the unwashed condition. The second portion is to be washed before use.

5.5 Preparing Washed Fine Aggregate:

5.5.1 Perform the washing and the rinsing of the fine aggregate with care to minimize the loss of fines, so that the aggregate after washing and rinsing has a fineness modulus within 0.10 of that of the unwashed aggregate.

5.5.2 *Establishing a Standard for Thoroughness of Rinsing* – Place a small amount of the water to be used for washing and rinsing in a clean, clear container, and determine the pH of the water by use of pH paper, pH meter, or add a drop of phenolphthalein to the wash water and retain for later comparison.

5.5.3 *Washing the Aggregate* – Place sufficient quantity of fine aggregate for three batches in a suitable container, flood with the sodium hydroxide solution, and agitate thoroughly with a spoon or trowel. At the end of the washing and after allowing the fines to settle, siphon off as much of the sodium hydroxide as possible, without

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removing any of the aggregate fines. Aggregates containing particles that float may be elutriated onto a No. 200 (75µm) sieve to capture any floating particles.

5.5.4 *Rinsing the Aggregate* – Add a large quantity of water to the washed aggregate, agitate, allow to stand for fines to settle, and then siphon off the rinse water. Repeat this operation several times, until the water used for rinsing has a pH equal to or lower than the pH of the water prior to contact with the fine aggregate. If phenolphthalein was used as an indicator, the color of the water is to be equal or lighter in color than the solution prepared in Section 5.5.2.

5.5.5 *Verifying Removal of Organic Impurities* – Repeat the ITP 21 procedure to determine if the washing has removed sufficient organic impurities to produce a satisfactory result (color lighter than the standard). If the fine aggregate continues to produce an unsatisfactory result (color darker than the standard), repeat the washing and rinsing procedure (described in Sections 5.5.3 and 5.5.4) as many times as necessary until a satisfactory result is obtained by ITP 21.

6. REAGENTS AND MATERIALS

6.1 Portland cement shall be Type I or Type II, meeting the requirements of AASHTO M 85.

7. APPARATUS

7.1 *Flow Table, Flow Mold, and Caliper*, as described in AASHTO M 152M/M 152.

7.2 *Tamper, Trowel, Cube Molds, and Testing Machine*, as described in AASHTO T 106M/T 106.

7.3 *Mixer, Bowl, and Paddle*, as described in AASHTO T 162.

7.4 *Balance*, conforming to AASHTO M 231 for Class G 5.

8. TEMPERATURE

8.1 The temperature of the mixing water, moist closet, and storage tank shall be maintained at 73.4±3˚F (23.0±1.7˚C).

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EFFECT OF ORGANIC IMPURITIES IN FINE AGGREGATE ON STRENGTH OF MORTAR (MORTAR STRENGTH)

Effective Date: January 1, 2018

9. PREPARATION OF MORTAR

9.1 Use a predetermined amount of cement (471g). The amount of fine aggregate is determined by the specific gravity of the fine aggregate. The amount of water is adjusted to achieve a flow that meets AASHTO T 106.

Note 2 – Use of cement, aggregate, and an appropriate amount of water for a 3-cube batch is recommended to assure uniform mixing of the mortar.

9.2 Using fine aggregate that has been brought to a saturated surface-dry condition as described in ITP 84, prepare a quantity of aggregate estimated to provide slightly more than needed to produce a batch of the desired consistency.

9.2.1 The mortar shall be proportioned to produce a consistency of 100 ± 5 inch 10 drops of the flow table, as determined by the flow test in AASHTO T 106.

9.3 Prepare the mortar in a mechanical mixer in accordance with the procedure for mixing mortars described in AASHTO T 162, as modified below.

9.3.1 Mix the dry sand and cement together for 30 seconds. Add water slowly over a 30-second period. Scrape down the bowl within 15 seconds. Shift the mixer to second speed and mix for 1 minute. Bounce the flow table 10 times to get a flow of 100±5. If the flow is not enough, add more water and mix for 45 seconds more. If the flow is too great, discard the sample and start over.

10. PROCEDURE

10.1 Make a determination of the flow as described in AASHTO T 106M/T 106.

10.1.1 Should the flow be too great, discard the sample and start over.

10.1.2 If the mortar is too dry, add additional water and remix for an additional 45 seconds.

10.2 *Molding Test Specimens* – Immediately following completion of a flow test indicating acceptable consistency, return the mortar from the flow table to the mixing bowl, scrape down the bowl, and then remix the entire batch 15 seconds at medium speed. Upon completion of mixing, shake the excess mortar from the paddle into the bowl. Place the mortar in cube molds in two layers in accordance with the procedures described in AASHTO T 106M/T 106.

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EFFECT OF ORGANIC IMPURITIES IN FINE AGGREGATE ON STRENGTH OF MORTAR (MORTAR STRENGTH)

Effective Date: January 1, 2018

10.3 Store the test specimens and determine compressive strength after 14 days ± 6 hours.

11. CALCULATION AND REPORT

11.1 Calculate the average psi of the 3 test specimens and the average of the standard sample. The relative strength of the test sample compared to the standard is calculated by dividing the test sample’s psi by the standard sample’s psi.

11.2 Report the relative strength for the aggregate being tested as a percentage.

11.3 If the fine aggregate was sieved to remove particles coarser than the No. 4 (4.75 mm) sieve (as described in Section 5.3), so state in the report and indicate the quantity of material removed as a percentage of the original sample mass.

ILLINOIS TEST PROCEDURE 87

DRY PREPARATION OF DISTURBED SOIL AND SOIL AGGREGATE SAMPLE FOR TEST

Effective Date: January 1, 2018

1. SCOPE

1.1 This method describes the dry preparation of soil and soil-aggregate samples, as received from the field, for mechanical analysis, physical test, moisture-density relations test, and other tests as may be desired.

1.2 This method provides qualitative information only; therefore, a precision statement is not applicable.

1.3 The values stated in English units are to be regarded as the standard. The SI values given in parentheses are for information only.

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

2. REFERENCED DOCUMENTS

2.1 Illinois Test Procedure (ITP):

- ITP 2, Sampling of Aggregates
- ITP 11, Materials Finer Than No. 200 (75µm) Sieve in Mineral Aggregates by Washing
- ITP 84, Specific Gravity and Absorption of Fine Aggregate
- ITP 85, Specific Gravity and Absorption of Coarse Aggregate
- ITP 248, Reducing Samples of Aggregate to Testing Size

2.2 AASHTO Standards:

- M92, Wire-Cloth Sieves for Testing Purposes
- M231, Weighing Devices Used in the Testing of Materials
- T88 (Illinois Modified), Particle Size Analysis of Soils

2.3 ASTM Standards:

- C 125, Terminology Relating To Concrete and Concrete Aggregates

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DRY PREPARATION OF DISTURBED SOIL AND SOIL AGGREGATE SAMPLE FOR TEST

Effective Date: January 1, 2018

3. TERMINOLOGY

3.1 Definitions – For definitions of terms used in this test method, refer to ASTM C 125.

3.2 Constant Mass – is defined as the sample mass at which there has not been more than a 0.5g mass loss during an additional 1 hour of drying. This should be verified occasionally.

4. APPARATUS

4.1 Balance – The balance shall conform to the requirements of AASHTO M 231, for the class of general purpose balance required for the principal sample mass of the sample being tested.

4.2 Oven – An oven of sufficient size, capable of maintaining a uniform temperature of 230±9˚F (110±5˚C). The oven shall be specifically designed for drying.

4.3 Sieves – A series of sieves of the following sizes: 3/4 inch (19.0 mm), No. 4 (4.75 mm), No. 10 (2.00 mm), No. 40 (0.425 mm) and others as required for the preparing the sample for a specific test. The sieves shall conform to AASHTO M 92.

Note 1 – A 2 inch (50 mm) sieve is required if the sample includes particles retained on the 3/4 inch (19.0 mm) sieve, and it is desired that the sample for moisture-density relations (T 99 or T 180) contain material between 3/4 inch (19.0 mm) and No. 4 (4.75 mm) sieve size to represent the fraction between 2 inch and 3/4 inch (50 mm and 19 mm).

4.4 Splitter – The splitter shall conform to ITP 248 "Reducing Field Samples of Aggregate to Testing Size".

5. SAMPLE SIZE

5.1 The amounts of soil material required to perform the individual tests are as follows:

5.1.1 Particle Size Analysis of Soils (AASHTO T 88 [Illinois Modified]) – Reduce field sample by use of a sample splitter or by quartering according to ITP 248, to obtain approximately 2500g of fine aggregate. Dry the aggregate in a suitable pan or vessel in a drying oven to a constant mass at a temperature of 230±9˚F (110±5˚C) and allow it to cool to room temperature. Using a fine aggregate sample splitter, separate out approximately 525±25g for test sample.

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DRY PREPARATION OF DISTURBED SOIL AND SOIL AGGREGATE SAMPLE FOR TEST

Effective Date: January 1, 2018

Diameter of Largest Particle, inch, (mm)	Approximate Minimum Mass of Portion, kg
3/8 (9.5)	0.5
1 (25)	2.0
2 (50)	4.0
3 (75)	5.0

5.1.2 Specific Gravity – The bulk specific gravity test, ITP 84 or ITP 85 as appropriate, shall be performed on a separate sample of the material being tested.

6. INITIAL PREPARATION OF TEST SAMPLES

6.1 The portion of the dried sample selected for particle-sized analysis and physical test (including specific gravity) shall be weighed, and that mass recorded as the mass of total sample uncorrected for hygroscopic moisture. This portion shall then be separated into fractions by the following method:

6.1.1 Standard Method Using No. 10 (2.00 mm) Sieve – The dried sample shall be separated into two fractions, one fraction being plus No. 10 (2.00 mm) sieve material while the other fraction is minus No. 10 (2.00 mm) sieve material. The fraction representing the plus No. 10 (2.00 mm) sieve material shall be washed over the No. 10 (2.00 mm) sieve using ITP 11 procedure. The wash water shall be retained. The plus No. 10 (2.00 mm) material shall be discarded after washing. The wash water shall be dried back to a constant mass at 230±9˚F (110±5˚C). The dried residue shall be then be added back to the minus No. 10 (2.00 mm) material.

7. TEST SAMPLE FOR PARTICLE SIZE ANALYSIS AND SPECIFIC GRAVITY

7.1 The fraction representing the minus No. 10 (2.00 mm) material in Section 5.1.1 shall be thoroughly mixed together and, by the use of the sampler or by splitting or quartering (ITP 2), a representative portion having approximate mass of 100-110g shall be obtained for the hydrometer analysis. Bulk dry specific gravity shall be determined according to Section 5.1.2.

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ILLINOIS TEST PROCEDURE 88

PARTICLE SIZE ANALYSIS OF SOILS

Effective Date: January 1, 2018

1. SCOPE

1.1 This method describes a procedure for the quantitative determination of particle sizes in soil.

1.2 The following applies to all specified limits in this standard; For the purpose of determining conformance with these specifications, an observed value or a calculated value shall be rounded off "to the nearest unit" in the last right-hand place of figures used in expressing the limiting value, in accordance with ASTM E 29.

1.3 The values stated in English units are to be regarded as the standard. The SI values given in parentheses are for information only.

1.4 Refer to R 16 for regulatory information for chemicals.

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

2. REFERENCED DOCUMENTS

2.1 Illinois Test Procedure (ITP):

- ITP 87, Dry Preparation of Disturbed Soil and Soil-Aggregate Samples for Test

2.2 AASHTO Standards:

- M 92, Wire-Cloth Sieves for Testing Purposes
- M 145, Classification of Souls and Soil-Aggregate Mixtures for Highway Construction Purposes
- M 147, Materials for Aggregate and Soil-Aggregate Subbase, Base, and Surface Course
- M 231, Weighing Devices Used in the Testing of Materials
- R 16, Regulatory Information for Chemicals Used in AASHTO Tests
- T 100, Specific Gravity of Soils
- T 146, Wet Preparation of Disturbed Soil Samples for Test
- T 265, Laboratory Determination of Moisture Content of Soils

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PARTICLE SIZE ANALYSIS OF SOILS

Effective Date: January 1, 2018

2.3 ASTM Standards:

- C 670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
- E 29, Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
- E 100, Standard Specification for ASTM Hydrometers

3. APPARATUS

3.1 The apparatus shall consist of the following:

3.1.1 Oven – An oven of sufficient size, capable of maintaining a uniform temperature of 230±9˚F (110±5˚C). The oven shall be specifically designed for drying.

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

3.1.3 Hydrometer – An ASTM hydrometer, graduated to read in either specific gravity of the suspension or grams per liter of suspension, and conforming to the requirements of hydrometers 151 H or 152 H in ASTM E 100. Dimensions of both hydrometers are the same, the scale being the only item of difference.

3.1.4 Sedimentation Cylinders – A glass cylinder approximately 18 inch (460 mm) in height and 2 ½ inch (60 mm) in diameter and marked for the volume of 1000 mL. The inside diameter shall be such that the 1000 mL mark is 14±1.0 inch (360±20 mm) from the bottom on the inside.

3.1.5 Thermometer – A calibrated thermometer readable to 1˚F (0.5˚C).

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PARTICLE SIZE ANALYSIS OF SOILS

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3.1.6 Sieves - A series of sieves of square mesh woven cloth, conforming to the requirements of AASHTO M 92. The sieves normally required are as follows:

Standard Designation, Inch	Alternate Designation, mm
3	75
2	50
1	25
3/8	9.25
No. 4	4.75
No. 10	2.00
No. 40	0.425
No. 200	0.075

Note 1 – The above sieves fulfill the requirements of AASHTO M 145 and M 147. If desired, intermediate sieve sizes may be used in such sizes as:

Standard Designation, Inch	Alternate Designation, mm
3	75
1 ½	37.5
¾	19
3/8	9.5
No. 4	4.75
No. 8	2.36
No. 16	1.18
No. 30	0.60
No. 50	0.30
No. 100	0.15
No. 200	0.075

3.1.7 Water Bath or Constant Temperature Room – A water bath or constant temperature room for maintaining the soil suspension at a constant temperature during the hydrometer analysis. A satisfactory water bath is an insulated tank that maintains the suspension at a convenient constant temperature as near 68˚F (20˚C) as the room and faucet-water temperature will permit. Such a device is illustrated in Figure 4. In cases where the work is performed in a room at an automatically controlled constant temperature, the water bath is not necessary and subsequent reference to a constant temperature bath shall be interpreted as meaning either a water bath or a constant temperature room.

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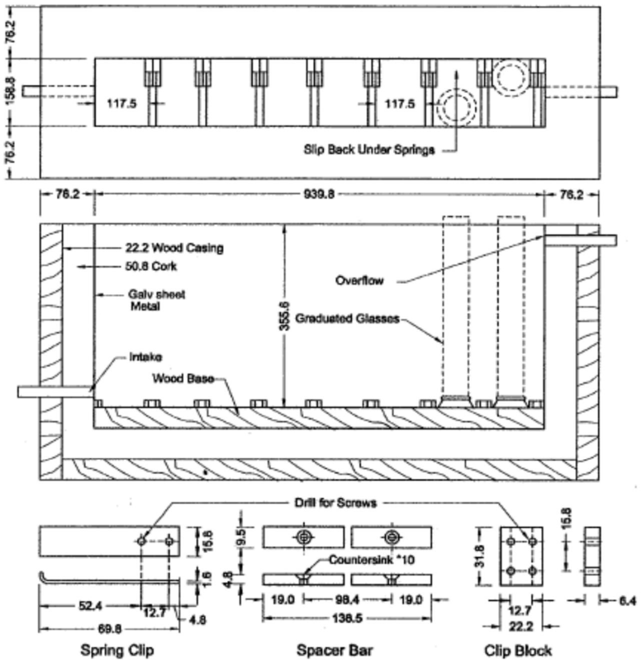
3.1.8 Beaker – A glass beaker having a capacity of at least 250mL and not greater than 500mL.

3.1.9 Timing Device – A watch or clock with a sweep second hand.

3.1.10 Glass Rod – Suitable for stirring the sample mixture.



Dimensional Equivalents

mm	in.	mm	in.
939.8	37	31.8	1 1/4
355.6	14	22.2	7/8
158.8	6 1/4	19.0	3/4
136.5	5 3/8	15.8	5/8
117.5	4 5/8	12.7	1/2
98.4	3 7/8	9.5	3/8
76.2	3	6.4	1/4
69.8	2 3/4	4.8	3/16
52.4	2 1/16	1.6	1/16
50.8	2		

Note: All dimensions are in millimeters unless otherwise noted.

Figure 4 – Tank for Maintaining Soil Suspension at Constant Temperature During Hydrometer Analysis

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4. DISPERSING AGENT

4.1 A solution of sodium hexametaphosphate shall be used in distilled or demineralized water, at the rate of 40g of sodium hexametaphosphate per liter of solution.

4.1.1 Solutions of this salt, if acidic, slowly revert or hydrolyze back to the orthophosphate form with a resultant decrease in dispersing action. Solutions shall be prepared frequently (at least once a month) or adjusted to pH of 8 or 9 by means of sodium carbonate. Bottles containing solutions shall have the date of preparation marked on them.

5. GENERAL REQUIREMENTS FOR WEIGHING

5.1 The masses of subsamples and size fractions in the hydrometer analysis and hygroscopic moisture determination shall be determined to the nearest 0.01g. The mass of the subsample for mechanical analysis of the fraction retained on the No. 4 (4.75 mm) sieve, the No. 10 (2.00 mm) sieve, or the No. 40 (0.425 mm) sieve for coarse sieve analysis, and each size fraction in the coarse sieve analysis, shall be determined to within 0.1 percent of the mass of the subsample. For example, a subsample with a mass of 1000g, its size factions in the coarse sieve analysis, must be weighed to the nearest gram.

6. SAMPLES

6.1 The test sample for particle size analysis shall be prepared in accordance with ITP 87 “Dry Preparation of Disturbed Soil and Soil Aggregate Samples for Test”. The representative portion of the original air dry sample selected for test shall be weighed. The mass of this sample shall be sufficient to yield quantities for particle size analysis as follows:

6.1.1 The minimum amount required of material retained on the No. 4 (4.75 mm), the No. 10 (2.00 mm), or the No. 40 (0.425 mm) sieve depends on the maximum particle size, but shall not be less than the amount shown in the following table:

Normal Size of Largest Particles Inch (mm)	Approximate Minimum Weight Of Portion
3/8 (9.5)	500g
1 (25)	2000g
2 (50)	4000g
3 (75)	5000g

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6.1.2 The size of the portion passing the No. 10 (2.00 mm) or No. 40 (0.425 mm) sieve shall be: (a) for the hydrometer test, approximately 100g for sandy soil and approximately 50g for silty or clayey soils, and (b) for hygroscopic moisture determination, at least 10g.

6.2 The test sample selected in Section 5.1 shall be processed by the method in Section 6.2.1.

6.2.1 Alternate Method Using No. 10 (2.00 mm) Sieve – The sample shall be separated on the No. 10 (2.00 mm) sieve as described in Section 6.1 of ITP 87. The fraction representing the minus No. 10 (2.00 mm) material shall be weighed and prepared as described in Section 6.1.1 of ITP 87. Subsamples for hygroscopic moisture and hydrometer analysis shall be weighed immediately or placed in airtight containers until tested.

HYDROMETER AND SIEVE ANALYSIS OF FRACTION PASSING THE NO.10 (2.00 mm) SIEVE

7. DETERMINATION OF COMPOSITE CORRECTION FOR HYDROMETER READING

7.1 Equations for percentages of soil remaining in suspension, as given in Section 12.3, are based on the use of distilled or demineralized water. A dispersing agent is used in the water, however, and the specific gravity of the resulting liquid is appreciably greater than that of distilled or demineralized water.

7.1.1 Both soil hydrometers are calibrated at 68˚F (20˚C); variations in temperature from this standard temperature produce inaccuracies in the actual hydrometer readings. The amount of the inaccuracy increases as the variation from the standard temperature increases.

7.1.2 Hydrometers are graduated by the manufacturer to be read at the bottom of the meniscus formed by the liquid on the stem. Since it is not possible to secure readings of soil suspensions at the bottom of the meniscus, readings must be taken at the top and a correction applied.

7.1.3 The net amount of the corrections for the three items enumerated is designated as the composite correction, and may be determined experimentally.

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7.2 For convenience, a graph or table of composite corrections for the series of 1-degree temperature differences for the range of expected test temperatures may be prepared and used as needed. Measurement of the composite corrections may be made at two temperatures spanning the range of expected test temperatures, and corrections for the intermediate temperatures calculated assuming a straight line relationship between the two observed values.

8. HYGROSCOPIC MOISTURE

8.1 Determine the mass of the sample for the hygroscopic moisture determination. Dry the sample according to AASHTO T 265, to determine the moisture content, and record the results.

9. HYDROMETER TEST

9.1 Determine the mass of the approximately 100g sample for hydrometer analysis. Place the sample in a 250mL beaker and cover with stock solution of the selected dispersing agent specified in Section 4. Stir the sample thoroughly with a glass rod and allow to soak for a minimum of 12 hours. The mixture shall then be transferred to the glass graduate, and distilled or demineralized water having the same temperature as the constant-temperature bath added until the mixture attains a volume of 1000mL. The graduate containing the soil suspension shall then be placed in the constant temperature bath. Remove the graduate after the soil suspension attains the temperature of the bath. Using the palm of the hand over the open end of the cylinder (or a rubber stopper in the open end), turn the cylinder upside down and back for a period of 60 seconds to complete the agitation of the slurry.

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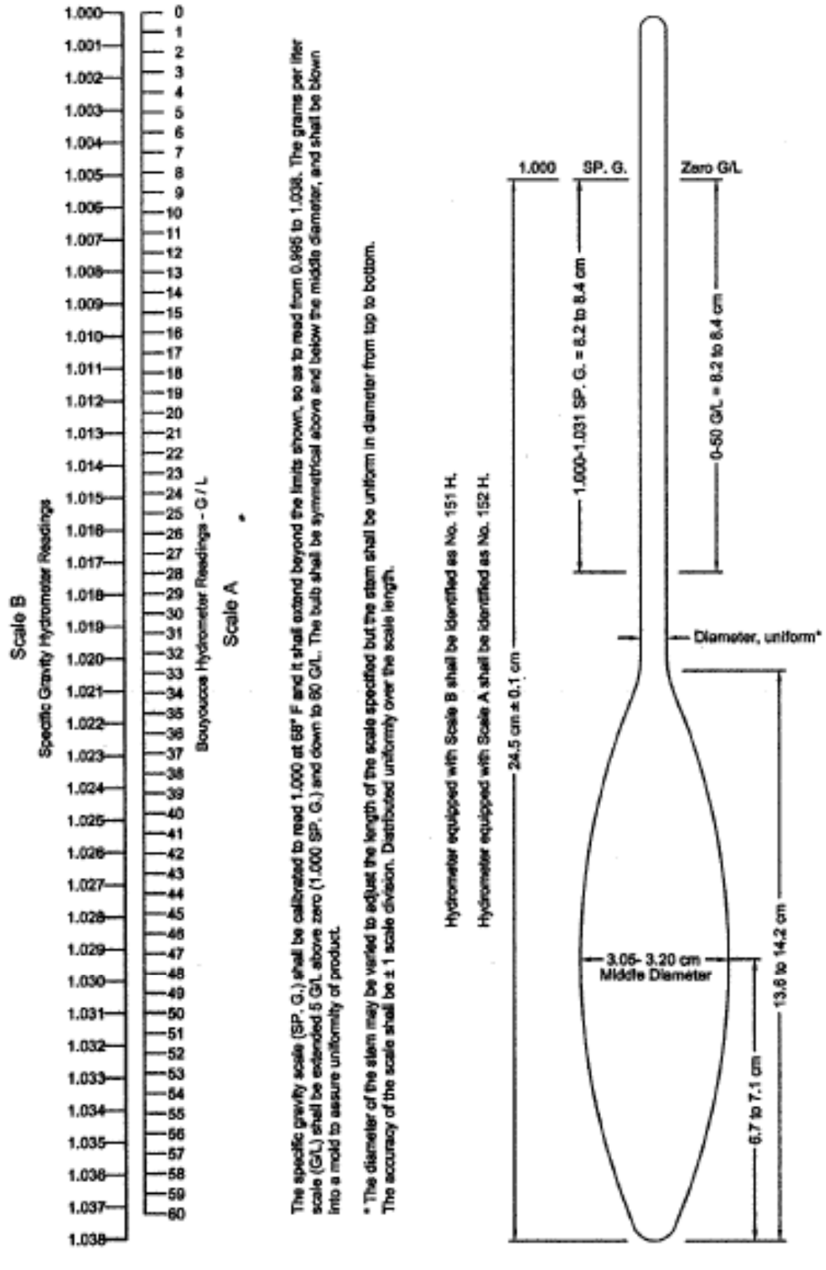

The specific gravity scale (SP. G.) shall be calibrated to read 1.000 at 68° F and it shall extend beyond the limits shown, so as to read from 0.995 to 1.038. The grams per liter scale (G/L) shall be extended 5 G/L above zero (1.000 SP. G.) and down to 60 G/L. The bulb shall be symmetrical above and below the middle diameter, and shall be blown into a mold to assure uniformity of product.

* The diameter of the stem may be varied to adjust the length of the scale specified but the stem shall be uniform in diameter from top to bottom. The accuracy of the scale shall be ± 1 scale division. Distributed uniformly over the scale length.

Hydrometer equipped with Scale B shall be identified as No. 151 H.

Hydrometer equipped with Scale A shall be identified as No. 152 H.

Figure 5—Hydrometer

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Note 2 – The number of turns during this minute should be approximately 60, counting the turn upside down and back as two turns. Any soil remaining in the bottom of the cylinder during the first few turns should be loosened by vigorous shaking of the cylinder while it is in the inverted position.

Note 3 – Upon completion of the agitation period, if necessary, any material clinging to the inside walls of the top of the cylinder may be rinsed into the suspension with a small amount of water.

9.2 At the conclusion of this shaking, the time shall be recorded, the graduate placed in the bath, and readings taken with the hydrometer at the end of 120 seconds. The hydrometer shall be read at the top of the meniscus formed by the suspension around its stem. The hydrometer shall float freely and not touch the wall of the graduate or cylinder. If hydrometer with scale A is used, it shall be read to the nearest 0.5g/L. Scale B shall be read to the nearest 0.0005 specific gravity. Subsequent readings shall be taken at intervals of 5, 15, 30, 60, 250, and 1440 minutes after the beginning of sedimentation. Readings of the thermometer placed in the soil suspension shall be made immediately following each hydrometer reading and recorded.

9.3 After each reading the hydrometer shall be very carefully removed from the soil suspension and placed with a spinning motion in a graduate of clean water. About 25 to 30 seconds before the time for a reading, it shall be taken from the clear water and slowly immersed in the soil suspension to assure that it comes to rest before the appointed reading time.

CALCULATIONS

10. PERCENTAGE OF HYGROSCOPIC MOISTURE

10.1 The hygroscopic moisture shall be expressed as a percentage of the mass of the oven-dried soil and shall be determined as follows:

$$\text{Percentage of hygroscopic moisture} = \frac{W-W_1}{W_1} \times 100 \qquad (1)$$

Where:
W = mass of air-dried soil, and
W_1 = mass of oven-dried soil.

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To correct the mass of the air-dried sample for hygroscopic moisture, the given value shall be multiplied by the expression:

$$\frac{100}{100 + percentage\ of\ hygroscopic\ moisture} \qquad (2)$$

10.2 Calculate the percentage of moisture to the nearest 0.001 as described in Section 10.1.

11. COARSE MATERIAL

11.1 The percentage of coarse material shall be calculated from the masses of the fractions recorded during the sieving of the material retained on the No. 10 (2.00 mm) sieve, and the total mass recorded in Section 6.1. The calculations shall be made as follows:

11.1.1 From the mass of the air-dried sample, obtained in Section 6.1, subtract the mass of the fraction retained on the No. 10 (2.00 mm) sieve. The difference is assumed to equal the mass of the air-dried fraction passing the No. 10 (2.00 mm) sieve (Note 5).

11.1.2 Correct the mass of the fraction passing the No.10 (2.00 mm) sieve for hygroscopic moisture, determined in Section 10.1.

11.1.3 To the corrected mass obtained in Section 11.1.2, add the mass of the fraction retained on the No. 10 (2.00 mm) sieve to obtain the mass of the total test sample corrected for hygroscopic moisture.

11.1.4 The fractions retained on the No. 10 (2.00 mm) and coarser sieves shall be expressed as percentages of the corrected mass obtained in Section 11.1.3.

Note 4 – According to this assumption, no hygroscopic moisture is contained the air-dried particles retained on the No. 10 (2.00 mm) sieve when as a matter of fact a small percentage of moisture may be present in this fraction. This amount of moisture, compared with that held in the pores of the fraction passing the No. 10 (2.00 mm) sieve, is relatively small. Therefore, any error produced by the assumption as stated may be considered negligible in amount.

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Note 5 – Somewhat different computations are required when the test sample is processed in accordance with Section 6.2.1 (Alternate Method Using No.4 (4.75 mm) and No. 10 (2.00 mm) sieves). In Section 11.1, substitute the No. 4 (4.75 mm) sieve for the No. 10 (2.00 mm) sieve. The percentage passing the No. 10 (2.00 mm) sieve shall be calculated as follows: (1) correct the mass of the test fractions passing the No. 4 (4.75 mm) and No. 10 (2.00 mm) sieves for hygroscopic moisture; (2) divide the dry mass of the faction passing the No. 10 (2.00 mm) sieve by the dry mass of the subsample passing the No. 4 (4.75 mm) sieve, and multiply this value by 100, giving the percent passing the No. 10 (2.00 mm) sieve in the selected subsample (Section 6.2.1); and (3) multiply this percentage by the percentage of the total sample passing the No. 4 (4.75 mm) sieve, to give the percentage passing the No. 10 (2.00 mm) sieve in the total sample.

12. PERCENTAGE OF SOIL IN SUSPENSION

12.1 Hydrometer readings shall be correct by applying the approximate composite correction as determined by Section 7 to account for the dispersing agent used, temperature of the suspension, and height of the meniscus on the stem of the hydrometer.

12.2 The percentage of the dispersed soil in suspension represented by different corrected hydrometer readings depends upon both the amount and the specific gravity of the soil dispersed. The percentage of dispersed soil remaining in suspension shall be calculated as follows:

For hydrometer 152 H

$$P = \frac{Ra}{w} \times 100 \qquad (3)$$

For hydrometer 151 H

$$P = \frac{1606\,(R-1)a}{w} \times 100 \qquad (4)$$

Where:
P = percentage of originally dispersed soil remaining in suspension,
R = corrected hydrometer reading,
w = mass in grams of soil originally dispersed minus the hygroscopic moisture, and
a = constant depending on the density of the suspension.

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For an assumed value of G for the specific gravity of the soil, and a water density of 1.000 at 68˚F 20.0˚C), the value of “a” may be obtained by the formula:

$$a = \frac{2.6500-1.000}{2.6500} \times \frac{G}{G-1.000}$$

The values of “a”, given to two decimal places, are shown in Table 1.

Table 1 – Values of a, for Different Specific Gravities

Specific Gravity, G	Constant, a
2.95	0.94
2.85	0.96
2.75	0.98
2.65	1.00
2.55	1.02
2.45	1.05
2.35	1.08

12.2.1 It is sufficiently accurate for ordinary tests to select the constant for the specific gravity nearest to that of the particular soil tested.

12.3 To convert the percentages of soil in suspension to percentages of the total test sample including the fraction retained on the No. 10 (2.00 mm) sieve, the percentage of originally dispersed soil remaining in suspension shall be multiplied by the expression:

$$\frac{100-the\ percentage\ retained\ on\ No.10\ (2.00mm) sieve}{100} \qquad (5)$$

13. DIAMETER OF SOIL PARTICLES IN SUSPENSION

13.1 The maximum diameter, d, of the particles in suspension, corresponding to the percentage indicated by a given hydrometer reading, shall be calculated by the use of Stokes’ law.

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According to Stokes' law:

$$d = \sqrt{\frac{30nL}{980\,(G-G_1)T}} \qquad (6)$$

where:

d = maximum grain diameter in millimeters;
n = coefficient of viscosity of the suspending medium (in this case water) in Pa's. Varies with changes in temperature of the suspending medium;
L = distance from the surface of the suspension to the level at which the density of the suspension is being measured, mm. (For a given hydrometer and sedimentation cylinder, values vary according to the hydrometer readings. This distance is known as effective depth (see Table 2).);
T = interval of time from beginning of sedimentation to the taking of the reading, min;
G = specific gravity of soil particles; and
G_1 = specific gravity of the suspending medium (approximately 1.0 for water).

Note 6 – As Stokes' law considers the terminal velocity of a single sphere falling in an infinity of liquid, the sizes calculated represent the diameter of spheres that would fall at the same rate as the soil particles.

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Table 2 – Values of Effective Depth Based on Hydrometer and Sedimentation Cylinder of Specified Sizes[a]

Hydrometer 151 H		Hydrometer 152 H			
Actual Hydrometer Reading	Effective Depth, L, mm	Actual Hydrometer Reading	Effective Depth, L, mm	Actual Hydrometer Reading	Effective Depth, L, mm
1.000	163	0	163	31	112
1.001	160	1	161	32	111
1.002	158	2	160	33	109
1.003	155	3	158	34	107
1.004	152	4	156	35	106
1.005	150	5	155		
1.006	147	6	153	36	104
1.007	144	7	152	37	102
1.008	142	8	150	38	101
1.009	139	9	148	39	99
1.010	137	10	147	40	97
1.011	134	11	145	41	96
1.012	131	12	143	42	94
1.013	129	13	142	43	92
1.014	126	14	140	44	91
1.015	123	15	138	45	89
1.016	121	16	137	46	88
1.017	118	17	135	47	86
1.018	115	18	133	48	84
1.019	113	19	132	49	83
1.020	110	20	130	50	81
1.021	107	21	129	51	79
1.022	105	22	127	52	78
1.023	102	23	125	53	76
1.024	100	24	124	54	74
1.025	97	25	122	55	73
1.026	94	26	120	56	71
1.027	92	27	119	57	70
1.028	89	28	117	58	68
1.029	86	29	115	59	66
1.030	84	30	114	60	65
1.031	81				
1.032	78				
1.033	76				
1.034	73				
1.035	70				
1.036	68				
1.037	65				
1.038	62				

[a] Values of effective depth are calculated from the equation:

$$L = L_1 + \tfrac{1}{2}\,[L_2 - (V_B/A)] \qquad (7)$$

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where:

L = effective depth, mm;
L_1 = distance along the stem of the hydrometer from the top of the bulb to the mark for a hydrometer reading, mm;
L_2 = overall length of hydrometer bulb, mm;
V_B = volume of hydrometer bulb, mm^3; and
A = cross-sectional area of sedimentation cylinder, $mm^{2.}$

For both hydrometers, 151 H and 152 H;
L_2 = 140 mm
V_B = 67000 mm^3
A = 2780 mm^2

For hydrometer 151 H;
L_1 = 105 mm for a reading of 1.000
L_2 = 23 mm for a reading of 1.031

For hydrometer 152 H;
L_1 = 105 mm for a reading of 0g/L
L_2 = 23 mm for a reading of 50g/L

13.2 For convenience in calculations the above equation may be written as follows:

$$D = K\sqrt{\frac{L}{T}} \qquad (8)$$

Where:

K = constant depending on the temperature of the suspension and the specific gravity of the soil particles. Values of K for a range of temperatures and specific gravities are given in Table 3. The value of K may not change for a series of readings constituting a test, while values of L and T do vary.

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Table 3 – Values of K for Use in Equation for Computing diameter of Particle in Hydrometer Analysis

Temp.	Specific Gravity of Soil Particles								
Deg F	2.45	2.50	2.55	2.60	2.65	2.70	2.75	2.80	2.85
60.8	0.004838	0.004759	0.004683	0.004607	0.004538	0.004471	0.004408	0.004345	0.004288
62.6	0.004778	0.004699	0.004623	0.004551	0.004481	0.004415	0.004351	0.004288	0.004231
64.4	0.004718	0.004639	0.004563	0.004494	0.004424	0.004358	0.004298	0.004234	0.004177
66.2	0.004661	0.004582	0.004506	0.004437	0.004370	0.004304	0.004244	0.004181	0.004127
68.0	0.004604	0.004525	0.004452	0.004383	0.004317	0.004250	0.004190	0.004133	0.004076
69.8	0.004547	0.004471	0.004399	0.004329	0.004263	0.004200	0.004139	0.004083	0.004026
71.6	0.004494	0.004418	0.004345	0.004279	0.004212	0.004149	0.004092	0.004035	0.003978
73.4	0.004440	0.004367	0.004294	0.004228	0.004165	0.004101	0.004045	0.003988	0.003931
75.2	0.004389	0.004317	0.004244	0.004177	0.004114	0.004054	0.003997	0.003940	0.003886
77.0	0.004339	0.004266	0.004196	0.004130	0.004067	0.004007	0.003950	0.003896	0.003842
78.8	0.004291	0.004218	0.004149	0.004083	0.004022	0.003962	0.003905	0.003852	0.003798
80.6	0.004244	0.004171	0.004101	0.004038	0.003978	0.003918	0.003861	0.003807	0.003757
82.4	0.004196	0.004124	0.004057	0.003997	0.003934	0.003875	0.003820	0.003766	0.003716
84.2	0.004149	0.004079	0.004013	0.003950	0.003890	0.003833	0.003779	0.003725	0.003675
86.0	0.004105	0.004035	0.003972	0.003909	0.003848	0.003792	0.003738	0.003684	0.003633

14. REPORT

14.1 Clay, smaller than 0.000079 inch (0.002 mm), shall be reported to the nearest 0.1%.

15. PRECISION

15.1 Criteria for judging the acceptability of the particle size analysis of soils is as follows:

Note 7 – Colloids (smaller than 0.000039 inch (0.001 mm) are not normally required. However, if it is desired to obtain this size, it will then be necessary to extend the reading time to a minimum of 2880 minutes.

Note 8 – The figures in Table 4, Column 2 are the standard deviations that have been found to be appropriate for the test described in Column 1. The figures in Column 3 are the limits that should not be exceeded by the difference between the results of two properly conducted tests.

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Table 4 – Single Operator Precision		
Single-Operator Precision:		
Test Performed	Standard Deviation[a]	Acceptable Range Of Two Results[a]
Hygroscopic Moisture in Percent Moisture:		
No. 4 (4.75 mm)	0.15	0.4
No. 10 (2.00 mm)	0.21	0.6
Sieve Analysis in Percent Passing:		
No. 10 (2.00 mm)	0.66	1.9
No. 40 (0.425 mm)	1.07	3.0
No. 200 (0.075 mm)	1.19	3.4
Hydrometer Analysis in Percent Smaller Than:		
0.00079in (0.02 mm)	1.98	5.6
0.000079in (0.002 mm)	1.34	3.8
0.000039in (0.001 mm)	1.45	4.1

Multi-laboratory Precision:		
Test Performed	Standard Deviation[a]	Acceptable Range Of Two Results[a]
Hygroscopic Moisture in Percent Moisture:		
No. 4 (4.75 mm)	0.89	2.5
No. 10 (2.00 mm)	0.88	2.4
Sieve Analysis in Percent Passing:		
No. 10 (2.00 mm)	1.39	3.9
No. 40 (0.425 mm)	1.98	5.6
No. 200 (0.075 mm)	2.31	0.5
Hydrometer Analysis in Percent Smaller Than:		
0.00079in (0.02 mm)	4.32	12.2
0.000079in (0.002 mm)	3.19	9.0
0.000039in (0.001 mm)	3.16	8.9

[a] These numbers represent, respectively, the (1_s) and ($d2_s$) limits as described in ASTM C 670 for Preparing Precision Statements for Test Methods for Construction Materials.

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Chapter 5 - Illinois Test Procedure 96

Resistance To Degradation Of Small-Size Coarse Aggregate By Abrasion And Impact In The Los Angeles Machine (Wear)

Effective Date: April 16, 2019

1. SCOPE

1.1 This test method covers a procedure for testing sizes of coarse aggregate smaller than 1 ½ inch (37.5 mm) for resistance to degradation using the Los Angeles testing machine.

1.2 The values stated in English units are to be regarded as the standard. The SI values given in parentheses are for information only.

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

2. REFERENCED DOCUMENTS

2.1 Illinois Test Procedures (ITP):

- ITP 2, Sample of Aggregates
- ITP 27, Sieve Analysis of Fine and Coarse Aggregates
- ITP 248, Reducing Samples of Aggregate to Testing Size

2.2 AASTHO Standards:

- M 231, Weighing Devices Used in the Testing of Materials
- M 92, Woven Wire Test Sieve Cloth and Test Sieves

2.3 ASTM Standards:

- A 6/A 6M, Specification for General Requirements for Rolled Structural Steel Bars, Plates, and Sheet Piling
- C 125, Terminology Relating to Concrete and Concrete Aggregates

3. TERMINOLOGY

3.1 *Definitions* – For definitions of terms used in this test method, refer to ASTM C 125.

3.2 *Constant Mass* – Constant mass is defined as the sample mass at which there has not been more than a 0.5 gram mass loss during an additional 1 hour of drying. This should be verified occasionally.

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Resistance To Degradation Of Small-Size Coarse Aggregate By Abrasion And Impact In The Los Angeles Machine (Wear)

Effective Date: **April 16, 2019**

4. SUMMARY OF TEST METHOD

4.1 This test is a measure of degradation of aggregates of standard gradings resulting from a combination of actions including abrasion or attrition, impact, and grinding in a rotating steel drum containing a specified number of steel spheres, the number depending upon the grading of the test sample. As the drum rotates, a shelf plate picks up the sample and the steel spheres, carrying them around until they are dropped to the opposite side of the drum, creating an impact-crushing effect. The contents then roll within the drum with an abrading and grinding action until the shelf plate picks up the sample and the steel spheres, and the cycle is repeated. After the prescribed number of revolutions, the contents are removed from the drum and the aggregate portion is sieved to measure the degradation as percent loss.

5. SIGNIFICANCE AND USE

5.1 This test has been widely used as an indicator of the relative quality or competence of various sources of aggregate having similar mineral compositions. The results do not automatically permit valid comparisons to be made between sources distinctly different in origin, composition, or structure. Assign specification limits with extreme care in consideration of available aggregate types and their performance history in specific end uses.

6. APPARATUS

6.1 *Los Angeles Machine* – A Los Angeles machine equipped with a counter and conforming in all essential characteristics to the design shown in Fig. 1, shall be used. The machine shall consist of a hollow steel cylinder, with a wall thickness of not less than 1/2 ±1/8 inch (12.7±3.2 mm) (Note 1) closed at both ends, conforming to the dimensions shown in Fig. 1, having an inside diameter of 28 ± 0.2 inch (711 ± 5 mm), and an inside length of 20 ± 0.2 inch (508 ± 5 mm). The interior surface of the cylinder shall be free from protrusions disrupting the path of the sample and steel spheres except for the shelf described below.

The cylinder shall be mounted on stub shafts attached to the ends of the cylinder but not entering it, and shall be mounted in such a manner that it rotates with the axis in a horizontal position within a tolerance in slope of 1 in 100. An opening in the cylinder shall be provided for the introduction of the test sample. A suitable, dust-tight cover shall be provided for the opening with means for bolting the cover in place. The cover shall be so designed as to maintain the cylindrical contour of the interior surface unless the shelf is

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Resistance To Degradation Of Small-Size Coarse Aggregate By Abrasion And Impact In The Los Angeles Machine (Wear)

Effective Date: April 16, 2019

so located that the charge will not fall on the cover, or come in contact with it during the test.

A removable steel shelf shall extend along the length of the cylinder to within 0.2 inch (5 mm) of the full inside length of the cylinder, project inward 3.5±0.1 inch (89± 2 mm) and shall be mounted on the interior cylindrical surface of the cylinder, or on the inside surface of the cover, in such a way that a plane centered between the large faces coincides with an axial plane. The position of the shelf (Note 2) shall be such that the sample and the steel spheres shall not impact on or near the opening and its cover, and that the distance from the shelf to the opening, measured along the outside circumference of the cylinder in the direction of rotation, shall be not less than 50 inches (1270 mm). Inspect the shelf periodically to determine that it is not bent either lengthwise or from its normal radial position with respects to the cylinder. If either condition is found, repair or replace the shelf before further tests are conducted.

Note 1 – This is the minimum tolerance permitted on 1/2±1/8 inch (12.7±3.2 mm) rolled steel plate as described in ASTM A6/A 6M. Due to its mass, the location of the shelf relative to the opening influences the “at rest” position of the opening. The shelf location should be chosen to provide a convenient position of the opening to facilitate the loading of aggregate and spheres and to avoid impact of the charge on the cover.

Note 2 – The use of a shelf of wear-resistant steel, rectangular in cross section and mounted independently of the cover, is preferred. However, a shelf consisting of a section of rolled angle, properly mounted on the inside of the cover plate, may be used provided the direction of rotation is such that the charge will be caught on the outside face of the angle.

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Resistance To Degradation Of Small-Size Coarse Aggregate By Abrasion And Impact In The Los Angeles Machine (Wear)

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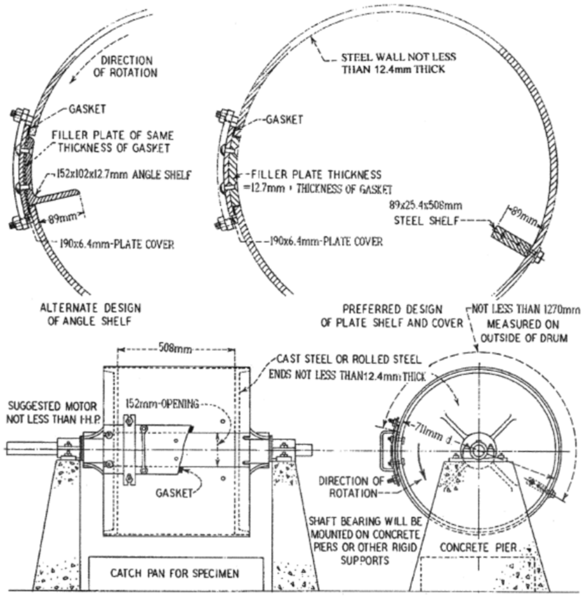

Inch Equivalents

mm	6.4	12.7	25.4	89	102	152	190	508	711	1270
in.	¼	½	1	3½	4	6	7½	20	28	50

FIG. 1 Los Angeles Testing Machine

6.1.1 The machine shall be so driven and so counterbalanced as to maintain a substantially uniform peripheral speed (Note 3). If an angle is used as the shelf, the direction of rotation shall be such that the charge is caught on the outside surface of the angle.

Note 3 – Back-lash or slip in the driving mechanism is very likely to show test results which are not duplicated by other Los Angeles machines producing constant peripheral speed.

6.2 *Sieves* - conforming to AASHTO M 92.

6.3 *Balance* – The balance shall conform to AASHTO M 231, Class G 5.

6.4 *Oven* – An oven of sufficient size, capable of maintaining a uniform temperature of 230±9˚F (110±5˚C). The oven shall be specifically designed for drying.

6.5 *Charge* – The charge shall consist of steel spheres averaging approximately 1 27/32 inch (46.8 mm) in diameter and each having a mass of between 420g and 445g.

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Resistance To Degradation Of Small-Size Coarse Aggregate By Abrasion And Impact In The Los Angeles Machine (Wear)

Effective Date: **April 16, 2019**

6.5.1 The charge, depending upon the grading of the test sample as described in Section 8, shall be as follows:

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

7. SAMPLING

7.1 Obtain the field sample in accordance with ITP 2, and reduce the field sample to adequate sample size in accordance with ITP 248.

8. TEST SAMPLE PREPARATION

8.1 Wash the reduced sample and oven dry at 230±9˚F (110±5˚C). Separate into individual size fractions, and recombine to the grading of Table 1 most nearly corresponding to the range of sizes in the aggregate as furnished for the work. Record the mass of the sample prior to test to the nearest 1g.

Chapter 5 - Illinois Test Procedure 96

Resistance To Degradation Of Small-Size Coarse Aggregate By Abrasion And Impact In The Los Angeles Machine (Wear)

Effective Date: **April 16, 2019**

TABLE 1 – GRADINGS OF TEST SAMPLES

Gradation	Material Passing	Material Retained On	Grading							Charges
			A	Modified	B	Modified	C	Modified	D	
CA02	1 1/2” 1” 3/4“ 1/2”	1” 3/4” 1/2“ 3/8”	1250g 1250g 1250g 1250g	+/- 250g +/- 250g +/- 250g +/- 250g						12
			Total 5000g+/-5g							
CA06 to CA11	3/4” 1/2”	1/2” 3/8”			2500g 2500g	+/-500g +/-500g				11
					Total 5000g+/-5g					
CA12 to CA20 except CA14	3/8” 1/4”	1/4” #4					2500g 2500g	+/-500g +/-500g		
							Total 5000g+/-5g			
CA14*	1/2" 3/8”	3/8” 1/4”					2500g 2500g	+/-500g +/-500g		8
							Total 5000g+/-5g			
CA21 to CA22	#4	#8							Total 5000g +/-5g	6

*If unable to attain these weights, run a standard B or C grading.

9. PROCEDURE

9.1 Before performing new testing conduct a visual inspection of the inside of the drum to make sure there are no contaminates attached to the surface. Make sure that the rotation counter has been set to 500 revolutions.

9.2 Place the test sample and the charge in the Los Angeles testing machine and rotate the machine at a speed of 30 to 33 r/min for 500 revolutions. After the prescribed number of revolutions, discharge the material and shake over a nest of sieves. The nest of sieves shall at minimum have the No. 4 (4.75 mm), No. 8 (2.36 mm), and No. 12 (1.70 mm).

Chapter 5 - Illinois Test Procedure 96

Resistance To Degradation Of Small-Size Coarse Aggregate By Abrasion And Impact In The Los Angeles Machine (Wear)

Effective Date: April 16, 2019

The larger sieves are used to protect the No. 12 (1.70 mm) sieve from being damaged. Sieve the finer portion on a No. 12 sieve in a manner conforming to ITP 27.

10. CALCULATION

10.1 Calculate the loss (difference between the original mass and the final mass of the test sample) as a percentage of the original mass of the test sample. Report this value as the percent loss.

11. REPORT

11.1 Report the following information:

11.1.1 Identification of the aggregate as to source, type, and nominal maximum size;

11.1.2 Grading designation from Table 1 used for the test; and

11.1.3 Loss by abrasion and impact of the sample expressed to the nearest 1% by mass.

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ILLINOIS TEST PROCEDURE 104

SOUNDNESS OF AGGREGATE BY USE OF SODIUM SULFATE

Effective Date: January 1, 2018

1 SCOPE

1.1 This method covers the procedure to be followed in testing aggregates to determine their resistance to disintegration by saturated solutions of sodium sulfate. This is accomplished by repeated immersion in saturated solutions of sodium sulfate followed by oven drying to partially or completely dehydrate the salt precipitated in permeable pore spaces. The internal expansive force, derived from the rehydration of the salt upon re-immersion, simulates the expansion of water on freezing. This test method furnishes information helpful in judging the soundness of aggregates subject to weathering action, particularly when adequate information is not available from service records of the material exposed to actual weathering conditions.

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

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

2 REFERENCE DOCUMENTS

2.1 *ASSHTO Standards:*

- M 231, Weighing Devices Used in the Testing of Materials
- R 16, Regulatory Information for Chemicals Used in AASHTO Tests
- M 92, Woven Wire Test sieve Cloth and Test Sieves

2.2 *ASTM Standards:*

- C 670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
- E 100, Standard Specification for ASTM Hydrometers

3 APPARATUS

3.1 *Sieves* – With square openings of the following size conforming to AASHTO M 92, for sieving the samples in accordance with Sections 5, 6, and 8:

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SOUNDNESS OF AGGREGATE BY USE OF SODIUM SULFATE

Effective Date: January 1, 2018

Sieves Conforming to ASTM E 11	
Fine Aggregate	*Coarse Aggregate*
No. 4 (4.75 mm)	2 ½ in. (63 mm)
No. 5 (4.00 mm)	2 in. (50 mm)
No. 8 (2.36 mm)	1 ½ in. (37.5 mm)
No. 16 (1.18 mm)	1 ¼ in. (31.5 mm)
No. 30 (600µm)	1 in. (25.0 mm)
No. 50 (300µm)	¾ in. (19.0 mm)
No. 100 (150µm)	5/8 in. (16.0 mm)
	½ in. (12.5 mm)
	3/8 in. (9.5 mm)
	5/16 in. (8.0 mm)

3.2 *Containers for Samples* – Solid bread pans (approximately 9 inch x 5 ½ inch x 2 ½ inch [228.6 mm x 139.7 mm x 63.5 mm]) shall be used instead of perforated containers or baskets. Solid covers shall be used to eliminate contamination during testing.

3.3 *Thermometer* – A thermometer covering the recommended temperature range for solutions during test and readable to 0.2°F (0.1°C).

3.4 *24-Hour Continuous Temperature Recorder* – A unit capable of recording solution temperature a minimum of once every 10 minutes for the duration of the test with an accuracy of 0.5°F (0.3°C).

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

3.6 *Oven* –An oven of sufficient size, capable of maintaining a uniform temperature of 230±9˚F (110±5˚C). The oven shall be specifically designed for drying.

3.7 *Specific Gravity Measurement* – Hydrometers conforming to the requirements of ASTM E 100 or a suitable combination of graduated glassware and balance, capable of measuring the solution specific gravity within ± 0.001.

3.8 *Laboratory Jaw Crusher* – The crusher should be adjustable up to 6 inch and down to ¼ inch material.

3.9 *Test Chamber* - A test chamber of sufficient size, capable of maintaining a temperature of 68.5 to 71.5˚F (20.3 to 21.9˚C) and a minimum of 90 percent humidity, for the specified immersion period. The temperature in the test chamber shall be plotted on a 24-hour continuous temperature recorder.

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SOUNDNESS OF AGGREGATE BY USE OF SODIUM SULFATE

Effective Date: January 1, 2018

4 SPECIAL SOLUTIONS REQUIRED

4.1 Prepare the solution for immersion of test samples from sodium sulfate in accordance with Section 4.1.1.

4.1.1 *Sodium Sulfate Solution* – Prepare a new saturated solution of sodium sulfate by dissolving the salt (purified, dried [anhydrous], Na_2SO_4 powder – Avantor Code #8028-20) in water (Note 1) at a temperature of 82±5˚F (28±3˚C). Add sufficient salt (Note 1) of the anhydrous (Na_2SO_4) form to ensure not only saturation but also the presence of excess crystals when the solution is ready for use in the tests. Thoroughly stir the mixture during the addition of the salt and stir the solution at frequent intervals until used. To reduce evaporation and prevent contamination, keep the solution covered at all times when access is not needed. Allow the solution to cool to 68.5 to 71.5°F (20.3 to 21.9°C). Again stir, and allow the solution to remain at the designated temperature for at least 48 hours before use. No new saturated solution shall be used by itself. New saturated solution shall be combined at a maximum of 50 percent with used solution before use. All solution for test use shall be stored in the test chamber at required test temperature. Prior to each use, break up the salt cake, if any, in the container, stir the solution thoroughly, and determine the specific gravity of the solution. When used, the solution shall have a specific gravity not less than 1.154 or more than 1.171. Discolored solution shall not be used to check for specific gravity, only clear solution.

Note 1 – For the solution, 195g of anhydrous salt per liter of water is sufficient for saturation at 71.6°F (22°C). However, since this salt is not completely stable and since it is desirable that an excess of crystals be present, the use of not less than 225g of the anhydrous salt per liter of water is recommended.

5 SAMPLES

5.1 *Fine Aggregate* – Fine aggregate for the test shall be passed through a No. 4 (4.75 mm) sieve. The sample shall be of such size that it will yield a minimum of 30g of each of the following sizes, expressed in terms of the following sieves:

Passing Sieve	Retained on Sieve
No. 4 (4.75 mm)	No. 8 (2.36 mm)
No. 8 (2.36 mm)	No. 16 (1.18 mm)
No. 16 (1.18 mm)	No. 30 (600µm)
No. 30 (600µm)	No. 50 (300µm)

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5.2 *Coarse Aggregate* – Coarse aggregate for the test shall consist of materials from which the sizes finer than the 4.75 mm (No. 4) sieve have been removed. Use the test set in Table 1 that most closely matches the gradation being tested. The sample shall be of such a size that it will yield the amounts indicated in Table 1.

5.2.1 When testing RR1, RR2, CA1 or CA3, use the following procedure: The entire sample is introduced into the laboratory jaw crusher, set at approximately 1 ½ inch and crushed down. Then the crushed material is run in accordance with Section 6.2. If the proper sizes of material are not obtained, the sample shall be reintroduced into the crusher and crushed again until the proper sizes are obtained.

TABLE 1 Coarse Aggregate Sample

Size of Gradation	No. of Pans	Material Size	Weight	Total Weight
RR1, RR2 CA01 to CA04	3	- 1 ½ inch (-37.5 mm); + 1 inch (25 mm)	1000g	1500g
		- 1 inch (-25 mm); + 3/4 inch (19.0 mm)	500g	
		-3/4 inch (-19.0 mm); +1/2 inch (12.5 mm)	1000g	1500g
		-1/2 inch (-12.5 mm); + 3/8 inch (9.5 mm)	500g	
		-3/8 inch (-9.5 mm) + No. 4 (4.75 mm)	1000g	1000g
CA05	2	-1 ½ inch (-37.5 mm) +1 inch (25 mm)	1000g	1500g
		-1 inch (-25 mm) + 3/4 inch (19.0 mm)	500g	
		-1 ½ inch (-37.5 mm) + 1 inch (25 mm)	1000g	1500g
		-1 inch (-25 mm) + 3/4 inch (19.0 mm)	500g	
CA06 to CA11	2	-3/4 inch (-19.0 mm) + 1/2 inch (12.5 mm)	1000g	1500g
		-1/2 inch (-12.5 mm) + 3/8 inch (9.5 mm)	500g	
		-3/8 inch (-9.5 mm) + No. 4 (4.75 mm)	1000g	1000g
CA12 to CA20	1	-3/8 inch (-9.5 mm) + No. 4 (4.75 mm)	1000g	1000g

If the above weights cannot be obtained, smaller amounts of that size may be run as long as the pan weights stay proportional and do not go below half of the original weight.

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6 PREPARATION OF TEST SAMPLE

6.1 *Fine Aggregate* –Thoroughly wash the sample of fine aggregate and decant off excess water. Dry to constant mass (as defined in Note 2) at 230±9˚F (110±5˚C), and separate into different sizes by sieving, as follows: Make a rough separation of aggregate using the No. 4 (4.75 mm), No. 8 (2.36 mm), No. 16 (1.18 mm), No. 30 (600µm) and No. 50 (300µm) sieves. This should be verified occasionally. Place approximately 150g of each size into its respective sieve and place divider pans between each sieve. The nest of sieves No. 8 through No. 50 [2.36 mm through 300µm]) is run five times for 7 minutes each time, and the particles sticking in the sieves are removed between each run. After the fifth run, obtain a 100.0g sample of each desired size fraction. Weigh up and put into separate pans. If the 100g sample size cannot be obtained, that individual size fraction may be reduced. A minimum of 30.0g may be run on an individual pan.

6.2 *Coarse Aggregate* – Thoroughly wash and dry the sample of coarse aggregate to constant mass (as defined in Note 2) at 230°± 9°F (110°±5°C) and separate into the different sizes shown in section 5.2 by sieving to refusal. Weigh out quantities of the different sizes within the tolerances of Section 5.2 and combine them to the designated total mass. Record the masses of the test samples and their fractional components.

Note 2 – Constant mass is defined as the sample mass at which there has not been more than a 0.5 gram mass loss during an additional1 hour of drying.

7 PROCEDURE

7.1 Storage of Samples in Solution – Immerse the samples in the prepared solution of sodium sulfate for not less than 16 hours nor more than 18 hours in such a manner that the solution covers them. Cover the aggregate containers to reduce evaporation and prevent the accidental addition of extraneous substances.

Place the sample immersed in the saturated solution in a test chamber, which maintains a temperature of 68.5 to 71.5˚F (20.3 to 21.9˚C) and a minimum of 90 percent humidity, for the immersion period. The temperature in the test chamber shall be plotted on a 24 hour continuous temperature recorder.

7.2 *Drying Samples after Immersion* –After the immersion period, pour the solution off the sample and place the sample in the drying oven. The temperature of the oven shall have been brought previously to 230±9˚F (110±5˚C). Dry the samples at the specified temperature until constant mass has been achieved. When the sample has achieved constant mass, place the pans on cooling shelves and cool to 75.5±5˚F (24±3˚C). Check the sample for proper temperature by placing a thermometer in various pans and, when required temperature is reached, place the pans in the test chamber and add saturated solution.

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Note 3 – Drying time required to reach constant mass may vary considerably for several reasons. Efficiency of drying will be reduced as cycles accumulate because of salt adhering to particles and, in some cases, because of increase in surface area due to breakdown. The different size fractions of aggregate will have differing drying rates. The smaller sizes will tend to dry more slowly because of their larger surface area and restricted inter-particle voids, but this tendency may be altered by the effects of container size and shape.

7.3 *Number of Cycles* – Repeat the process of alternate immersion and drying until five cycles have been completed. If the test is interrupted, leave the samples in the oven at 230±9˚F (110±5˚C) until the test can be resumed.

7.4 Review the temperature record from the recording unit. Verify solution temperature limits were not exceeded.

8 QUANTITATIVE EXAMINATION

8.1 *Make the quantitative examination as follows:*

8.1.1 *Coarse Aggregate* – After the completion of the fifth cycle and the sample is cooled to room temperature, soak the sample in hot tap water for a minimum of 30 minutes. Place the sample in a solid wash pan and rinse any remaining crystals/aggregate from the test pan into the wash pan. Pour off and rinse the sample in the wash pan in hot water several times. Reintroduce the sample into the test pan, cover with hot water, and allow to soak for a minimum of 5 minutes. Pour the water off, place a screen over the test pan, and vigorously agitate the pan under hot water until the water running off the sample is clear.

Fine Aggregate – After completion of the fifth cycle and the sample is cooled to room temperature, soak the sample in hot tap water for a minimum of 30 minutes. Wash the sample onto a No. 200 sieve, with a No. 10 sieve on top for protection. Wash the sample with hot water until the water is clear and any consolidated particles are broken apart. Wash sample back into test pan.

8.1.2 After the sodium sulfate has been removed, dry each fraction of the sample to constant mass at 230°± 9°F (110°± 5°C). Sieve the fine aggregate over the same sieve on which it was retained before the test, and sieve the coarse aggregate over the sieve shown below for the appropriate size of particle. For fine aggregate, the method and duration of sieving shall be the same as were used in preparing the test samples. For coarse aggregate, the final sieving for loss determination shall be done on a 12 inch mechanical sieve shaker for 5 minutes. Determine the mass of the material retained on each sieve and record each amount. The difference between each of these amounts and the initial mass of the fraction of the sample tested is the loss in the test and is to be expressed as a percentage of the initial mass for use in Table 2.

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SOUNDNESS OF AGGREGATE BY USE OF SODIUM SULFATE

Effective Date: January 1, 2018

Table 2

Size of Aggregate	Sieve Used to Determine Loss
2 ½ to 1 ½ inch (63 mm to 37.5 mm)	1 ¼ inch (31.5 mm)
1 ½ to ¾ inch (37.5 mm to 19.0 mm)	5/8 inch (16.0 mm)
¾ to ⅜ inch (19.0 mm to 9.5 mm)	5/16 inch (8.0 mm)
3/8 to No. 4 (9.5 mm to 4.75 mm)	No. 5 (4.0 mm)

9 REPORT

9.1 The report shall include the following data:

9.1.1 Mass of each fraction of each sample before test.

9.1.2 Material from each fraction of the sample finer than the sieve designated in Section 8.1.2 for sieving after test, expressed as a percentage of the original mass of the fraction.

9.1.3 The weighted average loss is calculated by multiplying a standard gradation factor (IDOT Table 3) times each pan loss (%) and summing the results of that calculation.

ILLINOIS TEST PROCEDURE 104

SOUNDNESS OF AGGREGATE BY USE OF SODIUM SULFATE

Effective Date: January 1, 2018

IDOT Table 3
Standard Gradation Factors for Calculating Weighted Average Loss

Coarse Aggregate*		
Number of Pans	Standard Gradation Factor	Material Size
3	51	-1 ½ inch (-37.5 mm) + 3/4 inch (19 mm)
	36	-3/4 inch (-19 mm) + 3/8 inch (9.5 mm)
	13	-3/8 inch (-9.5 mm) + No. 4 (4.75 mm)
2	75	-3/4 inch (-19 mm) + 3/8 inch (9.5 mm)
	25	-3/8 inch (-9.5 mm) + No. 4 (4.75 mm)
1	100	-3/8 inch (-9.5 mm) + No. 4 (4.75 mm)
Fine Aggregate**		
4	13	-No. 4 (-4.75 mm) + No. 8 (2.36 mm)
	15	-No. 8 (-2.36 mm) + No. 16 (1.18 mm)
	25	-No. 16 (-1.18 mm) + No. 30 (600µm)
	34	-No. 30 (-600µm) + No. 50 (300µm)

*For gradation CM05 (CA05), use 100 for both sets of pans and divide total loss by 2.
**For gradations FA/FM22 and FA/FM04 use 44% for the -No. 4 (-4.75 mm) +No. 8 (+2.36 mm) and 43% for -No. 8 (-2.36 mm) +No. 16 (+1.18 mm).

9.1.4 Report the weighted percentage loss to the nearest whole number.

ILLINOIS TEST PROCEDURE 113

LIGHTWEIGHT PIECES IN AGGREGATE
(DELETERIOUS CHERT)

Effective Date: January 1, 2018

1 SCOPE

1.1 This procedure covers the determination of the percentage of lightweight pieces in aggregate by means of sink-float separation in a heavy liquid of suitable specific gravity.

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

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

2 REFERENCED DOCUMENTS

2.1 Illinois Test Procedures (ITP):

- ITP 85, Specific Gravity and Absorption of Coarse Aggregate
- ITP 203, Deleterious Particles In Coarse Aggregate

2.2 *AASHTO Standards:*

- M 6, Fine Aggregate for Hydraulic Cement Concrete
- M 80, Coarse Aggregate for Hydraulic Cement Concrete
- M 231, Weighing Devices Used in the Testing of Materials
- R 16, Regulatory Information for Chemicals used in AASHTO Tests
- M 92, Woven Wire Test Sieve Cloth and Test Sieves

3 SIGNIFICANCE AND USE

3.1 This method is used to determine conformance with provisions of AASHTO M 6 and AASHTO M 80 pertaining to the amount of deleterious chert in coarse aggregate.

4 APPARATUS

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

4.2 *Containers* - suitable for drying the aggregate sample, and containers suitable for holding the heavy liquid during the sink-float separation.

4.3 *Skimmer* –A spoon with No. 8 (2.36 mm) holes drilled into the bowl and a 90˚ bend in the handle to separate the floating pieces from the heavy liquid.

ILLINOIS TEST PROCEDURE 113

LIGHTWEIGHT PIECES IN AGGREGATE
(DELETERIOUS CHERT)

Effective Date: January 1, 2018

4.4 *Oven* – An oven of sufficient size, capable of maintaining a uniform temperature of 230±9˚F (110±5˚C). The oven shall be specifically designed for drying.

4.5 *Sieves* – No. 4 (4.75 mm) conforming to AASHTO M 92.

4.6 *Specific Gravity Measurement* – A hydrometer conforming to the requirements of Section 5 through 11 of ASTM E 100 or suitable combination of graduated glassware and balance, capable of measuring the liquid specific gravity within ±0.01.

4.7 *Water Bath* – A water batch of sufficient size, capable of maintaining a uniform temperature of 73±2˚F (23±1˚C).

5 ZINC BROMIDE SOLUTION

5.1 The Zinc Bromide Solutions shall consist of zinc bromide and de-ionized water: The zinc bromide ($ZnBr_2$) shall be mixed as follows. In a suitable container of sufficient size to accommodate 20.29 fl. oz. (600mL) of solution, mix 500g of zinc bromide ($ZnBr_2$) with approximately 4.32 fl. oz. (127.6mL) of de-ionized water. Mix the solution sufficiently to consolidate the dry chemical with the de-ionized water. Place the solution container into a water bath for a sufficient time period to allow the solution to stabilize at a temperature of 73±2˚F (23±1˚C). Once the temperature has stabilized at the required temperature, determine the specific gravity of the solution. If the solution is not at the required specific gravity adjust the solution by adding zinc bromide ($ZnBr_2$) or de-ionized water dependent upon which way the adjustment needs to be made. If an adjustment was made place the solution container back into the water bath to stabilize the temperature. Repeat the adjustment procedure until the desired specific gravity is obtained. (See Note 1)

5.2 The specific gravity of the heavy liquid shall be maintained within ±0.01 of the specified value at all times during the test. A heavy liquid with a specific gravity of 2.35±0.01 shall be used to check the percentages of deleterious chert in gravel/crushed gravel. A heavy liquid with a specific gravity of 2.55±0.01 shall be used to check the percentages of deleterious chert in crushed stone.

Note 1 – Caution: zinc bromide is toxic, both by absorption through the skin and by inhalation. It shall be used only in a hood. Care shall be taken to avoid inhalation or contact with the eyes or skin.

ILLINOIS TEST PROCEDURE 113

LIGHTWEIGHT PIECES IN AGGREGATE
(DELETERIOUS CHERT)

Effective Date: January 1, 2018

6 SAMPLING

6.1 Obtain sample per Illinois Test Procedure 203.

7 PROCEDURE

7.1 After performing the deleterious count, the chert particles shall be soaked in water for a minimum of 16 hours and then brought to a saturated-surface-dry condition by means of the procedure specified in ITP 85. The chert particles are then introduced into the zinc bromide solution in a suitable container. The volume of liquid shall be a least three times the absolute volume of the aggregate. Using the skimmer stir the sample and remove the pieces that are floating to the surface then place them in warm water and wash until the particles are free of Zinc Bromide. Place the particles in a separate pan. Drain the Zinc Bromide off the remainder of the particles and repeat the washing procedure, and then place the particles in a separate pan, taking care to label each pan correctly. Dry both pans to a constant mass in a drying oven set at 230±9˚F (110±5˚C) and allow to cool to a comfortable handling temperature. Constant mass is defined as the sample mass at which there has not been more than 0.5 gram mass loss during an additional 1 hour of drying. This should be verified occasionally.

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ILLINOIS TEST PROCEDURE 161

RESISTANCE OF CONCRETE TO RAPID FREEZING AND THAWING

Effective Date: January 1, 2018

1 SCOPE

1.1 This procedure covers the determination of the resistance of concrete specimens to rapidly repeated cycles of freezing and thawing in the laboratory by freezing in air and thawing in water. This procedure is intended for use in determining the effects of variations in the properties of concrete on the resistance of the concrete to the freezing and thawing cycles specified in this particular procedure. This procedure is not intended to provide a quantitative measure of the length of service that may be expected from a specific type of concrete.

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

2 REFERENCED DOCUMENTS

2.1 *Illinois Test Procedures (ITP):*

- ITP 2, Sampling of Aggregates
- ITP 11, Materials Finer Than No. 200 (75-µm) Sieve in Mineral Aggregates by Washing
- ITP 27, Sieve Analysis of Fine and Coarse Aggregate
- ITP 84, Specific Gravity and Absorption of Fine Aggregate
- ITP 85, Specific Gravity and Absorption of Coarse Aggregate

2.2 *AASHTO Standards:*

- M 194, Chemical Admixtures for Concrete
- M 210, Use of Apparatus for the Determination of Length Change of Hardened Cement Paste, Mortar, and Concrete
- M 231, Weighing Devices Used in the Testing of Materials
- R 39, Making and Curing Concrete Test Specimens in the Laboratory
- T 157, Air-Entraining Admixtures for Concrete

2.3 *ASTM Standards:*

- C 215, Standard Test Method for Fundamental Transverse, Longitudinal, and Torsional Resonant Frequencies of Concrete Specimens.
- C 823/C 823M, Standard Practice for Examination and Sampling of Hardened Concrete in Constructions
- C 39, Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens
- C 1260 (Illinois Modified), Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)

ILLINOIS TEST PROCEDURE 161

RESISTANCE OF CONCRETE TO RAPID FREEZING AND THAWING

Effective Date: January 1, 2018

3 SIGNIFICANCE AND USE

3.1 As noted in the scope, the procedure described in this method is intended to determine the effects of variations in both properties and conditioning of concrete in the resistance to freezing and thawing cycles specified in this particular procedure. Specific applications include specified use in AASHTO M 194, AASHTO T 157, and ranking for coarse aggregates as to their effect on concrete freeze-thaw durability, especially where soundness of the aggregate is questionable.

3.2 It is recognized that the procedure may not exhibit significantly damaging effects on frost-resistant concrete which may be defined as (1) any concrete not critically saturated with water (that is, not sufficiently saturated to be damaged by freezing) and (2) concrete made with frost-resistant aggregates and having an adequate air-void system that has achieved appropriate maturity and thus will prevent critical saturation by water under common conditions.

3.3 If, as a result of performance tests as describe in this method, concrete is found to be relatively unaffected, it indicates that it was either not critically saturated, or was made with “sound” aggregates, a proper air-void system, and allowed to mature properly.

3.4 No relationship has been established between the resistance to cycles of freezing and thawing of specimens cut from hardened concrete and specimens prepared in the laboratory.

4 APPARATUS

4.1 *Freezing and Thawing Apparatus:*

4.1.1 The freezing and thawing apparatus shall consist of a suitable chamber, or chambers, in which the specimen may be subjected to the specified freezing and thawing cycle. Together with the necessary refrigerating and heating equipment and controls to produce continuously and automatically reproducible cycles within the specified temperature requirements.

4.1.2 The apparatus shall be so arranged that, except for necessary supports, each specimen is completely surrounded by air during the freezing phase of the cycle and by water during the thawing phase. Length change specimens in vertical containers shall be supported in a manner to avoid damage to the gauge studs.

4.2 *Temperature Measuring Equipment* – thermometers, resistance thermometers, or thermocouples, capable of measuring the temperature at various points within the specimen chamber and at the centers of control specimens to within 2˚F (1°C).

4.3 *Dynamic Testing Apparatus* – Conforming to the requirements of ASTM C 215.

ILLINOIS TEST PROCEDURE 161

RESISTANCE OF CONCRETE TO RAPID FREEZING AND THAWING

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4.4 *Length Change Comparator* – Capable of measure to 0.0001 inch (0.00254 mm). A length reference bar, approximately 15.25 inch (388 mm) in length, measured to the nearest 0.0001 inch (0.00254 mm) shall be furnished.

4.5 *Balance* – The balance shall have sufficient capacity, be readable to 0.1 percent of the sample mass, or better, and conform to the requirements of AASHTO M 231. When obtaining the weights as specified in Table 1 the balance shall have sufficient capacity and be readable to 0.01 lbs.

4.6 *Tempering Tank* – With suitable provisions for maintaining the temperature of the test specimens in water, such that when removed from the tank for length measurement the specimens will be within a temperature range of 73˚±1˚F (23˚±0.5˚C).

4.7 *Sample Rack* – Welded sectional stainless steel racks (18 specimens per rack) for keeping the specimens in a vertical position, with sufficient net free space around them to allow circulation for the heat exchange medium to produce the temperature conditions specified. Each welded section shall have two hooks to use a hoist for specimen relocation. The racks shall be designed such that the pins in the ends of the specimens will not contact the racks or supports. Neoprene pads shall be secured to the rods at the bottom of the sample basket. Each pad shall have a hole [approximately ¾ inch (19 mm) diameter] drilled to allow the measuring stud to rest inside instead of on the pad. The pad shall be sufficient thickness to protect the studs from contact with the metal rods of the basket. The pad shall be secured by a plastic strap which raises the beam slightly off the pad and allows water or air to reach the bottom of the sample.

4.8 *Thermocouple Beam:* Refer to the BMPR Thermocouple Manufacturing Procedure. This procedure can be found at the following internet site. http://www.idot.illinois.gov/Assets/uploads/files/Doing-Business/Manuals-Guides-&-Handbooks/Highways/Materials/Concrete/Thermocouple%20Beams.pdf

4.9 *Fine Aggregate* – The fine aggregate gradation will be separated as per section 7 Table 3. On an every other month basis a Specific Gravity sample will be sized per Table 3 and conducted in accordance with Illinois Test Procedure 84. When new standard sand is obtained a Gradation (ITP 11 & ITP 27), Specific Gravity (ITP 84), and ASR (ASTM C 1260) test shall be performed.

5 FREEZING AND THAWING CYCLE

5.1 Thermocouple beams shall be placed in such a way as to indicate the extremes of temperature variation at different locations in the specimen cabinet. A minimum of 3 beams shall be utilized in each chamber.

5.2 The nominal freezing and thawing cycle for this method shall consist of alternately lowering the temperature of the specimens from 40 to 0°F (4 to -18°C) and raising it from 0 to 40°F (-18 to 4°C) in not less than 2 nor more than 5 hours. In addition, no less than 20 percent of the time shall be used for thawing. At the end of the cooling period, the temperature at the centers of the specimens shall be 0±3°F (-18±2°C), and at the end of the heating period the temperature shall be 40±3°F (4±2°C), with no specimen at any time reaching a temperature lower than -3°F (-20°C) nor higher than 43°F (6°C). The time required for the temperature at the center of any single specimen to be reduced from 37 to 3°F (3 to -16°C) shall be no less than one-half of the length of the cooling period, and the time required for the temperature at the center of any single specimen to be raised from 3 to 37°F (-16 to 3°C) shall be not less than one-half of the length of the heating period. For specimens to be compared with each other, the time required to change the temperature at the centers of any specimens from 35 to 10°F (2 to -12°C) shall not differ by more than one-sixth of the length of the cooling period from the time required for any specimen and the time required to change the temperature at the centers of any specimens from 10 to 35°F (-12 to 2°C) shall not differ by more than one-third of the length of the heating period from the time required for any specimen.

In the event that a capacity load of test specimens is not available, dummy specimens shall be used to fill empty spaces.

5.3 The difference between the temperature at the center of a specimen and the temperature at its surface shall at no time exceed 50°F (28°C) for more than 1 hour.

6 SAMPLING

6.1 Constituent materials for concrete specimens made in the laboratory shall be sampled according to ITP 2 and shall be sized according to Table 1.

Table 1

Freeze-Thaw Gradation						
	1”	3/4 ”	1/2 ”	3/8”	#4	#8
CA05 Grade A	19.2 lbs	12.0 lbs	13.8 lbs	9.0 lbs	6.0 lbs	
CA07 Grade B	3.0 lbs	15.0 lbs	15.0 lbs	15.0 lbs	12.0 lbs	
CA11 Grade C		3.0 lbs	24.0 lbs	12.0 lbs	21.0 lbs	
CA14 Grade D			3.0 lbs	30.0 lbs	25.2 lbs	1.8 lbs

The weights noted in Table 1 above are the minimum weight needed to cast sample beams. Field sample sizes are to be collected as specified in the BMPR Aggregate Freeze-Thaw Criteria document.

Each sampled gradation shall have a specific gravity sample obtained and tested in accordance with Illinois Test Procedure 85.

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The remainder of the material to be used for testing shall be washed and oven dried.

6.2 Samples cut from hardened concrete are to be obtained in accordance with ASTM C 823/C 823M.

7 TEST SPECIMENS

7.1 The test specimens used in this test shall be prisms made and cured in accordance with the applicable requirements of AASHTO T 39-09, “Making and Curing Concrete Test Specimens in the Laboratory”. The test specimens shall be 3 inch x 4 inch x 15 inch (76 mm x 102 mm x 380 mm). Gauge length shall be 14 inch (356 mm) and gauge studs shall be stainless steel hex bolts ¼ inch (6 mm) – 20 UNC x 0.75 inch (19 mm). Each hex bolt shall have a cap nut (acorn nut) applied and hand tightened with a small amount of “Loctite Thread locker 271” applied to secure the nut in place. AASHTO R 39-09, Article 6.3 shall govern aggregate preparation.

7.2 The gradations as specified in Table 2 shall be used for testing the coarse aggregate.

Table 2

Coarse Aggregate Gradations

Gradation	Sieve Size – Percent Passing						
	1 ½” (37.5 mm)	1” (25 mm)	¾” (19 mm)	½” (12.5 mm)	3/8” (9.5 mm)	#4 (4.75 mm)	#8 (2.36 mm)
A	100	68	48	25	10	0	0
B	100	95	70	45	20	0	0
C	100	100	95	55	35	0	0
D	100	100	100	95	45	3	0

The standard fine aggregate gradation as specified in Table 3 shall be used.

Table 3

Sieve Size – Percent Passing					
#4 (4.75 mm)	#8 (2.36 mm)	#16 (1.18 mm)	#300 (0.60 mm)	#50 (0.30 mm)	#100 (0.15 mm)
100	87	67	42	9	0

7.3 The concrete mix design used to fabricate the test specimens shall be designed with a water/cement ratio of 0.47 based upon weight. The cement content shall be 564 lb/yd^3 (335kg/m^3). A neutralized vinsol resin air entraining admixture (AEA) diluted to 10% AEA and 90% water shall be used to achieve an air content of 6.5%±1.5%. An absolute volume of saturated surface dry coarse aggregate of 0.40 shall be used.

Before casting, the individual coarse aggregate samples shall be placed in a suitable container equipped with a drain. This container will be referred to as a draining

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container. Sufficient water shall be added to completely submerge the coarse and fine aggregate. The appropriate amount of fine aggregate shall be placed on top of the coarse aggregate in the draining container. The draining container, with aggregates, shall be covered and allowed to stand for 18 hours, minimum.

Note 1 – Record the tare weight of the empty, dry draining container, and the dry weights of the coarse and fine aggregates.

At the end of the soaking period, the draining containers with drain side down are drained for a minimum of 1 hour by placing a block of 2 inch x 4 inch block of wood under one side of the container. Five gallon buckets shall be used to collect the water as it drains from the draining containers. Care shall be exercised to retain any aggregate flowing through the drain. The container with the saturated coarse and fine aggregates is weighed. The total weight of the dry container and the coarse and fine aggregates are subtracted from the total weight of the wet draining container with soaked aggregates. The difference equals the amount of water absorbed by the aggregates, including any free water. This difference must be subtracted from the water needed for the mix.

Next, the drained aggregates shall be emptied into the mixer. The weight of mixing water required by the mix design worksheet is then weighed in a metal pan and mixed with the required amount of 10% AEA solution. The water and AEA solution are then emptied into the draining container and used to wash any remaining sand from the sides of the container. Next, the draining container is emptied into the mixer. The cement is then added to the mixture. This is the start of the first three minutes of mixing time. The three minutes of mixing are followed by three minutes of rest. The mixer shall be covered with plastic sheeting to prevent evaporation during this three minute rest period. At the conclusion of the rest period, the plastic sheeting shall be removed and the concrete mixed for an additional two minutes. Additional water may be added at this time if the slump of the concrete appears to be low. Upon completion of the 8 minute mixing sequence, the air content and slump of the concrete shall be measured and recorded.

After the completion of the air content and slump tests, the concrete shall be placed in the freeze-thaw molds. Three specimens shall be molded from each mixture. In addition, one 4 inch x 8 inch compressive strength cylinder shall be molded from each mixture. All specimens shall be fabricated by use of a vibrating table or other means of external vibration. The surfaces shall be struck off with a wood float and then finished smooth with a metal trowel. The freeze-thaw specimens shall be covered with a metal form to prevent the burlap and plastic from touching the concrete. The specimens shall immediately be covered with wet burlap and then with plastic sheeting. The compressive strength cylinder shall be initially cured by use of a plastic cap.

At 24±4 hours of age, the specimens shall be de-molded. During de-molding, each sample shall be legibly marked with the sample identification. The beams will be numbered 1, 2, and 3 to represent the three different beams for one aggregate sample. The tops of the beams will show an “X” and include the sample designation and the beam number. The bottoms of the beams will only show the sample designation and the beam number. Each beam number 2 will also include the group number the sample belongs to. The group number will be reflected on the top, face, and bottom of each beam 2. Cap nuts will be affixed to the bolts by use of “Loctite Thread locker 271”. After placement of the cap nuts, the specimens shall be placed in the moist room for the final curing until placement in the freeze-thaw chamber.

8 PROCEDURE

8.1 Molded beam specimens shall be wet cured for 14 days prior to testing unless otherwise specified. On the 14th day a 4 inch x 8 inch compressive strength cylinder shall tested in accordance with ASTM C 39.

8.2 Immediately after the specified curing period, bring the specimen to a temperature of 73±1˚F (23±0.5˚C) and measure the initial length using the length change comparator. Protect the specimens against loss of moisture between the time of removal from curing and start of the freezing-and-thawing cycles.

8.3 Freeze-Thaw Expansion Measurement Procedure (BMPR Concrete Lab Use)

8.3.1 *Freeze Thaw Expansion Measurement Procedure:* Refer to the BMPR Freeze-Thaw Expansion Measurement Procedure. This procedure can be found at the following internet site. http://www.idot.illinois.gov/Assets/uploads/files/Doing-Business/Manuals-Guides-&-Handbooks/Highways/Materials/Concrete/Freeze%20Thaw%20Expansion.pdf.

8.4 Start freezing-and-thawing tests by placing the specimens in the thawing water at the beginning of the thawing phase of the cycle. Remove the specimens from the apparatus, in a thawed condition, at intervals of approximately 50 cycles of exposure to the freezing-and-thawing cycles, and measure the length using the length change comparator at the temperature of 73±1˚F (23±0.5˚C) and return to the apparatus. To ensure that the specimens are completely thawed and at the specified temperature, place them in the tempering tank for a sufficient time for this condition to be attained throughout each specimen to be tested. Data have shown that 1.5 to 2 hours is sufficient to stabilize specimens in the tempering tank. Return the specimens either to random positions in the apparatus or to positions according to some predetermined rotation scheme that will ensure that each specimen that continues under test for any length of time is subjected to conditions in all parts of the freezing apparatus. Continue each specimen in the test until it has been subjected to 350 cycles (+0 to 20 cycles) or has obviously failed. Replace all failed beams with dummy beams.

When specified the relative dynamic modulus of elasticity shall be determined using ASTM C 215.

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8.5 If there is an interruption in cycles for a protracted period of time store the specimens in a frozen condition in such a way to prevent loss of moisture. Wrap and seal them, in as wet a condition as possible, in moisture-proof material to prevent dehydration, and store in a freezer or cold room maintained at 0±3˚F (-18±1.5˚C).

9. CALCULATIONS

9.1. *Length change in percent* –

Calculate the percent elongation (length change) each time the specimen length is measured. Final length change data shall be interpolated back to 350 cycles, if necessary. The final calculation shall be made using data for 350 cycles.

$$Lc = \frac{1_2 - 1_1}{Lg} \times 100$$

Where:

L_c = Length change of the test specimen after c cycles of freezing and thawing, percent,
1_1 = Length comparator reading at 0 cycles,
1_2 = Length comparator reading after c cycles, and
L_g = the effective gauge length between the innermost ends of the gauge studs as shown in the mold diagram in AASHTO M 210-01.

10 REPORT

10.1 The report shall include such of the following data as are pertinent to the variables or combination of variables studied in the tests:

10.2 *Properties of Concrete Mixture:*

10.2.1 Type and proportions of cement, fine aggregate, and coarse aggregate, including maximum size and grading (or designated grading indices), and ratio of net water content to cement.

10.2.2 Kind and proportion of any addition or admixture used.

10.2.3 Air content of fresh concrete.

10.2.4 Consistency of fresh concrete (slump).

10.2.5 Number of freeze -thaw cycles performed.

10.3 *Mixing, Molding, and Curing Procedure*:

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10.3.1 Departures from the standard procedures for mixing, molding, and curing as prescribed in Section 7.

10.4 *Characteristics of Test Specimens:*

10.4.1 Any defects in each specimen present at 0 cycle of freezing-and-thawing.

10.5. *Results:*

10.5.1. A summary listing of percent elongation calculated for each reading point (# of cycles) and percent elongation for 350 cycles, interpolated if necessary.

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ILLINOIS TEST PROCEDURE 203

DELETERIOUS PARTICLES IN COARSE AGGREGATE

Effective Date: January 1, 2018

1. SCOPE

1.1 This Illinois test procedure covers the procedure for the approximate determination of deleterious particles in coarse aggregate.

1.2 The test will be done with the Central Bureau of Materials (CBM) and Bureau of Physical Research (BPR).

2. REFERENCED DOCUMENTS

2.1 Illinois Test Procedures (ITP):

- ITP 2, Sample of Aggregates
- ITP 27, Sieve Analysis of Fine and Coarse Aggregates
- ITP 248, Reducing Samples of Aggregate to Testing Size
- ITP 113, Lightweight Pieces in Aggregate

2.2 *AASHTO Standards*:

- M 92, Woven Wire Test Sieve Cloth and Test Sieves
- M 231, Weighing Devices Used in the Testing of Materials

3. APPARATUS

3.1 *Balance* - The balance or scale shall conform to AASHTO M 231, "Standard Specification for Balances Used in the Testing of Materials".

3.2 *Sieves* - The sieves shall conform to AASHTO M 92, "Wire-Cloth Sieves for Testing Purposes".

3.3 *Splitter* - The splitter shall conform to ITP 248, "Reducing Field Samples of Aggregate to Testing Size".

3.4 *Other Apparatus* - Ice pick (cut off, point rounded, and hardness range of C 40 ± 10); a lighted magnifying lamp.

3.5 *Oven* - An oven of sufficient size, capable of maintaining a uniform temperature of 230 ± 9 °F (110 ± 5 °C). The oven shall be specifically designed for drying.

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DELETERIOUS PARTICLES IN COARSE AGGREGATE

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4. PREPARATION OF SAMPLE

4.1 Reduce field sample by use of a coarse aggregate sample splitter or by quartering method according to ITP 248. Sieve over No. 4 (4.75 mm) sieve. Obtain a sample mass of plus No. 4 (4.75 mm) material according to Table 1 below:

TABLE 1	
GRADATION	SAMPLE SIZE
CA01 (CM01) through CA05 (CM05)	4250g ± 250g
CA06 (CM06) through CA11 (CM11)	2500g ± 200g
CA12 (CM12) through CA20 (CM20)	1250g ± 150g

5. PROCEDURE

5.1 Hand-examine each individual particle of the sample to determine if it is deleterious. Water may be used while counting and to facilitate the determination of deleterious particles. Caution should be used when clay lumps are identified in the sample. Clay lumps will disintegrate readily in water. Pick out the deleterious particles, keeping each kind of particle separate for determining mass. After the hand-examination, soak any chert from Class A Quality aggregate in water in a suitable pan for a minimum of 16 hours. Run the heavy media test (ITP 113) on Class A Quality chert to determine deleterious chert. Dry each kind of deleterious particle and the remainder of the sample separately in suitable containers in a drying oven to constant mass at a temperature of 230±9 °F (110±5 °C) and allow to cool to a comfortable handling temperature. Constant mass is defined as the sample mass at which there has not been more than a 0.5 gram mass loss during an additional 1 hour of drying. This should be verified occasionally. Determine the mass of each kind of deleterious particle and the remainder of the sample to the nearest gram.

5.2 Oil Stained Count – After completing section 5.1, check any Class A Quality count sample for oil-staining. If oil-stained aggregate is present, separate any particles that are 90% or more oil-stained. Determine the mass of these particles and the remainder of the sample to the nearest gram.

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DELETERIOUS PARTICLES IN COARSE AGGREGATE

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6. DELETERIOUS MATERIALS

6.1 *Total Chert and Deleterious Chert* - Very fine-grained siliceous rock composed of crypto-crystalline quartz, chalcedony, or opal, or any combination of the three; very hard; exhibits conchoidal (shell-like) fracture in dense varieties and splintery fracture in porous varieties; has waxy to greasy luster in dense varieties and chalky surface in porous varieties. Dense type varies from gray to black, white to brown, less frequently green, red-blue. Porous, chalky type usually white or stained yellowish, brownish, and reddish. Usually occurs as nodules, lenses, or beds in sedimentary carbonate rocks and as particles in sand and gravels from such rocks.

Test:
1. Physical appearance (conchoidal fracture)
2. Scratch Test (Ice pick will not scratch and will usually leave some metal on the surface-dark streak.)
3. Heavy Media Test (ITP 113) to determine deleterious chert.

6.2 *Shale* - Sedimentary rock, composed mainly of clays and silts, relatively soft and massive, exhibits platy or fissile appearance, various colors (gray, black, green, red).

Test:
1. Physical appearance
2. Breaks easily with ice pick.

6.3 *Clay Lumps* - Unconsolidated sediment, mainly contains microscopic and sub-microscopic clay particles from rock decomposition, may contain some rock particles, characteristically sticky with high water content; usually light yellow or yellow-brown. Also includes clay-shales which may exhibit a platy or fissile appearance but readily disintegrate in water; usually of gray, green or greenish-gray color.

Test:
1. Physical appearance
2. Breaks easily with ice pick.
3. Readily dissolves or disintegrates in water.

6.4 *Coal and Lignite*

6.4.1 *Coal* - Organic mineral, usually black in color, composed of carbon.

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6.4.2 *Lignite* - Organic matter, one of the lesser stages of coal, brown to brownish black in color, some organic material noticeable.

Test: 1. Physical appearance.

6.5 *Soft and Unsound Fragments* - Particles exhibiting soft and unsound characteristics which are detrimental to their use in the aggregate.

6.5.1 Examples of Unsound Particles: (1) very argillaceous carbonate rock; (2) shale-laminated carbonate rock, minimum of 6 shale lines per ½ inch to 1 inch size particle, or several closely spaced lines forming a thick band; (3) limonites; (4) any other aggregate deemed unsound.

6.5.2 Examples of Soft Particles: (1) lightly cemented sandstone, (2) conglomerates, (3) carbonate rock having a weak crystal structure, (4) any other aggregate deemed soft.

6.5.2 Soft particles and unsound particles are put in separate pans. If their combined percentage fails the soft and unsound limit for the tested quality, the unsound particles are placed in a pan and tested according to ITP 104. The unsound particles that break down, crack, or flake off are still considered unsound whereas the particles that do not break down, crack, or flake off are considered non-deleterious and are returned to the original sample, and the soft and unsound percentage is recalculated.

Test: 1. Physical appearance

2. Material easily broken, cracked, or flaked using an ice pick.

6.6 *Other Deleterious:*

6.6.1 Any material present in the sample which, will affect the use of the aggregate in a deleterious manner. Examples: (1) roots, (2) wood, (3) contaminants, and (4) any other material deemed deleterious.

Test 1. Physical appearance

2. Breaks easily with ice pick

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6.6.2 For slag, the following materials shall be counted out as Other Deleterious:

(1) Puff balls - Particles consisting mainly of minus No. 200 (75µm) material lightly cemented together.

(2) Oxide particles - Particles consisting mainly of calcium or magnesium oxide (normally white in color). May also contain bigger slag bits cemented together.

Test: 1. Physical appearance

2. Breaks easily with ice pick.

6.6.3 For crushed concrete, the following materials shall be counted out as other deleterious.

(1) RAP (Recycled Asphalt Pavement) - Particles of sand, aggregate and/or asphalt binder cemented together forming a matrix of material.

(2) Other - (a) wood, (b) plastic, (c) wire, (d) cloth, (e) glass, (f) brick, (g) contaminants, (h) clay lumps, and (i) any other material deemed deleterious.

Test: 1. Physical appearance

7. REPORT

7.1 Calculate the percentage of each kind of deleterious particle as follows:

$$\%\ Deleterious\ Particle = \frac{A}{B}\ x\ 100$$

Where:

A = Dry mass of the specific kind of deleterious particle, grams.

B = Dry mass of the remainder of the sample plus the combined mass of the deleterious particles counted out, grams.

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DELETERIOUS PARTICLES IN FINE AGGREGATE

Effective Date: January 1, 2018

1. SCOPE

1.1 This Illinois test procedure covers the procedure for the approximate determination of deleterious particles in fine aggregate.

2. REFERENCED DOCUMENTS

2.1 Illinois Test Procedures (ITP):

- ITP 2, Sample of Aggregates
- ITP 27, Sieve Analysis of Fine and Coarse Aggregates
- ITP 248, Reducing Samples of Aggregates to Testing Size

2.2 *AASHTO Standards*:

- M 92, Woven Wire Test Sieve Cloth and Test Sieves
- M 231, Weighing Devices Used in the Testing of Materials

3. APPARATUS

3.1 *Balance* - The balance or scale shall conform to AASHTO M 231, "Standard Specification for Balances Used in the Testing of Materials".

3.2 *Sieves* - The sieves shall conform to AASHTO M 92 "Wire-Cloth Sieves for Testing Purposes".

3.3 *Splitter* - The splitter shall conform to ITP 248 "Reducing Field Samples of Aggregate to Testing Size".

3.4 *Other Apparatus* - A lighted magnifying lamp, forceps or similar tool to aid in sorting.

3.5 *Oven* - An oven of sufficient size, capable of maintaining a uniform temperature of 230±9°F (110±5°C). The oven shall be specifically designed for drying.

4. PREPARATION OF SAMPLE

4.1 Reduce field sample by use of a sample splitter or by quartering according to ITP 248, to obtain approximately 1000g of fine aggregate.

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DELETERIOUS PARTICLES IN FINE AGGREGATE

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4.2 Dry the aggregate in a suitable pan or vessel in a drying oven to a constant mass as a temperature of 230±9˚F (110±5˚C) and allow it to cool to comfortable handling temperature. Constant mass is defined as the sample mass at which there has not been more than a 0.5 gram mass loss during an additional 1 hour of drying. This should be verified occasionally.

4.3 Hand sieve the sample over the No. 30 (600µm) sieve, retaining the plus No. 30 (600µm) material. Obtain a 100.0g sample by use of a fine aggregate splitter.

5. PROCEDURE

5.1 Place the test sample on a flat surface that allows complete examination of each individual grain. Pick out the deleterious particles, keeping each kind of particle separate for determining mass. Determine the mass of each kind of deleterious particle to the nearest 0.1g.

6. DELETERIOUS MATERIALS

6.1 Shale - Sedimentary rock composed mainly of clays and silts, relatively soft and massive, exhibits platy or fissile appearance, various colors (gray, black green, red).

Test: 1. Physical appearance.

2. Mashes easily with forceps.

6.2 *Clay Lumps* - Unconsolidated sediment, mainly contains microscopic and sub-microscopic clay particles from rock decomposition, may contain some rock particles, characteristically sticky with high water content; usually light yellow or yellow-brown. Also includes clay-shales which may exhibit a platy or fissile appearance but readily disintegrate in water; usually of gray, green or greenish-gray color.

Test: 1. Physical appearance.

2. Mashes easily with forceps.

6.3 *Coal, Lignite, and Shells*:

6.3.1 Coal - Organic mineral, usually black in color, composed of carbon.

6.3.2 Lignite - Organic matter, one of the lesser stages of coal, brown to brownish black in color, some organic material noticeable.

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6.3.3 Shells - Shells of marine animals (clams, snails, etc.)

Test: 1. Physical appearance.

6.4 *Conglomerate* – Various size particles of sand or gravel or both, with or without interstitial and cementing material, cemented together.

Test: 1. Physical appearance.

2. May break apart with forceps.

6.1.5 *Other Deleterious* – Any material present in the sample which, will affect the use of the aggregate in a deleterious manner. Examples: (1) roots, (2) wood, (3) clay-coated aggregate, (4) highly weathered particles (soft), and (5) any other material deemed deleterious.

Test: 1. Physical appearance.

2. Mashes easily with forceps.

7. REPORT

7.1 Calculate the percentage of each kind of deleterious particle as follows:

$$\%\, Deleterious\ Particle = \frac{A}{B}\ x\ 100$$

Where:

A = Dry mass of the specific kind of deleterious particle, grams.

B = Dry mass of the remainder of the sample plus the combined mass of the deleterious particles counted out, grams.

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ILLINOIS TEST PROCEDURE 205

INSOLUBLE RESIDUE AND MAGNESIUM OXIDE IN COARSE AGGREGATES

Effective Date: January 1, 2018

1 SCOPE

1.1 This Illinois test procedure covers the procedure for the determination of insoluble residue and magnesium oxide in coarse aggregate.

2. REFRENCED DOCUMENTS

2.1 Illinois Test Procedures (ITP):

- ITP 2, Sample of Aggregates
- ITP 27, Sieve Analysis of Fine and Coarse Aggregates
- ITP 248, Reducing Samples of Aggregate to Testing Size

2.2 *AASHTO Standards*:

- M 92, Woven Wire Test Sieve Cloth and Test Sieves
- M 231, Weighing Devices Used in the Testing of Materials

2.3 *ASTM Standards*:

- E 832, Standard Specification for Laboratory Filter Papers
- D 1193, Standard Specification for Reagent Water

3 APPARATUS

3.1 *Balance* - The balance or scale shall conform to AASHTO M 231, "Standard Specification for Balances Used in the Testing of Materials".

3.2 *Sieves* - The sieves shall conform to AASHTO M 92 (as specified by Illinois) "Wire-Cloth Sieves for Testing Purposes".

3.3 *Splitter* - The splitter shall conform to Illinois Test Procedure 248 "Reducing Field Samples of Aggregate to Testing Size".

3.4 *Oven* - An oven of sufficient size, capable of maintaining a uniform temperature of 230±9˚F (110±5˚C). The oven shall be specifically designed for drying. No other source of drying is permitted during the initial preparation of sample.

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INSOLUBLE RESIDUE AND MAGNESIUM OXIDE IN COARSE AGGREGATES

Effective Date: January 1, 2018

3.5 *Analytical Balance* - The balance shall be capable of reproducing results within 0.0002g with an accuracy of ± 0.0002g. Direct-reading balances shall have a sensitivity not exceeding 0.0001g.

3.6 *Glassware and Laboratory containers* - Standard volumetric flasks and pipettes should be of precision grade or better.

3.1.7 *Electric hot plate* - A high temperature hot plate capable of being set to keep solutions at a just below boiling temperature.

3.8 *Filter Paper* - Filter paper shall conform to the requirements of ASTM E 832.

3.9 *Desiccator* - Desiccators shall be provided with a good desiccant, such as anhydrous calcium sulfate that has been treated with a color-change indicator to show when it has lost its effectiveness.

3.10 *Water* - Water should conform to the numerical limits for Type II reagent water described in ASTM D 1193. (Deionized or distilled water meeting a minimum electrical resistivity requirement of 1.0 MΩ*cm at 25°C conforms.)

3.11 *Acid* - Reagent grade chemicals shall be used in all tests. It shall be understood that the concentrated reagent Hydrochloric acid (HCl) intended shall have a specific gravity of 1.19.

3.12 *Muffle furnace* - The muffle furnace shall be capable of operation at the temperatures required and shall have an indicating pyrometer accurate within ± 77˚F (±25°C), as corrected, if necessary, by calibration.

3.13 *Atomic Absorption Spectrophotometer (A.A.S.)* - The A.A.S. should be an instrument qualified under section 4 of ASTM C 114 performance requirements for rapid test methods using Standard or Certified Reference Materials (SRM's or CRM's).

3.14 *Standards (NIST)* - Acceptable reference cement are NIST CRM's (SRM's) or other reference cements traceable to the NIST CRM's. The reference cement must have an assigned value for the analyte being determined. Standards should be selected with the lowest and highest percentages available for the analyte being measured for a two-point linear calibration curve. Standards concentrations are put in as weight percentages of the oxide for the curve.

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INSOLUBLE RESIDUE AND MAGNESIUM OXIDE IN COARSE AGGREGATES

Effective Date: January 1, 2018

4 PREPARATION OF SAMPLE

4.1 Mix the test specimen and reduce to a sample size of approximately 1000g of plus (+) No. 8 (2.36 mm) material in accordance to ITP 248. Wash the sample to remove any contaminations and dry the sample to a constant mass. Constant mass is defined as the sample mass at which there has not been more than a 0.5 gram mass loss during an additional 1 hour of drying. This should be verified occasionally. Cool the sample to room temperature.

4.2 Crush the material using a laboratory jaw crusher set at the smallest opening. Sieve the material over the No. 8 (2.36 mm) and No. 50 (300µm) sieves. Obtain a minimum sample size of 50g of minus (-) No. 50 (300 µm) material.

4.3 If the minimum sample size is not met, pulverize the remaining minus (-) No. 8 (2.36 mm) material to meet the minimum sample size requirement.

4.4 Repeat steps 4.2 and 4.3 as many times as necessary to obtain the minimum sample size.

4.5 Place the sample in a sealed container to minimize exposure to the atmosphere. Identify the sample as needed.

5 PROCEDURE

5.1 Place a 1g test specimen into an 8.45oz U.S. fluid (250ml) beaker (recording the weight to 4 decimal places).

5.2 Add 0.85oz U.S. fluid (25ml) cold water. Disperse the specimen in the water and while swirling the mixture, quickly add 0.17oz U.S. fluid (5ml) concentrated Hydrochloric acid.

5.3 If necessary, warm the solution gently, and grind material with flattened end of glass rod until it is evident that decomposition of the specimen is complete.

5.4 Dilute the solution to 1.69oz U.S. fluid (50ml) with hot water (nearly boiling) and heat the covered mixture rapidly to near boiling by means of a high-temperature hot plate.

5.5 Then digest the covered mixture for 15 minutes at a temperature just below boiling.

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5.6 Gravity filter the solution through 2 combined Whatman ash less filter papers (#44 and #42 respectively) into a 6.76oz U.S. fluid (200ml) volumetric flask (Doubling the paper prevents fine residue from creeping up over the edge and contaminating the filtrate and clogging the aspirating tube of the A.A.)

5.7 Wash the beaker, paper, and residue thoroughly with hot water (until flask is 2/3 to 3/4 full) and allow to cool to room temperature before final dilution.

5.8 For insoluble residue, remove the filter paper and place into a weighed porcelain crucible. Dry, ignite, and muffle at 1832˚F (1000℃). Cool in a desiccator, weigh and calculate using the following formula:

$$\frac{Weight\ of\ Residue\ x\ 100}{Sample\ Weight} = \%\ Insoluble\ Residue$$

5.9 For MgO analysis, dilute the room temperature solution in the volumetric flask up to the line, stopper, and mix well. Using a volumetric pipette, transfer a 0.03oz U.S. fluid (1ml) aliquot of this sample into a16.9oz U.S. fluid (500ml) flask and dilute up to line with room temperature water for weight % MgO analysis on A.A. Calculate using the following formula (see note):

$$Weight\ \%\ MgO = \frac{Weight\ \%\ reading\ from\ A.A.x\ 5}{Sample\ Weight}$$

Note: Cement standards for equipment/procedure qualification are made up by the above procedure using a 1.0000g sample into a 6.76oz U.S. fluid (200ml) volumetric flask with a further dilution of a 0.03oz U.S. fluid (1ml) aliquot into a 3.38oz U.S. fluid (100ml) flask. The cement standard range maximums for weight percent MgO are under 5% for NIST SRM's. Since a dolomitic sample may have a reading around 20%, it is necessary to make a 0.03oz U.S. fluid (1ml) to 16.9oz U.S. fluid (500ml) dilution for our aggregate test specimens to place the dolomitic samples within our 5% range. Therefore, the numerical readings must be multiplied by 5 to account for the differences in the dilution factors between samples and standards.

ILLINOIS TEST PROCEDURE 327

RESISTANCE OF COARSE AGGREGATE TO DEGRADATION BY ABRASION IN THE MICRO-DEVAL APPARATUS

Effective Date: January 1, 2018

1. SCOPE

1.1 This method covers a procedure for testing coarse aggregate for resistance using the Micro-Deval apparatus.

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

1.3 The text of this method references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the test methods.

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

2. REFERENCED DOCUMENTS

2.1 Illinois Test Procedure (ITP):

- ITP 27**,** Sieve Analysis of Fine and Coarse Aggregates

2.2 AASHTO Standards:

- M 231, Weighing Devices Used in the Testing of Materials
- M 92, Woven Wire Test Sieve Cloth and Test Sieves

2.3 ASTM Standards:

- C 670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

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RESISTANCE OF COARSE AGGREGATE TO DEGRADATION BY ABRASION IN THE MICRO-DEVAL APPARATUS

Effective Date: January 1, 2018

3. SUMMARY OF TEST METHOD

3.1 The Micro-Deval Test is a measure of abrasion resistance and durability of mineral aggregates resulting from a combination of actions including abrasion and grinding with steel balls in the presence of water. A sample with standard grading is initially soaked in water for not less than 1 hour. The sample is then placed in a jar mill with 27.63oz U.S. fluid (2.0L) of water and an abrasive charge consisting of 5000±5g of 3/8 inch (9.5 mm) diameter steel balls. The jar, aggregate, water, and charge are revolved according to Section 9.4. The sample is then washed and oven-dried. The loss is the amount of material passing the No. 16 (1.18 mm) sieve, expressed as a percent by mass of the original sample.

4. SIGNIFICANCE AND USE

4.1 The Micro-Deval abrasion test is a test of coarse aggregates to determine abrasion loss in the presence of water and an abrasive charge. Many aggregates are more susceptible to abrasion when wet than dry, and the use of water in this test incorporates this reduction in resistance in degradation, in contrast to some other tests that are conducted on dry aggregate. The test results are helpful in evaluating the toughness/abrasion resistance of coarse aggregate subject to abrasion when adequate information is not available from service records.

4.2 The Micro-Deval abrasion test is a useful test for detecting changes in properties of aggregate produced from an aggregate source as part of a quality control of quality assurance process.

5. TERMINOLOGY

5.1 *Constant Mass* – Constant mass is defined as the sample mass at which there has not been more than a 0.5 gram mass loss during an additional 1 hour of drying. This should be verified occasionally.

6. APPARATUS

6.1 *Micro-Deval Abrasion Machine* – A jar rolling mill capable of running at 100±5rpm (Figure1).

6.1.1 The machine shall be fitted with a counter so the test is conducted on the basis of number of revolutions (Section 9.4).

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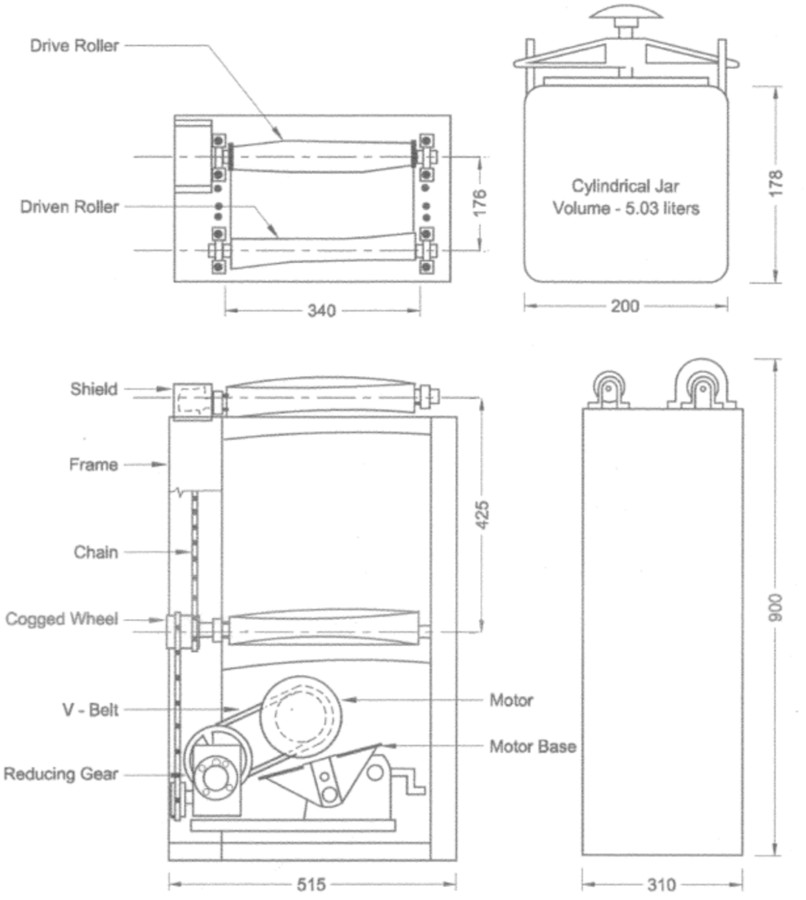

Note: All dimensions are shown in millimeters unless otherwise noted.

Figure 1—Micro-Deval Abrasion Machine and Container

6.2 *Containers* – Stainless steel Micro-Deval abrasion jars having a 169.07oz U.S. fluid (5L) capacity with a rubber ring in the rotary locking cover; an external diameter of 7.64 to 7.95 inches (194 to 202 mm), and an internal height of 6.69 to 6.97 inches (170 to 177 mm). The inside and outside surfaces of the jars shall be smooth and have no observable ridges of indentations (Figure 1).

6.3 *Abrasion Charge* – Magnetic stainless steel balls are required. These shall have a diameter of 0.38±0.02 inch (9.5±0.5 mm). Each jar requires a charge of 5000±5g of balls.

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6.4 *Sieves* – Sieves with square openings that conform to AASHTO M 92 specifications.

6.5 *Oven* – An oven of sufficient size, capable of maintaining a uniform temperature of 230±9˚F (110±5˚C). The oven shall be specifically designed for drying.

6.6 *Balance* – A balance or scale accurate to 1.0g.

7. REFERENCE AGGREGATE

7.1 *Calibration Aggregate* – An adequate supply of aggregate, established by the laboratory to use for calibration of the test method (see Section 11.1).

8. TEST SAMPLE

8.1 The test sample shall be washed and oven-dried at 230±9˚F (110±5˚C) to constant mass, separated into individual size fractions in accordance with ITP 27, and recombined to meet the grading as shown in Section 8.2, 8.3, and 8.4.

8.2 For gradations CA06 thru CA11, a sample of 1500±5g shall be prepared as in Table 1:

Table 1		
Passing	Retained	Mass
¾ inch (19.0 mm)	½ inch (12.5 mm)	750g
½ inch (12.5 mm)	⅜ inch (9.5 mm)	750g

Run the machine at 100±5rpm for 12,000±100 revolutions for the grading show in Section 8.2; for 10,500±100 revolutions for the grading shown in Section 8.3, and for 9500±100 revolutions for the grading shown in Section 8.4.

8.3 For gradations CA12 thru CA14 , a sample of 1500±5g shall be prepared as in Table 2:

Table 2		
Passing	Retained	Mass
½ inch (12.5 mm)	⅜ inch (9.5 mm)	750g
⅜ inch (9.5 mm)	No. 4 (4.75 mm)	750g

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8.4 For gradations CA15 thru CA20, a sample 1500±5g shall be prepared as in Table 3:

Table 3

Passing	Retained	Mass
⅜ inch (9.5 mm)	¼ inch (6.3 mm)	750g
¼ inch (6.3 mm)	No. 4 (4.75 mm)	750g

9. TEST PROCEDURE

9.1 Prepare a representative sample as described in Section 8.2, 8.3, or 8.4 tables. Determine the Mass “A” and record to the nearest 1.0g.

9.2 Immerse the sample in 2.0±0.05 liters of tap water at a temperature of 68±9˚F (20±5˚C) for a minimum of 1 hour either in the Micro-Deval container or some other suitable container. The aggregate shall not be allowed to soak overnight.

9.3 Place the sample in the Micro-Deval abrasion container with 5000±5g of steel balls and the water used in Section 9.2 to saturate the sample. Install the cover and place the Micro-Deval container in the machine.

9.4 Carefully pour the sample and steel balls over a No. 4 (4.75 mm) sieve superimposed on a No. 16 (1.18 mm) sieve. Take care to remove the entire sample from the stainless steel jar. Wash and manipulate the retained material on the sieve with water until the washings are clear and all material smaller than No. 16 (1.18 mm) passes that sieve. Hand manipulation may be necessary to remove all the finer material.

9.5 Standard method for removing steel balls from sample – Combine the material retained on the No. 4 (4.75 mm) and No. 16 (1.18 mm) sieves and steel balls, being careful not to lose any material. Oven-dry the test sample and steel balls to a constant mass at 230±9˚F (110±5˚C). Constant mass is defined as the sample mass at which there has not been more than a 0.5 gram mass loss during an additional 1 hour of drying. Remove the steel balls from the dry sample using a magnet or other suitable means.

9.6 Weigh the sample to the nearest 1.0g. Record the Mass “B.”

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10. CALCULATIONS

10.1 Calculate the Micro-Deval abrasion loss, as follows, to the nearest 0.1 percent.

Percent Loss = (A – B)/A x 100

Where:

A = mass, as determined in Section 9.1.
B = mass, as determined in Section 9.7.

11. USE OF THE CALIBRATION AGGREGATE

11.1 *Calibration Aggregate* – The laboratory will establish an adequate supply of material to use for calibration of the test method. A suitable material with a loss between 10 and 20 percent shall be established. From this material, 10 samples shall be taken randomly and tested.

11.1.1 Every 10 samples, but at least every week in which a sample is tested, a sample of the calibration aggregate shall be tested. The material shall be taken from a stock supply and prepared according to Section 8. When 20 samples of calibration material have been tested, and the results show satisfactory variation, the frequency of testing may be changed to a minimum of one sample every month.

11.1.2 Contact Central Bureau of Materials for calibration aggregate information.