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Standard Test Method for Evaluation of Durability of Rock for Erosion Control Under Freezing and Thawing Conditions[1]

This standard is issued under the fixed designation D5312/D5312M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method covers the procedures for evaluating the durability of rock for erosion control by evaluating the performance of slabs of rock when exposed to freezing and thawing conditions. This weathering test exposes the rock to freezing and thawing cycles similar to natural weather conditions. The rock slabs, prepared in accordance with procedures in Practice D5121, are intended to be representative of erosion control rock and its weaknesses. The test is appropriate for breakwater stone, armor stone, riprap, and gabion sized rock materials.

1.2 ~~This test method covers the procedures for evaluating the durability of rock for erosion control when exposed to freezing and thawing conditions on slabs of rock. This weathering test exposes the rock to freezing and thawing cycles similar to natural weather conditions. The rock slabs, prepared in accordance with procedures in Practice D5121, are intended to be representative of erosion control rock and its weaknesses. The test is appropriate for breakwater stone, armor stone, riprap, and gabion sized rock materials.~~
The limitations of the test are twofold. ~~First the size of the cut rock slab specimens may eliminate some of the internal defects present in the rock structure. The test specimens may not be representative of the quality of the larger rock samples used in construction. Careful examination of the rock source and proper sampling are essential in minimizing this limitation. Secondly the test requires the rock slabs to be exposed to up to 55 freezing-thawing cycles. The test is time intensive and may require up to two or more months to complete the sample preparation, testing, and analysis portions of the procedure.~~

1.2.1 First, the size of the cut rock slab specimens may eliminate some of the internal defects present in the rock structure. The test specimens may not be representative of the quality of the larger rock samples used in construction. Careful examination of the rock source and proper sampling are essential in minimizing this limitation.

1.2.2 Second, the test requires the rock slabs to be exposed to up to 55 freezing-thawing cycles. The test is time intensive and the entire procedure including sample preparation, testing, and analysis may require in excess of two months if automated freezing-thawing equipment is available and in excess of 5 months if the manual method is used. This limitation makes this test most useful as an initial source approval type test and may limit its practical usefulness as a more frequent quality control test during construction.

1.3 The use of reclaimed concrete and other such materials is beyond the scope of this test method.

1.4 *Units*—The values stated in either SI units or inch-pound units [presented in brackets] are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

[1] This test method is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.17 on Rock for Erosion Control.

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***A Summary of Changes section appears at the end of this standard**

1.4.1 The gravitational system of inch-pound units is used when dealing with inch-pound units. In this system, the pound (lbf) represents a unit of force (weight), while the unit for mass is slugs. The slug unit is not given unless dynamic (F=ma) calculations are involved.

1.4.2 It is common practice in the engineering/construction profession to concurrently use pounds to represent both a unit of mass (lbm) and of force (lbf). This practice implicitly combines two separate systems of units; the absolute and the gravitational systems. It is scientifically undesirable to combine the use of two separate sets of inch-pound units within a single standard. As stated, this standard includes the gravitational system of inch-pound units and does not use/present the slug unit of mass. However, the use of balances and scales recording pounds of mass (lbm) or recording density in lbm/ft 3 shall not be regarded as nonconformance with this standard.

1.5 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026, unless superseded by this ~~standard.~~test method.

1.5.1 For purposes of comparing measured or calculated value(s) with specified limits, the measured or calculated value(s) shall be rounded to the nearest decimal or significant digits in the specified limits.

1.5.2 The procedures used to specify how data are collected/recorded or calculated, in this standard are regarded as the industry standard. In addition, they are representative of the significant digits that generally should be retained. The procedures used do not consider material variation, purpose for obtaining the data, special purpose studies, or any considerations for the user's objectives; and it is common practice to increase or reduce significant digits of reported data to be commensurate with these considerations. It is beyond the scope of this standard to consider significant digits used in analytical methods for engineering design.

1.6 *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 standard to establish appropriate ~~safety~~ safety, health, and ~~health~~environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D2216 Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass

D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction

D4753 Guide for Evaluating, Selecting, and Specifying Balances and Standard Masses for Use in Soil, Rock, and Construction Materials Testing

D4992 Practice for Evaluation of Rock to be Used for Erosion Control

D5121 Practice for Preparation of Rock Slabs for Durability Testing

D6026 Practice for Using Significant Digits and Data Records in Geotechnical Data

E145 Specification for Gravity-Convection and Forced-Ventilation Ovens

3. Terminology

~~3.1 *Definitions*—See Terminology D653 for general definitions.~~

3.1 ~~*Definitions*~~*Definitions—*~~ of Terms~~See Terminology D653 ~~Specific to This~~ for general definitions.~~*Standard:*~~

3.1.1 ~~*rock saw,*~~*gabion-fill stone, n—*~~*a saw*~~*in rock,* ~~capable of cutting rock. The term "rock saw" shall include the blade which saws the rock, any components that control or power the sawing process or both, and framework on which the blade and any other associated components are mounted.~~stone generally less than 22 kg [50 lb] and placed in baskets of wire or other suitable material that is tied together to form an integral structure designed to resist erosion along stream banks and around bridge piers as well as

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

stabilize shorelines, stream banks or slopes as well as retaining walls, noise barriers, temporary flood walls, silt filtration from runoff, for small or temporary/permanent dams, or channel lining.

3.1.2 *slab, n—in rock,* a section of rock having two smooth, approximately parallel faces, produced by two saw cuts. The cuts spaced such that the thickness of the slab is generally less than the other dimensions of the rock. The slab will be the specimen of a rock which will subsequently undergo durability tests. The words "slab" and "specimen" are interchangeable throughout the test method.

3.1.2.1 *Discussion—*

The slab will be the rock specimen which will subsequently undergo durability tests. The words "slab" and "specimen" are interchangeable throughout the test method.

3.2.3 *armor stone, n*—stone generally 900 to 2,700 kg [one to three tons] resulting from blasting, cutting, or by other methods placed along shorelines or in jetties to protect the shoreline from erosion due to the action of large waves.

3.2.4 *breakwater stone, n*—stone generally 2,700 to 18,000 kg [three to twenty tons] resulting from blasting, cutting, or by other methods placed along shorelines or in jetties to protect the shoreline from erosion due to the action of large waves.

3.2.5 *riprap stone, n*—stone generally less than 1,800 kg [two tons] specially selected and graded, when properly placed prevents erosion through minor wave action, or strong currents and thereby preserves the shape of a surface, slope, or underlying structure.

3.2.6 *gabion-fill stone, n*—stone generally less than 22 kg [50 lb] and placed in baskets of wire or other suitable material. These baskets are then tied together to form an integral structure designed to resist erosion along stream banks and around bridge piers.

4. Summary of Test Method

4.1 Erosion control rock samples are trimmed into saw-cut slab specimens. Each slab is structurally examined macroscopically and under 20× magnification. The specimens are exposed to up to 55 freezing-thawing cycles. The trimmed slabs are initially After being immersed in an alcohol/water solution for a minimum of 12 h. The slabs are thenh, the specimens are exposed to up to 55 freezing-thawing cycles. Each cycle consists of the slab being frozen for a minimum of 12 h then thawed for 8 to 12 h. At the completion of the test, the percent loss by mass for each specimen set is determined. A visual examination of the slabs is performed throughout and at the end of testing. The type of deterioration and changes to previously noted planes of weakness are recorded.

5. Significance and Use

5.1 Rock for erosion control consists of individual pieces of natural stone. The ability of these individual pieces of stone to resist deterioration due to weathering action affects the stability of the integral placement of rock for erosion control and hence, the stability of construction projects, structures, shorelines, and stream banks.

5.2 This test method is designed to determine the effects of freezing and thawing action on the individual pieces of rock for erosion control and the resistance of the rock to deterioration. This test method was developed to be used in conjunction with additional test methods listed in Practice D4992. This test method does not provide an absolute value but rather an indication of the resistance to freezing and thawing; therefore, the results of this test method are not to be used as the sole basis for the determination of rock durability.

NOTE 1—The quality of the result produced by this standard is dependent upon the competence of the personnel performing it, and the suitability of the equipment and facilities used. Agencies that meet the criteria of Practice D3740 are generally considered capable of competent and objective testing/sampling/inspection/etc. Users of this standard are cautioned that compliance with Practice D3740 does not in itself assure reliable results. Reliable results depend on many factors; Practice D3740 provides a means of evaluation some of those factors.

6. Apparatus

6.1 *Rock Saw*—A laboratory diamond saw used to cut geological and concrete specimens, or a diamond saw used for lapidary purposes, shall be acceptable. A minimum blade diametercut capacity of 3618 cm [14[7 in.] will be needed to obtain the required slab sizes (a larger one is preferable). The blade shallsizes, and often a larger cut capacity will be required. In most cases, the blade will be a circular diamond blade.blade, but a band saw may also be configured to perform the cutting operations.

6.1.1 The rock saw apparatus shall have a fixed or removable vise to hold the samples during the cutting process. An automatic feed (either gravity, hydraulic, or screwfeed operated) that controls the cutting action is preferred; however, a manual feed is also acceptable. The saw shall have a platform to prevent the cut slab from falling and shattering.

6.2 *Freeze-Thaw Chamber or Home Freezer*—A timer-controlled freeze-thaw chamber specifically designed for timed cycling of 16 h of freezing at -18–18 ± 2.5 °C [0 ± 5 °F] followed by a minimum of 8 h of thawing at 32 ± 2.5 °C [90 ± 5 °F] on a daily basis is the most desirable option. This type of apparatus is commercially available and allows for the completion of one freeze-thaw cycle every day including weekends and holidays.

6.2.1 If a timer-controlled freeze-thaw chamber is not available, a standard chest-type home freezer capable of reaching and maintaining the required freezing temperature range in accordance with 6.2 may be used.

6.2.2 The limitations associated with this option are related to the fact that the freeze-thaw cycling must be accomplished manually. Typically only four cycles of freezing and thawing may be accomplished during a normal work week.

6.3 *Thawing Oven* (if option 6.2.1 is used)—Thermostatically controlled oven meeting the requirements of Specification used)—Vented, thermostatically-controlled oven E145 and capable of maintaining a constant temperature of 32 ± 2.5 °C [90 ± 5 °F]. °F] throughout the drying chamber. These requirements typically require the use of a forced-draft type oven. Preferably the oven should be vented outside the building.

6.4 *Drying Oven*—Thermostatically controlled oven meeting the requirements of Specification Vented, thermostatically-controlled oven E145 and capable of maintaining a uniform temperature of 110 ± 5 °C [230 ± 9 °F] throughout the drying chamber. These requirements typically require the use of a forced-draft type oven. Preferably the oven should be vented outside the building.

6.4.1 A single oven may be used in lieu of the thawing and drying ovens if it meets the requirements of both 6.3 and 6.4.

NOTE 2—A single oven may be used in lieu of the thawing and drying ovens if it meets the requirements of both 6.3 and 6.4.

6.5 *Containers*—Of sufficient size to hold the specimens partially immersed in an alcohol/water solution. It is advised that these containers be non-reactive, resistant to breakage and resistant to deformation and degradation when exposed to temperatures encountered in this test method.

6.6 *Absorptive Pads*—6-mm [¼ in.] thick felt pads, blotters, synthetic fiber carpeting or similar absorptive material for placing between specimens and the container bottom.

6.7 *Balance*—A balance capable of determining the mass of the specimen to the nearest 0.1 % of the total mass meeting the requirements of Specification D4753.

6.8 *Camera*—A digital or film camera capable of producing good quality, clear, color photographs for "before" and "after" photographs.documenting specimen conditions before and after testing.

6.9 *Stereomicroscope*—A microscope or other suitable magnifying device, capable of at least 20× magnification for examination of the specimen prior to and after testing. Ideally, a camera body could be mounted to the stereomicroscope, allowing the user to document the small-scale bedding or potential planes of weakness within the test specimen.

6.10 *Photographic Scale*—A scale of appropriate dimension and division when compared to the field of view and the detail being studied. When selecting a scale, always choose the scale that will provide at least as precise a measurement as the system that will be measuring the photographic information. If For exampe, if the system has a precision to one millimeter, make sure the scale used is accurate and precise to at least one millimeter across the entire scale.

7. Special Solutions

7.1 The special solution required for this test method consists of a 0.5 % isopropyl alcohol/water solution. This solution may be mixed and stored ahead of time. It will be used to replenish the solution as the test proceeds. Commercially available isopropyl alcohol as opposed to reagent grade is suitable.

NOTE 3—The 0.5 % isopropyl alcohol contained in the special solution is to lower the viscosity of water, allowing for more thorough penetration of the water into the test specimen's micro-pores prior to freezing.

8. ~~Sampling, Test Specimens, and Test Units~~Sampling and Sample Sets

8.1 ~~A~~ Sampling for a source of rock ~~to be sampled~~ shall be guided by the principles in Practice D4992.

8.2 Rock sources may be from mine, quarry, outcrop, or field boulders. Visual observation of color, texture, mineralogy, or some other feature, will be the key to proper representative sampling.

8.2.1 A rock source that is macroscopically uniform shall be represented by a minimum of five pieces of the material obtained from separate locations within the source area. This group is considered as a ~~specimen~~sample set.

8.2.2 A rock source that is macroscopically non-uniform shall be represented by a minimum of eight pieces of the material obtained from separate locations within the source area. This group is considered as a ~~specimen~~sample set.

8.2.3 Sample the rock types in their approximate proportion to the types that occur at the source.

8.3 Planes of weakness will be included in each sample such that a determination may be made as to ~~the durability of the various planes of weakness~~ their durability and their effect on the overall durability of a rock mass that would contain these planes of weakness.

8.4 Each rock ~~sample~~ piece within the sample set shall be of sufficient size to provide the finished size specimens described in Section 9.

8.5 In all cases, the rock pieces selected for the sample set shall be chosen to be representative of the majority of the rock at the source. Rock pieces, as determined by their macroscopic properties, which comprise less than 5 percent of the source material, may be ignored unless their presence in a sample will significantly affect the test results and subsequent proposed use of the rock.

8.6 Each rock piece will be of a size such that testing may proceed without further mechanical crushing; however, the chosen pieces shall be as large as the laboratory can handle but in no case shall the sample be less than 125 mm (5 in.) on a side.

9. Preparation of Test Specimens

9.1 Prepare a separate slab specimen for each orientation of the various planes of weakness unless all such planes can be intersected with one orientation.

9.2 Saw each ~~sample,~~ rock piece within the sample set, as obtained in accordance with 8.2.1 and 8.2.2, in accordance with Practice D5121. Cut each slab specimen to 65 ± 5 mm [2.5 ± 0.25 in.] thick and cut normal to bedding or any potential planes of weakness which may be observed in the samples. In no case will the size of the slab be less than 125 mm [5 in.] on a side, excluding the thickness.

NOTE 4—Test specimens may also be prepared by cutting a 65 ± 5 mm [2.5 ± 0.25 in.] thick slab from a 150-mm [6-in.] diameter diamond drill core such that any apparent zones of weakness are included.

NOTE 5—The best estimates of rock durability are those estimates that are based on the results of tests performed on the largest possible slabs of rock. The maximum slab size shall be limited only by the capacity of the laboratory and its equipment.

10. Procedure

10.1 Examine each slab both macroscopically and microscopically using a minimum of 20× magnification. Note the presence of bedding planes, microfractures, and other planes of weakness and their condition. Describe each slab in accordance with Practice D5121.

10.2 Label each test specimen with a suitable waterproof marker. Photograph each test specimen digitally or using color film and in such a way that the slab fills most of the photograph. Wet or partially wet test specimens usually show more detail than dry specimens. Include a scale in all photographs.

10.3 Dry each trimmed slab in an oven to a constant mass (±0.1 % of total mass) at 110 ± 5 °C [230 ± 9 °F] and record the ~~mass.~~ mass to the nearest 1 g [0.002 lb]. When determining constant mass, rock that contains gypsum, (calcium sulfate dihydrate), shall be dried at the ~~60~~60 ± 5 °C ~~[140~~[140 ± 9 °F] temperature as recommended in Test Method D2216.

10.4 Place each test specimen, sawed surface down, in a container on an absorptive pad. Add enough of the alcohol/water solution to the container such that the solution covers the test specimen and let stand for a minimum of 12 h.

10.5 Decant enough liquid such that the absorptive pad is just immersed.

10.6 Begin the freezing sequence by placing the container and test specimen in the freeze-thaw chamber or freezer and subject the specimen to a freezing temperature of -18 ± 2.5 °C [0 ± 5 °F] for a minimum of 12 h (there is no upper limit for storage time during freezing). Upon completing the minimum required time for freezing, subject the container and specimen to complete thawing at a temperature of 32 ± 2.5 °C [90 ± 5 °F] for 8 to 12 h. The required thawing sequence may be accomplished either in the freeze-thaw chamber or in ~~an~~ a thawing oven; however, the test specimen must be left in its container during the entire thawing process. Replenish the alcohol/water solution to maintain coverage of the absorptive pad.

10.7 The completion of ~~the~~a freezing and thawing sequences constitutes one freezing-thawing cycle.

10.8 Repeat the process of freezing and thawing for a total number of cycles equivalent to the index number rounded to the nearest five cycles of the geographic area of intended use as determined by Fig. 1.[3]

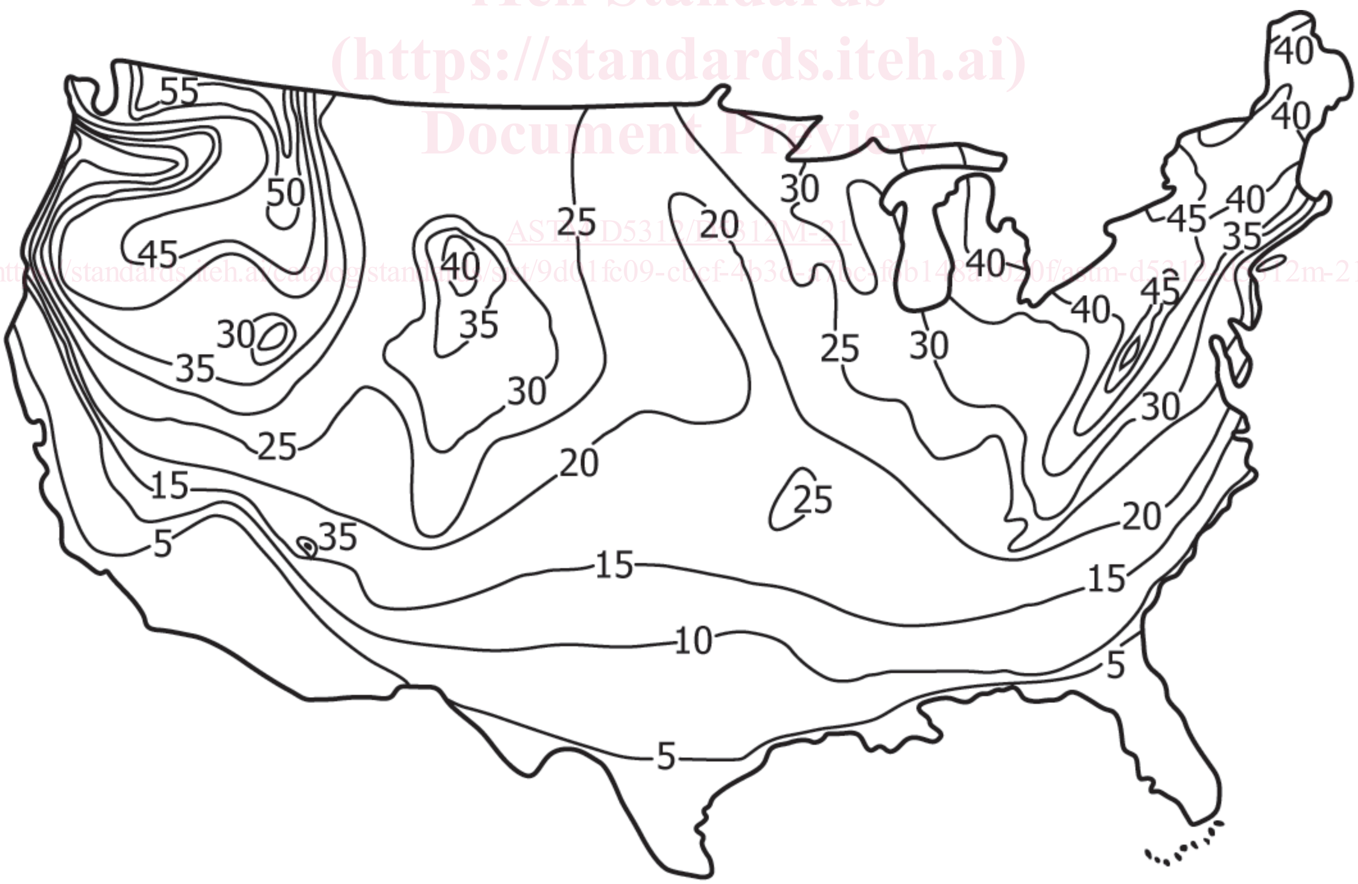

FIG. 1 Isoline Map of the Freeze-Thaw Severity Index for the Contiguous 48 United States

[3] Lienhart, D. A., "The Geographic Distribution of Intensity and Frequency of Freeze-Thaw Cycles," *Bulletin of the Association of Engineering Geologists*, Vol XXV, No. 4, 1988, pp. 465–471.

10.9 Preferably, the test shallshould be performed continuously until the specified number of cycles is obtained. However, if the test must be interrupted, leave the specimens in the freezer until the testing can be resumed.

10.10 Photograph and perform a qualitative examination on each slab as specified in Section 11.

10.11 Upon completion of the specified number of cycles, dry up to the four largest remaining piecepieces of each slab in an the drying oven to a constant mass and record the mass as of each piece in accordance with 10.3. Each piece should be greater than or equal to approximately 10% of the original mass of the slab. If fewer than four such pieces are available, dry as many pieces greater than or equal to approximately 10 % of the original slab mass as are available.

NOTE 6—Fig. 1 is an index map based on National Oceanic and Atmospheric Agency (NOAA) climatic data and was developed to determine the geographic distribution of the severity of freeze-thaw cycles. cycles for the contiguous United States. The figure not only takes into account the annual number of freeze-thaw cycles, but also the amount of moisture associated with each cycle and the temperature extremes of the freeze-thaw cycle. The index number, therefore, is not a prediction of the annual number of freeze-thaw cycles, but rather, is an indicator of the severity of the freeze-thaw process by geographic area. Since the freeze-thaw severity varies from one geographic location to another, it is not possible to provide a reliable indication of the serviceability of rock for erosion control for a given locality unless the test procedure is customized for that locality. The freeze-thaw severity index allows for this type of customization.

NOTE 7—Subcommittee D18.17 is currently unaware of similar information to that provided in Fig. 1 for other geographic areas and recognizes this as a limitation to the current standard. If the user is aware of additional information that could improve the standard in this regard, please bring it to the attention of the subcommittee.

NOTE 8—A more complete evaluation regarding the performance of the rock can be made by reporting the percentages represented by the four largest remaining pieces in addition to the percent loss represented by the single largest remaining piece. For example, while a given source of rock that is in close proximity to the project site might fail typical criteria due to the % loss based on the single largest remaining piece, a user might decide that it is in fact acceptable based on breakdown characteristics represented by the four largest pieces.

11. Calculation

11.1 *Quantitative Examination*—For each slab perform the following calculation:Calculate the percent loss based on the largest remaining piece to the nearest 0.1% for each specimen in the sample set according to:

$$\% \text{ loss} = (A - B)/A \times 100 \quad (1)$$

where:

A = oven-dried mass of the specimen prior to testing, and
B = oven-dried mass of the largest remaining piece of each slab after testing.

A = oven-dried mass of the specimen prior to testing, nearest 1 g [0.002 lb], and
B = oven-dried mass of the single largest remaining piece of each specimen after testing, nearest 1 g [0.002 lb].

11.2 Calculate the mean of the percent loss determined to the nearest 0.1 percent for each specimen.the sample set.

11.3 Calculate the percentage of the original slab represented by each of the up to four largest remaining pieces to the nearest 0.1 % for each specimen in the sample set according to:

$$\%X = X/A \times 100 \quad (2)$$

where:

X = mass of remaining piece B, C, D, or E, nearest 1 g [0.002 lb].

11.4 Calculate the mean of the percent loss determined residual (fragment) mass to the nearest 1 g [0.002 lb] and percent represented by fragments to the nearest 0.1 percent for the specimen set.0.1 % for each specimen in the sample set according to:

$$\text{Residual (Fragments)} = A - (B + C + D + E) \quad (3)$$

$$\%\text{Fragments} = \text{Residual (Fragments)}/A \times 100 \quad (4)$$