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Standard Guide for
Petrographic Examination of Aggregates for Concrete[1]

This standard is issued under the fixed designation C295/C295M; 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.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This guide outlines procedures for the petrographic examination of samples representative of materials proposed for use as aggregates in cementitious mixtures or as raw materials for use in production of such aggregates. This guide is based on Ref (**1**).[2]

1.2 This guide outlines the extent to which petrographic techniques should be used, the selection of properties that should be looked for, and the manner in which such techniques may be employed in the examination of samples of aggregates for concrete.

1.3 The rock and mineral names given in Descriptive Nomenclature C294 should be used, insofar as they are appropriate, in reports prepared in accordance with this guide.

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

1.5 *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 standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C33 Specification for Concrete Aggregates
C117 Test Method for Materials Finer than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing
C136 Test Method for Sieve Analysis of Fine and Coarse Aggregates
C294 Descriptive Nomenclature for Constituents of Concrete Aggregates
C702 Practice for Reducing Samples of Aggregate to Testing Size
D75 Practice for Sampling Aggregates
E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves
E883 Guide for Reflected–Light Photomicrography

3. Qualifications of Petrographers

3.1 All petrographic examinations of aggregate for use in concrete as described in this guide should be performed by a petrographer with at least 5 years experience in petrographic examination of concrete or concrete-making materials. The petrographer should have completed college-level course work pertaining to basic geology, mineralogy, petrography, and optical mineralogy or have obtained equivalent knowledge through experience and on-the-job training. Completion of course work in concrete materials is also advantageous. The petrographer should have experience evaluating the effects of aggregates on the physical and chemical properties of hardened concrete. Identification of individual minerals in aggregate particles, classification of rock types, and categorizing the physical and chemical properties of rocks and minerals should also be included in the petrographer's experience. The petrographer should have expertise to properly use the equipment and apparatus described in Section 6 and provide detailed interpretations of the petrographic examination. If the petrographer does not meet these qualifications, the individual may perform such examinations under the technical direction of a full-time supervising petrographer who meets these qualifications. A resume of the professional experience and education of the petrographer shall be available.

3.1.1 Licensing, certification, or other accreditation by a governmental agency or other organization stating the individual is a professional geologist should not, by itself, constitute sufficient qualification for examination of aggregates for concrete.

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[1] This guide is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.65 on Petrography.

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[2] The boldface numbers in parentheses refer to the list of references at the end of this standard.

[3] 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.

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

4. Summary of Method

4.1 The specific procedures employed in the petrographic examination of any sample will depend to a large extent on the purpose of the examination and the nature of the sample. In most cases the examination will require the use of optical microscopy. Complete petrographic examinations for particular purposes and to investigate particular problems may require examination of aggregates or of selected constituents by means of additional procedures, such as X-ray diffraction (XRD) analysis, differential thermal analysis (DTA), infrared spectroscopy, or other scanning electron microscopy (SEM) energy-dispersive x-ray analysis (EDX). In some instances, such procedures are more rapid and more definitive than are microscopical methods.

4.2 Identification of the constituents of a sample is usually a necessary step towards recognition of the properties that may be expected to influence the behavior of the material in its intended use, but identification is not an end in itself. The value of any petrographic examination will depend to a large extent on the representativeness of the samples examined, the completeness and accuracy of the information provided to the petrographer concerning the source and proposed use of the material, and the petrographer's ability to correlate these data with the findings of the examination.

4.3 This guide does not attempt to describe the techniques of petrographic work since it is assumed that the guide will be used by persons who are qualified by education and experience to employ such techniques for the recognition of the characteristic properties of rocks and minerals and to describe and classify the constituents of an aggregate sample. In some cases, the petrographer will have had experience adequate to provide detailed interpretation of the results. In others, the interpretation will be made in part by engineers or others qualified to relate the observations to the questions to be answered.

5. Significance and Use

5.1 Petrographic examinations are made for the following purposes:

5.1.1 To determine the physical and chemical characteristics of the material that may be observed by petrographic methods and that have a bearing on the performance of the material in its intended use.

5.1.2 To describe and classify the constituents of the sample,

5.1.3 To determine the relative amounts of the constituents of the sample that are essential for proper evaluation of the sample when the constituents differ significantly in properties that have a bearing on the performance of the material in its intended use, and

5.1.4 To compare samples of aggregate from new sources with samples of aggregate from one or more sources, for which test data or performance records are available.

5.2 This guide may be used by a petrographer employed directly by those for whom the examination is made. The employer should tell the petrographer, in as much detail as necessary, the purposes and objectives of the examination, the kind of information needed, and the extent of examination desired. Pertinent background information, including results of prior testing, should be made available. The petrographer's advice and judgment should be sought regarding the extent of the examination.

5.3 This guide may form the basis for establishing arrangements between a purchaser of consulting petrographic service and the petrographer. In such a case, the purchaser and the consultant should together determine the kind, extent, and objectives of the examination and analyses to be made, and should record their agreement in writing. The agreement may stipulate specific determinations to be made, observations to be reported, funds to be obligated, or a combination of these or other conditions.

5.4 Petrographic examination of aggregate considered for use in hydraulic-cement concrete is one aspect of the evaluation of aggregate, but petrographic examination is also used for many other purposes. Petrographic examinations provide identification of types and varieties of rocks present in potential aggregates. However, as noted above, identification of every rock and mineral present in an aggregate source is not required.

5.5 The petrographic examination should establish whether the aggregate contains chemically unstable minerals such as soluble sulfates, unstable sulfides that may form sulfuric acid or create distress in concrete exposed to high temperatures during service, or volumetrically unstable materials such as smectites (formerly known as the montmorillonite-saponite group of minerals or swelling clays). Specifications may limit the quartz content of aggregates for use in concrete that may be subject to high temperature (purposefully or accidentally) because of the conversion to beta-quartz at 573 °C [1063 °F], with accompanying volume increase.

5.6 Petrographic examination should identify the portion of each coarse aggregate that is composed of weathered or otherwise altered particles and the extent of that weathering or alteration, whether it is severe, moderate, or slight, and should determine the proportion of each rock type in each condition. If the concrete in which the aggregate may be used will be exposed to freezing and thawing in a critically saturated condition, finely porous and highly weathered or otherwise altered rocks should be identified because they will be especially susceptible to damage by freezing and thawing and will cause the aggregate portion of the concrete to fail in freezing and thawing. This will ultimately destroy the concrete because such aggregates cannot be protected by adequately air-entrained mortar. Finely porous aggregates near the concrete surface are also likely to form popouts, which are blemishes on pavements and walls.

5.7 Petrographic examinations may also be used to determine the proportions of cubic, spherical, ellipsoidal, pyramidal, tabular, flat, and elongated particles in an aggregate sample or samples. Flat, elongated, and thin chip-like particles in aggregate increase the mixing water requirement and hence decrease concrete strength.

5.8 Petrographic examination should identify and call attention to potentially alkali-silica reactive and alkali-carbonate reactive constituents, determine such constituents quantitatively, and recommend additional tests to confirm or refute the presence in significant amounts of aggregate constituents capable of alkali reaction in concrete. See Specification C33. Alkali-silica reactive constituents found in aggregates include: opal, chalcedony, cristobalite, tridymite, highly strained quartz, microcrystalline quartz, volcanic glass, and synthetic siliceous glass. Aggregate materials containing these constituents include: glassy to cryptocrystalline intermediate to acidic volcanic rocks, some argillites, phyllites, graywacke, gneiss, schist, gneissic granite, vein quartz, quartzite, sandstone, and chert. Criteria are available for identifying the minerals in the list above by their optical properties or by XRD (**2**),(**3**). Criteria are available for identifying rocks by their mineral composition and texture (**4**). Examination in both reflected and transmitted light may be necessary to provide data for these identifications. X-ray microanalysis using energy-dispersive x-ray spectrometers with scanning electron microscopy (SEM/EDX) or wavelength-dispersive x-ray spectrometers in electron microprobes (EMPA/WDX) may provide useful information on the chemical composition of minerals and rocks. Potentially deleterious alkali-carbonate reactive rocks are usually calcareous dolomites or dolomitic limestones with clayey insoluble residues. Some dolomites essentially free of clay and some very fine-grained limestones free of clay and with minor insoluble residue, mostly quartz, are also capable of some alkali-carbonate reactions, however, such reactions are not necessarily deleterious.

5.9 Petrographic examination may be directed specifically at the possible presence of contaminants in aggregates, such as synthetic glass, cinders, clinker, or coal ash, magnesium oxide, calcium oxide, or both, gypsum, soil, hydrocarbons, chemicals that may affect the setting behavior of concrete or the properties of the aggregate, animal excrement, plants or rotten vegetation, and any other contaminant that may prove undesirable in concrete.

5.10 These objectives, for which this guide was prepared, will have been attained if those involved with the evaluation of aggregate materials for use in concrete construction have reasonable assurance that the petrographic examination results wherever and whenever obtained may confidently be compared.

6. Apparatus and Supplies

6.1 The apparatus and supplies listed as follows comprise a selection that will permit the use of the procedures described in this guide. All specific items listed have been used, in connection with the performance of petrographic examinations, by the procedures described herein; it is not, however, intended to imply that other items cannot be substituted to serve similar functions. Whenever possible the selection of particular apparatus and supplies should be left to the judgment of the petrographer who is to perform the work so that the items obtained will be those with the use of which the petrographer has the greatest experience and familiarity. The minimum equipment regarded as essential to the making of petrographic examinations of aggregate samples are those items, or equivalent apparatus or supplies that will serve the same purpose, that are indicated by asterisks in the lists given as follows.

6.1.1 *Apparatus and Supplies for Preparation of Specimens:*

6.1.1.1 *Rock-Cutting Saw,* * preferably with 350-mm [14-in.] diameter or larger diamond blade, and automatic feed.

6.1.1.2 *Horizontal Grinding Wheel,* * preferably 400-mm [16-in.] diameter.

6.1.1.3 *Polishing Wheel,* preferably 200- to 300-mm [8 to 12-in.] diameter.

6.1.1.4 *Abrasives*,* Silicon carbide grit No. 100 [122 µm], 220 [63 µm], 320 [31 µm], 600 [16 µm], and 800 [12 µm]; alumina M-305 [5 µm].[4]

6.1.1.5 *Geologist's Pick or Hammer.*

6.1.1.6 *Microscope Slides*,* clear, noncorrosive, 25 by 45 mm [1 by 2 in.] in size.

6.1.1.7 *Mounting Medium for Powder Mounts**—Canada balsam, neutral, in xylene; suitable low-viscosity epoxy resins; or Lakeside 70.

6.1.1.8 *Xylene*.*

6.1.1.9 *Mounting Medium*,* suitable for mounting rock slices for thin sections.

6.1.1.10 *Laboratory Oven*.*

6.1.1.11 *Plate-Glass Squares*,* about 300 mm [12 in.] on an edge for thin-section grinding.

6.1.1.12 *Sample Splitter* with pans.*

6.1.1.13 *Micro Cover Glasses,* * noncorrosive, square, 12 to 18 mm, 25 mm, [0.5 to 0.75 in., 1.0 in.] etc.

6.1.1.14 *Plattner Mortar.*

6.1.2 *Apparatus and Supplies for Examination of Specimens:*

6.1.2.1 *Petrographic Microscope*,* with mechanical stage; oculars and objective lenses that will allow magnifications of up to 600 x, and objective-centering devices; full- and quarter-wave compensators; quartz wedge; micrometer eyepiece; Bertrand lens.

6.1.2.2 *Microscope Lamps**

6.1.2.3 *Stereoscopic Microscope*,* with objectives and oculars to give final magnifications from about 6× to about 150×.

6.1.2.4 *Magnet*,* preferably Alnico, or an electromagnet.

6.1.2.5 *Needleholder and Points*.*

6.1.2.6 *Dropping Bottle,* 60-mL [2 oz.] capacity.

6.1.2.7 *Petri Culture Dishes.*

6.1.2.8 *Forceps,* smooth, straightpointed.

6.1.2.9 *Lens Paper.**

6.1.2.10 *Immersion Media*,* n = 1.410 to n = 1.785 in steps of no more than 0.005.

6.1.2.11 *Counter.*

6.1.2.12 *Photomicrographic Camera* and accessories.

6.2 The items under Apparatus and Supplies include those used to make thin sections. Semiautomatic thin section machines are available, and there are several thin-section makers who advertise in *Geotimes*, the *American Mineralogist*, and other mineralogical or geological journals. Laboratories may find it reasonable to buy a thin-section machine or use a commercial thin-section maker. Remotely located laboratories have more need to be able to make their own thin sections.

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[4] The values given in micrometres are the approximate average grain size of commercial silicon carbide grit in the designated size classification.

6.3 It is necessary that facilities be available to the petrographer to check the index of refraction of the immersion media. If accurate identification of materials is to be attempted, as for example the differentiation of quartz and chalcedony, or the differentiation of basic from intermediate volcanic glass, the indices of refraction of the media need to be known with accuracy. Media will not be stable for very long periods of time and are subject to considerable variation due to temperature change. In laboratories not provided with close temperature control, it is often necessary to recalibrate immersion media several times during the course of a single day when accurate identifications are required. The equipment needed for checking immersion media consists of an Abbé refractometer. The refractometer should be equipped with compensating prisms to read indices for sodium light from white light, or it should be used with a sodium arc lamp.

6.4 A laboratory that undertakes any considerable amount of petrographic work should be provided with facilities to make photomicrographic records of such features as cannot adequately be described in words. For illustrations of typical apparatus, reference may be made to Ref (**1**) and manufacturers of microscopes equipped with cameras and photomacrographic equipment may be consulted. Much useful guidance regarding photomicrography, especially using reflected light, is found in Guide E883.

7. Sampling

7.1 Samples for petrographic examination should be taken by or under the direct supervision of a geologist familiar with the requirements for random sampling of aggregates for concrete and in general following the requirements of Practice D75. Information on the exact location from which the sample was taken, the geology of the site, and other pertinent data should be submitted with the sample. The amount of material actually studied in the petrographic examination will be determined by the nature of the examination to be made and the nature of the material to be examined, as discussed below.

7.1.1 *Undeveloped quarries* should be sampled by means of cores drilled through the entire depth expected to be exploited. Drilling of such cores should be in a direction that is essentially perpendicular to the dominant structural feature of the rock. Massive material may be sampled by “NX” (50-mm [2-in.] diameter) cores. Thinly bedded or complex material should be represented by cores not less than 100 mm [4 in.] in diameter. There should be an adequate number of cores to cover the limits of the deposit proposed for the project. The entire footage of the recovered core should be included in the sample and accurate data given as to elevations, depths, and core losses.

7.1.2 *Operating quarries and operating sand and gravel deposits,* in which stock piles of the material produced are available, should be represented by not less than 45 kg [100 lb] or 300 pieces, whichever is larger, of each size of material to be examined. Samples from stock piles should be composed of representative portions of larger samples collected with due consideration given to segregation in the piles.

7.1.3 *Exposed faces of nonproducing quarries,* where stock piles of processed material are not available, should be represented by not less than 2 kg [4 lb] from each distinctive stratum or bed, with no piece having a mass less than 0.5 kg [1 lb], or by a drilled core as described above.

7.1.4 *Undeveloped sand and gravel deposits* should be sampled by means of test pits dug to the anticipated depth of future economic production. Samples should consist of not less than the quantities of material indicated in Table 1, selected so as to be representative of the deposits.

NATURAL GRAVEL AND SAND

8. Procedure

8.1 *Selection of Samples for Examination*—Samples of gravel and natural sand for petrographic examination should be dry sieved in accordance with Method C136 to provide samples of each sieve size. In the case of sands an additional portion should then be tested in accordance with Test Method C117, with the wash water being saved and removed by drying in order to provide a sample of the material passing the 75-μm (No. 200) sieve (See Specification E11).[5] The results of the sieve analysis of each sample made in accordance with Method C136 should be provided to the petrographer making the examination and used in calculating results of the petrographic examination. Each sieve fraction should be examined separately, starting with the largest size available. Rocks are more easily recognized in larger pieces; the breakdown of a heterogeneous type present in the larger sizes may have provided particles of several apparently different types in the smaller sizes. Some important and easily confused types may be recognizable using the stereoscopic microscope if they are first recognized and separated in the larger sizes, but may require examination using the petrographic microscope if they are first encountered in the smaller sizes.

8.2 The number of particles of each sieve fraction to be examined will be fixed by the required precision of determination of the less abundant constituents. Assuming that the field sampling and laboratory sampling procedures are accurate and reliable, the number of particles examined, identified, and counted in each sieve fraction will depend on the required accuracy of the estimate of constituents present in small

TABLE 1 Minimum Sizes for Samples from Undeveloped Sand and Gravel Deposits

Sieve Size	Quantity		
	kg	[lb]	Pieces
Larger than 150-mm (6-in.)[A]	...	...	[B]
75 to 150-mm (3 to 6-in.)[A]	...	...	300[B]
37.5 to 75-mm (1½ to 3-in.)[A]	180	[400]	...
19.0 to 37.5-mm (¾ to 1½-in.)[A]	90	[200]	...
4.75 to 19.0-mm (No. 4 to ¾-in.)[A]	45	[100]	...
Finer than 4.75-mm (No. 4)[A,C]	23	[50]	...

[A] Sieve size is identified by its standard designation in Specification E11. The alternative designation given in parentheses is for information only and does not represent a different standard sieve size.

[B] Not less than one piece from each apparent type of rock.

[C] Fine aggregate.

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[5] Sieve size is identified by its standard designation in Specification E11. The alternative designation given in parentheses is for information only and does not represent a different standard sieve size.

quantities. The numbers given in this method are minimal. They are based on experience and on statistical considerations (**5**, **6**). It is believed that at least 150 particles of each sieve fraction should be identified and counted in order to obtain reliable results. Precise determinations of small quantities of an important constituent will require counts of larger numbers of particles. If the sample of a sieve fraction contains many more particles than need to be identified, the sample shall be reduced in accordance with one of the procedures in Practice C702, so as to contain a proper number of particles for examination.

9. Procedure for Examination of Natural Gravel

9.1 *Coatings*—The particles should be examined to establish whether exterior coatings are present. If coatings are present, it should be determined whether the coatings consist of materials likely to be deleterious in concrete (opal, gypsum, easily soluble salts, organic matter). It should also be determined qualitatively how firmly the coatings are bonded to the particles.

9.2 *Rock Types*—The sieve fraction should be sorted into rock types by visual examination. If all or most of the groups present are types easily identifiable in hand specimen by examination of a natural or broken surface, and by scratch and acid tests, no further identification may be needed. Fine-grained rocks that cannot be identified macroscopically or that may consist of or contain constituents known to be deleterious in concrete should be checked by examination with the stereoscopic microscope. If they cannot be identified by that means, they should be examined by means of the petrographic microscope. The amount of work done in identifying fine-grained rocks should be adapted to the information needed about the particular sample. Careful examination of one size of a sample, or study of information from previous examination of samples from the same source, will usually reveal the amount of additional detailed microscopical work required to obtain information adequate for the purpose. In some instances, petrographic methods other than microscopy, such as X-ray diffraction, may be required or might most rapidly serve to identify fine-grained rock materials.

9.3 *Condition*—The separated groups belonging to each rock type should be examined to determine whether a further separation by physical condition is necessary. If all of the particles of a rock type are in a similar condition, that fact should be noted. More frequently, particles in several degrees of weathering will be found in a group. They should be sorted into categories based on condition and on the expectation of comparable behavior in concrete. The types of categories intended are: (*1*) fresh, dense; (*2*) moderately weathered; (*3*) very weathered; or (*1*) dense; (*2*) porous (or porous and friable). It usually is not practicable to recognize more than three conditions per rock type, and one or two may be sufficient. An important constituent present in larger quantities may sometimes require separation into four groups by condition. The conspicuous example is chert when it is the major constituent of a gravel sample. It may be present as dense, unfractured chert; as vuggy chert; as porous chert; and as dense but highly fractured chert. The determination of which of these four conditions characterizes a particle may be expected to have an important influence on prediction of the behavior of the particle in concrete.

9.4 *Record:*

9.4.1 Notes should be taken during the examination. Each rock type should be described; the relevant features may include the following:

9.4.1.1 Particle shape,

9.4.1.2 Particle surface texture,

9.4.1.3 Grain size,

9.4.1.4 Internal structure, including observations of pore space, packing of grains, cementation of grains,

9.4.1.5 Color,

9.4.1.6 Mineral composition,

9.4.1.7 Significant heterogeneities,

9.4.1.8 General physical condition of the rock type in the sample,

9.4.1.9 Coatings or incrustations, and

9.4.1.10 Presence of constituents known to cause deleterious chemical reaction in concrete.

9.4.2 Particle counts should be recorded so that tables can be made for inclusion in the report. When the examination has been completed, the notes should contain enough information to permit the preparation of tables and descriptions. Tables should be prepared showing the composition and condition of the samples by sieve fractions, and the weighted average composition, based on the grading of the sample as received and on the distribution of constituents by sieve fractions. Descriptions of constituent groups should be prepared containing the relevant features among those enumerated in the preceding list.

10. Procedure for Examination of Natural Sand

10.1 The procedure for the examination of natural sand is similar to that for the examination of gravel, with the modifications necessitated by the differences in particle size.

10.1.1 *Sizes Coarser than 600 µm* (*No. 30*)—Each sieve fraction present that is coarser than the 600-µm (No. 30) sieve should be reduced in accordance with one of the procedures in Practice C702 until a split or splits containing at least 150 particles are obtained. The reduced sample of each sieve fraction should be examined, and its constituents identified and counted, using the stereoscopic microscope. It is convenient to spread out the sample in a flat-bottom glass dish such as a Petri dish and manipulate the grains with a forceps and dissecting needle. The identification of grains in the coarser sand sizes is often easier when the grains are just submerged in water. The submergence lessens reflection from the outer surfaces and may show diagnostic features that cannot be seen when the grains are dry. There are exceptions to this generalization. Where identification is difficult, the examination includes examination of the natural surface (dry and wet), examination of a broken surface (dry and wet), and scratch and acid tests. Only after all of these steps have been taken and the grain is still unidentified should the petrographer resort to the petrographic microscope. Grains that cannot be identified using the stereoscopic microscope, or that are suspected of consisting of or containing substances known to react deleteriously in concrete, should be set aside to be examined with the petrographic microscope. If the question of reaction with alkalies is important in the examination of the sample, certain additions to the procedure are indicated. If the coarser sand sizes contain fine-grained, possibly glassy igneous rocks, several typical particles of each variety of such rocks should be selected for a more thorough examination. The petrographer should determine the presence or absence of glass by crushing typical grains and examining them in immersion media, using the petrographic microscope. In difficult or especially important cases, it may be necessary to break suspected grains and to make immersion mounts of part of the grain and a thin section of another part. Where the sand contains chert and the potential reactivity of the chert is an important consideration, a number of chert particles from the fractions retained on the 600-µm (No. 30) sieve should be set aside for determinations of the index of refraction. Methylene blue staining techniques may be useful in identifying the presence of smectite (**7**).

10.1.2 *Sizes Finer than 600 µm* (*No. 30*)—The sieve fractions finer than the 600-µm (No. 30) sieve should each be reduced in a sample splitter or by quartering (Note 1). These splits should be further reduced on a miniature sample splitter or by coning and quartering with a spatula on a clean sheet of paper. The examination may be conducted as described previously for the coarser sizes. As required, the petrographic microscope should be used. For this purpose, a representative portion of each reduced split should be mounted in immersion oil on a clean glass slide and covered with a clean cover glass. No entirely satisfactory method of reducing a split to a predetermined number of grains is known. The reduced split can be sampled by spreading it in a thin layer on glass or clean paper, dragging the end of a dissecting needle moistened in immersion oil through the sample and transferring the grains that adhere to the needle to a drop of immersion oil on a clean slide. If this is done carefully, a fairly representative sample will be obtained. If the dissecting needle is made of magnetized steel, a concentration of magnetic minerals may result. It is usually necessary to make several mounts of the 300-µm (No. 50) and 150-µm (No. 100) sieve fractions to obtain at least 150 grains of each. The refractive index of the immersion oil should be selected to make the identification of the important constituents as easy and as definite as possible. The use of an immersion oil with an index of or just below the lower index of quartz (1.544) is recommended. The slide should be mounted on a petrographic microscope equipped with a mechanical stage. Several traverses should be made, and each grain that passes under the intersection of the cross hairs should be identified and counted. Care should be taken to move the slide on the north-south adjustment between traverses so that no grain will be counted twice. Each sieve fraction passing the 600-µm (No. 30) and retained on the 75-µm (No. 200) sieve should be examined. Ordinarily, the material passing the 75-µm (No. 200) sieve is mounted on a slide following the procedure described above, examined by means of the petrographic microscope, and its composition estimated. If an unusually large amount of this size is present, or if it contains constituents that may be expected to have an important effect on the suitability of the aggregate for the intended use, it should be counted. In this event, it is suggested that the fraction passing the 75-µm (No. 200) sieve be washed over the 45-µm (No. 325) sieve before being counted.

NOTE 1—About 4 or 5 g is usually sufficient and the volume will usually be less than a level teaspoonful. In some gradings the fractions retained on the 150-µm (No. 100) and 75-µm (No. 200) sieves may be present in such small amounts that reduction is unnecessary.

10.1.3 Grain thin sections using an epoxy as mounting medium also may be useful in classifying particles passing the 300-µm (No. 50) sieve.

DRILLED CORE, LEDGE ROCK, CRUSHED STONE, AND MANUFACTURED SAND

11. Procedure for Examination of Drilled Core

11.1 Each core should be examined and a log prepared showing length of core recovered, core loss and location; location and spacing of fractures and parting planes; lithologic type or types; alternation of types; physical condition and variations in condition; toughness, hardness (**8**), coherence; obvious porosity; grain size, texture, variations in grain size and texture; type or types of breakage; and presence of constituents capable of deleterious reaction in concrete. If the size of the core permits, the probability that the rock will make aggregate of the required maximum size should be considered. If the surface of the core being examined is wetted, it is usually easier to recognize significant features and changes in lithology. Most of the information usually required can be obtained by careful visual examination, scratch and acid tests, and hitting the core with a hammer. In the case of fine-grained rocks, it may be necessary to examine parts of the core, using the stereoscopic microscope, or to prepare thin sections of selected portions. Some considerations and procedures are more applicable to particular rock types than to others. Ordinarily, the layered rocks considered for concrete aggregate will be limestone, and occasionally metamorphic rocks, such as phyllite, gneiss, or schist. One of the most important questions arising in the examination of limestone is that of the presence, type, and distribution of argillaceous impurities. Limestones that contain intercalated thin beds of soft shale may make suitable sources of aggregate if the shale is so distributed that it does not prevent manufacture of the required maximum size, and if the shale can be eliminated or reduced in processing. Where argillaceous impurities are present, it should be determined whether they actually consist of clay minerals or of other minerals in clay sizes. If they do consist of clay minerals, it should be established whether the clay minerals include smectites (**9**). X-ray diffraction analysis is especially valuable in identification and quantitative determination of clay minerals. Methylene blue staining techniques (**7**) are useful in identifying smectite. In the examination of fine-grained igneous rocks, particular attention should be directed to the nature of the groundmass. This examination should include determination of the presence or absence of opal, chalcedony, natural glass, and swelling clays; if any of these are found the amount should be estimated; if natural glass is found the type should be determined.

12. Procedure for Examination of Ledge Rock

12.1 The procedure used in examination should be the same as for core samples to the extent that the spacing of samples and size of the individual pieces allow. If the sample consists of a relatively large quantity of broken stone produced by blasting, it is desirable to inspect the whole sample, estimate the relative abundance of rock types or varieties present, and sample each type before further processing. Subsequent procedure should be the same as given below for crushed stone.

13. Procedure for Examination of Crushed Stone

13.1 The procedure for examination of crushed stone should be similar to that for core, except that necessary quantitative data should be obtained by particle counts of the separated sieve fractions obtained as described in the section on Natural Gravel and Sand.

14. Procedure for Examination of Manufactured Sand

14.1 The examination procedure should be similar to that for natural sand, with particular emphasis on the amount and extent of fracturing and the amount and nature of rock dust developed by the milling operations. If a sample of the rock from which the sand was produced is available, examination of it will provide useful information.

CALCULATION AND REPORT

15. Calculation

15.1 Calculate the composition of each sieve fraction of a heterogeneous sample and the weighted average composition of the whole sample as follows:

15.1.1 Express the composition of each sieve fraction by summing the total number of particles of that fraction counted, and calculating each constituent in each condition as a percentage of the total amount (as number of particles in percent, in each sieve fraction). It is convenient to calculate and record the percentages to tenths at this stage. An example of these calculations is given in the upper half of Table 2.

15.1.2 Obtain the percentage by mass of the sieve fraction in the whole sample (individual percentages retained on consecutive sieves) from the grading of the sample as determined by Method C136.

15.1.3 By multiplying the percentage of the constituent in the sieve fraction, determined as described above by the percentage of the sieve fraction in the whole sample, obtained

TABLE 2 Calculation of Results of Particle Counts[A]

Individual Percentage Retained on Sieve	Composition of Fractions Retained on Sieves Shown Below							
	19.0-mm (¾-in.)[B]		12.5-mm (½-in.)[B]		9.5-mm (⅜-in.)[B]		4.75-mm (No. 4)[B]	
	17.4		32.6		29.5		20.5	
Constituents[C]	Number of Particles	%	Number of Particles	%	Number of Particles	%	Number of Particles	%
A_1	250	50.0	200	40.0	150	30.0	50	10.0
A_2	50	10.0	100	20.0	125	25.0	100	20.0
A_3	10	2.0	50	10.0	75	15.0	100	20.0
B_1	107	21.4	70	14.0	62	12.4	32	6.4
B_2	76	15.2	53	10.6	19	3.8	87	17.4
B_3	...	...	20	4.0	43	8.6	96	19.2
C_1	5	1.0	5	1.0	20	4.0	20	4.0
C_2	2	0.4	2	0.4	6	1.2	10	2.0
C_3	...	...	...	...	...	...	5	1.0
Totals	500[D]	100	500[D]	100	500[D]	100	500[D]	100

	Weighted Percentages of Constituents in Each Sieve Fraction				Weighted Composition of Sample
	19.0-mm (¾-in.)[B]	12.5-mm (½-in.)[B]	9.5-mm (⅜-in.)[B]	4.75-mm (No. 4)[B]	
A_1	8.7	13.0	8.9	2.1	32.7 64.6 (Total A)
A_2	1.7	6.5	7.4	4.1	19.7
A_3	0.4	3.3	4.4	4.1	12.2
B_1	3.7	4.6	3.7	1.3	13.3 31.8 (Total B)
B_2	2.6	3.5	1.1	3.6	10.8
B_3	...	1.3	2.5	3.9	7.7
C_1	0.2	0.3	1.2	0.8	2.5 3.6 (Total C)
C_2	0.1	0.1	0.3	0.4	0.9
C_3	...	...	...	0.2	0.2
Total in sieve fraction	17.4	32.6	29.5	20.5	
Total in sample, condition 1					48.5
Total in sample, condition 2					31.4
Total in sample, condition 3					20.1

[A] This table indicates a convenient method of setting up a work sheet for recording results and calculations. The results developed here are entered in the form indicated by Table number 3. Table number 3 is included in the petrographic report. Table number 2 is not.

[B] Sieve size is identified by its standard designation in Specification E11. The alternative designation given in parentheses is for information only and does not represent a different standard sieve size.

[C] Letters (A, B, C) refer to the various constituents found, subscript numbers (1, 2, 3) refer to the various conditions in which each constituent has been found, such as relative degree of weathering.

[D] The recommendation concerning the number of particles to be counted has been met; the selection of 500 particles per fraction for the example is to illustrate the calculation; it is not intended to suggest that a predetermined number of particles per fraction should be selected.

as described above, calculate the percentage in the whole sample of that constituent in that size (weighted percentage of constituents in sieve fraction, Table 2). It is convenient to calculate and record these percentages to tenths.

15.1.4 By adding the weighted percentages of each constituent in each sieve fraction, obtain the weighted percentage of each constituent in the whole sample (see under weighted composition of sample in Table 2).

15.1.5 Construct a table to show the composition of each sieve fraction and the weighted composition of the whole sample. Report values to the nearest whole number. Report constituents amounting to 0.5 % or less of a sieve fraction or of the whole sample as traces. Table 3 is an example constructed from the data obtained in Table 2. As a convention, the total in each sieve fraction and the total in the whole sample shall each be 100 % without the traces. Difficulties in abiding by this convention can usually be avoided by grouping minor constituents of little engineering importance. It is preferable to tabulate constituents known to react deleteriously in concrete so that their distribution will be apparent from inspection of the table, even though the amount in the whole sample or in any fraction is very small.

16. Report

16.1 The report of the petrographic examination should summarize the essential data needed to identify the sample as to source and proposed use, and include a description giving the essential data on composition and properties of the material as revealed by the examination. The report should record the test procedures employed, and give a description of the nature and features of each important constituent of the sample, accompanied by such tables and photographs as may be required. The findings and conclusions should be expressed in terms likely to be intelligible to those who must make decisions as to the suitability of a material for use as concrete aggregate.

16.2 When the sample has been found to possess properties or constituents that are known to have specific unfavorable effects in concrete, those properties or constituents should be described qualitatively and, to the extent practicable, quantitatively. The unfavorable effects that may be expected to ensue in concrete should be mentioned. When appropriate, it should be stated that a given sample was not found to contain any undesirable features. When such is the case it may also be appropriate, especially if the report of the petrographic examination is not accompanied by reports of results of physical and chemical tests for which numerical limits may be applicable, to add that the material appears acceptable for use provided the applicable acceptance tests are made and the results are within the appropriate limits. The report should not, however, contain conclusions other than those based upon the finding of the examination unless the additional data to support such conclusions are included in or with the petrographic report and the petrographer has been authorized to analyze the other relevant nonpetrographic data.

16.3 The petrographic report should include recommendations regarding any additional petrographic, chemical, physical, or geological investigations that may be required to evaluate adverse properties that are indicated by the petrographic examination that has been performed. Supplementary petrographic investigations might include qualitative or quantitative analysis of the aggregate or of selected portions thereof by X-ray diffraction, differential thermal methods, or other procedures that are directed to identification and description of the constituents of the aggregate.

17. Precision and Bias

17.1 Those test methods that are used in connection with this guide that have been standardized in ASTM are subject to having precision and bias sections. Those that have not been standardized will each be provided with such a section, if and when standardized. None of the nonstandardized procedures mentioned for optional use in this practice are used in ways that lend themselves to the preparation of precision and bias statements.

18. Keywords

18.1 aggregate; analysis; composition; crushed rock; crushed stone; examination; ledge rock; manufacture sand; natural sand; petrography; quarry

TABLE 3 Composition and Condition of an Aggregate Sample (Table Constructed from Calculations Shown in Table Number 2)[A]

Constituents	Amount, as Number of Particles in Percent							
	In Fractions Retained on Sieves Shown Below[B]				In Whole Sample[C]			
	19.0-mm (¾-in.)[D]	12.5-mm (½-in.)[D]	9.5-mm (⅜-in.)[D]	4.75-mm (No. 4)[D]	Condition 1	Condition 2	Condition 3	Totals
A	62	70	70	50	33	20	12	65
B	37	29	25	43	13	11	8	32
C	1	1	5	7	2	1	tr	3
Total	100	100	100	100	...	...	...	100
Weighted average					48	...	...	...
Weighted average					...	32	...	...
Weighted average					...	...	20	...

[A] For other forms of presentation of results of petrographic analysis, see Table numbers 1- 4 in **(10)**.

[B] Based on count of 500 particles in each sieve fraction. (The number of particles of each sieve fraction counted should be shown in the report and this may conveniently be done as a footnote to the table.)

[C] Based on grading of the sample as received, and on the distribution of constituents by sieve fractions shown at the left above. (If the petrographic report forms part of a complete investigation of the sample, including a report of the grading, the grading need not be shown. If the petrographic report is to be submitted alone, the grading of the sample should be included with it.)

[D] Sieve size is identified by its standard designation in Specification E11. The alternative designation given in parentheses is for information only and does not represent a different standard sieve size.

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SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this guide since the last issue, C295/C295M–11, that may impact the use of this guide. (Approved April 1, 2012)

(*1*) Revised 10.1.2 and Note 1 to clarify precision of measurement.

Committee C09 has identified the location of selected changes to this guide since the last issue, C295–08, that may impact the use of this guide. (Approved July 1, 2011)

(*1*) Revised the standard as a dual units guide.