



Standard Guide for Petrographic Examination of Aggregates for Concrete¹

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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 concrete 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 C 294 should be used, insofar as they are appropriate, in reports prepared in accordance with this guide.

1.4 The values stated in SI units are to be regarded as the standard. The values given in parentheses are provided for information purposes only.

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:

- C 33 Specification for Concrete Aggregates³
- C 117 Test Method for Materials Finer than 75- μ m (No. 200) Sieve in Mineral Aggregates by Washing³
- C 136 Test Method for Sieve Analysis of Fine and Coarse Aggregates³
- C 294 Descriptive Nomenclature of Constituents of Natural Mineral Aggregates³
- C 702 Practice for Reducing Field Samples of Aggregate to Testing Size³

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

³ *Annual Book of ASTM Standards*, Vol 04.02.

D 75 Practice for Sampling Aggregates⁴

E 11 Specification for Wire-Cloth Sieves for Testing Purposes⁵

E 883 Guide for Metallographic Photomicrography⁶

3. Summary of Method

3.1 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.

3.2 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.

3.3 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

⁴ *Annual Book of ASTM Standards*, Vol 04.03.

⁵ *Annual Book of ASTM Standards*, Vol 14.02.

⁶ *Annual Book of ASTM Standards*, Vol 03.01.

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.

4. Significance and Use

4.1 Petrographic examinations are made for the following purposes:

4.1.1 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.

4.1.2 To describe and classify the constituents of the sample,

4.1.3 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

4.1.4 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.

4.2 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.

4.3 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.

4.4 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.

4.5 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.

4.6 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.

4.7 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.

4.8 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 C 33. Alkali-silica reactive constituents found in aggregates include: opal, cristobalite, tridymite, siliceous and some intermediate volcanic glass, chert, glassy to cryptocrystalline acid volcanic rocks, synthetic siliceous glasses, some argillites, phyllites, metamorphic graywackes, rocks containing highly metamorphic quartz such as graywackes, phyllites, schists, gneisses, gneissic granites, vein quartz, quartzite, and sandstone. Criteria are available for identifying the minerals in the list above by optical properties XRD or EDX and for identifying the rocks in the list by mineral composition and texture in thin section. 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.

4.9 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.

4.10 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.

5. Apparatus and Supplies

5.1 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.

5.1.1 Apparatus and Supplies for Preparation of Specimens:

5.1.1.1 *Rock-Cutting Saw*, * preferably with 350-mm or larger diamond blade, and automatic feed.

5.1.1.2 *Horizontal Grinding Wheel*, * preferably 400 mm in diameter.

5.1.1.3 *Polishing Wheel*, preferably 200 to 300 mm in diameter.

5.1.1.4 *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).⁷

5.1.1.5 *Geologist's Pick or Hammer*.

5.1.1.6 *Microscope Slides**, clear, noncorrosive, 25 by 45 mm in size.

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

5.1.1.8 *Xylene**.

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

5.1.1.10 *Laboratory Oven**.

5.1.1.11 *Plate-Glass Squares**, about 300 mm on an edge for thin-section grinding.

5.1.1.12 *Sample Splitter* with pans.*

5.1.1.13 *Micro Cover Glasses*, * noncorrosive, square, 12 to 18 mm, 25 mm, etc.

5.1.1.14 *Plattner Mortar*.

5.1.2 *Apparatus and Supplies for Examination of Specimens*:

5.1.2.1 *Polarizing Microscope**, with mechanical stage; low-, medium-, high-power objectives, and objective-centering devices; eyepieces of various powers; full- and quarter-wave compensators; quartz wedge.

5.1.2.2 *Microscope Lamps**.

5.1.2.3 *Stereoscopic Microscope**, with objectives and oculars to give final magnifications from about 6 \times to about 150 \times .

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

5.1.2.5 *Needleholder and Points**.

5.1.2.6 *Dropping Bottle*, 60-mL capacity.

5.1.2.7 *Petri Culture Dishes*.

5.1.2.8 *Forceps*, smooth, straightpointed.

5.1.2.9 *Lens Paper*.*

5.1.2.10 *Immersion Media**, $n = 1.410$ to $n = 1.785$ in steps of 0.005.

5.1.2.11 *Counter*.

5.1.2.12 *Photomicrographic Camera* and accessories.

5.2 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.

5.3 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.

5.4 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 photomicrographic equipment may be consulted. Much useful guidance regarding photomicrography, especially using reflected light, is found in Guide E 883.

6. Sampling

6.1 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 D 75. 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.

6.1.1 *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" (53-mm (2 $\frac{1}{8}$ -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

⁷ The values given in micrometres are the approximate average grain size of commercial silicon carbide grit in the designated size classification.

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.

6.1.2 *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.

6.1.3 *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.

6.1.4 *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

7. Procedure

7.1 *Selection of Samples for Examination*—Samples of gravel and natural sand for petrographic examination should be dry sieved in accordance with Method C 136 to provide samples of each sieve size. In the case of sands an additional portion should then be tested in accordance with Test Method C 117, with the wash water being saved and removed by drying in order to provide a sample of the material passing the 75- μ m (No. 200) sieve. The results of the sieve analysis of each sample made in accordance with Method C 136 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.

7.2 The number of particles of each sieve fraction to be examined will be fixed by the required precision of determi-

nation 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 quantities. The numbers given in this method are minimal. They are based on experience and on statistical considerations (2,3). 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 C 702, so as to contain a proper number of particles for examination.

8. Procedure for Examination of Natural Gravel

8.1 *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.

8.2 *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.

8.3 *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

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
75 to 150-mm (3 to 6-in.)	300 ^A
37.5 to 75-mm (1½ to 3-in.)	180	(400)	...
19.0 to 37.5-mm (¾ to 1½-in.)	90	(200)	...
4.75 to 19.0-mm (No. 4 to ¾-in.)	45	(100)	...
Finer than 4.75-mm (No. 4) ^B	23	(50)	...

^ANot less than one piece from each apparent type of rock.

^BFine aggregate.