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Standard Descriptive Nomenclature for Constituents of Concrete Aggregates[1]

This standard is issued under the fixed designation C294; 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 U.S. Department of Defense.

1. Scope*

1.1 This descriptive nomenclature provides brief descriptions of some of the more commonly occurring, or more important, natural and artificial materials of which mineral aggregates are composed. The descriptions provide a basis for understanding these terms as applied to concrete aggregates. When appropriate, brief observations regarding the potential effects of using the natural and artificial materials in concrete are discussed.

NOTE 1—These descriptions characterize minerals and rocks as they occur in nature and blast-furnace slag or lightweight aggregates that are prepared by the alteration of the structure and composition of natural material. Information about lightweight aggregates is given in Specifications C330, C331, and C332.

1.2 This standard does not include descriptions of constituents of aggregates used in radiation shielding concrete. See Descriptive Nomenclature C638.

1.3 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.4 *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]

C125 Terminology Relating to Concrete and Concrete Aggregates

C227 Test Method for Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar-Bar Method) (Withdrawn 2018)[3]

C289 Test Method for Potential Alkali-Silica Reactivity of Aggregates (Chemical Method) (Withdrawn 2016)[3]

C330 Specification for Lightweight Aggregates for Structural Concrete

C331 Specification for Lightweight Aggregates for Concrete Masonry Units

C332 Specification for Lightweight Aggregates for Insulating Concrete

C638 Descriptive Nomenclature of Constituents of Aggregates for Radiation-Shielding Concrete

3. Terminology

3.1 For definitions of terms in this standard, refer to Terminology C125.

4. Significance and Use

4.1 This descriptive nomenclature provides information on terms commonly applied to concrete aggregates. This standard is intended to assist in understanding the meaning and significance of the terms.

4.2 Many of the materials described frequently occur in particles that do not display all the characteristics given in the descriptions, and most of the described rocks grade from varieties meeting one description to varieties meeting another with all intermediate stages being found.

4.3 The accurate identification of rocks and minerals can, in many cases, be made only by a qualified geologist, mineralogist, or petrographer using the apparatus and procedures of these sciences. Reference to these descriptions may, however, serve to indicate or prevent gross errors in identification. Identification of the constituent materials in an aggregate may assist in characterizing its engineering properties, but identification alone cannot provide the sole basis for predicting behavior of aggregates in service. Aggregates of any type or combination of types may perform well or poorly in service depending upon the exposure to which the concrete is subjected, the physical and chemical properties of the matrix in

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[1] This descriptive nomenclature 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] 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.

[3] The last approved version of this historical standard is referenced on www.astm.org.

*A Summary of Changes section appears at the end of this standard which they are embedded, their physical condition at the time they are used, and other factors. Constituents that may occur only in minor amounts in the aggregate may or may not decisively influence its performance. Information about concrete aggregate performance in concrete has been published by ASTM.[4]

CONSTITUENTS OF NATURAL MINERAL AGGREGATES

5. Classes and Types

5.1 The materials found as constituents of natural mineral aggregates are minerals and rocks.

5.2 Minerals are naturally occurring inorganic substances of more or less definite chemical composition and usually of a specific crystalline structure. The physical nature of the rock-forming minerals and aspects of crystal chemistry determine the important physical and chemical properties of natural mineral aggregates. Certain assemblages of rock-forming minerals possess desirable qualities for use as aggregates in cementitious materials.

5.2.1 Minerals are characterized by their crystallographic, physical, and optical properties and their chemical composition. The crystallographic properties of minerals may be determined by x-ray diffraction and optical properties (**1-6**). The physical properties of minerals include but are not limited to crystal habit, cleavage, parting, fracture, hardness, specific gravity, luster, color, streak, magnetism, luminescence, and pyroelectricity (**7**). The optical properties of minerals include but are not limited to refractive index, birefringence, optic sign, pleochroism, and sign of elongation (**2-5**). Methods to determine the chemical composition of minerals include but are not limited to optical properties (**5**), flame photometry (**7**,**8**), chemical spot tests (**9**,**10**), various staining techniques (**11**), x-ray fluorescence, and electron microscopy (**12-14**).

5.2.2 Different minerals may have the same chemical composition but different crystallographic and physical properties. Such sets of minerals are known as polymorphs. Distinguishing between some polymorphs can be important for determining the suitability of aggregates for use in cementitious materials.

5.3 Rocks are classified according to origin into three major divisions: igneous, sedimentary, and metamorphic. These three major groups are subdivided into types according to mineral and chemical composition, texture, and internal structure. Most rocks are composed of several minerals but some are composed of only one mineral. Certain examples of the rock quartzite are composed exclusively of the mineral quartz, and certain limestones are composed exclusively of the mineral calcite. Individual sand grains frequently are composed of particles of rock, but they may be composed of a single mineral, particularly in the finer sizes.

5.3.1 Igneous rocks form from molten matter either at or below the earth's surface.

5.3.2 Sedimentary rocks form near the earth's surface by the accumulation and consolidation of the products of weathering and erosion of existing rocks, or by direct chemical precipitation. Sedimentary rocks may form from pre-existing igneous, metamorphic, or sedimentary rocks.

5.3.3 Metamorphic rocks form from pre-existing igneous, sedimentary, or metamorphic rocks by the action of heat or pressure or both.

6. Silica Minerals

6.1 *Quartz*—a very common hard mineral composed of silica (SiO_2). It will scratch glass and is not scratched by a knife. When pure it is colorless with a glassy (vitreous) luster and a shell-like (conchoidal) fracture. It lacks a visible cleavage (the ability to break in definite directions along even planes) and, when present in massive rocks such as granite, it usually has no characteristic shape. It is resistant to weathering and is therefore an important constituent of many sand and gravel deposits and many sandstones. It is also abundant in many light-colored igneous and metamorphic rocks. Some strained, or intensely fractured (granulated), and microcrystalline quartz may be potentially deleteriously reactive with the alkalies in the hydraulic cement paste.

6.2 *Opal*—a hydrous form of silica ($SiO_2 \cdot nH_2O$) which occurs without characteristic external form or internal crystalline arrangement as determined by ordinary visible light methods. When X-ray diffraction methods are used, opal may show some evidences of internal crystalline arrangement. Opal has a variable water content, generally ranging from 3 to 9 %. The specific gravity and hardness are always less than those of quartz. The color is variable and the luster is resinous to glassy. It is usually found in sedimentary rocks, especially some cherts, and is the principal constituent of diatomite. It is also found as a secondary material filling cavities and fissures in igneous rocks and may occur as a coating on gravel and sand. The recognition of opal in aggregates is important because it is potentially deleteriously reactive with the alkalies in hydraulic cement paste or with the alkalies from other sources, such as aggregates containing zeolites, and ground water.

6.3 *Chalcedony*—chalcedony has been considered both as a distinct mineral and a variety of quartz. It is frequently composed of a mixture of microscopic fibers of quartz with a large number of submicroscopic pores filled with water and air. The properties of chalcedony are intermediate between those of opal and quartz, from which it can sometimes be distinguished only by laboratory tests. It frequently occurs as a constituent of the rock chert and is potentially deleteriously reactive with the alkalies in hydraulic cement paste.

6.4 *Tridymite and cristobalite*—high temperature crystalline forms of silica (SiO_2) sometimes found in volcanic rocks. They are metastable at ordinary temperatures and pressures. They are rare minerals in aggregates except in areas where volcanic rocks are abundant. A type of cristobalite is a common constituent of opal. Tridymite and cristobalite are potentially deleteriously reactive with the alkalies in hydraulic cement paste.

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[4] Klieger, P., and Lamond, J. F., editors, Significance of Tests and Properties of Concrete and Concrete-Making Materials, ASTM STP 169C, 1994.

7. Feldspars

7.1 The minerals of the feldspar group are the most abundant rock-forming minerals in the crust of the earth. They are important constituents of all three major rock groups, igneous, sedimentary, and metamorphic. Since all feldspars have good cleavages in two directions, particles of feldspar usually show several smooth surfaces. Frequently, the smooth cleavage surfaces show fine parallel lines. All feldspars are slightly less hard than, and can be scratched by, quartz and will, when fresh, easily scratch a penny. The various members of the group are differentiated by chemical composition and crystallographic properties. The feldspars *orthoclase, sanidine*, and *microcline* are potassium aluminum silicates, and are frequently referred to as *potassium feldspars*. The *plagioclase* feldspars include those that are sodium aluminum silicates and calcium aluminum silicates, or both sodium and calcium aluminum silicates. This group, frequently referred to as the "soda-lime" group, includes a continuous series, of varying chemical composition and optical properties, from *albite*, the sodium aluminum feldspar, to *anorthite*, the calcium aluminum feldspar, with intermediate members of the series designated *oligoclase, andesine, labradorite*, and *bytownite*. Potassium feldspars and sodium-rich plagioclase feldspars occur typically in igneous rocks such as granites and rhyolites, whereas, plagioclase feldspars of higher calcium content are found in igneous rocks of lower silica content such as diorite, gabbro, andesite, and basalt.

8. Ferromagnesian Minerals

8.1 Many igneous and metamorphic rocks contain dark green to black minerals that are generally silicates of iron or magnesium, or of both. They include the minerals of the amphibole, pyroxene, and olivine groups. The most common amphibole mineral is hornblende; the most common pyroxene mineral is augite; and the most common olivine mineral is forsterite. Dark mica, such as biotite and phlogopite, are also considered ferromagnesian minerals. The amphibole and pyroxene minerals are brown to green to black and generally occur as prismatic units. Olivine is usually olive green, glassy in appearance, and usually altered. Biotite has excellent cleavage and can be easily cleaved into thin flakes and plates. These minerals can be found as components of a variety of rocks, and in sands and gravels. Olivine is found only in dark igneous rocks where quartz is not present, and in sands and gravels close to the olivine source.

9. Micaceous Minerals

9.1 Micaceous minerals have perfect cleavage in one direction and can be easily split into thin flakes. The mica minerals of the muscovite group are colorless to light green; of the biotite group, dark brown to black or dark green; of the lepidolite group, white to pink and red or yellow; and of the chlorite group, shades of green. Another mica, phlogopite, is similar to biotite, commonly has a pearl-like luster and bronze color, and less commonly is brownish red, green, or yellow. The mica minerals are common and occur in igneous, sedimentary, and metamorphic rocks, and are common as minor to trace components in many sands and gravels. The muscovite, biotite, lepidolite, and phlogopite minerals cleave into flakes and plates that are elastic; the chlorite minerals, by comparison, form inelastic flakes and plates. Vermiculite (a mica-like mineral) forms by the alteration of other micas and is brown and has a bronze luster.

9.2 Because micaceous materials have a high surface area, they can influence the properties of freshly mixed and hardened concrete. Aggregates with a high mica content can reduce workability and increase the water demand of the concrete (**15**). The shape and perfect cleavage of micaceous minerals may result in a poor bond to the cementitious paste (**16**).

10. Clay Minerals

10.1 The term "clay" refers to natural material composed of particles in a specific size range less than 2 μm (0.002 mm). Mineralogically, clay refers to a group of layered silicate minerals including the clay-micas (illites), the kaolin group, very finely divided chlorites, and the swelling clays—smectite including montmorillonites. Members of several groups, particularly micas, chlorites, and vermiculites, occur both in the clay-size range and in larger sizes. Some clays are made up of alternating layers of two or more clay groups. Random, regular, or both types of interlayering are known. If smectite is a significant constituent in such mixtures, then fairly large volume changes may occur with wetting and drying.

10.2 Clay minerals are hydrous aluminum, magnesium, and iron silicates that may contain calcium, magnesium, potassium, sodium, and other exchangeable cations. They are formed by alteration and weathering of other silicates and volcanic glass. The clay minerals are major constituents of clays and shales. They are found disseminated in carbonate rocks as seams and pockets and in altered and weathered igneous and metamorphic rocks. Clays may also be found as matrix, void fillings, and cementing material in sandstones and other sedimentary rocks.

10.3 Most aggregate particles composed of, or containing, large proportions of clay minerals are soft and, because of the large internal surface area of the constituents, they are porous. Some of these aggregates will disintegrate when wetted. Rocks in which the cementing matrix is principally clay, such as clay-bonded sandstones, and rocks in which swelling clay minerals (smectite) are present as a continuous phase or matrix, such as in some altered volcanics, may slake in water or may disintegrate in the concrete mixer. Rocks of this type are unsuitable for use as aggregates. Rocks having these properties less well developed will abrade considerably during mixing, releasing clay, and raising the water requirement of the concrete containing them. When such rocks are present in hardened concrete, the concrete will manifest greater volume change on wetting and drying than similar concrete containing non-swelling aggregate.

11. Zeolites

11.1 The zeolite minerals are a large group of hydrated aluminum silicates of the alkali and alkaline earth elements which are soft and usually white or light colored. They are formed as a secondary filling in cavities or fissures in igneous rocks, or within the rock itself as a product of hydrothermal alteration of original minerals, especially feldspars. Some zeolites, particularly *heulandite, natrolite*, and *laumontite*, reportedly produce deleterious effects in concrete, the first two having been reported to raise the alkali content in concrete by releasing alkalies through cation exchange and thus increasing alkali reactivity when alkali-reactive aggregate constituents are present. Laumontite and its partially dehydrated variety *leonhardite* are notable for their substantial volume change with wetting and drying. Both are found in rocks such as quartz diorites and some sandstones.

12. Carbonate Minerals

12.1 The most common carbonate mineral is *calcite* (calcium carbonate, $CaCO_3$). The mineral *dolomite* consists of calcium carbonate and magnesium carbonate ($CaCO_3 \cdot MgCO_3$ or $CaMg(CO_3)_2$) in equivalent molecular amounts, which are 54.27 and 45.73 mass percent, respectively. Both calcite and dolomite are relatively soft, the hardness of calcite being 3 and that of dolomite 3½ to 4 on the Mohs scale, and are readily scratched by a knife blade. They have rhombohedral cleavage, which results in their breaking into fragments with smooth parallelogram shaped sides. Calcite is soluble with vigorous effervescence in cold dilute hydrochloric acid; dolomite is soluble with slow effervescence in cold dilute hydrochloric acid and with vigorous effervescence if the acid or the sample is heated or if the sample is pulverized.

13. Sulfate Minerals

13.1 Carbonate rocks and shales may contain sulfates as impurities. The most abundant sulfate mineral is *gypsum* (hydrous calcium sulfate; $CaSO_4 \cdot 2H_2O$); *anhydrite* (anhydrous calcium sulfate, $CaSO_4$) is less common. Gypsum is usually white or colorless and characterized by a perfect cleavage along one plane and by its softness, representing hardness of 2 on the Mohs scale; it is readily scratched by the fingernail. Gypsum may form a whitish pulverulent or crystalline coating on sand and gravel. It is slightly soluble in water.

13.2 Anhydrite resembles dolomite in hand specimen but has three cleavages at right angles; it is less soluble in hydrochloric acid than dolomite, does not effervesce and is slightly soluble in water. Anhydrite is harder than gypsum. Gypsum and anhydrite occurring in aggregates can cause sulfate attack in concrete and mortar.

14. Iron Sulfide Minerals

14.1 The sulfides of iron, *pyrite, marcasite*, and *pyrrhotite* are frequently found in natural aggregates. Pyrite is found in igneous, sedimentary, and metamorphic rocks; marcasite is much less common and is found mainly in sedimentary rocks; pyrrhotite is less common but may be found in many types of igneous and metamorphic rocks. Pyrite is brass yellow, and pyrrhotite bronze brown, and both have a metallic luster. Marcasite is also metallic but lighter in color and finely divided iron sulfides are soot black. Pyrite is often found in cubic crystals. Marcasite readily oxidizes with the liberation of sulfuric acid and formation of iron oxides, hydroxides, and, to a much smaller extent, sulfates; pyrite and pyrrhotite do so less readily. Marcasite and certain forms of pyrite and pyrrhotite are reactive in mortar and concrete, producing a brown stain accompanied by a volume increase that has been reported as one source of popouts in concrete. Reactive forms of iron sulfides may be recognized by immersion in saturated lime water (calcium hydroxide solution); upon exposure to air the reactive varieties produce a brown coating within a few minutes.

15. Iron Oxide Minerals, Anhydrous and Hydrous

15.1 There are two common iron oxide minerals: (*1*) Black, magnetic: *magnetite* (Fe_3O_4), and (*2*) red or reddish when powdered: *hematite* ($Fe_2\ O_3$); and one common hydrous oxide mineral, brown or yellowish: *goethite* (FeO(OH)). Another common iron-bearing mineral is black, weakly magnetic, *ilmenite* ($FeTiO_3$). Magnetite and ilmenite are important accessory minerals in many dark igneous rocks and are common detrital minerals in sediments. Hematite is frequently found as an accessory mineral in reddish rocks. Limonite, the brown weathering product of iron-bearing minerals, is a field name for several varieties of hydrous iron oxide minerals including goethite; it frequently contains adsorbed water, and various impurities such as colloidal or crystalline silica, clay minerals, and organic matter. The presence of substantial amounts of soft iron-oxide minerals in concrete aggregate can color concrete various shades of yellow or brown. Very minor amounts of iron minerals color many rocks, such as ferruginous sandstones, shales, clay-ironstones, and granites. Magnetite, ilmenite, and hematite ores are used as heavy aggregates.

DESCRIPTIONS OF IGNEOUS ROCKS

16. General

16.1 Igneous rocks are those formed by cooling from a molten rock mass (magma). They may be divided into two classes: (*1*) plutonic, or intrusive, that have cooled slowly within the earth; and (*2*) volcanic, or extrusive, that formed from quickly cooled lavas. Plutonic rocks have grain sizes greater than approximately 1 mm, and are classified as coarse- or medium-grained. Volcanic rocks have grain sizes less than approximately 1 mm, and are classified as fine-grained. Volcanic rocks frequently contain glass. Both plutonic and volcanic rocks may consist of porphyries, that are characterized by the presence of large mineral grains in a fine-grained or glassy groundmass. This is the result of sharp changes in rate of cooling or other physico-chemical conditions during solidification of the melt.

16.2 Igneous rocks are usually classified and named on the basis of their texture, internal structure, and their mineral composition which in turn depends to a large extent on their chemical composition. Rocks in the plutonic class generally have chemical equivalents in the volcanic class.

17. Plutonic Rocks

17.1 *Granite*—granite is a medium- to coarse-grained, light-colored rock characterized by the presence of potassium feldspar with lesser amounts of plagioclase feldspars and quartz. The characteristic potassium feldspars are orthoclase or microcline, or both; the common plagioclase feldspars are albite and oligoclase. Feldspars are more abundant than quartz.