

An ACI Education Bulletin

# Aggregates for Concrete

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## Aggregates for Concrete

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## Aggregates for Concrete

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*Aggregate properties and gradation significantly affect workability and finishability of freshly placed concrete and properties of hardened concrete including compressive strength, durability and abrasion resistance. Properties and accepted test methods discussed in this bulletin include: aggregate gradation; fine and coarse aggregate fineness moduli; relative bulk densities of wet, saturated surface dry, air-dry, and oven-dry aggregates; moisture absorption; shape angularity and surface texture; abrasion and impact resistance; permeability resistance to freeze thaw cycles and alkali-silica reaction; and chemical stability. Aggregate types including normalweight, lightweight and heavyweight natural aggregate; blast furnace slag aggregates; and recycled aggregates from crushed reclaimed concrete pavements are covered. Examples are provided on how to calculate and evaluate fineness modulus, batch mixture proportions adjusted for aggregate absorption, batch mixing water proportions, water cementitious ratio, and bulk densities. Sampling aggregate methods to estimate average aggregate properties of large volumes or stockpiles, batches, or truck-loads of aggregates are also covered.*

**Keywords:** abrasion resistance, absorption, aggregate angularity, aggregate gradation, aggregate surface texture, air-dry bulk density, alkali-silica reaction, batch mixture proportions, blast furnace slag aggregate, bulk density, compaction, fineness modulus, heavyweight aggregate, lightweight aggregate, mixing water, normalweight aggregate, oven-dry bulk density, recycled aggregate, relative bulk density, saturated surface-dry bulk density, sampling, surface moisture, water-cementitious ratio.

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## CHAPTER 1—INTRODUCTION

Concrete is a mixture of hydraulic cement, aggregates, and water, with or without admixtures, fibers, or other cementitious materials. Aggregates are granular materials such as sand, gravel, crushed stone, crushed hydraulic-cement concrete, or iron blast-furnace slag. Coarse aggregate is that portion retained on the 4.75 mm (No. 4) sieve. Fine aggregate is that portion passing the 4.75 mm (No. 4) sieve and predominantly retained on the 75  $\mu\text{m}$  (No. 200) sieve. Aggregate classifications include normalweight, lightweight, or heavy-weight. The selection of aggregate to be used for concrete mixtures depends on the intended concrete properties. For instance, heavyweight aggregates such as barite, magnetite, hematite, limonite, ilmenite, iron, or steel are used in heavyweight concrete mixtures. Heavyweight concrete is used for applications such as radiation shielding, ballast for offshore pipelines, or other similar applications. Lightweight aggregate, such as expanded or sintered clay, shale, slate, diatomaceous shale, perlite, vermiculite, slag, pumice, scoria, volcanic cinders, tuff, diatomite, sintered fly ash, or industrial cinders, are used in lightweight concrete applications.

Coarse and fine aggregate constitute approximately 60 to 75 percent of the concrete mixture. Therefore, the properties of the aggregates have a significant influence on the properties of the concrete mixture. Aggregate properties significantly affect the workability of plastic concrete, and the durability, strength, volume stability, thermal properties, and density of hardened concrete.

This bulletin describes types of aggregates normally used in concrete, aggregate properties affecting performance of the concrete, tests used to measure aggregate properties, and methods used to obtain test samples. Normalweight, lightweight, and heavyweight aggregates are discussed.

## CHAPTER 2—CLASSIFICATION OF AGGREGATES

Aggregates may be broadly classified as natural or manufactured, both with respect to source and method of preparation. Natural sands and gravels are the product of weathering and the action of wind or water whereas manufactured crushed fine aggregate and crushed stone are produced by crushing natural stone. Screening and washing may be used to process either natural or manufactured aggregates. Aggregates may be produced from igneous, sedimentary, or metamorphic rocks, but the presence or absence of any geological type does not, by itself, make an aggregate suitable or unsuitable for use in concrete. The acceptance of an aggregate for use in concrete on a particular job or in a specification should be based on specific information obtained from tests used to measure the aggregate quality, its service record, or both. A typical consensus specification for both fine and coarse concrete aggregate is **ASTM C33/C33M**.

Manufactured aggregates may be either by-products of an industrial process, such as blast-furnace slag, or products of processes developed to manufacture aggregates with special properties, such as expanded clay, shale, or slate that are used for lightweight aggregates. Some lightweight aggregates such as pumice or scoria also occur naturally.

Other classifications of aggregates may be based on bulk density (previously termed unit weight) (**ASTM C33/C33M**; **ASTM C330/C330M**; and **ASTM C637**), mineralogical composition (**ASTM C294**), and particle shape; these, as well as the ones previously discussed, serve mainly as aids in describing an aggregate. To understand the role played by aggregate in the performance of concrete, it is necessary to define specific aggregate properties and show their effect on concrete properties.

## CHAPTER 3—AGGREGATE PROPERTIES AND TEST METHODS

### 3.1—Grading

**3.1.1 Definition and test method**—Grading refers to the distribution of particle sizes present in an aggregate. The grading is determined in accordance with **ASTM C136/C136M**, “**Sieve Analysis of Fine and Coarse Aggregates**.” A representative sample of the aggregate that has been properly prepared is shaken through a series of sieves nested one above the other in order of size, with the sieve having the largest openings on top and the one having the smallest openings at the bottom (**Fig. 3.1.1a**). These wire-cloth sieves have square openings. A pan is used to catch material passing the smallest sieve. Sieve sizes commonly used for concrete aggregates are detailed in **Table 3.1.1a**, and various physical properties of normalweight aggregates, with typical range values, are shown in **Table 3.1.1b**.

Coarse and fine aggregates are generally sieved separately. That portion of an aggregate passing the 4.75 mm (No. 4) sieve and predominantly retained on the 75  $\mu\text{m}$  (No. 200) sieve is called fine aggregate or sand, and larger aggregate is called coarse aggregate. Coarse aggregate may be available in several different size groups, such as 19 to 4.75 mm (3/4 in. to No. 4), or 37.5 to 19 mm (1-1/2 to 3/4 in.). **ASTM C33/C33M**, “**Standard Specification for Concrete Aggregates**,” lists several such size groups using the simplified practice



Fig. 3.1.1a—Nest of sieves.