IN-LB	Inch-Pound Units
SI	International System of Units

Guide for Proportioning Concrete Mixtures with Ground Calcium Carbonate and Other Mineral Fillers

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Guide for Proportioning Concrete Mixtures with Ground Calcium Carbonate and Other Mineral Fillers

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The use of ground calcium carbonate (GCC) and other mineral fillers can enhance the performance, economy, and sustainability of concrete mixtures. Modifications to the conventional proportioning method in ACI 211.1 are needed to incorporate these materials. This guide describes GCC and dust-of-fracture aggregate mineral fillers, including their properties, characterization, and qualification, and effects on concrete properties and sustainability. Recom-

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mendations are provided for proportioning concrete mixtures with these materials.

Keywords: aggregate mineral filler; dust-of-fracture; ground calcium carbonate; ground limestone; mixture proportioning; paste volume; powder content; proportioning.

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CHAPTER 1—INTRODUCTION

This guide provides recommendations for proportioning normalweight concrete with ground calcium carbonate (GCC) and dust-of-fracture aggregate mineral fillers (AMF). It also provides background information on these materials, techniques for their characterization, and their effects on concrete properties; however, it is not intended to be a comprehensive literature review and the reader should conduct trial batches to evaluate specific materials being used and to confirm concrete performance. It is intended to supplement ACI 211.1 and is for materials meeting ASTM C1797. Proportioning methods for GCC and for dust-of-fracture AMF are discussed separately.

Mineral filler is defined as a finely divided mineral product at least 65 percent of which passes the No. 200 (75 µm) sieve. This definition includes the materials addressed herein; namely, GCC as specified in ASTM C1797 and dust-of-fracture AMF from quarried rock as specified in either ASTM C1797 or ASTM C33/C33M.

GCC, also known as ground limestone, is a manufactured fine product composed primarily of calcium carbonate and with particles sized within narrow ranges. GCC has been used successfully in concrete in Europe for decades, either added to the concrete mixture separately from the cement or interground with clinker to form portland-limestone cement (European Committee for Standardization 2009).

Dust-of-fracture AMF is rock dust created during production, processing, or handling of quarried stone. Such materials can vary in mineral composition and other physical characteristics, depending on the parent stone from which they are derived, the crushing process, and the washing or air separation process. Dust-of-fracture AMF can be provided as a dry bulk powder meeting ASTM C1797 or as part of manufactured sand as described in ASTM C33/C33M.

This guide does not address precipitated calcium carbonate or material finer than the No. 200 (75 µm) sieve in natural sand, nor the use of limestone as a cement ingredient, which is addressed in ASTM C150/C150M, C595/C595M, and C1157. Although GCC typically falls within the definition of AMF, it is dealt with separately in this guide. It is manufactured under controlled conditions to be a consistent product. Dust-of-fracture AMF consisting primarily of calcium carbonate is not considered GCC.

The aggregate suspension mixture proportioning method described in ACI 211.6T has been used to proportion concrete with GCC and dust-of-fracture AMF.

The use of both GCC and dust-of-fracture AMF can improve the sustainability of concrete production. GCC has a lower embodied energy and lower CO_2 emission during its production than an equivalent mass of portland cement. Dust-of-fracture AMF is typically a by-product of the blasting and crushing of aggregate. This guide can facilitate the use of GCC and aggregate mineral fillers as a means of optimizing the powder content of concrete, thereby increasing sustainability.

Applicability of these materials is not limited to a select class or type of concrete but can be considered for use in a wide variety of applications and production methods. The

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described proportioning methods provide a first approximation of proportions intended for trial batches in the laboratory or field, which should be adjusted as necessary to produce the desired characteristics of the concrete.

GCC and AMF can also be used in structural lightweight concrete. The principles described herein can be similarly used to modify ACI 211.2 to incorporate these materials.

CHAPTER 2—DEFINITIONS

Please refer to the latest version of ACI Concrete Terminology for a comprehensive list of definitions. Definitions provided herein complement that resource.

aggregate mineral filler—a finely divided inorganic material derived from quarried stone, for use as an ingredient in hydraulic cementitious mixtures and meeting specified chemical and physical requirements.

ground calcium carbonate—finely divided inorganic material consisting predominantly of calcium carbonate or the carbonates of calcium and magnesium and produced by milling the rock to a specific particle size distribution.

paste volume—volume of cementitious materials and other powders, water, and chemical admixtures.

powder—solid materials finer than approximately No. 200 (75 µm) including hydraulic cement, supplementary cementitious materials, and the portion of fine aggregate, ground calcium carbonate, and other minerals fillers finer than No. 200 (75 µm).

water-powder ratio—ratio of the mass of water, excluding that absorbed by the aggregate, to the mass of powder in a mixture, stated as a decimal and abbreviated *w/p*.

CHAPTER 3—CONSTITUENT MATERIALS

3.1—Introduction

The selection of constituent materials when proportioning concrete with ground calcium carbonate (GCC) or dust-of-fracture aggregate mineral filler (AMF) is very similar to the typical selection process described in ACI 211.1. Mixture constituents such as coarse and fine aggregate (ACI 221R), cementitious materials (ACI 225R; ACI 232.2R; ACI 233R; ACI 234R), admixtures (ACI 212.3R), and water that are commonly used for proportioning concrete are usually suitable when proportioning with GCC and dust-of-fracture AMF. The most significant adjustments to proportions will be in amount of water used, the type and dosage of admixtures, and minor changes to coarse and fine aggregate ratios.

3.2—Ground calcium carbonate

GCC is manufactured to a specific and consistent particle size distribution, typically using roller or ball mills and air classifiers. It is also produced for different purposes beyond its use in concrete, such as for paints, oil drilling fluids, paper, glass, adhesive, sealants, and plastics. It is available in dry and wet (slurry) form, with dry powder more common for concrete applications. A wide variety of different median particle sizes is available. GCC is made up primarily of calcium carbonate and is produced for concrete to meet ASTM C1797, Type A or B. Calcium carbonate occurs in three distinct crystal forms: calcite, aragonite, and vaterite. Calcite is predominant in nature. The mineral form may affect grinding efficiency during manufacturing of GCC; however, all three mineral forms can be used successfully in concrete.

GCC may be used to increase the total powder content in the mixture without increasing the cementitious materials content. The amount of cementitious materials in a concrete mixture may be reduced in cases where a portion of the cementitious materials is not needed for strength and durability and where the use of GCC maintains workability and finishability. The amount used depends on the characteristics of the GCC and the desired concrete properties.

3.3—Dust-of-fracture aggregate mineral filler

Dust-of-fracture AMF is produced during crushing of quarried stone or gravel. The shape and particle size distribution can vary depending on the parent material and methods of production. This material should be essentially free of clay for use in concrete, as indicated by a methylene blue value within the limits of ASTM C1797. Dust-of-fracture AMF may be supplied in one of two forms:

1. *Dry*—This material is mechanically processed as a dry and loose powder, stored in silos, and transported in pneumatic tankers. It is addressed in ASTM C1797.
2. *Wet*—This material is usually combined with manufactured sand. The combined material is commonly called No. 10 screening, dry screening, crusher fines, or simply manufactured sand. It usually has a moisture content greater than 1 percent. The moisture comes from the water used for dust suppression and exposure to precipitation while in a stockpile. It is addressed in ASTM C33/C33M.

Dust-of-fracture AMF finer than the No. 200 (75 mm) sieve in unwashed manufactured sand typically ranges from 10 to 20 percent of the sand mass. Washing is often performed to reduce this amount to less than 5 or 7 percent as required by the standard fine aggregate gradation in ASTM C33/C33M.

CHAPTER 4—GROUND CALCIUM CARBONATE AND AGGREGATE MINERAL FILLER CHARACTERIZATION AND QUALIFICATION

4.1—Introduction

Ground calcium carbonate (GCC) and dust-of-fracture aggregate mineral filler (AMF) are derived from a variety of sources and can differ widely in their characteristics. The main characteristics affecting concrete properties are particle morphology (shape, angularity, and texture), mineralogy, particle size, particle size distribution, deleterious materials, and density. These characteristics ultimately determine concrete performance.

4.2—Morphology (shape, angularity, and texture)

The particle morphology of GCC and dust-of-fracture AMF can be described in terms of shape, angularity, and texture. Shape generally describes geometrical characteristics at the coarsest scale, angularity at an intermediate scale, and texture at the finest scale. Shape, angularity, and texture

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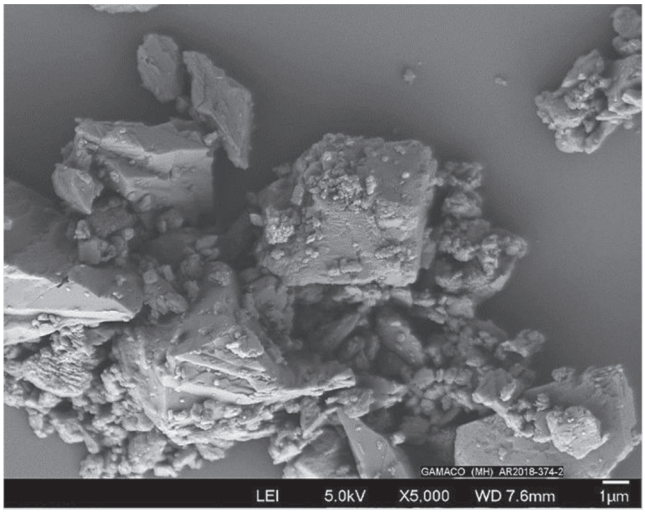

Fig. 4.2.1—SEM image of ground calcium carbonate.

are independent of each other, although they may be correlated for certain sets of particles (Graves 2006). Shape is frequently defined in terms of the three principle dimensions of a particle. Angularity generally describes the sharpness of the corners of particles. Texture describes the surface roughness of particles.

Morphology can be characterized directly, such as by image analysis of micrographs or by computed tomography. It can also be characterized indirectly, such as by measuring packing density or determining the amount of water or admixture to reach a certain workability in mortar or concrete. Rounded particles require less water or admixture and normally result in higher packing density. Note that other factors, such as particle size distribution, can significantly affect packing density and workability. The particle shape of GCC and dust-of-fracture AMF is influenced by many factors, including the equipment used in milling or crushing and the geology of the parent rock.

4.2.1 *Ground calcium carbonate*—Most GCC is cubical and moderately angular in shape such as shown in Fig. 4.2.1.

4.2.2 *Dust-of-fracture aggregate mineral filler*—Several typical materials are shown in SEM images in Fig. 4.2.2a through 4.2.2d. The particle shape can range from flat and elongated to cubical. Specific types of crushing equipment may be used to shape the aggregates into more cubical and less angular particles, but are not required. As with larger-size aggregates, different shapes of dust-of-fracture AMF can be used in concrete mixtures, provided that the mixture proportions are adjusted accordingly.

4.3—Mineralogy

Mineralogy describes the chemistry, crystal structure, and physical properties of the rock. Mineralogy affects factors such as morphology and mechanical properties of the GCC or dust-of-fracture AMF.

4.3.1 *Ground calcium carbonate*—GCC typically consists primarily of calcium carbonate ($CaCO_3$) but can include magnesium carbonate ($MgCO_3$) and other minerals. Specifications typically require a minimum percentage of $CaCO_3$

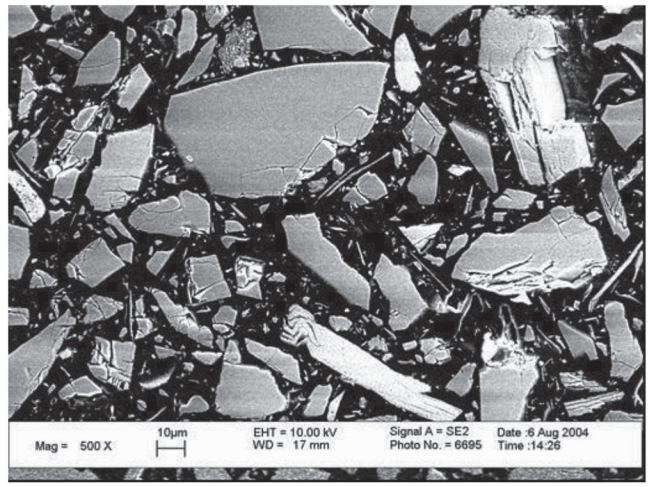

Fig. 4.2.2a—SEM image of a traprock dust-of-fracture AMF (Stewart et al. 2006).

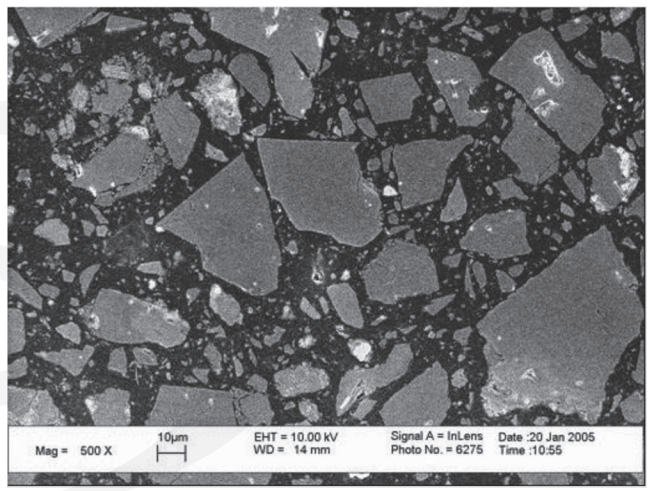

Fig 4.2.2b—SEM image of a limestone dust-of-fracture AMF (Stewart et al. 2006).

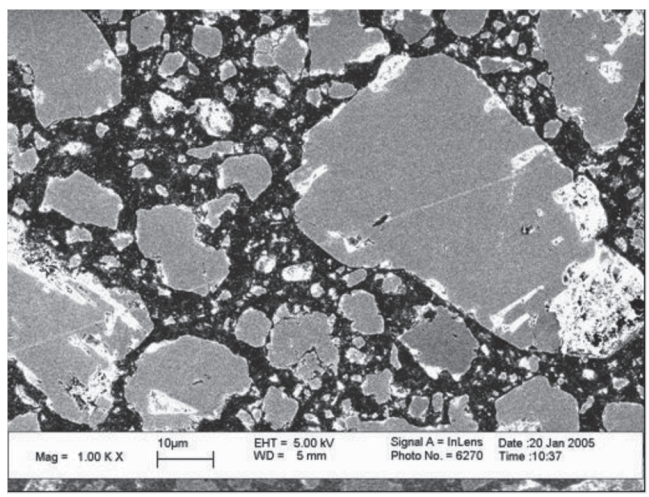

Fig. 4.2.2c—SEM image of a limestone dust-of-fracture AMF (Stewart et al. 2006).

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