

ACI 523.3R-14

Guide for Cellular Concretes above 50 lb/ft³ (800 kg/m³)

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Guide for Cellular Concretes above 50 lb/ft³ (800 kg/m³)

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This guide addresses the materials, properties, design, production, and placement of cellular concretes with as-cast densities greater than 50 lb/ft³ (800 kg/m³). The usual density range of cellular concrete is 20 to 120 lb/ft³ (320 to 1920 kg/m³). Cellular concretes in the lower portion of this range are used for many applications, such as roof thermal insulation and geotechnical fills. Cellular concretes in the higher density range are used for cast-in-place, precast applications and nonstructural floor fills.

Keywords: cellular concrete; compressive strength; fire resistance; insulating concrete; lightweight concrete; mixture proportioning; modulus of elasticity; precast concrete; recyclability; shear properties; splitting tensile strength; structural design; sustainability; thermal conductivity.

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CHAPTER 1—INTRODUCTION AND SCOPE

1.1—Introduction

This guide includes cellular concretes with as-cast densities in the range of 50 to 110 lb/ft³ (800 to 1760 kg/m³). Applications include, but are not limited to, insulating or geotechnical fills and cast-in-place and precast elements. A wide range of applications is possible by controlling the as-cast density and mixture proportioning that influence the main physical properties, such as strength, modulus of elasticity, and thermal conductivity. Commercial uses include cast-in-place, nonstructural floor fills; precast or cast-in-place elements such as wall panels; architectural applications such as annular pipe fills (Fig. 1.1a); and pipeline abandonments (Fig. 1.1b).

Cellular concretes referenced in this guide contain stable gas cells uniformly distributed in a cementitious mixture (Fig. 1.1c). Typically, macroscopic bubbles are added at the mixer as stable preformed foam metered from a calibrated nozzle and thoroughly blended into the slurry. This guide does not cover the addition of an in-place-foam admixture that may require vigorous mixing to entrap air. Cellular concretes in the density range covered by this guide may contain natural or manufactured aggregates.

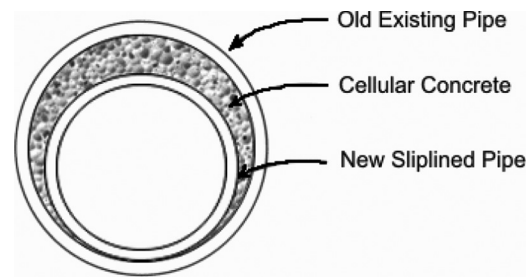


Fig. 1.1a—Sliplined pipe.

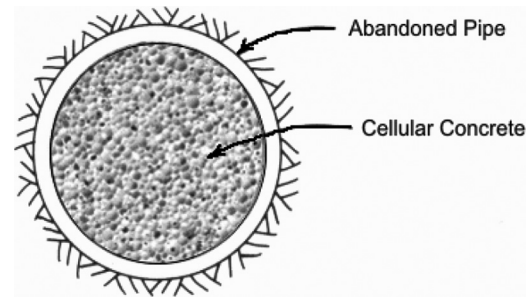


Fig. 1.1b—Pipeline abandonment.

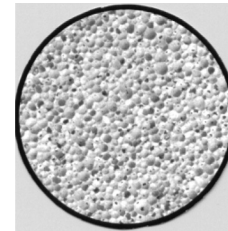


Fig. 1.1c—Typical cell structure of cellular concrete.

1.2—Scope

This guide applies to cellular concretes with cast densities greater than 50 lb/ft³ (800 kg/m³). Precast and cast-in-place cellular concretes are within the scope of this guide. Compressive strengths may vary widely and are specified based on a particular application. To assist in selection, proportioning, and production of cellular concretes, the available material property information and applications of cellular concretes are also addressed.

CHAPTER 2—NOTATION AND DEFINITIONS

2.1—Notation

- A = dry mass of aggregate, lb/yd³ (kg/m³)
- A_v = air content, percentage
- C = mass of cement, lb/yd³ (kg/m³)
- D = oven dry density, lb/ft³ (kg/m³)
- d = diameter of test specimen, in. (mm)
- E_c = static modulus of elasticity of concrete, ksi (MPa)
- F = resistance to freezing and thawing, cycles
- f'_c = specified compressive strength of concrete, psi (MPa)
- f_{ct} = splitting tensile strength of concrete, psi (MPa)
- G_c = specific gravity of cement

G_s	=	specific gravity of sand
k	=	thermal conductivity of concrete, BTU/ft·°F (W/(m·K))
l	=	length of test specimen, in. (mm)
P	=	applied load, lb (N)
S	=	dry mass of sand, lb/yd ³ (kg/m ³)
w_p	=	moisture content, percentage
γ_f	=	as-cast density of concrete, lb/ft ³ (kg/m ³)
γ	=	air-dry density of concrete, lb/ft ³ (kg/m ³)
ρ_w	=	density of water, lb/ft ³ (kg/m ³)

2.2—Definitions

ACI provides a comprehensive list of definitions through an online resource, “ACI Concrete Terminology,” <http://concrete.org/Tools/ConcreteTerminology.aspx>.

CHAPTER 3—MATERIALS

3.1—Cement and supplementary cementitious materials

Cement for cellular concrete should meet the requirements of ASTM C150/C150M (portland cement), ASTM C595/C595M (blended hydraulic cements), or ASTM C1157/C1157M (performance specification for hydraulic cement). Blended cements include portland cement with pozzolans, slag cement, or other hydraulic cements alone or combined. Blended cement may result in slower rates of strength development during the first 3 to 5 days after placement. High-early-strength cement, such as Type III portland cement, produces cellular concrete with higher rates of early strength development.

Cellular concrete may incorporate supplementary cementitious materials (SCMs) such as fly ash, silica fume, metakaolin, or slag cement to provide specific properties to the mixture. Reduced heat of hydration and increased flowability are a few of the attributes gained by using these cementitious materials. Because these mineral admixtures may differ considerably in composition, fineness, and other properties, trial batching should be used to confirm final properties.

3.2—Water

Water for cellular concrete should be potable and free of deleterious amounts of acids, alkali, salts, oils, and other organic materials (ASTM C94/C94M). Nonpotable water may be used if testing shows that it produces the required physical properties (ASTM C109/C109M; ASTM C191).

3.3—Preformed foam

Preformed foam is created by diluting a liquid foam concentrate with water in predetermined proportions and passing this mixture through a foam generator. The density of the preformed foam is typically between 2.0 and 5.0 lb/ft³ (32 and 80 kg/m³).

The foam concentrate should have a chemical composition capable of producing and maintaining stable air cells that can resist the physical forces and chemical interactions imposed during mixing, pumping, and concrete setting

within the concrete mixture. If the cellular (air-cell) structure is unstable, it could break down during these steps, resulting in an increased concrete density. ASTM C796/C796M and C869/C869M contain procedures for evaluating foam concentrates used to produce a standard preformed foam mixture. The most commonly used proprietary foam concentrate formulations contain protein hydroxylates or synthetic surfactants. Further information concerning these formulations and procedures for using them is available from foam manufacturers.

3.4—Aggregates

3.4.1 Aggregates for cellular concrete should conform to ASTM C33/C33M, C144, C330/C330M, or C332. The authority with jurisdiction might permit aggregates not meeting these specifications if they are shown by test or actual service to produce cellular concrete that meets the required unit weight, strength, durability, and fire resistance.

3.4.2 The maximum aggregate size should not exceed one-fifth of the narrowest dimension between form sides, three-fourths of the minimum clear spacing between individual reinforcing bars or bundles of bars, or one-third of the depth of slabs. These limitations may be waived if workability and consolidation methods allow concrete placement without honeycombing or excessive voids.

3.5—Fibers

Cellular concrete may contain fiber reinforcement. Commercially available fibers include steel; alkali-resistant glass; synthetic fibers such as acrylic, aramid, carbon, nylon, polyester, polyethylene, and polypropylene; and natural fibers such as refined and raw cellulose, coconut, and bamboo.

Fibers can affect flow characteristics and improve the stability of the cellular structure of a fresh mixture. They can enhance cellular concrete's characteristics in the plastic state by controlling plastic shrinkage cracking by improving early-age tensile strength. They also enhance cellular concrete's characteristics in the hardened state, including post-cracking flexural and tensile strength, impact resistance, energy absorption, and spalling resistance (Zollo and Hays 1998).

Specifiers should choose fibers based on performance requirements. ASTM test methods such as ASTM C1399/C1399M and C1609/C1609M are useful in verifying performance. Specifiers should also verify durability of the selected fiber in the specific intended application.

3.6—Chemical admixtures

Cellular concretes may incorporate chemical admixtures such as water-reducing admixtures or accelerators. Water-reducing admixtures can improve compressive strength and reduce shrinkage cracking. Hot water, high-early-strength (Type III) cement, and chemical accelerators—used alone or in combination—accelerate setting. Cellular concrete in contact with steel should exclude admixtures containing intentionally added chloride ions. To avoid compatibility with the foaming agent, chemical admixtures used in cellular

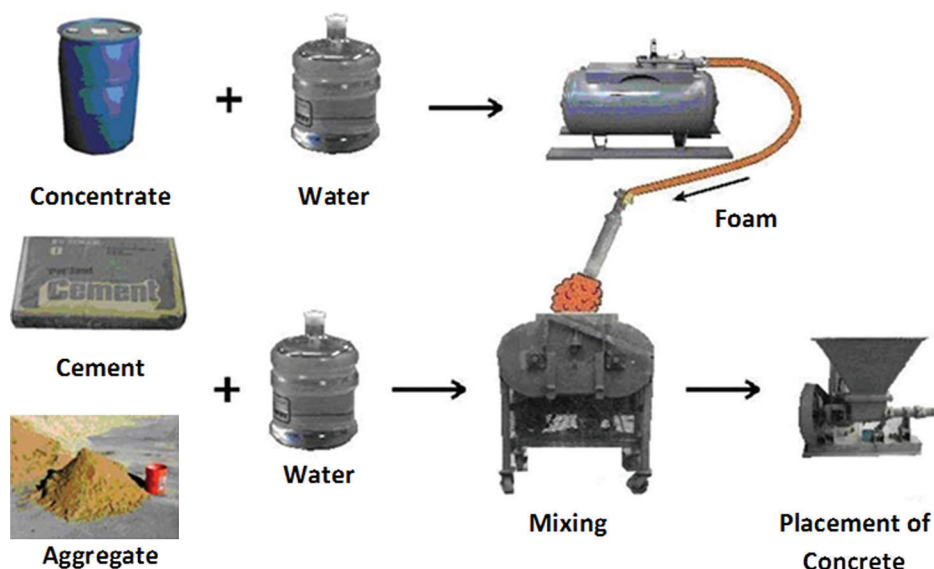


Fig. 4.3—Example of mixing sequence.

concrete should conform to ASTM C494/C494M following manufacturer's instructions, or should be evaluated in trial batches.

CHAPTER 4—MIXING AND HANDLING

4.1—Storage of materials

Materials should be stored in a manner that prevents deterioration and contamination by deleterious material. Manufacturers of specific foam concentrates should be consulted for storage and handling procedures. For example, some materials should not be stored in extreme temperatures.

4.2—Mixture proportioning

Manufacturers of foam concentrates should be consulted for specific mixture proportions, as-cast densities, and physical properties based on reliable test data for each individual application. Further details on cellular concrete mixture proportioning are given in Chapter 8.

4.3—Mixing procedure

Cellular concrete should be mixed mechanically to produce uniform distribution of materials at the specified as-cast density. Excessive mixing should be avoided, as it can cause changes in density and consistency. An example of the mixing sequence is shown in Fig. 4.3.

Specific batching and mixing sequences should be followed. Water and water-soluble admixtures are added to the mixer first, followed by cement, aggregate(s), and other admixtures. All ingredients except the preformed foam, which is added last, should be mixed to a uniform consistency. This sequence minimizes the destruction of gas cells. Varying the recommended sequence is permissible if it proves advantageous. Materials are proportioned to obtain design cast density at point of placement. Make allowances for any changes in cast density caused by method of placement, such as pumping.

When using transit-mix equipment, preformed foam should be added at the job site immediately prior to conveying the concrete to its final placement. The mixing time of 2 to 3 minutes is sufficient to integrate the foam into the mixture; however, actual mixing time can be longer, depending on the output of foam generator and concrete density. Add preformed foam at the batching plant if trial batches indicate the material maintains the required density and other properties to the point of placement at the job site.

4.4—Conveying

All conveying and placing equipment, whether manual or mechanical, should ensure a homogeneous mixture having a uniform cast density at the point of placement. Progressive cavity, peristaltic, or piston pumps are commonly used to place these cellular concretes. The pump hose diameter should be sufficient, usually 2 to 3 in. (50 to 75 mm), to ensure a continuous flow of uniform cellular concrete at the point of placement without mixture separation or substrate damage.

4.5—Curing

When rapid drying conditions exist, use a curing compound or wet curing. Traffic should be kept off freshly placed cellular concrete until it reaches adequate strength. Generally, it is not necessary to cure mass fill applications because they usually have fresh lifts placed over them on successive days. For precast applications, standard curing methods of ACI 308R would apply.

4.6—Weather considerations

Cellular concrete should not be mixed or placed during freezing weather, rain, or snow unless special precautions are taken. Use special precautions when anticipating ambient temperatures below 32°F (0°C) within 8 hours after placement. The use of Type III cement or heated mixing water increases the initial internal temperature of concrete and



Fig. 5.1.1—Reusable formwork for a wall panel



Fig. 5.1.2—Flowability of cellular concrete (video courtesy of Elastizell). See related video at http://www.concrete.org/Portals/0/Files/Media/ACI_523.3_Figure_5.1.2_Self-Leveling.mp4

accelerates the setting time. These precautions are usually adequate because of relatively high cement content and insulative properties of cellular concrete.

CHAPTER 5—FORMING AND FINISHING

5.1—Form systems

5.1.1 Formwork constructed of wood, steel, rigid plastic, aluminum, concrete, or other acceptable material can be either stay-in-place forms, which become part of the structure, or removable/reusable forms (Fig. 5.1.1). Forms should be designed to prevent undue deflection and distortion from the weight of the cellular concrete during placement. Reinforced cellular concrete should include provisions for accurately placing reinforcement in the forms. To prevent the forms from bonding with the cellular concrete, they should be coated with a form-release agent before placing. The forming guidance of ACI 347 is applicable.

5.1.2 Cellular concrete without coarse aggregates is very fluid (Fig. 5.1.2). For floor slabs and other installa-



Fig. 5.2—Finishing a cellular concrete floor.

tions where the hydrostatic pressure of the fresh concrete is relatively low, the normal forming procedures used with concretes containing coarse aggregates should be followed. For cast-in-place vertical walls or other applications where substantial casting depths are required, the forms should be tight, nonabsorptive, and designed to resist hydrostatic pressure that may cause openings in the forms through which the fluid cellular concrete or cement paste could flow.

5.2—Finishing

Cellular concrete should be finished to the elevation specified on the project drawings. The surface should be smooth and free from ridges, projections, and depressions (Fig. 5.2).

5.2.1 Finishing flatwork—The procedures for finishing cast-in-place cellular concrete flatwork vary with each application. After screeding to level or a specified slope with a straightedge and darby, floors may be steel-trowelled, if required. The cellular concrete finish should be compatible with the specified floor covering material.

5.2.2 Plastic shrinkage—Plastic shrinkage is principally caused by rapid evaporation of moisture from the surface that exceeds the bleeding rate, and is a potential cause of cracks in floor fill slabs and other applications. The use of fibers in the mixture may reduce the width of drying shrinkage cracks (Fig. 5.2.2).

When practical, frequent applications of light moisture (fogging) to the surface may maintain adequate moisture in the cellular concrete. Weather conditions may require a