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

Shotcrete—Guide

Reported by ACI Committee 506

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This guide is a companion document to ACI 506.2, "Specification for Shotcrete," and provides information on materials and properties of both dry-mix and wet-mix shotcrete. Most facets of the shotcrete process are covered, including application procedures, equipment requirements, and responsibilities of the shotcrete crew. Other aspects, such as preconstruction trials, craftsman qualification tests, materials tests, finished shotcrete acceptance tests, and equipment, are also discussed.

Keywords: dry-mix shotcrete; mixture proportioning; placing; quality control; shotcrete; wet-mix shotcrete.

CONTENTS

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PREFACE

This guide, based on many years of practice and experience, covers aspects of shotcrete construction, including materials, equipment, crew organization, preliminary preparation, proportioning, shotcrete placement, and quality assurance/quality control. Procedures vary from one region to another due to different materials, equipment, and techniques; therefore, adjustments for a particular project are often necessary.

New construction, repair, linings, coatings, refractories, underground support, and other special applications are also discussed. No attempt is made to provide guidelines for the design of shotcrete installations. The purpose of this document is to serve as a guide to engineers and contractors and as commentary to ACI 506.2, "Specification for Shotcrete."

Introduction

Shotcrete is an important and widely used construction technique. Because of continuing research and development in materials, equipment, and construction procedures, this guide is revised periodically to reflect current industry practice. Shotcrete is concrete placed by a high-velocity pneumatic projection from a nozzle. Shotcrete is thus a unique placement method for concrete. For the sake of readability, however, the word "shotcrete" is often used either to identify the shotcrete process (method of placement) or the shotcrete mixture.

Shotcrete has been used for structural concrete sections for decades. Although many engineers allowed shotcrete placement in their projects, there were no code provisions directly in ACI 318. In 2019, ACI 318 recognized the value of shotcrete in structural concrete for buildings and added shotcrete-specific code requirements.

History

In 1910, a double-chambered cement gun (dry-mix), based on a design developed by Carl Akeley, was introduced to the construction industry. The sand-cement product produced by this device was given the proprietary name "gunite". In the ensuing years, trademarks such as Guncrete, Pneucrete, Blastcrete, Blocrete, Jetcrete, and the terms "pneumatically applied mortar or concrete" and "sprayed concrete" were introduced to describe similar processes. Between 1930 and 1950, gunite/shotcrete gained wide acceptance around the world because, at that time, gunite/shotcrete strength was superior to concrete and permitted the contractor to easily transport a sand cement mixture over long distances to difficult-to-reach areas. In the early 1930s, The American Railway Engineering Association introduced the term "shotcrete" to describe the gunite process. In 1951, the American Concrete Institute adopted the term "shotcrete" to describe the dry-mix process. It is now also applied to the wet-mix process and has gained widespread acceptance in the United States and around the world.

In the 1950s, wet-mix shotcrete, the use of coarse aggregate in both processes, the rotary gun for dry-mix shotcrete, and more efficient concrete pumps for wet-mix shotcrete were introduced. Many improvements were made to wet-mix equipment, primarily concrete pumps and materials, in the 1970s and 1980s. These improvements allowed pumping low-slump shotcrete mixtures longer distances at greater volumes. These innovations enhanced the utility, flexibility, and general effectiveness of the process. More recently, there have been advances and developments in admixtures and robotic placement of shotcrete, broadening the range of shotcrete applications.

Centrifugally applied concrete and low-pressure, low-velocity, wet-process mortar and concrete are not considered shotcrete and not covered in this guide because they do not comply with the current definition of shotcrete; they do not

achieve sufficient consolidation to be considered shotcrete ("Application and Use of Shotcrete" 1981).

Applications

Shotcrete can be used instead of conventional concrete in many instances, the choice being based on convenience and cost. Shotcrete offers advantages over conventional concrete in a variety of new construction and repair work.

Reinforcement details may complicate the use of shotcrete, but shotcrete is particularly cost effective where formwork is impractical or where forms can be reduced or eliminated; access to the work area is difficult; thin layers, variable thickness, or both, are required; or normal casting techniques cannot be employed. The excellent bond of shotcrete to many materials is sometimes an important design consideration.

New developments

The future of shotcrete is limited only by the speed of development of new materials, equipment, and techniques. A prime example of major expansion in the use of shotcrete is in early and final lining ground support in tunnels and mines. Improvements in prepackaged products; accelerating and setting-control admixtures; the use of fibers; and specially designed equipment, including robotic and remote-control shotcrete devices, have spurred the development of ground support techniques competitive with conventional steel rib and lagging supports (ACI 506.5R; ACI PRC-506.1).

Research and development

The ability of the shotcrete process to handle and place materials that have almost instantaneous hardening capabilities should result in expanding applications in the future. Areas of future research and development include shotcrete structural design, nozzle design, in-place testing techniques, materials, equipment mechanization, substrate evaluation, process automation, surface finish, and evaluation of reinforcement encasement. The use of shotcrete in the construction industry will increase as more aspects of the shotcrete method from design to installation are developed.

PART 1—GENERAL

1.1—Scope

1.1.1 *Work specified (shotcreting processes)*—The work should be classified as either structural or nonstructural. Shotcrete having a specified compressive strength of 4000 psi (28 MPa) or greater is considered structural shotcrete. Shotcreting can be applied by one of the two processes: wet-mix or dry-mix. Shotcrete is further described according to the size of aggregate used (coarse or fine). Refer to Table 1.1.1 for fine-aggregate grading (No. 1) and coarse-aggregate grading (No. 2).

Table 1.1.1—Grading limits for combined aggregates

Sieve size, U.S. standard square mesh	Percent by weight passing individual sieves	
	Grading No. 1	Grading No. 2
3/4 in. (19 mm)	—	—
1/2 in. (12 mm)	—	100
3/8 in. (10 mm)	100	90 to 100
No. 4 (4.75 mm)	95 to 100	70 to 85
No. 8 (2.4 mm)	80 to 98	50 to 70
No. 16 (1.2 mm)	50 to 85	35 to 55
No. 30 (600 µm)	25 to 60	20 to 35
No. 50 (300 µm)	10 to 30	8 to 20
No. 100 (150 µm)	2 to 10	2 to 10

1.1.1.1 *Dry-mix process*—The dry-mix process consists of five steps and are as follows:

1. All dry ingredients, except water, are thoroughly mixed. Dry ingredients are predampened to contain approximately 6% moisture.
2. The cementitious aggregate mixture is fed into a special mechanical feeder or gun called the delivery equipment.
3. The mixture is usually introduced into the delivery hose by a metering device such as a feed wheel, rotor, or feed bowl. Some equipment uses air pressure alone (orifice feed) to deliver the material into the hoses.
4. The material is carried by compressed air through the delivery hose to a nozzle body. The nozzle body is fitted inside with a water ring through which water is introduced under pressure and thoroughly mixes with the other ingredients.
5. The material is jetted from the nozzle at high velocity onto the surface to be shotcreted.

1.1.1.2 *Wet-mix process*—The wet-mix process consists of five steps and are as follows:

1. All ingredients, including mixing water, are thoroughly mixed.
2. The shotcrete mixture is introduced into the chamber of the delivery equipment.
3. The mixture is metered into the delivery hose and moved by positive displacement.
4. Compressed air is injected at the nozzle to increase velocity and improve the shooting pattern.
5. The concrete is jetted from the nozzle at high velocity onto the surface to be shotcreted.

1.1.1.3 *Comparison of processes*—Either process can produce shotcrete suitable for typical construction requirements. Differences in capital and maintenance cost of equipment, operational features, suitability of available aggregate, and placement characteristics, however, may make one or the other more attractive for a particular application. Table 1.1.1.3 gives differences in operational features and other properties that merit consideration.