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# Guide for Specifying Underground Shotcrete

Reported by ACI Committee 506

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# Guide for Specifying Underground Shotcrete

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**American Concrete Institute**
**38800 Country Club Drive**
**Farmington Hills, MI 48331**
**U.S.A.**
**Phone: 248-848-3700**
**Fax: 248-848-3701**

**www.concrete.org**

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# Guide for Specifying Underground Shotcrete

Reported by ACI Committee 506

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| John R. Fichter | | | |

*Subcommittee members who produced this report.
†Subcommittee Co-chairs who produced this report.
The Committee acknowledges Bill Edgerton, Janice Lindell, J. Denis O'Donnel, Sr., a[illegible] Fred Sherrill for their contributions to this report.

*This document provides a guide for owners, contractors, designers, and testing, specifying, and inspection organizations engaged in the application of shotcrete for underground support. The guide provides general information for the selection of constituent materials, and methods for proportion shotcrete. Typical methods of batching, mixing, and handling of proportioned shotcrete materials are detailed along with shotcrete placement methods and equipment.*

**Keywords:** acceptance criteria; batching; inspection; methods of payment; mine and tunnel support systems; mixing and placement equipment; mixture proportioning; preconstruction and construction testing; quality assurance; quality control; safety; shotcrete; shotcrete application.

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## CHAPTER 1—INTRODUCTION AND SCOPE

### 1.1—Introduction

Shotcrete, the method of spraying concrete onto a surface, is ideally suited for the support and construction of underground excavations in earth and rock structures. The pneumatic projection of shotcrete onto a surface at high velocity provides specific quality enhancements that interact with the ground surface and prepared substrates, providing superior bond characteristics; increased density; and resultant strength, durability, and toughness. These qualities are desirable in ground support and lining applications. In North America, shotcrete is conventionally defined as pneumatically applied concrete, while in Europe it is more commonly referred to as sprayed concrete.

Although concrete plays a very important role in underground construction, shotcrete has many advantages over concrete. Final concrete linings for tunnel and underground structures are typically composed of cast-in-place or precast concrete sections that provide a structurally sound and durable subsurface infrastructure. The principal disadvantage with these systems is that they are difficult to install during the excavation phase of tunnel construction. They require formwork or assembly systems that simply cannot be employed in tunnel openings where the immediate concern is ensuring a safe and stable excavation. Accordingly, the cast-in-place lining is often placed after excavation is complete, which results in a much longer time to complete the tunnel.

In contrast, shotcrete in combination with other support elements can provide early and effective ground support and, therefore, a means of ground control necessary for safe, viable, and economic tunnel construction under a wide range of geological conditions.

Shotcrete technology has been broadly developed throughout the construction industry over the last century. The evolution of mining and civil tunneling methods has placed unique demands on the materials, equipment, and personnel that comprise current concepts of a shotcrete system for underground support. With this gradual evolution in technology and trial and error, came acceptance, adaptation, and new means and methods of successful shotcrete application. The design and placement of shotcrete underground is much more challenging than shotcreting above ground.

Underground construction and shotcrete application are unique and very demanding. The primary focus is worker safety and the need to provide immediate and effective ground support. Whereas the industry as a whole would accept the performance associated with the compressive strength developed in shotcrete at 28 days, early 8-hour to 1-day strength is critical to the performance of underground shotcrete. Much of the shotcrete is applied overhead to irregular tunnel profiles immediately following blasting or other modes of excavation. Geological and groundwater conditions are not always predictable; opening stability and rockfalls present a clear hazard to the shotcrete crew. Conditions may be such that the window available for shotcrete application is minutes or a few hours. The use of accelerating admixtures is a unique feature of underground shotcrete application in that it provides a means of controlled and rapid strength gain immediately following application.

Tunnel or mining activities typically take place on a continuous and cyclical basis. The process of excavation, muck removal or mineral extraction, and ground support installation are repeated. To be viable and acceptable, shotcrete application should be an integral part of the overall cycle. This requires that the shotcrete system as a whole be reliable, efficient, and effective.

The underground environment can impose significant constraints and demands on the batching, mixing, handling, and placement of shotcrete. The unique logistical demands associated with underground shotcrete application may require access to the underground work area via shaft, adit, or ramp, and the subsequent use of long and restrictive haulage routes or dropping through a borehole or slickline. This frequently results in extended handling and discharge times. At any time, production can be disrupted, and shotcrete installation delayed or disrupted. This is particularly problematic if ground conditions deteriorate and the demand for shotcrete as ground support becomes more critical. Finally, the environment is hostile for worker safety, efficiency, and quality control, as well as for quality shotcrete placement and curing conditions. Figures 1.1 to 1.3 illustrate typical conditions at the heading of tunnels and mines.

These types of problems have led to specifically designed systems for batching and handling of shotcrete materials, admixtures, and placement equipment. These systems require significant investment not only in terms of capital, but also in providing experienced supervisory shotcrete and production personnel. Training and supervision have led to improvements in the quality and consistency of shotcrete in underground shotcrete applications. The consequences of deficient shotcrete in any ground support application are obvious. Quality assurance, quality control, and the associated inspection and testing activities are equally important in achieving a successful shotcrete program.

A major task faced by the underground shotcrete industry is the ability to demonstrate to owner, designer, specifier, and inspection and testing personnel that high-quality shotcrete can be produced consistently. It is therefore important that owners and others have an understanding and appreciation of how a shotcrete system—materials, batching, handling, placing equipment, and trained quality supervisory and production personnel—fits into their underground project so as to ensure that shotcrete specifications are met. The efforts

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