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

Specifying Underground Shotcrete—Guide

Reported by ACI Committee 506

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Specifying Underground Shotcrete—Guide

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Specifying Underground Shotcrete—Guide

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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 to 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(s); mixing; mixture proportioning; placement; quality assurance; quality control; safety; shotcrete; testing; tunneling.

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CHAPTER 1—INTRODUCTION AND SCOPE

1.1—Introduction

In North America, the term "shotcrete" is used and defined by the American Concrete Institute's "ACI Concrete Terminology" as "concrete placed by a high-velocity pneumatic projection from a nozzle", while in Europe, shotcrete is commonly referred to as "sprayed concrete".

Shotcrete is ideally suited for underground applications in tunneling and mining as an initial support measure in soft ground as well as hard rock, as an installation method for final linings, or in underground rehabilitation or expansion projects.

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, strength, durability, and toughness. In addition, shotcrete provides the geometric and operational flexibility required for many underground operations and—especially if sprayed using robotic equipment—provides a safer working environment, compared to other support installation methods under unsupported ground or if immediate support is needed. These qualities are desirable in ground support and lining applications and provide economic and technical advantages compared to the other initial support systems and materials.

Cast-in-place (CIP) concrete is widely used in underground tunneling for final linings, especially if a constant cross section geometry over long distances allows the use of highly mechanized formwork. However, if the geometry is changing or the tunnel is too short to justify the investment for a mechanized formwork, shotcrete has many advantages over CIP concrete for final linings due to the inherent flexibility of the method to cover a large range of opening shapes and sizes. This allows for certain structures such as enlarged cross sections, intersections, or penetrations to be constructed with less effort in comparison to CIP concrete.

Geometrical flexibility for final linings is also a key advantage for rehabilitation and expansion projects. In addition, many of these projects are constructed under stringent operational limitations, providing, for example, very limited and strict time windows for construction. The operational flexibility of shotcrete allows for a stop-and-go installation of concrete and provides a key advantage of shotcrete to other installation methods.

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 and lining construction. With this gradual evolution in technology and trial and error came acceptance, adaptation, and new means and methods of successful shotcrete application.

The design, working conditions, and placement of shotcrete underground are unique, very demanding, and generally much more challenging than shotcreting above ground. The majority of underground shotcrete is installed overhead or sub-vertical, making the correct installation technique and strength development over time crucial.

The primary focus during shotcrete installation underground is worker safety, due to the need to provide immediate and effective ground support and to use proper installation procedures to avoid fallouts of fresh concrete. For the construction industry as a whole, the specification of a 28-day compressive strength is typically sufficient; however, the early strength performance of underground shotcrete during the first hours or days is often critical. Much of the shotcrete is applied overhead to irregular surface substrate 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 underground workers. 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.

Tunneling 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 in every excavation and support round. To be viable and acceptable, shotcrete application should be an integral part of the overall cycle. This requires that the shotcrete system 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, and ramp, and the subsequent use of long and restrictive haulage routes or dropping concrete through a borehole or

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