SHOTCRETE FOR THE CRAFTSMAN (CCS-4)

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This education document for the shotcrete craftsman was prepared by Jean-François Dufour, Chair of ACI Committee C660, Shotcrete Nozzleman Certification, and Marc Jolin, ACI Committee C660 Secretary, from the original CCS-4 booklet that was developed by Lars Balck, Steven Gebler, Merlyn Isaak, Dudley Morgan, and Philip Seabrook. The review of this education document was performed by the aforementioned original authors and additional ACI Committee C660 members, including Patrick Bridger, Raymond Schallom, Lawrence Totten, Curtis White, George Yoggy, and Chris Zynda, who were all key in the improvement and support of this new document.

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Preface

The purpose of this document is to understand basic concrete technology, and describe and illustrate how to properly place quality shotcrete.

Shotcrete is a method of placing concrete at high velocity onto a surface and is used primarily in the construction of vertical and overhead surfaces. Shotcrete allows construction of walls and other structures using only a one-sided form. In some situations, it is more economical than conventionally-cast concrete. Tanks, swimming pools, tunnels, mines, sculptured rocks, structural walls, erosion control embankments, subterranean retaining walls, and shear walls are typical structures commonly built using shotcrete. In addition, a wide variety of repairs also employ the shotcrete process.

The nozzleman is the craftsman that physically directs the placement of the shotcrete. The nozzleman is responsible for the quality of the placed shotcrete and is the most important member of a shotcrete crew. The nozzleman must have an understanding of the equipment's operation, safety procedures, and the material being placed.

Although this workbook is directed to nozzlemen, they are not the only important people involved in a shotcrete project. The owner, engineer, contractor, job superintendent, foreman, and shotcrete crew are all important. Only with the cooperation and dedication by everyone involved will a project be successful.

Information in this workbook should be used as a guide to good practice. ACI 506.2, "Specification for Shotcrete," and ACI 506R, "Guide to Shotcrete," should also be consulted. The plans and specifications for a specific construction project must be followed.

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CHAPTER 1—WHAT THE SHOTCRETE CRAFTSMAN SHOULD KNOW ABOUT CONCRETE

It seems logical to expect that the craftsman should know the basics of concrete. A shotcrete craftsman should know what concrete is made of and how it behaves. Shotcrete workers should know the basic properties of concrete and should also recognize safety precautions needed to protect themselves and their fellow workers when they are placing and finishing concrete.

Understanding the basics of concrete will help workers to produce better concrete. Most of this manual deals with shotcrete use, but many of the principles discussed also apply to other types of concrete work.

As such, Chapter 1 of this workbook is an overview of plastic and hardened concrete properties in general. Chapter 2 describes various key ingredients of concrete mixtures and Chapter 3 presents general mixture proportions. Chapters 4 to 12 pertain to shotcrete technology and include topics such as materials, equipment, preparation before shooting, placement, principles and techniques, communication, environmental conditions and precautions, finishing and tolerance controls, safety, and testing/quality.

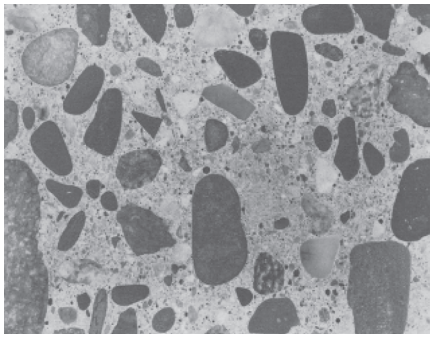

Fig. 1.1—Polished section sawed from concrete. The cement-and-water paste coats each piece of aggregate and fills all spaces between aggregate particles (photo courtesy of the Portland Cement Association).

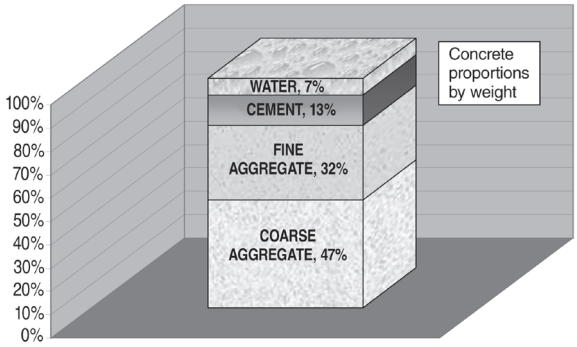

Fig. 1.2—Proportions by weight of materials in typical concrete mixture, freshly mixed. In other mixtures, total aggregate may range by weight from 70 to 80% and cement from 13 to 20%. Typical shotcrete mixture proportions by weight are presented in Table 3.1.

1.1—What is Concrete?

Concrete is the most widely used construction material today. Worldwide, approximately 1 ton is produced every year for every living human being. This happens because concrete is the least costly, most readily-available construction material. Fortunately, it is also strong and durable, resistant to water and fire, and readily formable to an infinite variety of sizes and shapes (a key advantage for shotcrete).

The success of concrete construction depends on the concrete developing the strength and other properties that the designer specified when the work was planned. Much of this concrete quality depends directly on the workers in the field. Because they work with it, they should understand some important factors affecting the properties of concrete.

Concrete is a mixture of two components: aggregate and paste. The paste is made of portland cement and water, and acts as the glue that binds the aggregates (sand and gravel or crushed stone) into a rock-like mass as the paste hardens, due to the chemical reaction of the cement and water (Fig. 1.1).

The term cement used throughout this section refers to portland cement unless otherwise stated (see Section 2.1). People sometimes refer to the mixture of cement, water, and aggregates as cement, but this is technically wrong; it is concrete. Only the binding powder is properly called cement.

Aggregates are usually divided into two groups: fine and coarse. Fine aggregates consist of natural or manufactured sand with particle sizes ranging up to 5 mm (1/4 in.); coarse aggregates are those with most particles retained on the 5 mm sieve (1/4 in.) and ranging up to 150 mm (6 in.). The most commonly used maximum aggregate size in concrete is 20 to 40 mm (3/4 to 1.5 in.) (see Section 2.3).

Paste comprises portland cement, water, and entrapped air or purposely entrained air. Cement paste ordinarily constitutes approximately 20 to 30% of the total weight of concrete. Figure 1.2 shows that the total weight of cement is usually between 13 and 20% and the water between 7 and 10% in a typical concrete mixture. The air content in air-entrained