OBJECTIVE SHEET

SHOTCRETE

5

INTRODUCTION

Shotcrete is a special application of concrete that requires the concrete mixture to be applied to a surface at a sufficient velocity in order to obtain compaction. Shotcrete is normally used for building and repairing vertical and overhead structures.

FOCUS ASSIGNMENTS

FOCUS ASSIGNMENTS

1. Research uses of shotcrete.
2. Give a brief presentation to the class.

UNIT OBJECTIVE

After completing this unit, you will show the following competencies by scoring at least 85% on the Written Test.

SPECIFIC OBJECTIVES

1. Define shotcrete.
2. Identify different uses for shotcrete.
3. Describe the two techniques for applying shotcrete.
4. List the advantages and disadvantages of each shotcrete method.
5. State the materials required for making shotcrete.
6. Explain the purpose of common admixtures used in shotcrete.
7. List the types of equipment used in shotcrete.
8. Describe the duties and responsibilities for each member of a shotcrete crew.
9. Identify the different methods for preparing a surface.
10. State the techniques for applying reinforcement.
11. Name the types of joints used in shotcrete.
12. Describe the methods for applying shotcrete.

13. List factors that affect the amount of rebound.

14. Describe the effects of different finishing techniques.

15. Explain the purpose of curing.

16. List methods for avoiding injury.

SHOTCRETE

OBJECTIVE 1

Define shotcrete.

Shotcrete is an all inclusive term referring to the application of concrete through a wet or dry mix process. The concrete is applied through a hose with air pressure at a high velocity. The process causes the concrete to be compacted and placed in one operation. Shotcrete can be applied over steel rods, steel mesh, or fibers. It can be applied to both horizontal and vertical surfaces.

OBJECTIVE 2

Identify different uses for shotcrete.

- Repair

  EXAMPLES: Bridges, marine structures, spillway surfaces, buildings

- Underground areas (Figure 1)

  FIGURE 1

  EXAMPLES: Tunnels, mines, quarries

- Slope stabilization

  EXAMPLES: Rock slopes, earth embankments, creek channels

- Walls

- New structures (Figure 2 & 3)

FIGURE 2

FIGURE 3

EXAMPLES: Swimming pools, dome structures, military structures, housing

- Architecture

  EXAMPLES: Zoo exhibits, sculptures, ponds and waterfalls, golf course architecture

OBJECTIVE 3

Describe the two techniques for applying shotcrete.

WORDS YOU SHOULD KNOW	
aggregate	sand, gravel, crushed stone, and other similar materials that are mixed with cement and water to make concrete
admixture	any material, other than cement, water, aggregates, and fiber reinforcement, that is added to the concrete mixture before or during the mixing process

- **Dry-mix shotcrete** — A dry mixture of cement, admixtures, and aggregates is pushed through a hose at a high velocity. Water is added as the mixture exits the nozzle. Dry-mix is sometimes referred to as gunite.

- **Wet-mix shotcrete** — Water, cement, admixtures, and aggregates are first mixed together. Using compressed air, the mixture is sent through the hose and released at the nozzle.

OBJECTIVE 4

List the advantages and disadvantages of each shotcrete method.

WORDS YOU SHOULD KNOW	
rebound	excess aggregate and cement that bounces away from the surface on which the shotcrete is being applied

- **Advantages of dry-mix shotcrete**

  - ❏ Allows for longer hose lengths

  - ❏ Stronger than regular concrete

- ❑ Lower equipment maintenance costs
- ❑ Higher bond strengths

- **Disadvantages of dry-mix shotcrete**
  - ❑ Poor resistance to freezing conditions
  - ❑ Lower rates of production
  - ❑ Greater occurrences of rebound
- **Advantages of wet-mix shotcrete**
  - ❑ Compatible with all ordinary admixtures
  - ❑ Resistant to freezing conditions
  - ❑ Higher rates of production
  - ❑ Less occurrences of rebound
- **Disadvantages of wet-mix shotcrete**
  - ❑ Allows limited hose lengths
  - ❑ No stronger than regular concrete
  - ❑ Higher equipment maintenance costs
  - ❑ Lower bond strengths (though usually higher than regular concrete)

OBJECTIVE 5

State the materials required for making shotcrete.

WORDS YOU SHOULD KNOW	
silica fume	extremely fine noncrystalline silica produced by electric arc furnaces as a byproduct of the production of metallic silicon or ferrosilicon alloys
air entrainment	tiny air bubbles added during the mixing process

- Cement
- Silica fume

- Coarse aggregate
- Concrete sand
- Water

✔ **NOTE:** Wet-mix shotcrete also requires water reducer and air entraining admixtures.

OBJECTIVE 6

Explain the purpose of common admixtures used in shotcrete.

WORDS YOU SHOULD KNOW	
pozzolan	powdery material that does not in itself contain cement-like properties, but that when combined with water and added to calcium hydroxide at normal temperatures, will display cement-like properties

✔ **NOTE:** Air-entraining, water-reducing, and retarding admixtures are only used in wet-mix shotcrete.

- **Air-entraining admixtures** — Creates tiny air bubbles in the concrete that enable the shotcrete to be more resistant to freezing and thawing and increases the ease at which the shotcrete mixture is pumped through the equipment.
- **Water-reducing admixtures** — Reduces the required amount of water, which increases the strength of the shotcrete.
- **Retardants** — Slows the time in which it takes the concrete to set in order to allow more time to work with the mixture. Retarding admixtures are used during high temperatures and when applying shotcrete to vertical surfaces where finishing is required.
- **Accelerators** — Decreases the time it takes the concrete to set, which enables the shotcrete to stick to overhead surfaces or to achieve strength in less time than is normally required. Accelerating admixtures are commonly used when building or repairing tunnels.
- **Pozzolans** — Improves the workability of the shotcrete mixture and increases the ease at which the shotcrete is pumped through the equipment. Certain pozzolans can increase the strength and sulfate resistance of the shotcrete.

- **Latex admixtures** — Increases the strength of the shotcrete and its bonding ability. Latex admixtures are commonly used in repairing concrete structures in marine environments.

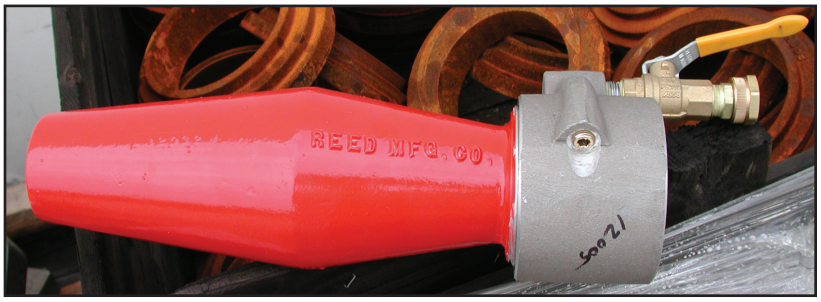
OBJECTIVE 7

List the types of equipment used in shotcrete.

- **Guns** — There are two types of guns used for both wet-mix shotcrete and dry-mix shotcrete. In wet-mix shotcrete there is the double-chamber gun and the continuous feed gun. In dry-mix shotcrete there are the single-chamber and double-chamber guns and the continuous feed gun. (Figures 4 and 5)

FIGURE 4

FIGURE 5



Photos courtesy of Reed Manufacturing.

- **Air compressors** — The air compressor must provide sufficient capacity and be in good working condition in order for the shotcrete to be successfully applied. The air compressor should maintain dry, clean, oil-free air. Higher volumes of air are required at higher elevations. The requirements for using compressed air are dependent upon the type of equipment being used, the conditions in which the shotcrete is being applied, and the methods used to apply the shotcrete. Check the gun or pump manufacturer's recommendations for the required capacity of the air compressor. (Figure 6)

FIGURE 6

Photo courtesy of Reed Manufacturing.

- **Mixing equipment** — Wet-mix shotcrete is normally prepared away from the site and transported to the location after the mixing process. Dry-mix shotcrete is normally prepared at the job location. There are two types of mixers used at a job location: batch mixers (Figure 7) and continuous mixers. (Figures 8)

FIGURE 7

FIGURE 8

Photos courtesy of Reed Manufacturing.

- **Hoses** — All hoses should be the proper size, type, and strength and should use safety restraints at all joints.

  - ❑ **Air hose** — Supplies air to the shotcrete gun, nozzle (used in wet-mix shotcrete only), blowpipe, and other air operated equipment; should be able to withstand twice the operating pressure, and should be light, flexible, noncollapsible, and resistant to kinking and abrasion. (Figure 9)

FIGURE 9

Photo courtesy of Reed Manufacturing.

- ❑ **Water hose** — Supplies water to the pump, mixer, and nozzle; must have at least a ¾ inch inside diameter.

- ❑ **Material hose** — Supplies concrete mix to the nozzle; must have an inside diameter of at least three times the size of the largest aggregate particle included in the mix (Figure 10).

  ✔ **NOTE:** When using dry-mix shotcrete, static electricity in the material hose can sometimes occur. To solve this problem, use a ground wire.

FIGURE 10

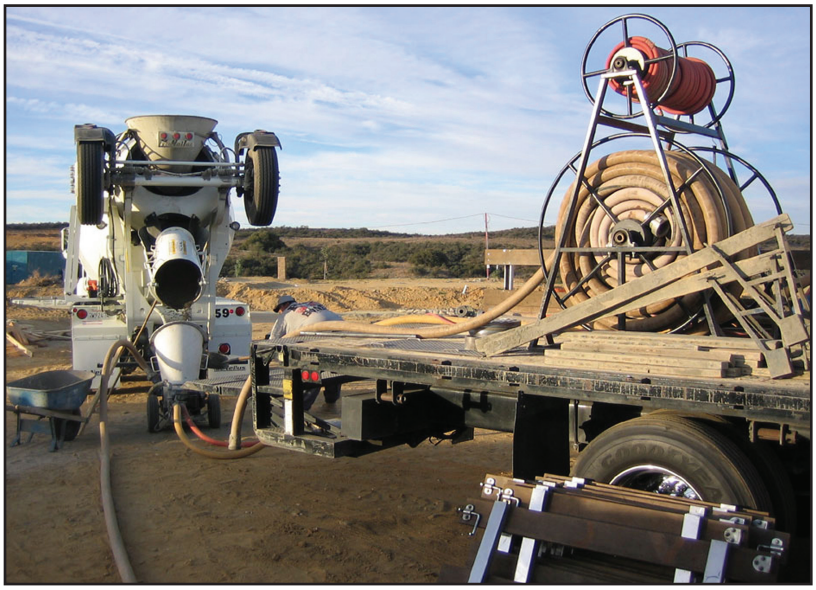


Photo courtesy of Reed Manufacturing.

- **Nozzles** — The nozzle is attached to the material hose. The dry-mix nozzle includes a nozzle tip, water ring, control valve, and water body (Figure 11). The wet-mix nozzle includes a rubber nozzle tip, air injection ring, control valve, and housing.

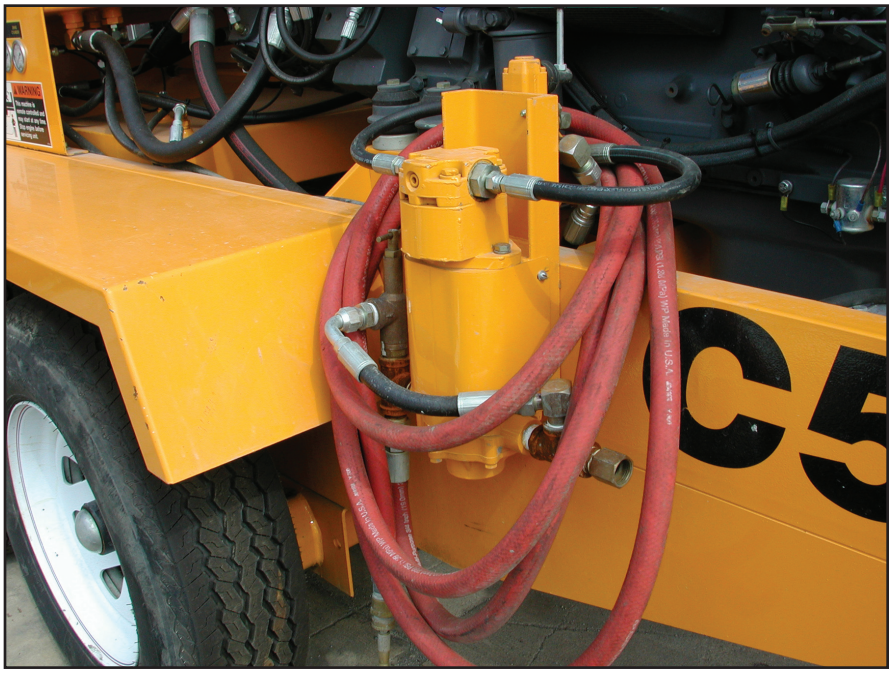
FIGURE 11

Photo courtesy of Reed Manufacturing.

- **Auxiliary equipment** — Auxiliary equipment includes water booster pumps, scaffolding, water heaters, air movers, communication devices, space heaters, lighting, blow pipes, aggregate dryers, fiber feeders, and admixture dispensers (Figures 12 & 13).

FIGURE 12

FIGURE 13



Photos courtesy of Reed Manufacturing.

OBJECTIVE 8

Describe the duties and responsibilities for each member of a shotcrete crew.

WORDS YOU SHOULD KNOW	
overspray	aggregates and cement particles that are deposited on nearby surfaces during the shotcrete process

- **Foreman** — The cement mason foreman is in charge of the overall shotcrete project. He or she schedules and organizes the workers, ensures all safety precautions are observed, confirms the shotcrete application is of acceptable quality, verifies all equipment is properly maintained, and orders all materials necessary for the completion of the project.

- **Nozzleman** — The nozzleman is considered the leader of the shotcrete operation. He or she works with the foreman, finishers, and gunman to organize the project activities. The main tasks of the nozzleman include operating the nozzle, controlling water addition in dry-mix shotcrete and controlling the volume of air in wet-mix shotcrete, and verifying all surfaces are properly prepared before the shotcrete is applied. A nozzleman is often an accomplished finisher and gunman.

- **Gunman** — The gunman is only present during dry-mix applications of shotcrete. He or she operates the delivery equipment, manages the process of mixing the shotcrete materials, operates and maintains the shotcrete machine, and ensures that the nozzleman receives a constant flow of shotcrete mixture during the application process.

- **Pump Operator** — The pump operator is only present during wet-mix applications of shotcrete. He or she operates the pump during the shotcrete application process, tests the shotcrete mixture to monitor the water content, and cleans and maintains the pump and material hose.

- **Mixer Operator** — The mixer operator measures and mixes together the concrete materials, cleans the equipment used for mixing, and is responsible for the storage, care, and accessibility of the concrete materials.

- **Finisher** — The finisher trims and shapes the shotcrete after it is applied to the surface. He or she can substitute for the nozzleman and gunman. The finisher and assistant nozzleman positions are sometimes combined.

- **Assistant Nozzleman** — The assistant nozzleman carries out the work of the nozzleman during the nozzleman's absence. He or she relays signals between the gunman and nozzleman and operates the blowpipe, if one is required. The assistant nozzleman can be a cement mason apprentice to the nozzleman and usually he or she requires gunman experience (Figure 14).

FIGURE 14

✔ **NOTE:** Other task assignments include the shotcrete equipment, removing rebound and overspray, and supporting all other workers on the project.

OBJECTIVE 9

Identify the different methods for preparing a surface.

- **Earth surfaces** — Apply a water control measure if the ground is wet; compact the earth and fill in all holes; trim to line and grade; keep surface damp for several hours before applying shotcrete. Do not apply shotcrete to frozen ground.

- **Rock surfaces** — Remove all lose debris from the surface.

- **Concrete and masonry surfaces** — Remove all lose debris and unsound elements; saturate the concrete with potable water.

OBJECTIVE 10

State the techniques for applying reinforcement.

WORDS YOU SHOULD KNOW	
plastic shrinkage cracking	cracking that occurs on freshly placed shotcrete; this is caused when the rate of evaporation is greater than the rate of bleeding
bleeding	water that appears on the surface of freshly applied concrete

✔ **NOTE:** Unreinforced shotcrete is like unreinforced concrete. It is a brittle material that can crack from drying and shrinkage, extreme weather conditions, and heavy weights.

- **Reinforcing bars** — Place the steel bars 6 to 12 inches apart. Using the appropriate air pressure, and holding the nozzle at the proper distance, apply the shotcrete so that it flows either around or behind the steel bars. Remove any rebound or overspray (Figure 15).

FIGURE 15

✔ **NOTE:** Do not allow the steel bars to vibrate during the shotcrete application process. Vibrating will create spaces between the steel bar and the surrounding shotcrete called rebar shadowing.

- **Welded wire mesh** — Tie the wire mesh securely in place. If more than one layer of wire mesh is required, cover the first layer of wire mesh before placing the second layer. Use one layer of wire mesh per every three inches of shotcrete. If both wire mesh and reinforcing bars are used, place the wire mesh over the steel bars.

- **Steel fibers** — Steel fibers increase the strength of shotcrete and reduce dry shrinkage and cracking. The nozzleman must make sure the fibers are evenly distributed. Safety goggles must always be worn when working with steel fibers. To apply steel fibers, follow the manufacturer's instructions.

- **Synthetic fibers** — Synthetic fibers reduce plastic shrinkage cracking. Ensure that the shotcrete is evenly distributed, and follow the manufacturer's instructions.

OBJECTIVE 11

Name the types of joints used in shotcrete.

- **Construction Joints** — Use a square compressive joint if the joint will be subjected to compressive stress. Remove any trapped rebound or overspray near the joint. Thoroughly clean the joint before applying any additional shotcrete. Square construction joints are normally not used because they can form a trap for rebound and overspray.

- **Contraction Joints** — Use contraction joints to control shrinkage cracking in shotcrete. Contraction joints can be created by using strips of metal, plastic, or wood, or by sawcutting the shotcrete shortly after it has set. Spacing of contraction joints depends on the architectural design of the structure.

OBJECTIVE 12

Describe the methods for applying shotcrete.

- Hold the nozzle at a 90 degree angle.

  ✔ **NOTE:** This rule does NOT apply if you are applying shotcrete to an interior corner, or if you are encasing reinforcing steel.

- Keep the nozzle approximately three feet away from the surface.

✔ **NOTE:** If the distance between the nozzle and the surface is greater than three feet, the amount of rebound increases and the compaction and strength of the shotcrete is reduced. If the distance between the nozzle and the surface is less than three feet, the amount of rebound is also increased if the pressure is not reduced.

- Move the nozzle in a circular motion across the surface as the shotcrete is being applied.

  ✔ **NOTE:** Do not point the gun at one spot for a long time. This causes the occurrence of rebound.

- Apply shotcrete to vertical and horizontal corners first.

- When applying shotcrete around a reinforcing steel bar, hold the nozzle at a slight angle.

  ✔ **NOTE:** Ensure that the front of the steel bar remains clean until the entire steel bar is encased. Use a blowpipe to remove rebound from either the top or behind the steel bar during the encasing process.

OBJECTIVE 13

List factors that affect the amount of rebound.

✔ **NOTE:** The control of rebound is essential to the quality of shotcrete.

- Nozzle position (Figure 16)

FIGURE 16

Photo courtesy of Reed Manufacturing.

✔ **NOTE:** The nozzle should always be held at a 90-degree angle.

- Distance between nozzle and surface
- Shotcrete mixture
- Equipment
- Skill of the nozzleman
- Air pressure
- Velocity
- Water content
- Size and gradation of aggregates
- Amount of reinforcement
- Layer thickness

✔ **NOTE:** Always remove rebound. Do not work rebound back into the shotcrete. Do not include removed segments of rebound in later batches of shotcrete.

OBJECTIVE 14

Describe the effects of the different finishing techniques.

WORDS YOU SHOULD KNOW	
consistency	the ability of freshly mixed concrete to flow easily and smoothly
cutting screed	a sharp-edged tool used to trim shotcrete (Figure 17)
finish coat	a final, thin coat of shotcrete that is applied before hand finishing
gun finish	the final and natural layer of shotcrete that is applied during the regular shotcrete process
flash coat	a light coat of shotcrete that is used to cover minor inconsistencies in the surface; usually applied at a distance of 8 to 12 feet

FIGURE 17

Photo courtesy of Reed Manufacturing.

✔ **NOTE:** It is easier to apply finishing techniques to wet-mix shotcrete because it contains a higher consistency in the mixture.

- **Natural (gun) finish** — Provides a textured, uneven surface that is suitable for most applications.

  ✔ **NOTE:** A natural finish provides structural soundness and durability. Additional finishing can cause problems with the durability of the shotcrete.

- **Flash and finish coats** — Smoothes out the texture left by a gun finish.

- **Final finishes** — Finishes a flash or finish coat.

  ❑ **Wood float** — Provides a uniform yet granular texture

- ❏ **Rubber float** — Applied to wood float finish or flash coat to leave a finer finish
- ❏ **Brush finish** — Provides a finely textured, sandy finish
- ❏ **Trowel finish** — Provides a dense, smooth finish

FIGURE 18

Photo courtesy of Reed Manufacturing.

OBJECTIVE 15

Explain the purpose of curing.

WORDS YOU SHOULD KNOW	
curing	maintaining sufficient moisture in the concrete during the early stages after its application in order to develop the desired properties

- Strengthens shotcrete
- Prevents shotcrete from losing moisture, which can cause shrinking and cracking
- Minimizes damages caused by freezing

✔ **NOTE:** Curing requires that the surface be continuously wet for at least seven days. Use fogging and misting tools to accomplish curing. Sprinklers and soaking hoses can also be used. An alternative method is to place plastic sheeting tightly over the surface to prevent moisture from escaping.

OBJECTIVE 16

List methods for avoiding injury.

- Always follow the manufacturer's instructions when using any type of equipment.
- Work cautiously around the dry-mix guns, concrete pumps, air compressors, and material hoses .
- Verify that all equipment is turned off and disconnected before cleaning or repairing.
- Inspect hoses, couplings, and nozzles on a regular basis.
- Always wear protective clothing (goggles, overalls, gloves, work boots, and hard hat).
- Use additional safety equipment when required (life jackets, harnesses with safety lines, helmet lamps, etc.).

  ✔ **NOTE:** Additional safety equipment should be kept in an easily accessible area. This includes eye wash, ear protection, respiratory protection, and a first aid kit.