

Shotcrete

CM-420
Temporary Structures



Field Application of Shotcrete
An overview of field shotcrete operations

CM-420 Temporary Structures

Excavate



UNIVERSITY OF WASHINGTON

2

CM-420 Temporary Structures

Muck



Material removed in the process of excavating or mining

UNIVERSITY OF WASHINGTON

3

Shotcrete

CM-420 Temporary Structures

Support



UNIVERSITY OF WASHINGTON 4

CM-420 Temporary Structures



UNIVERSITY OF WASHINGTON

CM-420 Temporary Structures

Introduction and History

- The shotcrete process has grown into an important and widely used construction technique.
- In 1910, a double chambered cement gun was introduced to the construction industry.
- The sand-cement product of this device was given the proprietary name Gunitite.
- In the ensuing years, trade marks such as Guncrete, pneucrete, Blastcrete, Blocrete, Jetcrete, and the terms pneumatically applied mortar and concrete, were introduced to describe similar processes.

UNIVERSITY OF WASHINGTON 6

Shotcrete

CM-420 Temporary Structures

Introduction and History

- The early 1930s saw the generic term “**shotcrete**” introduced by the American Railway Engineering Association to describe the Guniting process.
- In 1951, the American Concrete Institute (ACI) adopted the term shotcrete to describe the dry-mix process.
- Shotcrete is now applied to the wet-mix process and has gained universal acceptance in the United States.

UNIVERSITY OF WASHINGTON 7

CM-420 Temporary Structures


Definition Of Terms /References

- Guniting / Mortar: Maximum aggregate size = sand
- Shotcrete : Maximum aggregate size = 3/8” typical (1/2” max)
- AKA: Sprayed Concrete (Europe)
- Relevant ACI Publications
 - 506R-90 Guide to Shotcrete
 - 506.3R-91 Guide to Certification of Shotcrete Nozzlemen
 - 506.4R-94 Guide for the Evaluation of Shotcrete
 - 506.2-95 Specification for Materials, Proportioning and Application of Shotcrete
 - 506.1R-98 State of the Art Report on Fiber Reinforced Shotcrete

UNIVERSITY OF WASHINGTON 8

CM-420 Temporary Structures

American Concrete Institute Publications



Internet Address:
<http://aci-int.org>

506R-90 = \$52.95
(This is the base document)

UNIVERSITY OF WASHINGTON 9

Shotcrete

CM-120 Temporary Structures

Component Materials

- Aggregate
 - Fine = 60 - 70% of combined weight of aggregates
 - Coarse = 30-40% of combined weight of aggregate
- Portland Cement
 - Types I, II = 6.5 - 9.0 sack (611 - 846 lb/yd³)
- Water (potable)
 - Target W/C = 0.33 - 0.45
- WRA
 - Objective = workability with reduction of W/C ratio
- Microsilica
 - Typical range = 5% - 15% by weight of cement
- Latex Modifier
 - More commonly used in thin layer repair work than in ground support
- Accelerator
 - Silicates
 - Aluminates
 - Dosage = 2 - 5% by weight of cementitious material

10

CM-120 Temporary Structures

Strength Development

STRENGTH DEVELOPMENT OF SPRAYED CONCRETES

Compressive strengths in N/mm² (MPa)

Time	Wet sprayed concrete (aluminata)	Wet sprayed concrete (waterglass)	Dry sprayed ad concrete	Original concrete
6 minutes	~1	~1	~1	~1
15 minutes	~2	~2	~2	~2
30 minutes	~3	~3	~3	~3
1 hour	~4	~4	~4	~4
2 hours	~5	~5	~5	~5
5 hours	~10	~10	~10	~10
10 hours	~15	~15	~15	~15
24 hours	~20	~20	~20	~20
2 days	~25	~25	~25	~25
3 days	~28	~28	~28	~28
7 days	~30	~30	~30	~30
28 days	~35 (70%)	~35	~35	~35

11

CM-120 Temporary Structures

Shotcrete Applications

- Sealing of Ground Mass Interface
 - Prevent erosion and/or air slaking (crumbling)
 - Deter exfiltration/infiltration
- Component of Excavation Support System
 - Sole Support
 - Rockbolt / shotcrete system
 - Rockbolt / shotcrete / lattice girder system
- Final Lining
 - Practical, functional or esthetic considerations do not require formed concrete
- Repair Work

12

Shotcrete

CM-420 Temporary Structures

What is Shotcrete Good For?

- Very wet conditions
- Frozen ground conditions
- Ground conditions wherein bond is unreliable
- Intermittent application - small quantities - remote areas

UNIVERSITY OF WASHINGTON 13

CM-420 Temporary Structures

Dry Process Technique + Flow Chart

Dry process - Dry materials are combined in a "pot", transported pneumatically to a nozzle where water, any liquid admixtures and accelerator are introduced into the streamfeed and then immediately sprayed onto the target surface with a velocity developed by compressed air under a pressure of 90 - 100 psi.

UNIVERSITY OF WASHINGTON

CM-420 Temporary Structures

Wet Process Technique + Flow Chart

Wet process - All materials with exception of accelerator are combined within a batch/mix plant, transported via positive displacement pump to a nozzle where accelerator is introduced into the streamfeed and then immediately sprayed onto the target surface with a velocity developed by compressed air under a pressure of 90 - 100 psi.

UNIVERSITY OF WASHINGTON 15

Shotcrete

CM-120 Temporary Structures

Comparison of the Dry- and Wet-Mix Processes

Dry-mix process	Wet-mix process
1. Instantaneous control over mixing water and consistency of mix at the nozzle to meet variable field conditions.	1. Mixing water is controlled at the delivery equipment and can be accurately measured
2. Better suited for placing mixes containing lightweight aggregates, refractory materials and shotcrete requiring early strength properties	2. Better assurance that the mixing water is thoroughly mixed with other ingredients
3. Capable of being transported longer distances	3. Less dusting and cement loss accompanies the gunning operation
4. Start and stop placement characteristics are better with minimal waste and greater placement flexibility	4. Normally has less rebound resulting in less material waste
5. Capable of higher strengths	5. Capable of greater production

UNIVERSITY OF WASHINGTON 16

CM-120 Temporary Structures

Weigh Batch / mix Equipment Selection

- Batch/Mix Equipment
 - Weigh batcher
 - Drum (turbine-screw) mixer
 - Admixture feeder(s) - furnished by supplier
 - Fiber feeder - furnished by supplier
 - ASTM Spec ref = C94-90
Standard Specification for Ready-Mixed Concrete

UNIVERSITY OF WASHINGTON 17

CM-120 Temporary Structures

Volumetric Batch/mix Equipment Selection

- Volumetric batcher
 - Screw (drum, turbine) mixer
 - Admixture feeder(s) - furnished by suppliers
 - Fiber feeder - furnished by suppliers
 - ASTM Specification reference =C685-90
Standard Specification for Concrete Made By Volumetric Batching and Continuous Mixing

UNIVERSITY OF WASHINGTON 18

Shotcrete

CM-420 Temporary Structures

Transport Equipment Selection

- Transit (drum) mixer
- Agitating vessel
- Non-agitating vessel
- Pneumatic transport (dry process material)
- Pump Transport (wet process material)

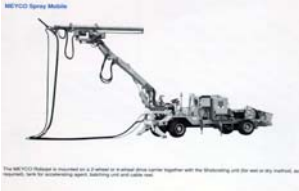


UNIVERSITY OF WASHINGTON 19

CM-420 Temporary Structures

Placement Equipment Selection

- Wet Process Equipment
 - Compressed Air
 - Water (construction water for cleanup)
 - Positive displacement pump (or shotcrete pot)
 - Accelerator dosing pump
 - Robotized placer



UNIVERSITY OF WASHINGTON 20

CM-420 Temporary Structures

Typical Wet Process Spread




UNIVERSITY OF WASHINGTON 21

Shotcrete

CM-420 Temporary Structures

Placement Equipment Selection

- Dry Process Equipment
 - Compressed Air
 - Water (potable)
 - Shotcrete Pot
 - Accelerator dosing device
 - Robotized placer



The MPCO Sprayer is designed on a 2 wheel to propel the carrier together with the Shotcrete with the use of dry method, an essential step in the spraying system. Auxiliary unit and water tank.

UNIVERSITY OF WASHINGTON 22

CM-420 Temporary Structures

Selected Dry Process Equipment

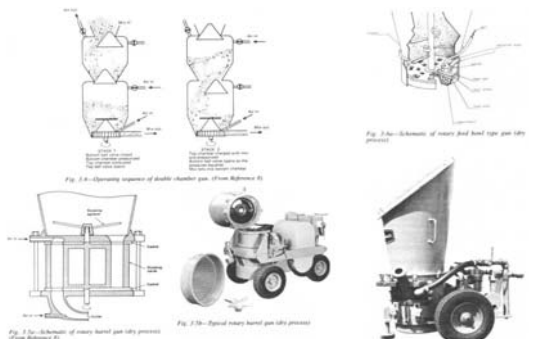


Fig. 2.18—Spraying system of mobile chamber gun (from Reference 6)

Fig. 2.19—Robotized sprayer with air tank (from Reference 6)

Fig. 2.20—Special spray gun (dry process)

Fig. 2.21—Special dry bed gun (dry process)

UNIVERSITY OF WASHINGTON 23

CM-420 Temporary Structures

Selected Dry Process Equipment



Fig. 2.22—Concrete pump (dry mix nozzle)

Fig. 2.23—Dry mix nozzle

Fig. 2.24—Auxiliary equipment

UNIVERSITY OF WASHINGTON 24

Shotcrete

CM-420 Temporary Structures

Other Selection Considerations

- Required operating parameters
 - Role of shotcrete in the intended operation
 - Strength gain constraints
 - Accessibility to appropriate equipment
- Process type selection as a function of labor supply
 - Recent volume of similar work in the area
 - Labor agreements, local economic situations which would deter importing skilled labor.
 - Quality and work ethic of labor force.
 - Wet process favored when any of preceding are negative.
- Opinion: wet process offers better control of more of the critical variables:
 - W/C ratio is determined by the batch/mix process
 - Moisture content of the raw materials is less critical
 - Calibrated accelerator dosage
 - Wet mix affords a more uniform mix in place (more coarse aggregate, less rebound)

UNIVERSITY OF WASHINGTON 25

CM-420 Temporary Structures

Preparation

- Although the dry process is similar, let's assume the wet process for procedural discussion. Preparation requires:
 - Procure materials (compatibility testing)
 - Develop trial mixes (compatibility testing!!!)
 - Mobilize equipment and labor force
 - Shoot test panels

UNIVERSITY OF WASHINGTON 26

CM-420 Temporary Structures

Operation

- Surface preparation is essential - will probably require pressure washing
- Make up a cement /water mix about the consistency of mayonnaise (a volume of $\pm 1 \text{ ft}^3$)
- Pour this lubricating mix into pump hose before starting to pump the production mixture
- When the pumped production mixture reaches the nozzle, turn on compressed air, accelerator and robotic placer motions
- Using good nozzle technique, apply shotcrete evenly to target surfaces
- Clean pump lines by blowing a rabbit and finishing with a thorough water flush of the entire system
- Cure of in place material = important consideration (+85% humidity = best solution)

UNIVERSITY OF WASHINGTON 27

Shotcrete

CM-120 Temporary Structures

Nozzle Technique

Fig. 8.1b—Correct gunning position—Nozzle perpendicular to receiving surface and feet changes the angle of impact, wastes material.

Fig. 8.2—Manipulating the nozzle to produce the best rebound.

Fig. 8.1a—Gunning positions.

Fig. 8.3—The position around reinforcing bars.

28

CM-120 Temporary Structures

Nozzle Technique

<p>WE DESIGN: The following table lists the advantages and disadvantages of shotcrete. Shotcrete is a dry mix concrete that is applied to a surface by the dry mix method. It is a highly versatile material that can be used in a wide range of applications. Shotcrete is a highly durable material that can be used in a wide range of applications.</p>	<p>THE ROCK VALUE: Shotcrete is a highly durable material that can be used in a wide range of applications. It is a highly versatile material that can be used in a wide range of applications. Shotcrete is a highly durable material that can be used in a wide range of applications.</p>	<p>VERSATILITY: Shotcrete is a highly versatile material that can be used in a wide range of applications. It is a highly durable material that can be used in a wide range of applications. Shotcrete is a highly durable material that can be used in a wide range of applications.</p>	<p>SPRAY ARMS: Shotcrete is a highly versatile material that can be used in a wide range of applications. It is a highly durable material that can be used in a wide range of applications. Shotcrete is a highly durable material that can be used in a wide range of applications.</p>
<p>OPTIONAL TOP SECRET: Shotcrete is a highly versatile material that can be used in a wide range of applications. It is a highly durable material that can be used in a wide range of applications. Shotcrete is a highly durable material that can be used in a wide range of applications.</p>			

29

CM-120 Temporary Structures

Administrative Nuances of Shotcrete

- Measurement For Payment
 - Shotcrete by the unit price
 - Measurement for payment = calculated area (volume)
 - All plant and process waste
 - All rebound
 - All variations in thickness
 - All variations in plant yield
 - All materials expended in test phase
 - Measurement for payment = plant cubic yard
 - It poses minimal risk
 - Shotcrete paid as a lump sum

30
