SHOTCRETE TODAY
NOT YOUR FATHER’S GUNITE

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American Shotcrete Association

Our Vision - "Structures built or repaired with the shotcrete process are accepted as equal or superior to cast concrete"

Our Mission - "ASA provides training, qualification, certification, education, networking, and leadership to increase the acceptance, quality, and safe practices of the shotcrete process".
Shotcrete - Definition

“Concrete placed by a high velocity pneumatic projection from a nozzle.”

As defined in ACI CT-16 Concrete Terminology

...It is simply a method of placing concrete
Shotcrete is not a product...

...It is simply a method of placing concrete
History of Shotcrete

Carl Akeley
Original Shotcrete Gun
1907

Gunite
1920’s
History of Shotcrete
History of Shotcrete

Dual chamber Shotcrete gun 1922

Dry-mix shotcrete 1922
History of Shotcrete

Dry-mix shotcrete
Today
History of Shotcrete

1951 – ACI adopted the term “shotcrete” for pneumatically applied mortar, previously called Gunite.

1966 - ACI adopted the terms Wet-mix and Dry-mix Shotcrete
History of Shotcrete
Wet-Mix Process

Wet process 1959

Wet-mix Process 1959
History of Shotcrete Wet-Mix Process

1958

Present Day 2016
Processes
Dry-mix

- Dry concrete mixture conveyed through a hose
- Water is added at the nozzle
- Mixing of water and concrete materials in the nozzle and on the receiving surface.
Dry Mix Nozzle tips help with the material mixing.

Removable tips increase the material velocity.

Tip lengths and shapes will change the material spray pattern.
Processes

Wet-mix

• Fully mixed concrete is pumped through a hose
• Air is added at the nozzle to accelerate the mixture to a high velocity.
Wet-Mix Shotcrete Nozzle

Nozzle Design for Wet Shotcrete Equipment

- Air
- Concrete flow
- Accelerator inlet if required
- Mixing chamber
- Air Valve
- Compressed Air
- Air ring with holes
- Nozzle tip slightly smaller opening than material hose
- Accelerator port and valve (if needed)
- Wet-Mix Material
- Nozzle body
Dry vs Wet Process?

- Specifications should be performance based
- Experienced shotcrete contractor
Parking Garage
Building Retrofits
Bridge Renovations
Canals and Aqueducts
Marine Structures
Dams
Ground Support in Mine
Robotic Underground
Ground support in mines and tunnels
Soil Nail
Foundation - Basement Walls
Structural Walls
Architectural
Architectural
Prestressed Tanks
Storage Domes
Bobsled Run
Skate Parks
Zoo Exhibit – Simulated Rock
Trees and...
Lions too!
Sustainability of Shotcrete

• Reduced formwork
• Most efficient sections
• Reduced equipment needs
• Flexible access and schedule
• Time savings
• Better bonding, more durable
• Creative shapes done economically
Environmental Conditions

Cold weather – (ACI 306R Cold Weather Concreting)

- 40°F (5°C) and falling unless protective measures taken
- Do not apply shotcrete on frozen surfaces
- Mix temperature above 50°F (10°C)
- Protect from freezing until it has reached at least 500 psi (4 MPa) in compressive strength
Environmental Conditions

Hot weather (ACI 305R *Hot Weather Concreting*)

- Keep mix temperature as low as possible
- **Do not apply shotcrete when ambient temperature above 100°F (38°C) unless precautions taken**
- Cool water
- Sun shades where possible
- Fogging / misting
Environmental Conditions

Wind

- Avoid applying shotcrete during high wind conditions
- Provide protective barriers
- Causes separation of fines in nozzle stream
- Causes high rates of evaporation
- Can cause plastic shrinkage cracking
Environmental Conditions

Rain

- Heavy rain
- Ponded or running water
- Protection possible
Preparation of Existing Structure

- Immediately before shotcrete application:
  - Pressure wash concrete surface
  - Ensure all loose debris, and potential bond reducers are removed
  - Bring surface to saturated, surface dry condition (SSD)
Preparation of Existing Structure

- Bonding agents are never recommended for wet or dry mix shotcrete applications.
- The nature of the shotcrete process ensures excellent bond to properly prepared SSD substrate.
- Bonding agents will create a “bond breaker” at the interface between the shotcrete and the substrate and will lead to bond failure.
Formwork

■ One-sided forms
  – Lighter
  – More than 50% less materials
  – No need for carrying high pressure

■ Many projects need no forms

■ Curved & tapered sections easily produced
The Application

FORM AND POUR

- Projects with easy two-sided access
- Large and thick walls

SHOTCRETE

- Free-form applications
- Projects with radiuses
- Constricted spaces
- Vertical and/or changing elevations
- Repair work on a larger scale is faster
Reinforcement

- Same concrete design
- Non-contact lap splices
- Multiple layers
Alignment Control

Use alignment control devices to establish line and grade. Devices include:

- Ground wires (piano wire)
- Pencil rods (1/4” high tension pre-stressing steel) for curved profiles
- Depth gages
- Guide strips/formwork

Figure 2: Ground wire delineates finish of a corner without restriction of nozzle trajectory.
Modern Admixture Technology for Shotcrete

- Super-plasticizers for very low w/c ratios and high workability
- Alkali-free accelerators for safety and durability
- Micro Silica and Slump Retainers
- Hydration control admixtures for maintaining workability from 3 to 72 hours
- Additions of steel and high performance polymer fibers, micro silica slurries
Typical Shotcrete Mixture

- Cement (Type I, II, III or V): 17 - 20%
  - Silica Fume: 2 - 10%
  - Fly Ash or Slag: 15% to 50%
- Water Reducing Admixtures: Wet mix only
- Blended Aggregates: 75 – 80%
- Air-entraining admixture*: Wet mix only
- Synthetic Fibers*: 1.7-3.4 lbs/yd³
- Steel Fibers*: 65-115 lbs/yd³
- w/cm: 0.30 – 0.45
Aggregates
ACI 506R – Guide to Shotcrete - Gradation No. 1 and 2

ACI Gradation Limit No. 1

ACI Gradation Limit No. 2
Aggregates

ASTM C 33

ACI Gradations

Gradation No. 1 - Fine aggregate shotcrete
1/4” maximum aggregate size

Gradation No. 2 - Fine and coarse aggregate
3/8” maximum aggregate size
Supplemental Cementitious Materials
Silica Fume, Fly Ash, Slag

• Higher compressive & flexural strengths
• Silica fume has better adhesion and cohesion
• Reduced porosity (permeability) - Improves durability
• Improves resistance to sulfate & chemical attack
• Reduces chloride ion penetration
• Class-F fly ash improves resistance against ASR
Air Entraining Admixtures
Dry-Mix Shotcrete

Spacing Factor: 101 μm

Air Entrained

Non-Air Entrained

Spacing Factor: 415 μm
Set Accelerators

• Thicker applications in a single pass
• Reduces set time and develops higher, early age compressive strength
• May be needed when retarders are used to initiate the reaction
• Accelerator dosage must be carefully controlled
Fiber Reinforcement

- Micro-Synthetic Fibers
- Steel Fibers
- Macro-Synthetic Fibers
Steel Fibers

- **Steel Fiber**
  - *Dosage rate of 60-100 lbs/yd$^3$ (40-60 kg/m$^3$)*
  - *Do not use with wire mesh*
  - *May help reduce shrinkage cracking*
  - *Will increase toughness and energy absorption*

- **Steel Fibers** - Typically used in mining, tunneling and rock slope stabilization applications to improve flexural toughness, impact resistance and ductility
Synthetic Fibers

- **Micro Fiber**
  - Dosage rate of 1 to 3 lbs/yd$^3$ (0.6-1.8 kg/m$^3$)
  - May help reduce early-age plastic shrinkage cracking

- **Macro Fiber**
  - Dosage rate of 3 to 12 lbs/yd$^3$ (1.8-7.2 kg/m$^3$)
  - May help reduce early-age plastic and drying shrinkage cracking
  - Can increase toughness and energy absorption
  - New designs equivalent to steel fiber
Slump and Set Control with Hydration Stabilizer

Traditional Sprayed Concrete

New Flexibility with Hydration Stabilizer

No control!

Take back control!
Shotcrete Evaluation and Testing

- Pre-construction testing
  - Most heavily congested area of the work is mocked up
  - Test panel is cored and can be cut for testing and approval
Quality Assurance (QA)  
Quality Control (QC)

• Shotcrete acceptance/rejection criteria
  – Plastic shotcrete
    • Age, air, temperature and setting time
    • Sags, sloughing, tears
    • Reinforcing encapsulation
    • Line, grade and cover
    • Finish and tolerance
Quality Assurance (QA)  
Quality Control (QC)

- Shotcrete acceptance/rejection criteria
  - Hardened shotcrete
    - Compressive strength (cores from panels)
    - Flexural strength (beams)
    - Toughness (circular panels)
Good Shooting Practices

Corners > Edges > Middle
Application Technique: Nozzle Angle

- Nozzle should always point 90° to the receiving surface
- For spraying onto steel arches / lattice girders / corners are exceptions
- Nozzle distance should be between 1 – 2 meters
- Influence of nozzle distance
  - Incorrect nozzle angle and distance have a significantly negative influence on concrete quality, such as poor compaction, strength, etc., and will dramatically increase rebound
Bench shooting

Material is directed 90 degrees to receiving surface.
Slope Construction Joints to an Angle
Impact Velocity vs Reinforcing Bar Encasement

Proper velocity = Clean bars and proper encasement
Types of Shotcrete Finish

Examples

- Natural or gun finish
- Cut
- Broom or brush finish
- Sponge finish
- Floated or troweled
- Carved
- Textured
- Exposed aggregate
- Painted & Stained
Rod Finish
Sponge

Float

Steel Trowel

Gun
Curved Sections – No Problem!
Easily Blend to Existing

No formwork!
Rockscapes
Architectural
Architectural
Curing Shotcrete

- It’s concrete, it needs curing!
- Exposed surface
- Fogging/misting immediately in hot, dry or windy conditions
Proper Curing Practices

Soaker hoses

Wet curing using burlene

Fogging after finishing, before placing burlene
Curing Compounds

- Alternative to wet curing
- Reduce evaporation, but does not add water
- Curing compound is a bond breaker
- Recommend 2 times the rate
So what are you still waiting for?

It's time to get your nozzlemen trained and certified!

The American Shotcrete Association, in partnership with the American Concrete Institute, has developed a comprehensive program to upgrade the knowledge and skills of shotcrete nozzlemen and to facilitate ACI examination and certification. Provide your clients with the assurance that your nozzlemen have demonstrated that they have the capabilities to perform the job right—the first time!

To learn more or to schedule an ASA training session and an ACI Shotcrete Nozzlemen Certification examination, visit www.shotcrete.org or call (248) 848-3730.
Requirements for Nozzleman Certification

• One day of ASA mandatory education
• Requires 500 hours of documented experience that can be verified by the examiner
• Written examination, oral examination, practical examination
• ACI Nozzleman Certification application is processed by ASA
ACI Certification Panel

USA: #4 METRIC: #13 CANADA: #15M
USA: #6 METRIC: #19 CANADA: #20M
USA: #3 METRIC: #25 CANADA: #25M CANADA: #15M

NOTES:  
1. CORE DIAMETER 4 IN (100 MM) NOMINAL  
2. CORE LOCATIONS MAY BE ADJUSTED SLIGHTLY AT THE DISCRETION OF THE EXAMINER, SO LONG AS THEY REMAIN ALONG THE AXES OF THE REINFORCING BARS, AND AT LEAST THREE BAR INTERSECTIONS ARE COVERED

SAMPLE CORE LOCATIONS FOR ENCASMENT INSPECTION

THE CLEAR DISTANCE BETWEEN THESE BARS MUST BE 1 1/2 X 1/4 IN (40 X 5 MM)

WIDTH OF SIDE FORMS 1-1/2 IN (38 MM) MIN

1 1/4 IN (25 X 5 MM) CLEAR

PLYWOOD BACK 3/4 IN (19 MM) MIN

2 3/8 IN (15 X 5 MM)

2 3/8 IN (15 X 5 MM)

PANEL INSIDE DIMENSION IS 30 X 1 IN (75 X 25 MM) SQUARE
Differences in application technique can be dramatic

- Same concrete mix from one truck, sprayed 10 minutes apart
- Sprayed by two different nozzlemen during training one ACI Certified one not
Reference for Shotcrete
ACI 506R-16 Guide to Shotcrete
ACI 506.2-13 Specification for Shotcrete
Useful Tools and Resources

■ www.Shotcrete.org (Buyer’s guide, many resources)

■ www.ACIcertification.org (nozzleman certification)

■ ASA Main Office – 248-848-3780 or info@Shotcrete.org

■ ASA Technical Inquiries – 248-848-3742 or Charles.Hanskat@Shotcrete.org
So What, why Shotcrete?

- Save time, no forms, no support, no strip, no rub and no patch
- Less equipment and more operating space for concurrent operations
- Less man-hours
This concludes our presentation

Questions?