Shotcrete - Definition

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

As defined in ACI CT-18 Concrete Terminology

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

Carl Akeley
Original Shotcrete Gun
1907

Dry-Mix Shotcrete
1920’s
Processes

Dry-mix shotcrete process

Wet-Mix shotcrete process
Dry-Mix Nozzle Water Pressure

Critical to in-place quality
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
- Accelerator port and valve (if needed)
- Wet-Mix Material
- Nozzle tip slightly smaller opening than material hose
- Nozzle body
- Wet-Mix Material
Dry vs Wet Process?

Specifications should be performance based and left to the choice of the contractor.
Parking Garage
Bridge Retrofits
Canals and Aqueducts
Marine Structures
Modern Admixture Technology for Shotcrete

- Super-plasticizers for very low w/c ratios and high workability
- Alkali-free accelerators for safety and durability
- Hydration control admixtures for maintaining workability from 3 to 72 hours
- Additions of steel and high performance polymer fibers, micro silica slurries
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
Rapid Set Accelerators

• Thicker applications in a single pass
• Reduces set time and develops higher, early age compressive strength
• Accelerator dosage must be carefully controlled
Fiber Reinforcement

- Micro-Synthetic Fibers
- Steel Fibers
- Macro-Synthetic Fibers
- Natural
Surface Preparation

- Remove loose or deteriorated concrete/masonry to sound concrete
  - Chipping or scarifying, followed by sandblasting or water blasting
  - Heavy duty sandblasting
  - Hydrodemolition
- If reinforcing bar is more than 50% exposed, remove concrete a minimum ½” (10 mm) behind the bar
- Surface brought to SSD before shooting
Preparation of Existing Structure

- Feather Edge (Not recommended)
- Sawcut Edges (Recommended)

Saw cut or chipped

3/4 in. (20 mm)

1/2 in. (13 mm)

Reinforcing bar
Preparation of Existing Structure

Bonding agents are *never* recommended for wet or dry mix shotcrete applications.
Bond quality of shotcrete is derived from the very high energy placement and abrasion at the surface.
The shotcrete process’ exceptional bonding quality to existing rock, masonry, or concrete surfaces is well documented.

**Typical bond strength test**

<table>
<thead>
<tr>
<th>Test Number</th>
<th>Core Depth (in)</th>
<th>Core Length (in)</th>
<th>Shotcrete Thickness (in)</th>
<th>Gage Reading (psi)</th>
<th>Applied Force (lb)</th>
<th>Core Diameter (in)</th>
<th>Core Area (in²)</th>
<th>Tensile Bond Strength (psi)</th>
<th>Failure Mode</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2-3/4</td>
<td>2-1/4</td>
<td>2-1/4</td>
<td>1578</td>
<td>818</td>
<td>2.75</td>
<td>5.94</td>
<td>138</td>
<td>50% shotcrete/substrate bond line, 40% substrate, 10% dip</td>
<td>Core contained a wire reinforcing clip impression that may have weakened the bond strength. Bond line appeared relatively smooth (low CSP).</td>
</tr>
<tr>
<td>2</td>
<td>2-7/8</td>
<td>2-7/8</td>
<td>2-3/4</td>
<td>4423</td>
<td>2404</td>
<td>2.75</td>
<td>5.94</td>
<td>405</td>
<td>60% shotcrete/substrate bond line, 40% substrate</td>
<td>A few small voids in the shotcrete on the side of core</td>
</tr>
<tr>
<td>3</td>
<td>2-5/8</td>
<td>2-1/4</td>
<td>1-3/4</td>
<td>5308</td>
<td>2897</td>
<td>2.75</td>
<td>5.94</td>
<td>488</td>
<td>100% substrate</td>
<td>Shotcrete well consolidated and well bonded to substrate. Core contained wire reinforcing with 1 inch cover</td>
</tr>
<tr>
<td>4</td>
<td>2-5/8</td>
<td>2-1/2</td>
<td>2-1/2</td>
<td>3447</td>
<td>1860</td>
<td>2.75</td>
<td>5.94</td>
<td>313</td>
<td>80% substrate, 20% shotcrete/substrate bond line</td>
<td>A few small voids near surface of shotcrete, Core contained wire reinforcing with 1-1/4 inch cover</td>
</tr>
<tr>
<td>5</td>
<td>2-5/8</td>
<td>1-1/2</td>
<td>2-1/2</td>
<td>4917</td>
<td>2679</td>
<td>2.75</td>
<td>5.94</td>
<td>451</td>
<td>100 % within shotcrete layer</td>
<td>Failure occurred within shotcrete layer at wire reinforcing. Remaider of core was removed by chipping to determine shotcrete layer thickness. Core contained wire reinforcing with 1-1/4 inch cover.</td>
</tr>
<tr>
<td>6</td>
<td>3-0</td>
<td>2</td>
<td>2 +</td>
<td>1832</td>
<td>959</td>
<td>2.75</td>
<td>5.94</td>
<td>162</td>
<td>100 % within shotcrete layer</td>
<td>Failure occurred within shotcrete layer at wire reinforcing. Core contained wire reinforcing with 2 inch cover.</td>
</tr>
</tbody>
</table>

**AVERAGE** 326 psi
Shotcrete applied to a properly prepared concrete substrate can form a bond that is stronger than the cohesive strength of the underlying layer.

Close up of repair shotcrete bond (right) to an existing concrete substrate (left).

Historic bridge renovation
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.
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
Multiple Layers

If placing layers of shotcrete, unsound material, excessively smooth surfaces, laitance, or curing compounds must be removed.
Curved Sections – No Problem!
Easily Blend to Existing

No formwork!
ACI Nozzleman Certification Program

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 Nozzleman Certification examination, visit www.shotcrete.org or call (248) 946-3780.
Reference for Shotcrete

ACI 506R-16 Guide to Shotcrete
ACI 506.2-13 Specification for Shotcrete
ACI 506.6T-17 Visual Shotcrete Core Eval
Useful Tools and Resources

- [www.Shotcrete.org](http://www.Shotcrete.org) (Buyer’s guide, magazine archive, many resources)
- [www.Concrete.org](http://www.Concrete.org) (nozzleman & inspector certification, ACI 506 docs)
50 ft. by 6 ft. Platforms weighing more than 6,000 lbs.