RAP-12

CONCRETE REPAIR BY SHOTCRETE

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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

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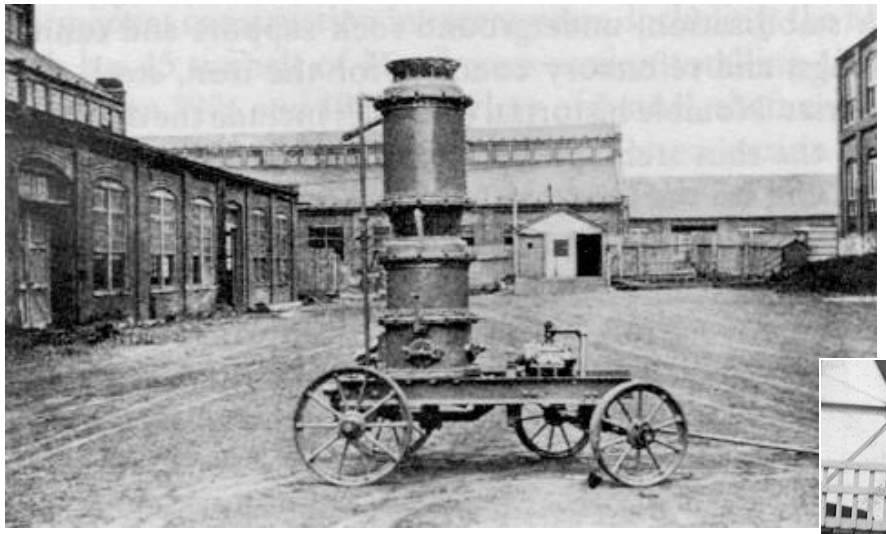
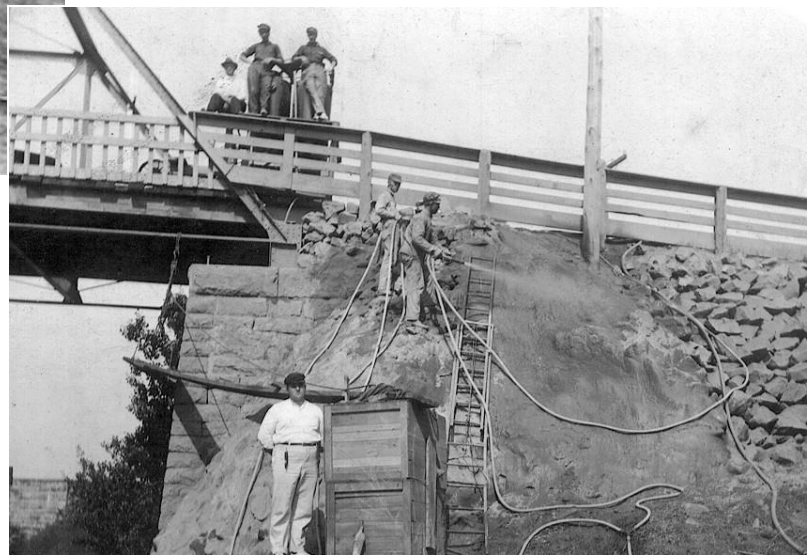
History of Shotcrete



Carl Akeley
Original Shotcrete Gun
1907



Dry-Mix Shotcrete
1920's

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Processes

Dry-mix shotcrete process

Wet-Mix shotcrete process

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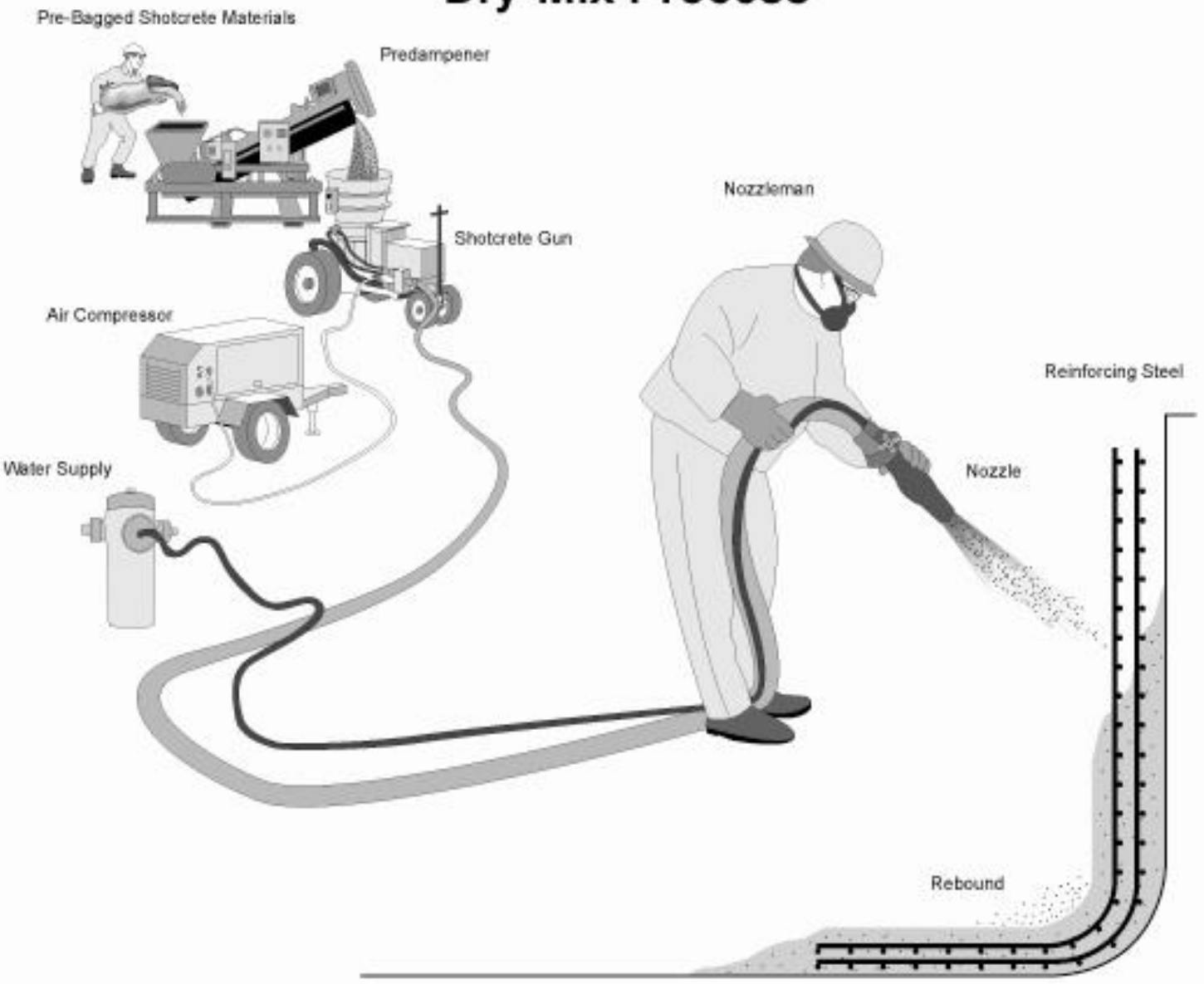
Dry-Mix Process



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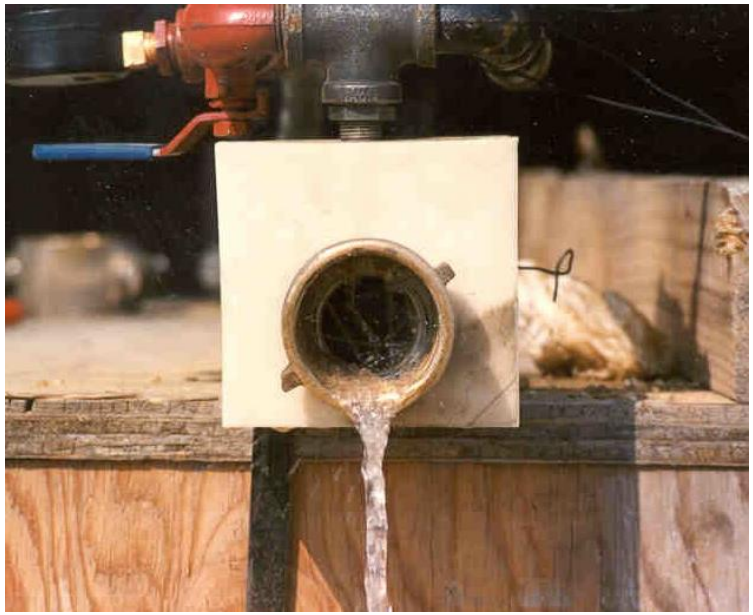
Dry-Mix Nozzle Water Pressure

Critical to in-place quality



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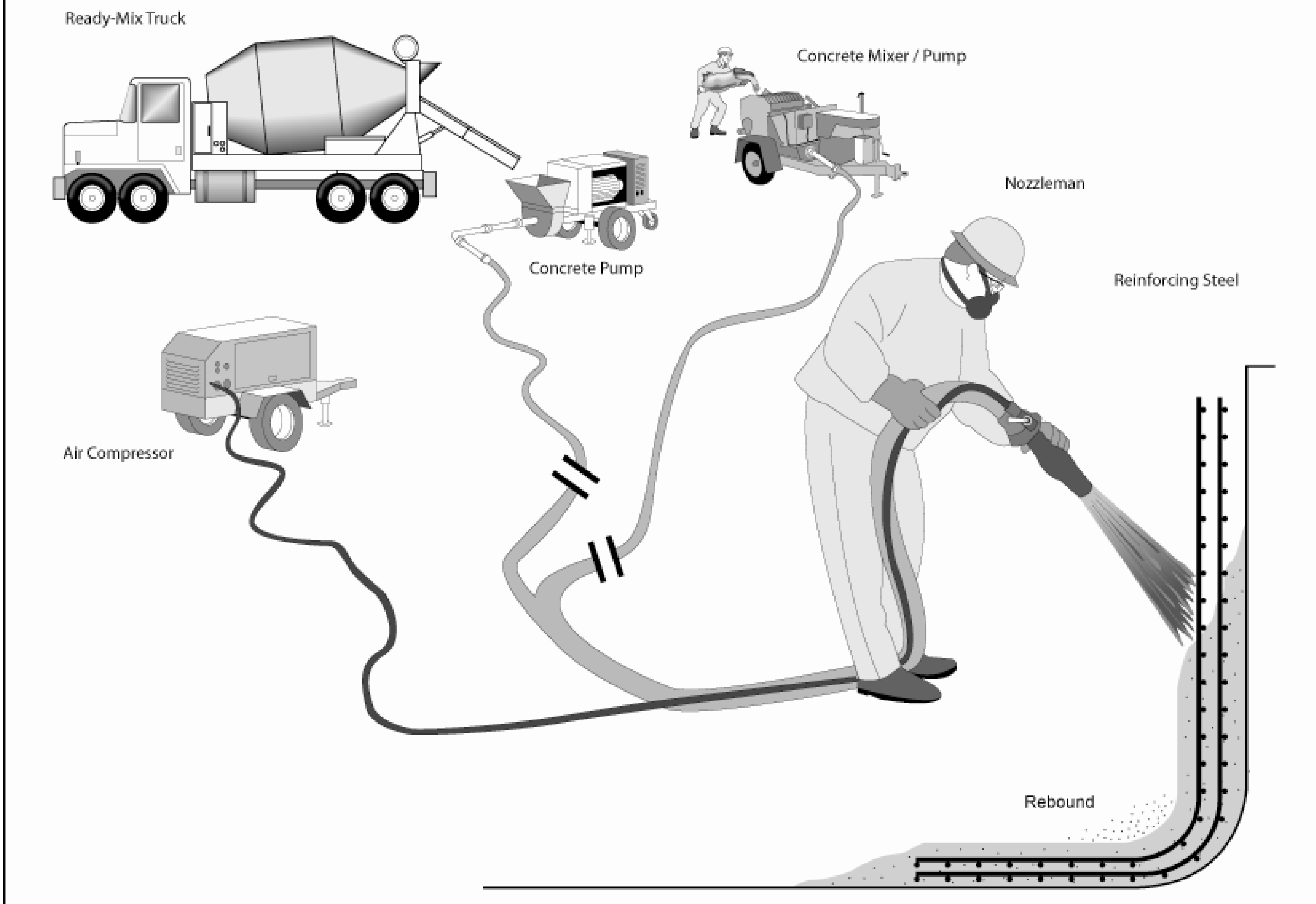
Allentown

Wet-Mix Process



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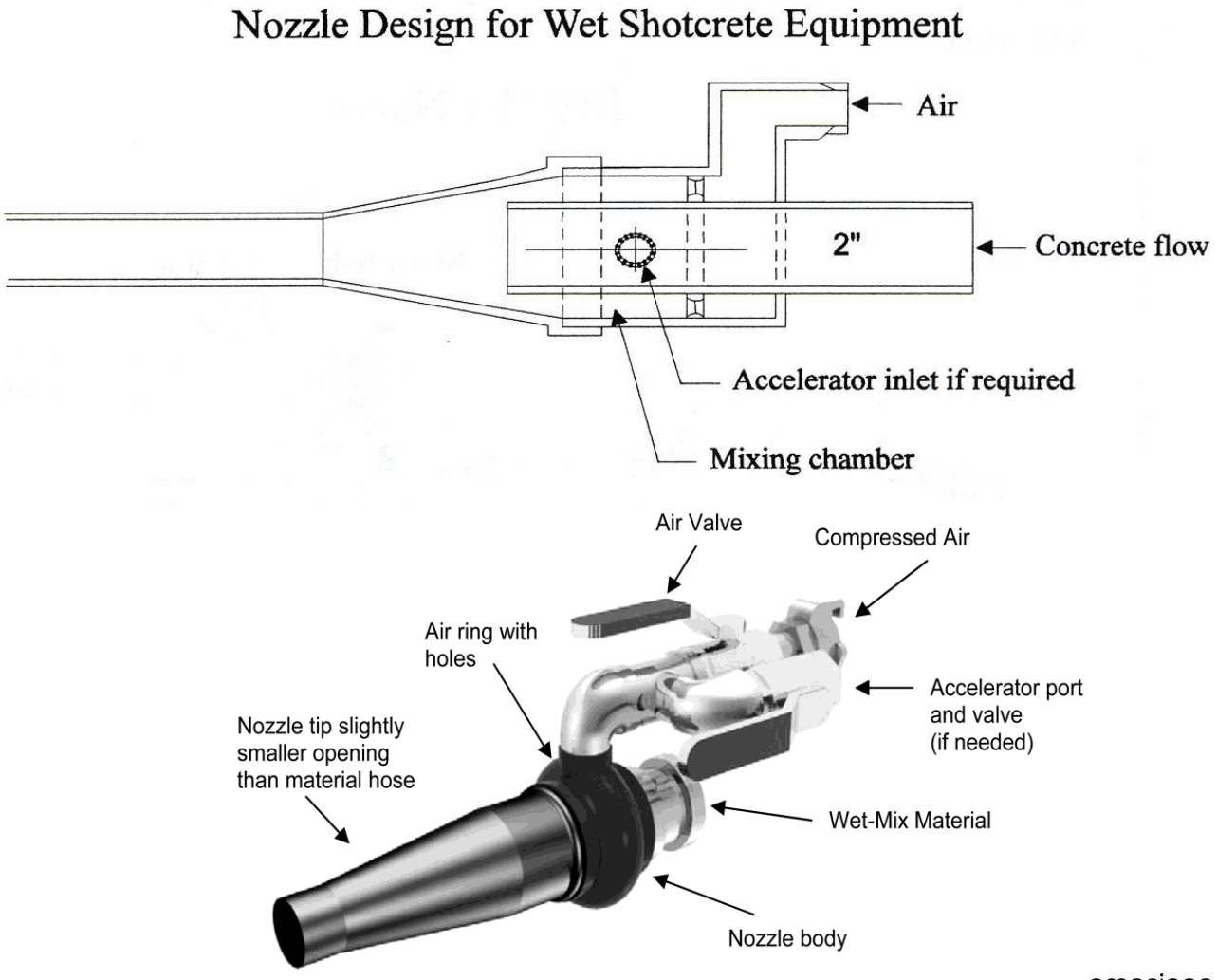
Wet-Mix Shotcrete Nozzle



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Dry vs Wet Process?

Specifications should be performance based and left to the choice of the contractor

Parking Garage

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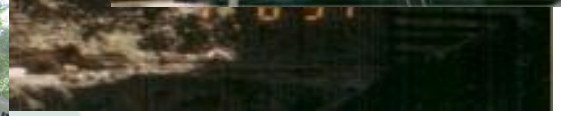
Bridge Retrofits



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Canals and Aqueducts

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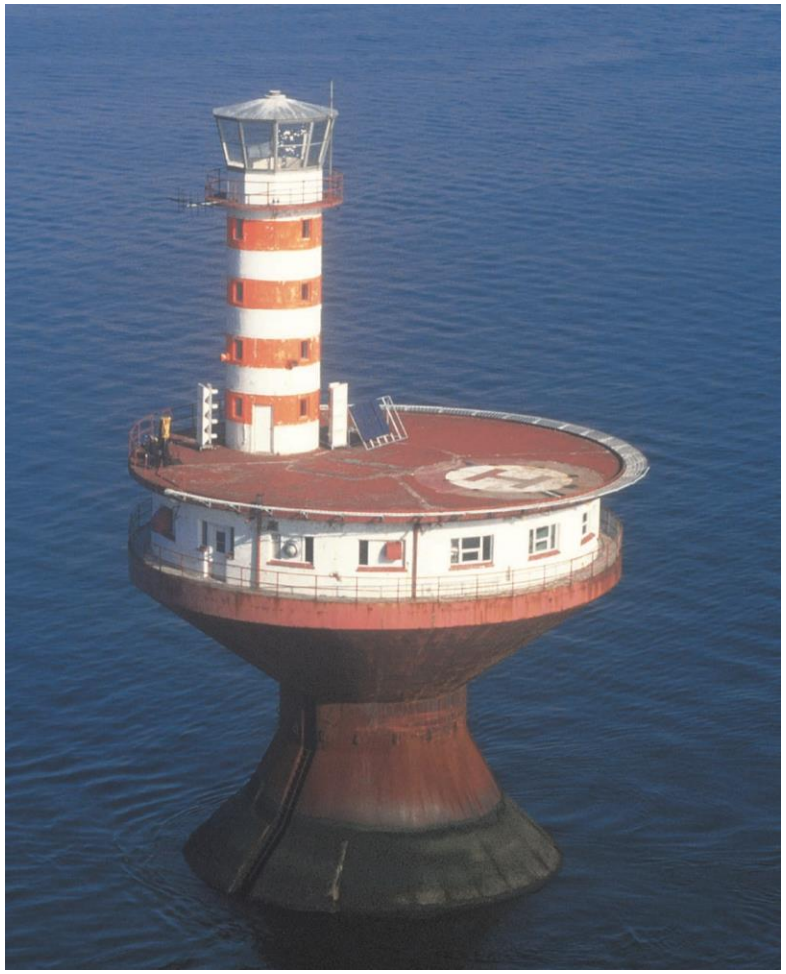
Marine Structures



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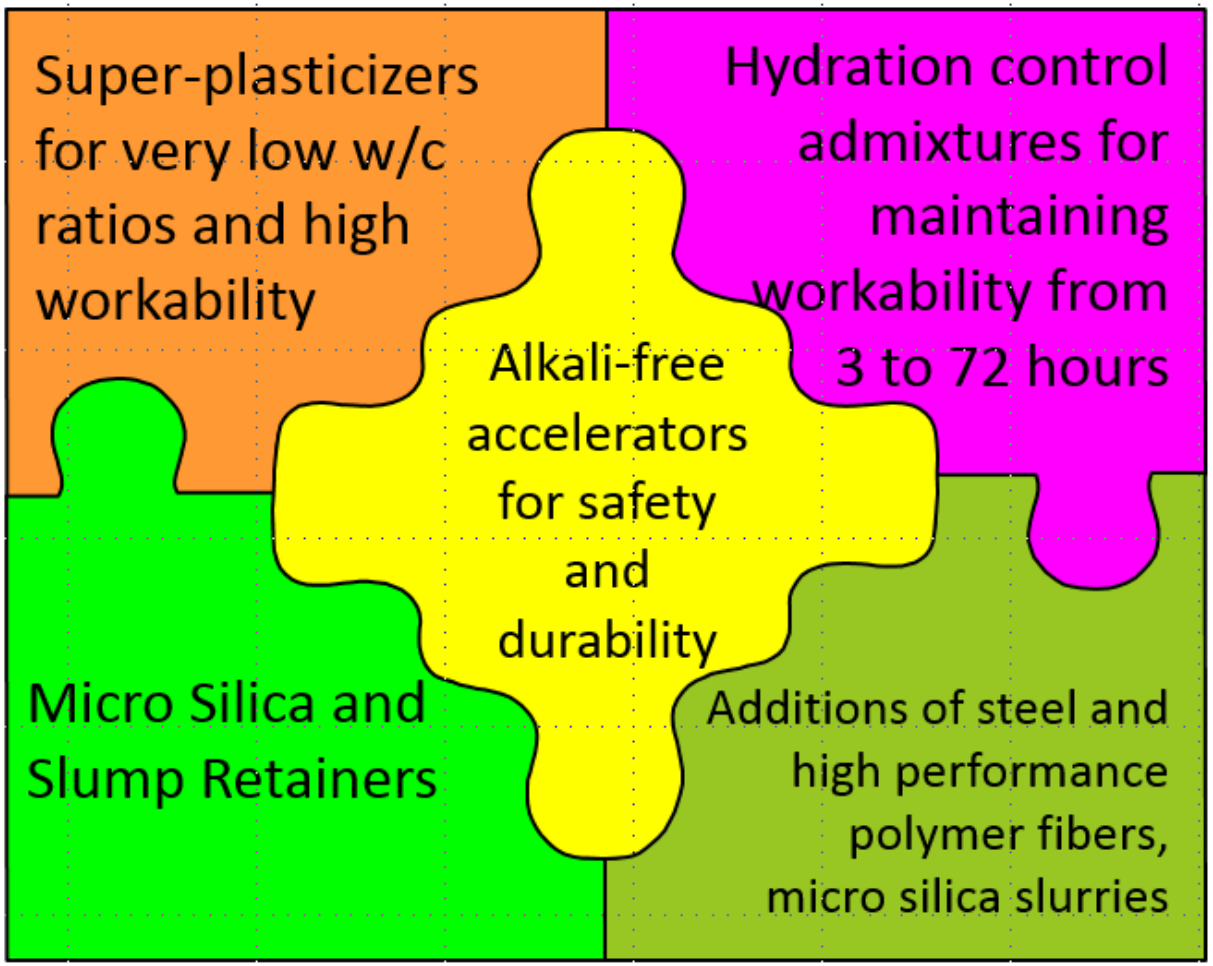
Modern Admixture Technology for Shotcrete



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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

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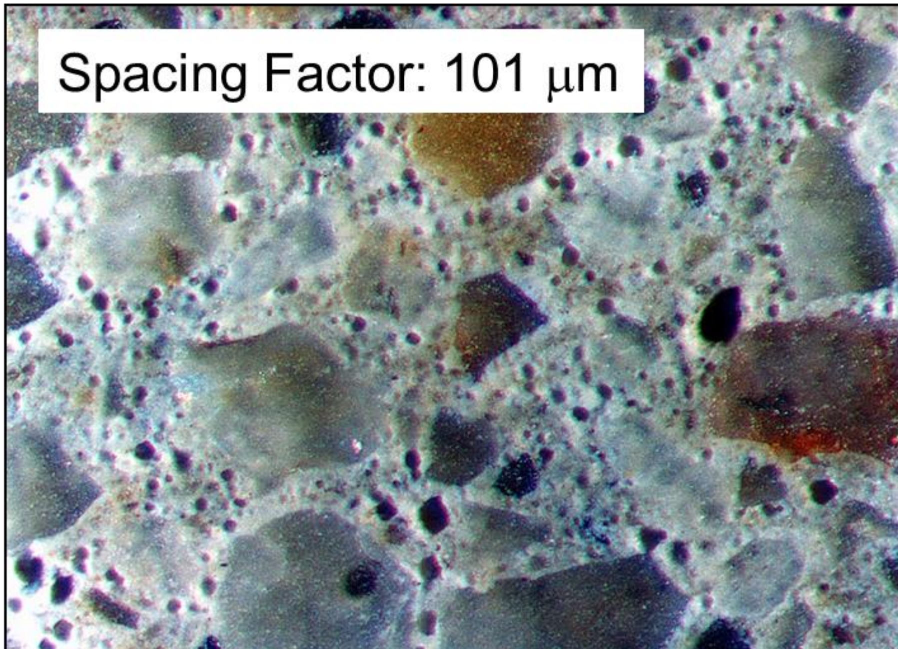
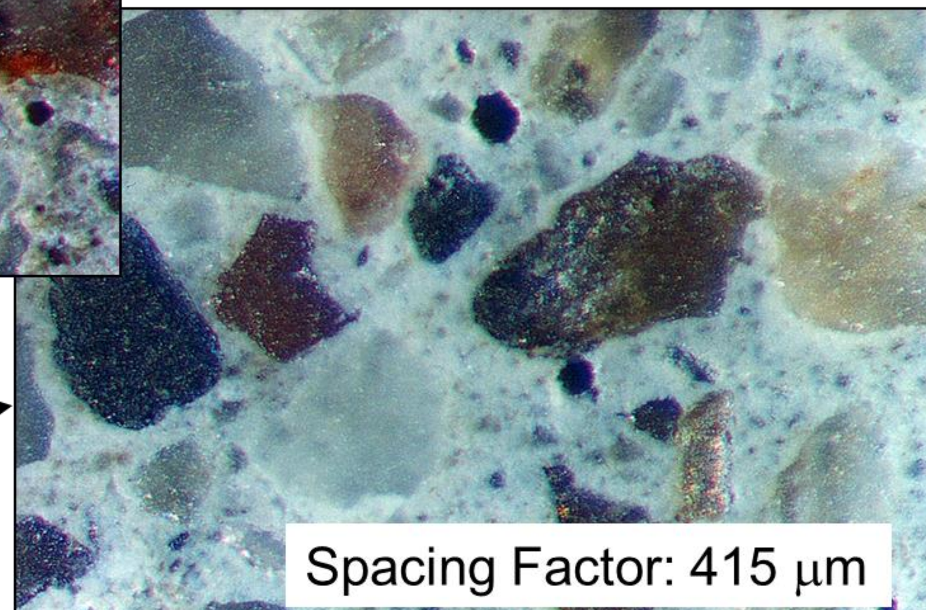
Air Entraining Admixtures

Dry-Mix Shotcrete

Air Entrained



Non-Air Entrained



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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

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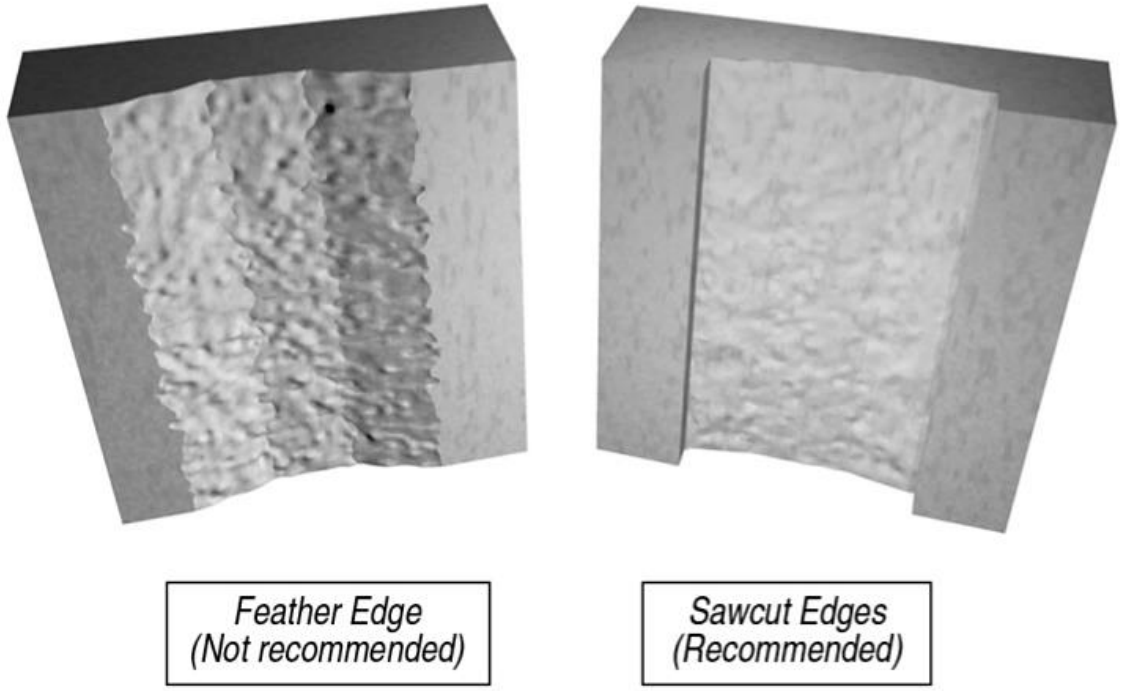
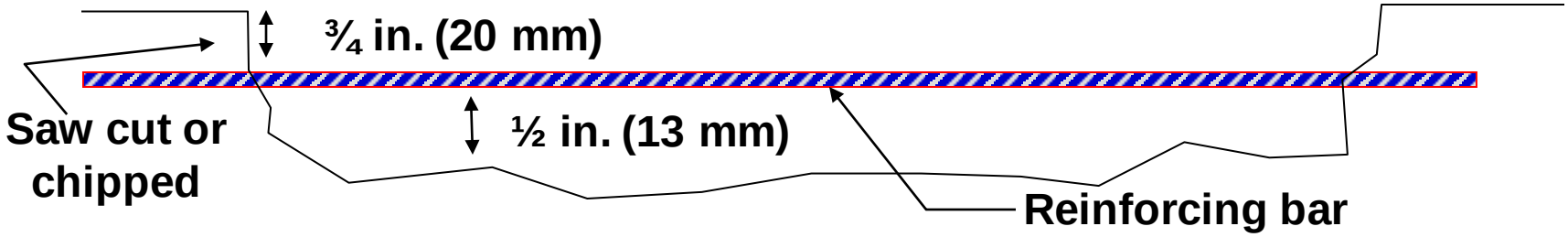
Preparation of Existing Structure





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Preparation of Existing Structure

Bonding agents are ***never*** recommended for wet or dry mix shotcrete applications

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Bond quality of shotcrete is derived from the very high energy placement and abrasion at the surface

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The shotcrete process' exceptional bonding quality to existing rock, masonry, or concrete surfaces is well documented

Typical bond strength test

Test Number	Core Depth (in)	Core Length (in)	Shotcrete Thickness (in)	Gage Reading (psi)	Applied Force (lb)	Core Diameter (in)	Core Area (in^2)	Tensile Bond Strength (psi)	Failure Mode	Comments
1	2-3/4	2-1/4	2-1/4	1578	818	2.75	5.94	138	50% shotcrete/substrate bond line, 40% substrate, 10% clip	Core contained a wire reinforcing clip impression that may have weakened the bond strength. Bond line appeared relatively smooth (low CSP).
2	2-7/8	2-7/8	2-3/4	4423	2404	2.75	5.94	405	60% shotcrete/substrate bond line, 40% substrate	A few small voids in the shotcrete on the side of core
3	2-5/8	2-1/4	1-3/4	5308	2897	2.75	5.94	488	100% substrate	Shotcrete well consolidated and well bonded to substrate. Core contained wire reinforcing with 1 inch cover
4	2-5/8	2-1/2	2-1/2	3447	1860	2.75	5.94	313	80% substrate, 20% shotcrete/substrate bond line	A few small voids near surface of shotcrete, Core contained wire reinforcing with 1-1/4 inch cover
5	2-5/8	1-1/2	2-1/2	4917	2679	2.75	5.94	451	100 % within shotcrete layer	Failure occurred within shotcrete layer at wire reinforcing. Remainder of core was removed by chipping to determine shotcrete layer thickness. Core contained wire reinforcing with 1-1/4 inch cover.
6	3-0	2	2 +	1832	959	2.75	5.94	162	100 % within shotcrete layer	Failure occurred within shotcrete layer at wire reinforcing. Core contained wire reinforcing with 2 inch cover.
							AVERAGE	326	psi	

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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)

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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.

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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

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Sponge

Steel Trowel

Float

Gun

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Multiple Layers

If placing layers of shotcrete, unsound material, excessively smooth surfaces, laitance, or curing compounds must be removed

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Curved Sections – No Problem!

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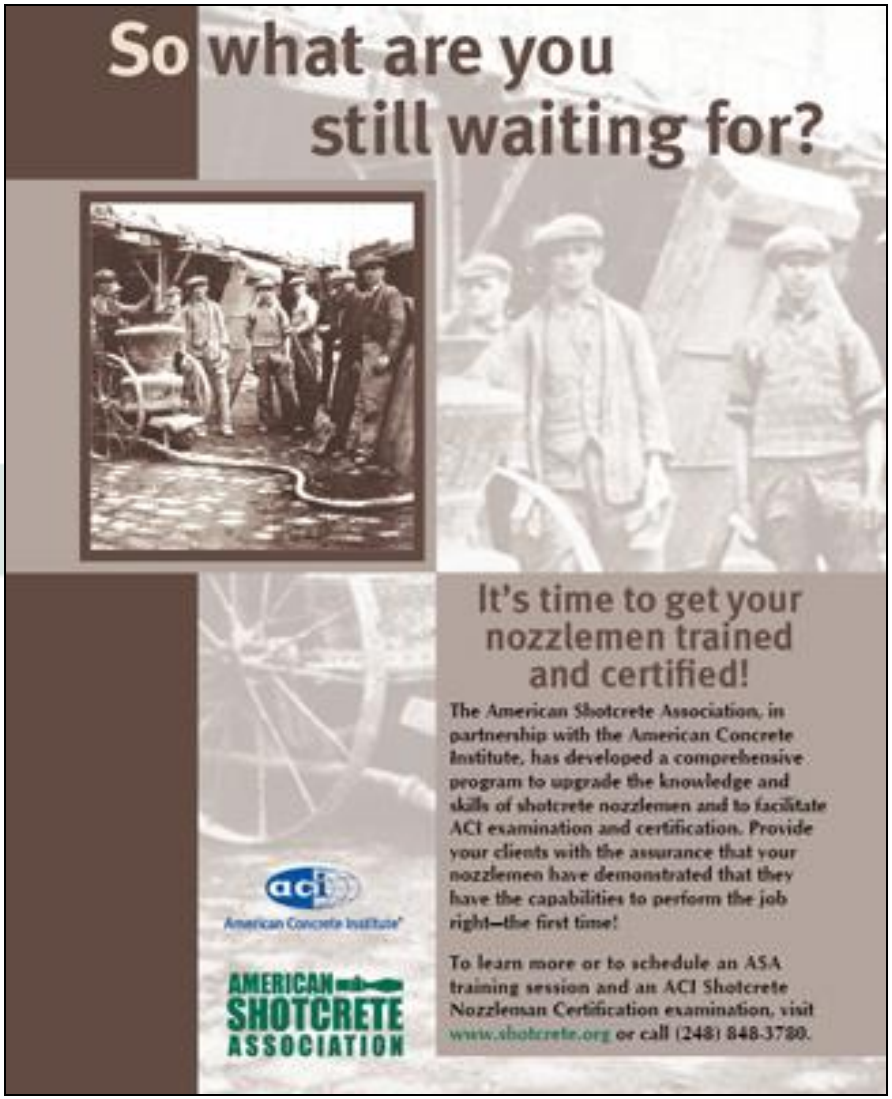
Easily Blend to Existing

No formwork!

ACI Nozzleman Certification Program



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Reference for Shotcrete

ACI 506R-16 *Guide to Shotcrete*

ACI 506.2-13 *Specification for Shotcrete*

ACI 506.6T-17 *Visual Shotcrete Core Eval*

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Useful Tools and Resources

- www.Shotcrete.org (Buyer's guide, magazine archive, many resources)
- www.Concrete.org (nozzleman & inspector certification, ACI 506 docs)

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50 ft. by 6 ft. Platforms weighing more than 6,000 lbs.

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