Trouble in the Air: Common Air System Errors Influence Shotcrete Quality

By Oscar Duckworth

Shotcrete, as defined in ACI CT-16 Concrete Terminology: "Concrete placed by a high velocity pneumatic projection from a nozzle."

Ever try to place wet-mix shotcrete without enough compressed air? To many, a crash course on the importance of sufficient air energy immediately follows an unexpected compressor malfunction. Clearly, experienced shotcrete workers realize the importance of compressed air in shotcrete placement. However, what means do workers have to readily identify that they are actually receiving the CORRECT amount of air energy necessary to achieve optimum placement consolidation and compaction quality?

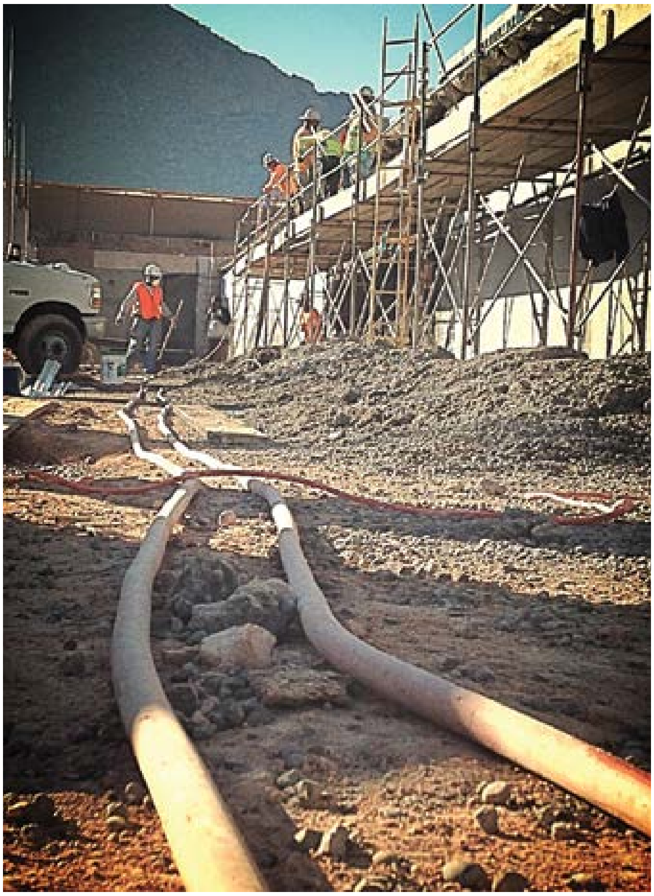


Fig 1: Longer hose lengths can lead to reduced air flow

To most, providing sufficient air energy is as simple as connecting a properly sized compressor to the opposite end of the hose supplying the nozzle (Fig. 1). A deeper look may reveal that the use of an appropriately sized compressor does not assure correct air energy. Many easy-to-overlook factors directly influence the ability to attain optimum air energy for wet-mix shotcrete placement. Do you know what they are?

IS YOUR COMPRESSOR *REALLY* FUNCTIONING PROPERLY?

Concrete material projected at high velocity differentiates shotcrete placement from traditional concrete placement methods. An adequate supply of compressed air is the energy source that provides sufficient impact velocity, the key element for full compaction and consolidation.

Without sufficient air energy, shotcrete placement simply conveys and loosely packs materials onto a receiving surface, resulting in less than required compaction and consolidation. Air compressor pressure and volume output is rated by a numerical value derived from the developed air pressure in pounds per square inch (psi), and the amount of compressed air that can be produced in cubic feet per minute (ft^3/min), at the rated pressure.

Example: A 375 ft^3/min (11 m^3/min) compressor is designed to provide air at a volume of 375 ft^3/min at an operating pressure of 125 psi (0.86 MPa).

Although compressors will produce at or above their rated output in "as-new" condition, air bypass within internal components due to wear, dirty filters/separators, or other factors will impact compressor output. Because wear and deferred maintenance reduce output levels gradually, workers may not realize that a problem exists (Fig. 2). A compressor that is running smoothly does not assure that a compressor is delivering its rated output. Many compressor problems have been identified only after mechanical repairs or replacement with a similar-sized compressor that produced far more air.

Fig 2: Although nice and clean outside, poorly maintained components may significantly reduce available air flow

WHY AIR ENERGY MATTERS

The dry-mix process requires much higher air volumes than wet-mix placement. Because dry-mix materials are conveyed through the delivery line by compressed air energy, more air volume is necessary to deliver material to the nozzle. With the dry-mix process, air compressors rated from 500 to 900 ft^3/min (14 to 25 m^3/min) at 100 to 125 psi (0.70 to 0.86 MPa) are necessary. Larger air flow also equates to the need for larger air delivery lines; 1.5 to 2 in. (38 to 50 mm) air delivery lines are common.

With wet-mix, hydraulic pumping equipment, rather than compressed air, conveys material through the delivery line. Compressed air introduced at the nozzle accelerates the concrete mixture delivered through the hose to create the high-velocity stream that impacts the receiving surface—the critical component to achieving quality compaction and consolidation. Wet-mix nozzle air requirements vary by nozzle size and design. Robotic-style 2.5 to 3 in. (64 to 75 mm) tunneling nozzles are designed to accelerate far more material per minute than a typical hand nozzle. These nozzles require air volumes of 600 ft^3/min (17 m^3/min) or more to function properly. Supplying sufficient air to these powerful nozzles requires large air supply lines often 2 in. (50 mm) and larger.

The most common hand nozzle is the 2 in. (50 mm) diameter nozzle. Hand nozzle designs differ significantly by manufacturer. Each configuration requires a predetermined minimum air flow rate and pressure at the nozzle to produce its designed impact velocity. Because these nozzles must be operated by hand, their weight and size limit efficiency at converting air flow energy into nozzle stream velocity (think short pistol versus long rifle). Therefore, unlike the larger (robotic) nozzles, small changes in supplied air volume and pressure to the nozzle directly correlate to very large changes in the impact energy generated from the nozzle material stream velocity.

SIZE MATTERS: THE RELATIONSHIP OF AIR LINE DIAMETER TO DELIVERY DISTANCE

Many shotcrete placement companies use 0.75 in. (19 mm) air delivery lines for wet-mix hand nozzle applications. In very short delivery line length applications, a 0.75 in. (19 mm) air delivery line may supply adequate air volume for proper nozzle function to some, but not for all hand nozzle designs. Occasionally, jobsite configurations require greater distances between the air compressor and the placement location. As air delivery line length increases, internal resistance restricts the delivery lines available air-carrying capacity. For air delivery lines longer than approximately 100 to 150 ft (30 to 45 m), a small 0.75 in. (19 mm) air delivery line would never be capable of supplying adequate air volume to most modern wet-mix hand nozzles. Conveying air for greater distances requires an air delivery system with a larger inside diameter. Air supply lines of 1 in. (25 mm) or (much) larger are necessary to provide adequate air energy for hand nozzles in longer-distance placement conditions. Using hoses too small to convey air long distances defeats the design of the nozzle by restricting incoming air energy. Workers must move compressors closer or increase air delivery hose inside diameter to maintain sufficient air energy to the nozzle (refer to Fig. 3).

Fig. 3: Larger-diameter air supply lines may be necessary to maintain sufficient nozzle velocity

Fig. 4: Although identical in exterior appearance, non-full-flow couplers (left) can be easily identified by their restrictive interior diameter

HIDDEN TROUBLE WITH COUPLERS

All air delivery systems rely on couplers as a means to connect various individual components, but coupler designs vary between manufacturer and country of origin. Most major coupler manufacturers have produced full flow couplers for decades.

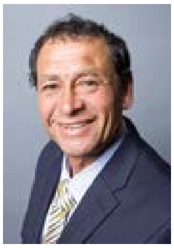
This type of coupler has an interior diameter that is nearly the same as the interior diameter of the delivery line to diminish internal restriction. Unfortunately, many currently available imported couplers do not incorporate a full-flow design (refer to Fig. 4).

Because a low-price, non-full-flow coupler may be identical in exterior appearance and primary function to a full-flow design, these couplers are currently in use on countless applications such as inexpensive prefabricated air supply lines, jackhammers, valves, or air-operated tools (refer to Fig. 5).

Fig. 5: Beware of prefabricated air hoses supplied with restrictive couplers

Unfortunately, if used in even one location within a 0.75 in. (19 mm) wet-mix shotcrete air delivery system, the coupler will act as an air restricting device, limiting air flow to levels well below the minimum requirement for nearly every common nozzle in current production. Because restrictive coupler designs do not create obvious differences in the sound or feel of the wet-mix equipment operation, workers may not realize that a serious problem is occurring. It is important to inspect each 0.75 in. (19 mm) air coupler within the system and replace any coupler or other delivery component that does not incorporate a full-flow design.

High-velocity placement is a key element for producing the full compaction and consolidation required for quality concrete. It is essential that the correct amount of air energy be delivered to the nozzle to achieve the needed velocity. Insufficient air delivery to the nozzle, whether caused by air delivery line choices, restrictive couplers, or the use of an air compressor with less than the required output present major obstacles to attaining acceptable compaction and consolidation. If low air energy is suspected, check by inspecting for poor air compressor function, restrictive couplers, or an air delivery system that may be too small for the project. Simple steps are useful to help assure that your air delivery system is functioning properly. Can you be sure yours is?



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