NEW

Are You Using the Right Wet-Mix Nozzle?

By Oscar Duckworth

My first shotcrete nozzle was a lot like my first car. I thought it was the best thing ever, until I replaced it and found out how truly bad it was. Like my first car, that nozzle was the only thing available to me at the time. And like my first car, it was unreliable, required constant attention, and rarely provided acceptable performance.

Today there are countless nozzle configurations available to the nozzleman, all of them superior to those early designs. But beware—unlike my first car, that first nozzle is still available on the shelf right next to all of the other choices.

Which Nozzle is Right for Me?

There is no single wet-mix nozzle that is right for all applications. One given nozzle configuration will, however, perform a specific task better than another.

Selecting a Wet-Mix Nozzle

Nozzle choices must be made for different job requirements, such as:

- Quantity (volume) of material placement;
- Velocity of the material being placed;
- Type of placement, such as tight access or overhead;
- Mixture proportions; and
- Use of accelerators at the nozzle.

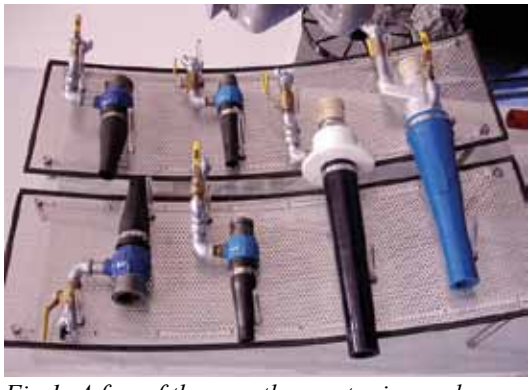

Fig 1: A few of the countless wet-mix nozzles currently available

Nozzle Sizes and Types

Wet-mix nozzles come in several sizes. The most common sizes used are 1.5, 2, and 2.5 in. (38, 51, and 64 mm). Both 1.5 and 2 in. (38 and 51 mm) are generally used for hand-nozzle work, while 2.5 in. (64 mm) or larger nozzles are primarily used in robotic operations.

The 1.5 in. (38 mm) nozzles are popular choices for small jobs and repair areas because they are much lighter and easier to handle than their larger counterparts. Their use may be limited, however, by the mixture proportions. Many shotcrete mixtures may not be pumpable through a 1.5 in. (38 mm) system without a reduction or elimination of the coarse 3/8 to 1/2 in. (10 to 13 mm) aggregates.

Two inch (51 mm) wet-mix nozzles and placement systems are the most popular hand nozzle size and work well with most mixture properties. This size will accommodate most popular mixture designs, including those with synthetic fiber below approximately 12 lb/yd^3 (7.2 kg/m^3) or steel fiber below approximately 75 lb/yd^3 (45 kg/m^3).

Nozzles that are 2.5 in. (64 mm) or larger are commonly used in robotic operations and allow the use of harsher mixtures and larger amounts of fiber without plugging. They can potentially allow placing material at over twice the speed of other systems. These nozzles require a much larger compressor air volume to maintain adequate velocity.

Admixture Nozzles

These special-purpose nozzles are configured with a second set of ports within the nozzle body that allow the injection of liquid chemicals into the mixture during placement to speed up the setting time or early-strength development of the in-place material. The admixture nozzle is commonly used in tunneling, overhead, or specialty earth retention projects such as low tide work. Admixture nozzles are available in popular robotic and hand nozzle configurations.

Admixture dosage rates are critical as they can affect shootability, strength, and durability of the in-place shotcrete. Therefore, calibration of the dosing system is very important and needs to be checked regularly.

The use of "jack tanks" or other devices that lack the ability to deliver a calibrated flow of admixture should not be used. Admixture nozzles must be used in conjunction with precise metering equipment and by nozzlemen familiar with the systems in use.

How Many Nozzles Do I Need?

The definition of shotcrete, as defined by the American Concrete Institute (ACI), is "concrete or mortar placed at sufficient velocity to achieve compaction." Therefore, the primary requirement of an acceptable wet-mix nozzle is that it is able to produce and maintain adequate velocity to ensure proper compaction at the receiving surface to achieve acceptable compaction for the application at hand. The receiving surface is the point where the mixture is compacted to its highest degree. Insufficient compaction will create low-quality, in-place material.

Material velocity drops sharply as the distance increases to the receiving surface so the nozzle must be kept close, usually 1 to 4 ft (0.3 to 1.2 m) from the receiving surface; or the nozzle must be reconfigured to maintain the higher exit velocity for special placement requirements such as overhead work. This may be accomplished by choosing a nozzle tip to increase exit velocity.

A well-designed wet-mix shotcrete nozzle must do many things to achieve acceptable compaction. The nozzle must allow enough air volume uniformly into the air ring and the ports within the nozzle body to completely break up the supplied mixture into fine particles. Unfortunately, many early nozzle designs were not up to this essential task. Most modern designs use much larger air rings and valves in conjunction with bigger drilled ports within the nozzle body to deliver higher diffusion energy to the mixture. If, for any reason, the material is not completely diffused into small particles during this step, they will exit the nozzle as larger masses. These "lumps" or "slugs" will then gather at the receiving surface as loosely consolidated masses. Typically, the larger the drilled port, the better it will diffuse the mixture. Always choose a nozzle that will allow adequate air volume to completely diffuse the mixture.

Fig 2: Note second valve supplying second row of drilled ports on wet-mix admixture nozzle

Fig 3: Nozzle body above with 1/8 in. (3.2 mm) drilled ports. Nozzle body below uses 3/16 in. (5 mm) ports and adds chamfer to increase air flow

The ports supplying air from the air ring through the nozzle body can plug with material during use if the air supply line is stopped or kinked for even a moment. When a nozzle is set down, always leave the air supply line open a little to maintain pressure to the air ring to prevent ports from plugging. A nozzle with partially plugged air ring holes will not be able to properly break up the material and will not provide an adequate velocity or spray pattern to the receiving surface. During placement, stop work immediately

Fig 4: Note plugged port within nozzle body

Fig 5: Nozzle tips are available in many lengths for varying placement conditions

Fig 6: After placing only 80 lb/yd³ (60 kg/m³), the worn tip on the right has become oversized and must be discarded

if you suspect a partially plugged nozzle, and clean or replace the nozzle.

The next aspect of a wet-mix nozzle is to provide the velocity required to achieve acceptable compaction at the receiving surface. Shorter nozzle tips provide less velocity for close-in work. Longer tips with tighter opening sizes create tremendous velocity. A skilled nozzleman should carry many different tips for varying job conditions.

The constricting shape of the nozzle tip is designed to control both the velocity and the spray pattern of the shotcrete material. The nozzle tip will wear rapidly through use. When the nozzle tip thins, impact energy is reduced and the tip must be replaced. Many nozzle tips begin to degrade immediately and are worn to the point that they need to be replaced in less than a few hundred yards of placement.

Using a worn nozzle tip will certainly create placement problems due to poor compaction at the receiving surface. A distinct reduction in nozzle velocity and a wider, poorly controlled spray pattern are clear indicators of a worn-out nozzle tip. Always replace worn parts. Never use cut-off tips. A cut-off tip will not generate sufficient impact energy.

Air flow requirements vary greatly depending on the type, size, and manufacturer of the nozzle. A wet-mix nozzle will only convey as much air as is allowed by its design and the size of the supply line, regardless of the size of the compressor it is connected to. Always follow the manufacturer's recommended compressor (cubic foot per minute [cfm]) requirements and use properly sized supply lines. Use 3/4 and 1 in. (19 and 25 mm) minimum for hand nozzles and much larger for robotic nozzles. A good nozzle requires plenty of air. The nozzle body at the bottom of Fig. 7 will flow nearly 180 ft^3/min (5.1 m^3/min).

A properly chosen wet-mix nozzle and its placement system must:

- Be able to convey the approved mixture design;
- Provide adequate volume for job conditions;
- Completely break up the mixture;
- Deliver a good spray pattern; and
- Create sufficient impact energy to the receiving surface for the intended purpose.

As noted previously, a primary component to acceptable shotcrete placement is impact energy. The wet-mix nozzle, as well as all the other components of the placement system, must be selected and maintained to provide adequate impact energy to the receiving surface.

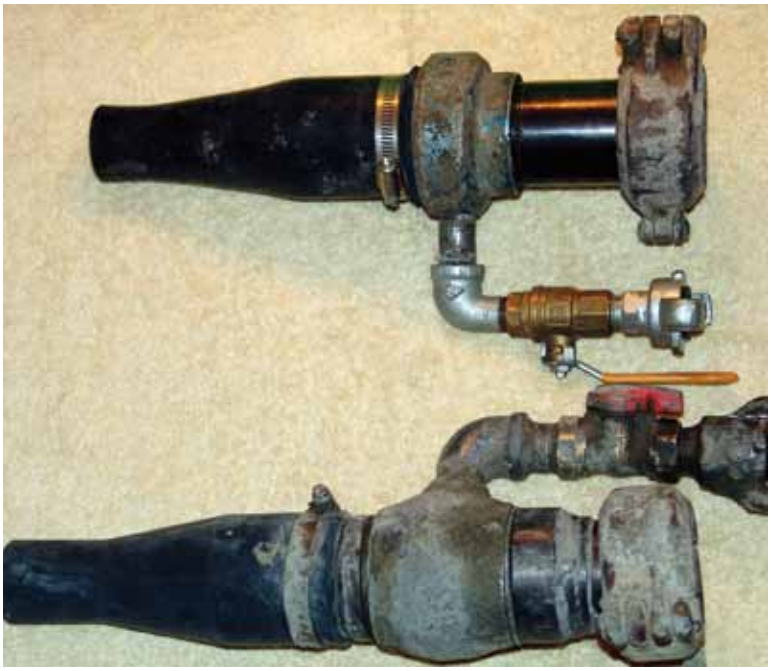

Fig 7: Note undersized 1/2 in. (13 mm) elbow and valve on upper nozzle and properly sized 3/4 in. (19 mm) parts on nozzle below. Half-inch (13 mm) elbow and valve will not flow sufficient air for adequate shotcrete placement

*ACI Certified Nozzleman **Oscar Duckworth** is an American Shotcrete Association (ASA) and ACI member with over 15,000 hours of nozzle time. He has worked as a nozzleman on over 2000 projects. Duckworth is currently an ACI examiner for the wet-mix process and is an approved ASA wet-mix and dry-mix Educator. He continues to work as a shotcrete consultant and a certified nozzleman.*

Wet-Mix Nozzle Checklist

- Choose a nozzle with adequately sized ports, usually 3/16 in. (5 mm) minimum;
- Use the right tip for the job—a short tip for low velocity, close-in work, a medium tip for shooting 2 to 4 ft (0.6 to 1.2 m) from the surface, and a long tip for high velocity for overhead or for greater distance from the receiving surface;
- Maintain your nozzle. Inspect nozzle tips, do not use cracked or worn nozzle tips. Always replace worn items. Keep nozzle body ports clean. If the nozzle becomes plugged, stop immediately, follow proper shut down procedures, and clean and or replace the nozzle; and
- Use adequate air volume and a properly sized compressor and supply lines.

The choice of the proper nozzle configuration is an often over-looked essential element to shotcrete quality. Routine inspection and maintenance of wet-mix nozzles must become part of the nozzleman's daily routine. This is one of many steps needed to assure ultimate product quality.