Gunite Versus Shotcrete in Swimming Pool Construction

By Mason Guarino and Ryan Oakes

The term "gunite pools" has been used for decades in the swimming pool industry and is commonly used to describe a pool using shotcrete placement, whether it is the wet-mix process or the dry-mix process. Pool builders and designers have often debated whether a pool should be "made from gunite or from shotcrete." In this article, we clarify the terminology that leads to the debate and then provide arguments for both sides of the discussion.

Gunite and shotcrete are not materials, but rather are placement methods for pneumatically placing (shooting) concrete materials at high velocity. In the history of shotcrete, the term "Gunite" was a tradename used for the dry sand-cement mixture pneumatically shot from the Cement Gun Company's equipment and hydrated at the nozzle. When ACI started writing standards for pneumatically placed mortar in 1951, it adopted the term "shotcrete," as proprietary tradenames were frowned upon in technical standards. When reliable concrete pumping equipment allowed pneumatic placement of ready mixed concrete, the terminology was modified to include "wet-mix shotcrete," while the original dry process became termed "dry-mix shotcrete." Many companies still use the original term "gunite" to refer to dry-mix shotcrete. Thus, the term "shotcrete" can really be applied to either the dry-mix or wet-mix process.

It has long been considered that shotcrete is the best way to place quality concrete for a swimming pool structure. Shotcrete requires less formwork, fewer touchups after form stripping, provides excellent strength and durability, and can be installed far more quickly than form-and-pour pool construction. Along with many other benefits of shotcrete, there is no question that shotcrete is how concrete pools should be constructed. However, with two shotcrete processes, which one is the best for swimming pool construction? The short answer is that both processes work exceptionally well when correctly placed with a well-trained crew using the proper materials, equipment, and placement techniques employed by experienced shotcrete companies.

THE DRY-MIX VERSUS WET-MIX DEBATE

Common points of debate are whether one method is stronger than the other and whether one method cracks more than the other. There are many variables that influence these points, including the mixture design and the placement of that mixture. If dry-mix shotcrete has a 5000 psi (35 MPa) compressive strength and wet-mix shotcrete has a 5000 psi compressive strength, they are indeed the same strength. This seems elementary, but actual compressive strength as measured by compressive values is often ignored during arguments of one method being stronger than the other.

Though many pool builders feel a 2500 psi (17 MPa) 28-day compressive strength is adequate for pool construction, ASA's position is that shotcrete must have a minimum 4000 psi (28 MPa) to allow proper encasement of reinforcement, low permeability, and long-term durability. This is especially important in shotcreted pool shells that are expected to be watertight and provide decades of trouble-free service. This topic is covered in more detail in the "Overview of ASA Position Statements" article on p. 28 of this issue and online in Pool and Recreational Shotcrete Committee Position Statement #1 (**www.shotcrete.org/media/pdf/ASAPositionPaper_PoolRec_1.pdf**).

When it comes to cracking, the debate becomes more difficult. There are many reasons why pool shells crack. Common reasons include inadequate reinforcing bars, construction on poor soil, poor curing practices, seasonal temperature changes, concrete shrinkage, and even whether rebound is left in the pool rather than being removed during the installation. Aside from not removing the rebound, most of the pool cracks that occur have nothing to do with the shotcrete placement. Shrinkage (autogenous, early-age plastic, and long-term drying) takes place in all concrete whether cast or shotcreted. We will only be covering shrinkage cracking in this article.

The wet-mix process typically uses a water-cementitious materials ratio (*w/cm*) range of 0.40 to 0.45 and the dry-mix process typically uses a lower *w/cm* range of 0.35 to 0.40. This lower *w/cm* reduces water in the concrete mixture and can reduce shrinkage cracking. Moreover, when wet-mix concrete leaves the plant or arrives to the jobsite with a 0.40 *w/cm*, it may have more water added if it has been aging and needs more fluidity to be pumped down the line. Unfortunately, adding additional water to the concrete mixture after the mixture has stiffened is a common practice in the pool industry, resulting in concrete placed in many pools having a *w/cm* higher than 0.50. This higher water content not only reduces the strength of the shell and increases the permeability but also creates the potential for more shrinkage.

The negative effects of a too-high *w/cm* cannot be over emphasized in creating watertight pool shells. ASA Position Statement #4, "Watertight Shotcrete for Swimming Pools," explains that ACI 350, "Code Requirements for

Environmental Engineering Concrete Structures," mandates a maximum *w/cm* of 0.45 with a minimum 4000 psi for concrete intended to have low permeability when exposed to water. If concrete water-containing structures are exposed to freezing and thawing while saturated (a common occurrence in northern climates), an even lower maximum *w/cm* of 0.42, with a minimum 4500 psi (31 MPa) is required.

A well-trained crew can mitigate this by using water-reducing admixtures rather than adding water. Strength is not an argument for one shotcrete process over the other, as both, with the proper concrete mixture designs, can produce strong, functionally impermeable concrete shells. With proper attention to shrinkage, cracking is typically not an argument for one process over the other.

WHAT IS THE DIFFERENCE BETWEEN DRY-MIX AND WET-MIX?

Dry-mix is the process of conveying dry concrete materials, often just a coarse sand and cement mixture, through a delivery hose, injecting the majority of water at the nozzle, then shooting the newly hydrated concrete at high velocity onto the receiving surface. The wet-mix process pumps premixed concrete (usually a coarse sand, 3/8 in. [10 mm] or less coarse aggregate, and cement mixture) down the delivery line and adds air at the nozzle to accelerate the concrete to a high velocity.

Benefits of Dry-Mix Shotcrete

The benefits of dry-mix shotcrete make it an exceptional method for all pool construction. Dry-mix really excels in pools with less than 1000 ft^2 (90 m^2) of water surface area and pools with a high level of detail such as perimeter overflow pools or vanishing-edge pools. Pools in this size range typically can be finished in a day barring any extravagant features that could delay the crew into a second or third day.

Pools this size are often found in backyards where there is very little area to work in and limited space for a concrete truck to clean out. Dry-mix shotcrete creates minimal mess and can be easily cleaned up, and that helps get crews in and out in a day. A wet-mix crew must provide a way for concrete delivery trucks to clean their chutes while a dry-mix crew simply shovels up any leftover materials at the end of the day. Additionally, these size pools often have only one curtain of reinforcing bars, making the shooting process and managing rebound easier for the nozzlemen.

The cleanup process after shooting dry-mix is easier than wet-mix. There are only dry concrete materials to scoop or vacuum up—no concrete wash water or leftover concrete to worry about, especially when having to shoot from city streets (Fig. 1, such as Commonwealth Ave. in Boston). Wet-mix would have added hours of cleanup to the job; even a good plastic washout pan can fail and then you are cleaning up wet concrete with nowhere to wash it to.

Residential pools commonly have a lot of intricate detail. This detail work is typically easier to place and finish with a mixture that only contains cement and concrete sand without a coarse aggregate. Many dry-mix shotcrete pool

Fig. 1: Volumetric mixer truck on a pool shoot

Fig. 2: The crew is able to walk on recently shot dry-mix material without sinking into the surface

contractors use volumetric mixer trucks to produce their concrete mixtures. This allows the crew to stop and start as necessary to ensure a quality placement and finish, while eliminating the concern of set time of premixed concrete material not yet placed. The concrete materials in the volumetric mixer truck are dry and can sit as long as needed until the crew is ready to start shotcreting again. A great advantage to dry-mix shotcrete is that with the correct mixture and placement, the in-place material can handle foot traffic immediately, leaving little more than a footprint (Fig. 2).

Unless a wet-mix concrete design uses a retarder or hydration control admixture, the batched concrete needs to be placed within 90 minutes of batching. By the time the concrete truck drives to the jobsite (hopefully not stuck in

traffic), waits their turn to pump, and then is shotcreted, it is often difficult to meet the 90-minute time frame.

Using volumetric mixer trucks for creating wet-mix concrete on site can help mitigate this problem. However, it still leaves the problem of walking on the freshly placed, relatively fluid concrete mixture and disrupting the surface.

Benefits of Wet-Mix Shotcrete

Wet-mix shotcrete has significant benefits for pools larger than 1000 ft^2 (90 m^2) of water surface area and when more than 1 day is required to complete a pool structure. Wet-mix shotcrete has substantial production advantages over dry-mix. At South Shore Gunite (SSG), a volumetric mixer truck is used to produce both dry-mix and wet-mix shotcrete. With dry-mix production, the mixer truck runs at about 8 to 12 rpm, whereas in producing wet-mix concrete, the truck runs between 20 and 25 rpm—both with similar output per rpm. Thus, using wet-mix can double the production rate of concrete as compared to dry-mix… when the job allows. Wet-mix shotcrete can be easier to place, especially when jobs have high amounts of reinforcing bars with multiple curtains of reinforcing bars to shoot through (Fig. 3 and 4). The wet-mix process typically has less rebound than dry-mix, making areas with complicated layouts easier to manage with an experienced nozzleman and blow pipe operator. In similar circumstances with dry-mix shotcrete, the speed that rebound collects can be more challenging for the blow pipe operator to control.

Fig. 3: Wet-mix shotcrete was used on this pool because of the congested reinforcing bar layout, as well as requiring about 300 yd^3 (230 m^3)

Fig. 4: The same pool shown in Fig. 3 contained over 55 tons (50 tonnes) of reinforcing bars. With an extremely tight schedule, wet-mix easily allowed placement of concrete in 5 days

Wet-mix shotcrete also allows the use of more complicated concrete mixtures than dry-mix. Wet-mix shotcrete is readily available from ready mixed plants with fibers, air entrainment, high-range water-reducing admixtures, accelerators, and other forms of concrete admixtures. Dry-mix can include supplemental materials or admixtures, but it involves a more advanced setup, or use of prebagged, plant-produced materials. Revolution Gunite (RG) has used supplementary cementitious materials (SCMs) such as silica fume and has added color or fiber to its mixture design when required for the job. However, it takes more planning and setup on the job, and is more difficult than simply ordering ready mixed concrete from a concrete plant.

SELECTING A PROCESS

SSG installs pools smaller than 1000 ft^2 (90 m^2) of surface area with dry-mix shotcrete (Fig. 5) and pools over 1000 ft^2 (90 m^2) with either method. SSG does not use wet-mix shotcrete for pools under 1000 ft^2 (90 m^2) because these pools can be done in 1 day, and thus require crews to walk on freshly placed concrete in the floor. With dry-mix shotcrete, the placed material is very stiff and walking on freshly shot material disturbs just the top surface (minor footprints) without disturbing the embedded reinforcing bars. Wet-mix shotcrete tends to be more plastic when shot and walking prematurely on the surface can disturb and displace the embedded reinforcing steel in the floor.

Some finishing takes a lot of time, meaning that the shotcrete crew often chooses between one of two methods:

1. Shooting the walls first and cutting the excess shotcreted wall material into the floor/wall cove and then attempting to clean this undesirable material out from under the reinforcing steel; or
2. Shooting the cove in first and then walking through the wet, freshly placed material, potentially disturbing the concrete well into its initial set time.

However, neither method is advised. It is especially difficult to properly remove ALL the shavings, rebound, and excess concrete from under the reinforcing steel in the floor/wall cove. For strength and watertightness of the concrete pool shell, it is essential that all concrete is well placed with high velocity from the nozzle, providing thorough compaction of the material. This is equally important for both wet-mix and dry-mix. Tight spaces with a lot of congestion in formwork, embeds, pipe penetrations, or reinforcing steel—such as a spa—can create excessive rebound and in most cases the floor should be shot or cast first.

SSG mostly uses its wet-mix equipment for larger jobs starting at around 200 yd^3 (150 m^3) and going up to 600 yd^3 (460 m^3) (Fig. 6). SSG typically works under tight schedules, so the ability to install a pool structure a week faster than with dry-mix is a huge advantage. However, before SSG started using the wet-mix process, it shot many large pools, including a 50 m (160 ft) pool for Brown University with

Fig. 5: SSG used dry-mix shotcrete for this smaller pool with about 50 yd³ (38 m³) of concrete and easily completed in 1 day with dry mix. Additionally, the steel schedule was light and with a tight jobsite it is easier to clean up a dry-mix setup than a wet-mix setup

Fig. 6: Wet-mix shotcrete pump and on-site volumetric mixer allowed for faster production, as there was no swapping out of concrete trucks

dry-mix equipment. This pool had multiple layers of reinforcing bars and tricky areas. Having an experienced ACI-certified shotcrete nozzleman and an experienced blow pipe operator, SSG was able to build an exceptional structure that easily passed the watertightness test.

RG shoots every pool, large or small, with the dry-mix process. RG found that when working on multiple-day shoots, using the dry-mix process has the added advantage of having a delivery hose that, when not conveying concrete material, can provide high-volume air and water.

This high-volume air-water blast allows crews to easily prepare the previous days' placement, creating an optimum clean, saturated surface-dry (SSD) surface before applying the new concrete. RG uses on-site volumetric mixers for continuous batching of dry concrete materials. RG has achieved rates as high as 110 yd^3 (84 m^3) per day with one gun. Though admittedly not as high a production rate as wet-mix, it is fast enough for one crew to keep up. When a higher placement rate is needed, RG simply adds another gun and finish crew to double the production. High production is important in large commercial pools; however, most residential pools average 50 to 60 yd^3 (38 to 46 m^3) in North Carolina and 25 yd^3 (19 m^3) in Florida, so the region may dictate the installation method as well.

RG recently transported its volumetric mixer, compressor truck, and a cement silo along with multiple loads of aggregate and cement by barge to a remote island, off the

Table 1: Dry-Mix Process

Pros	Cons
Low *w/cm* ratio (high strength and low shrinkage)	High investment cost to get started or add experienced crews
Finishers can walk on material without disturbing the placed material	Higher level of experience needed from the nozzleman and crew
Finishers can work more easily with the material	High level of maintenance for equipment and trucks when using volumetric mixers
Volumetric on-site batching facilitates logistics	Requires specialized equipment to meter the material deliveries and water must be available on site or trucked in
Hydration at the nozzle ensures that the concrete mixture is fresh	Lower production rates compared to wet-mix
Hoses are lighter and easier to manage for the crew	Procuring dry aggregate and cement in remote areas where batching facilities are not owned by the contractor can be extremely difficult
Hoses do not surge, making the delivery hose layout more flexible	
Running long distance (up to 500 ft [150 m]) does not require additional procedures or concerns	
Dry materials are easier to clean up and dispose of than wet-mix concrete	
All job logistics are typically handled by the Shotcrete Contractor	

Table 2: Wet-Mix Process

Pros	Cons
Higher production rates compared to dry-mix	Can be more difficult to coordinate timely deliveries to place material within allowed timeline
Easier to get material in most locales	If problems arise on the job, stopping batching of subsequent trucks is difficult
Easier to use specialized admixtures in the mixture	If lines plug, they are difficult to clear and provide an added risk to property and crew
Mixture comes ready to pump; no on-site water needed	Contractors are typically at the mercy of the concrete supplier and their schedules
Can also use on-site volumetric mixer rather than ready mixed	Tends to have a higher *w/cm* for pumpability
Low start-up cost relative to dry-mix process using volumetric mixers	Adding water to the mixture to facilitate pumping is often a problem
	Walking on previously placed material can disturb the concrete and embedded reinforcement
	Contractor must provide a place for cleanout of concrete trucks
	Hoses are heavy and require more strength and endurance from the nozzlemen and crew
	Coarse stone in the mixture makes it more difficult on the finishers to achieve required finishes
	Distances from the pump to nozzle are limited by line type and size, often requiring steel pipe or larger lines to pump as far as a dry-mix hose can deliver with ease

coast of North Carolina, to shoot three commercial pools. The winds that could result in barge closings, and ability to coordinate placement on the jobsite made dry-mix shotcrete ideal, even though these were larger pools with congested reinforcing steel layouts.

Another example where dry-mix excelled for RG was on a residential project where the delivery lines had to be routed through the home—and the nearly completed home was worth approximately $20 million! Because dry-mix delivery hoses are relatively low pressure and not surging from the stroke of the concrete pump swing tube, the crew felt more comfortable using dry-mix. Water hoses ran through the home too, requiring RG to take special care to assure the connections were not leaking. This job could theoretically have been done with a wet-mix shotcrete line; however, it would be precarious to say the least just to protect the floors from the surging lines and in the event of a plug and the hose break or a simple cleanout, things could quickly become scary and expensive.

Past arguments against dry-mix shotcrete for a pool have included the fact that the *w/cm* is not precisely measured, and injecting water with the concrete materials so soon before placement cannot adequately mix the concrete. However, injecting water at high pressure while the dry materials pass through the water body completely saturates the materials. RG assures a constant flow of high-pressure water to our dry-mix nozzles by using on-board hydraulic water pumps pulling from our water tanks to get uniform water pressure. Although RG uses flow meters to determine actual *w/cm*, those concerned with the precise *w/cm* will find if you shoot dry-mix too wet, it simply won't stand up. Generally, dry-mix used vertically (or overhead) has a lower *w/cm* than wet-mix because pumpability is not a concern. Another common argument against the dry-mix process is that the builder paying for the material does not really know how much is being delivered. At RG with its volumetric mixer trucks they can accurately meter and document the materials being delivered.

From the shotcrete contractor's standpoint, dry-mix has its disadvantages, too.

1. Because water addition to the concrete is controlled at the nozzle, dry-mix requires a more skilled nozzleman to place the material at the proper consistency.
2. Depending on the nozzleman, a job can experience more or less rebound, although the same can be said for the wet-mix process.
3. Finding water on site can be challenging, sometimes requiring water to be delivered to the job for the dry-mix placement.
4. The overall investment for a complete dry-mix operation with volumetric mixers can be 15 to 20 times (or greater) than that of a wet-mix setup. With the barrier of entry from an investment standpoint so high, it leaves the new startups competing with established giants in the industry.

Wet-mix also has a few drawbacks for the shotcrete contractor.

1. Unless site batching, they are relegated to working with the local ready mixed concrete companies and being constrained by their concrete availability and delivery schedules.
2. The overall pool builder, not the shotcrete contractor, often coordinates the concrete deliveries, adding a third party into the logistics.
3. The wet-mix delivery hoses are much heavier and must carry 10 times the internal pressure, making them not only more tiring for the nozzleman but also more dangerous for everyone on the project if there are plugs in the line.
4. The coarse aggregate typically used in the concrete mixture makes finishing harder on the crew.

CONCLUSIONS

In summary, both the dry-mix and the wet-mix process, when using quality materials, well-maintained and properly sized equipment, and placed by experienced shotcrete crews, are great for creating high-quality, durable, watertight swimming pools. Table 1 (Dry-Mix) and Table 2 (Wet-Mix) summarize our commentary on the advantages and disadvantages of both the dry-mix and wet-mix shotcrete processes.

Mason Guarino *started in the pool industry when he was 14, learning how to install reinforcing bars. Since then, he has worked on all phases of swimming pool construction. Guarino has been with South Shore Gunite Pools & Spas, Inc., full time since graduating from the Wentworth Institute of Technology with his BS in construction management in 2009. Guarino currently serves on ASA's Board of Directors and is an ACI Certified Nozzleman.*

Ryan Oakes *is a Managing Partner at Revolution Gunite and is a licensed pool contractor in North Carolina and Virginia. Oakes has been designing and building watershapes in the United States and abroad, from swimming pools to art pieces and even aquaculture systems, for the past 20 years. With a mission to change the way gunite is perceived and applied, Oakes started down a path of education for himself as well as their staff. He is an active member in the National Swimming Pool Foundation's Genesis University, which educates contractors around the world in various aspects of the pool building process, including the shotcrete process. Oakes is an SWD Master (Society of Watershape Designers) and an Allied member of the American Institute of Architects and member of the American Pool & Spa Association. In 2017, Oakes was appointed by the ACI Technical Activities Committee as a member of ACI Subcommittee 506-H, Shotcrete for Pools, and a member of ACI Committee 506, Shotcrete. He was recently appointed to the ASA Board of Directors while also serving as Vice Chair of the ASA Contractors Qualification Committee and a member of the ASA Pool & Recreational Shotcrete Committee.*