Volumetric Batching of Wet-Mix Shotcrete

By Mason Guarino

For decades, volumetric batching has been commonplace in the dry-mix shotcrete process. Everyone that has experience with it knows it is fairly easy, convenient, and reliable and allows for ultimate material control. Maintaining the trucks and equipment can be costly, but the expenses are easily covered by the less-expensive material, less wasted material, and any downtime or frustration with ready-mix companies. South Shore Gunite Pools & Spas, Inc. (SSG), has been using volumetric batch trucks since 2000 in the dry-mix process, so when SSG decided to venture into the wet-mix industry, it seemed like a no-brainer, as we already had a volumetric batch plant capable of producing concrete for the wet-mix process. After some trial and error and research, we were able to successfully produce wet-mix shotcrete material with our volumetric batch plant, place it into our pump, shoot it into place, and achieve compressive strengths of up to 6000 psi (41 MPa) in 28 days.

Selecting the Proper Volumetric Batching Machine

When making wet-mix shotcrete material with a volumetric batch plant, you first need to determine your desired expectations of the machine. Some questions you should ask yourself are: How fast do you want to produce wet-mix material? What is your desired mixture design? How do you want to control the water and admixtures? Do you want to set up a silo and machinery for continuous batching or do you want to run back and forth to reload the batch plant? All of these are important factors in determining the type of machinery that will live up to your expectations. I will also address how we use our machinery, calibrating the machine, and some of the advantages over conventional ready mixed concrete. Once started, we learned a lot about what our machine was and was not capable of. We had to modify certain things to get it to run the way we would have liked it to run right from the factory. These things could have been avoided if I had known what to discuss with the manufacturer beforehand.

Volumetric batch plants are often marketed by production rate per hour in cubic yards or cubic yards per hour (yd^3/h). However, their marketing of yd^3/h is based on a much different mixture design than that of a normal shotcrete mixture design. Their yd^3/h is based on a mixture design with less cement and a higher slump. This means that if you want to be able to batch at a speed of 20 yd^3/h (15 m^3/h), you will need to have a more in-depth conversation with the manufacturer. I have found that aiming for batching at 20 yd^3/h works best and gives you options to adjust speed by starting and stopping. Many batch plants are advertising their per-hour rate with a 5.5 cement bag mixture. Wet-mix shotcrete more commonly has an 8 bag or higher per cubic yard mixture. This is easy to overcome by letting the manufacturer know that you need more cement delivered faster than the standard model provides. You may want to specify a little higher rate than your standard mixture so there is an option to increase production. Additionally, the mix auger is typically sized to accommodate a 5 to 6 in. (125 to 150 mm) slump material. With shotcrete, we are commonly looking for a 2 to 4 in. (50 to 100 mm) slump, so the mix auger will need to have more power than provided in a smaller stock machine. Larger stock machines may have sufficient power to handle the lower slumps, but it should be discussed with the manufacturer before you find yourself unable to mix and convey your thicker shotcrete material to the pump. If you plan to run a large truck-mounted volumetric batch machine, this will typically have plenty of power to get the job done. Smaller and stand-alone rigs may not have the necessary power out of the factory.

Mixture Design and Batching Considerations

Mixture designs for volumetric batch plants are not the same as ready mixed, plant-batched mixture designs. A volumetric batch plant typically has some limitations. Some of the limitations I have found relate directly to two of the more favorable additives we use in wet-mix

shotcrete: fly ash and mid- to high-range water reducer/plasticizers.

We have found producing a shotcrete mixture with fly ash is currently unfeasible. There are three ways to enable running a fly ash mixture, but they are either not available or very expensive. One way would be to have a supplier blend it for you, but I have not been able to find a supplier in the northeast that will do that for us. The next way would be to run two different powder hoppers on the batch machine, one for cement and one for fly ash. The third way would be to self-blend it before placing the material in the hopper. As a result, we do not currently have the option of using fly ash in our mixture. Since we do not have fly ash, we just use a straight cement mixture.

The specific water reducer/plasticizer considered for a shotcrete mixture needs to be researched. Sometimes a technical data sheet will have all the information, but other times, you may need to get in contact with the manufacturer. Some water reducers/plasticizers require several minutes of mix time, but with a volumetric batch plant, the mix time is under 30 seconds, and that is generous. With some of the plasticizers that take time to react in the mixture, the mixture will look thick with a low slump at the pump. However, as the mixture travels through the hose, the water reducer will start to activate, and by the time it gets to the nozzle, the slump will be undesirably higher. Make sure all of the admixtures can start working quickly with very little mixing time; otherwise, you will just be wasting money and potentially hindering the final shot material. As long as all the admixtures in the mixture can handle a short mixing time, the dosage amounts can typically be kept about the same as a ready-mix design.

Accurate control of water and admixture is very important with a volumetric batch plant. Adding a few gallons to a ready-mix truck to get the mixture where you want it may be okay if the required water-cement ratio (*w*/*c*) is not exceeded, but always be careful not to go over, or you will potentially ruin the entire batch in the truck and render the concrete unusable. Onsite batching has some advantages over ready-mixed concrete regarding the control of water in the concrete. First of all, the volumetric machine should be equipped with a flow meter that has a flow control unit installed at a location that is easily accessible by the operator (refer to Fig. 1). An extra gallon (4 L) in a 7 yd^3 (5 m^3) truck won't do much to the mixture, but if your water flow is high by 1 gal. (4 L) per minute, that is adding an extra 3 gal./yd^3 (15 L/m^3) of material based on a 20 yd^3/h (15 m^3/h) material rate. Having a good flow meter with easily accessible adjustment allows accurate and consistent control of the water. After calibrating the batch plant, I can determine how much water is acceptable in the material. With that information, I can give the operator a maximum water flow rate, so that as long as he stays under that number, I know the *w*/*c* will be adequate.

Similar to the water, a little too much admixture can be highly detrimental to the concrete. Our batch plant was originally designed to dilute admixtures into the water and then pump the water into the mixture. We found it difficult to keep up with constantly mixing the proper amount of admixture in mix water because of our continuous batch methods. We also found the standard admixture pumps were not as consistent as we would have hoped. Most likely, volumetric batch plant suppliers offer highly accurate pumps, but we ended up custom-fitting our machine with swimming pool chemical pumps. These pumps have variable frequency drives, allowing us to adjust them based on our needs, and they are incredibly accurate. I have found that monitoring them is unnecessary because once they are set, the accuracy doesn't change. However, I will check—and sometimes recalibrate—the flow if there are substantial temperature changes during the day.

Fig. 1: Flow control flow meter

Calibrating the Batch Plant

We require calibrating the batch plant at the beginning of each job. Our typical job lasts at least 3 days. Perhaps the machine could be trusted to maintain all the adjustments and settings throughout the last job and during transport between jobs. However, recalibration at the beginning of the job will also give you an opportunity to re-check everything, and you may find a new issue with the machine or that a valve or gate got moved and does not seat itself the same way. The manufacturer provides a list of steps for calibrating the machines. Our method could be a little different than other users' methods, so I will not go into depth on the entire process, but will highlight some of the important things. The manufacturer should supply an Excel spreadsheet that will allow you to take measurements from the machine, plug them into the sheet, and then tell you how to calibrate for proper supply of sand, stone, cement, water, and admixtures based on your mixture design. Volumetric batch plants have a tendency to be a little inconsistent at times if mistakes are made or assumptions are taken in the calibration process. I always diligently follow the manufacturer's guidelines for calibrating the machine and have had great results.

Setting the conveyor belt speed is an important step because it will set the pace of your job. Too slow and the job will take too long; too fast and

you will drive the operator crazy by having to shut down the machine too often. Setting the correct belt speed is something you will learn over time with some trial and error. I find that we shoot most walls and thin surfaces slower than we shoot floors and thick walls, so I adjust the belt speed slightly to meet the production rate the application requires. It makes it easier for the operator if he doesn't have to stop and start the batch plant to keep the pump hopper from overflowing. Never adjust conveyor speed mid-job unless you are ready to do some recalibration too. Since the cement is delivered at a fixed speed, the admixtures and water are both based on the rate of cement delivery. So if belt speed is changed, the water and admixtures need to be changed to maintain the same final concrete mixture design. Once calibration is complete per the guidelines, you should be ready to start mixing and pumping.

Fig. 2: Batch setup

Fig. 3: Alternate view of equipment setup

Loading Operations

There are two main ways to use a volumetric batch plant. One way is by filling the truck with all the materials at a facility and transporting the unit to the job site, where it is emptied and then run back to refill. The other way, which is the way we do it, is to set up the volumetric batch plant at a job site, park a portable cement silo and excavator next to it, and continuously batch throughout the job (refer to Fig. 2 and 3). Our batch plant is a stand-alone unit mounted on a trailer with a motor to supply hydraulic power. We only use this unit on larger jobs that will take at least 3 days or require over 130 yd^3 (100 m^3) of material because mobilization is a little costly. Regarding manpower, we have one crew member who oversees the volumetric batch plant and the shotcrete pump. However, the nozzleman still has ultimate control over the shotcrete pump via a remote control. The batch plant operator also has support from the excavator operator, who keeps the batch plant properly fed with cement, sand, stone, admixtures, and water. Using volumetric batch plants would work incredibly well for big projects that are far away from a ready-mix plant.

Advantages of On-site Volumetric Batching versus Ready-mix

There are many advantages of volumetric batching on site over plant-produced ready-mix. I understand a lot of shotcrete contractors in many parts of the country have no problem dealing with their local ready-mix companies. Unfortunately, that does not seem to be the case in our part of the country. I often find it difficult to deal with the ready-mix companies, especially on a job where you want to shoot 60 to 80 yd^3 (45 to 60 m^3) a day and are often requesting short loads with less-than-maximum truck capacity.

Some ready-mix trucks may take a little longer than others. On site, when shooting shotcrete, if there is a small issue that delays the shooting, one can find that several concrete trucks are very quickly waiting in line. With the volumetric batch plant, our crew leader doesn't even have to think about the mixture and can concentrate on his job, which is to shoot and finish a good project. The batch plant can produce material as fast or as slow as you want it, so you never have to worry about shooting speed and backing up trucks. Hot loads

are nonexistent with the batch plant because the only mix time is in the auger. If there is a pump issue that takes an hour to fix, the auger is just cleaned out and ready to go again. Without the batch plant, you need to send back the 7 yd^3 (5 m^3) in the ready-mix truck already on site waiting to discharge its load and worry about the next truck, which is likely already being batched.

We work mainly on large swimming pools with our volumetric setup. On these large pool projects, we are shooting floors and walls the same day. With the ability to adjust the mixture on site, we can make the shotcrete mixture for the floor a little bit wetter (while still not exceeding the maximum *w*/*c*) and then dry it up a bit when moving back to the wall, simply by adjusting a knob. This is not possible with a ready-mix truck.

In remote areas where ready-mix isn't available, volumetric batching can be easily used. Mixture adjustments can also be easily made. If a ready-mix truck shows up with an unpumpable mixture, the only options are to send the truck back and figure out what to do or add a pumping agent to the mixture, which can be detrimental to the final product. With the volumetric batch plant, some parameters can be adjusted if pumpability is suffering, without hurting the final outcome of the material. Having ultimate material control on-site can definitely save time and money on the right job.

I have found that volumetric batching is not very common in the wet-mix shotcrete industry, and I welcome any questions concerning the subject—whether you are looking to get into it, need it done for a specific project, or just want to learn more.

Mason Guarino *started in the pool industry when he was 14, learning how to install reinforcing bar. Since then, he has worked in 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 is an ASA Board member and an ACI Certified Nozzleman.*