

Workmanship Issues in Swimming Pool Wet-Mix Shotcrete Construction

by Ron Lacher

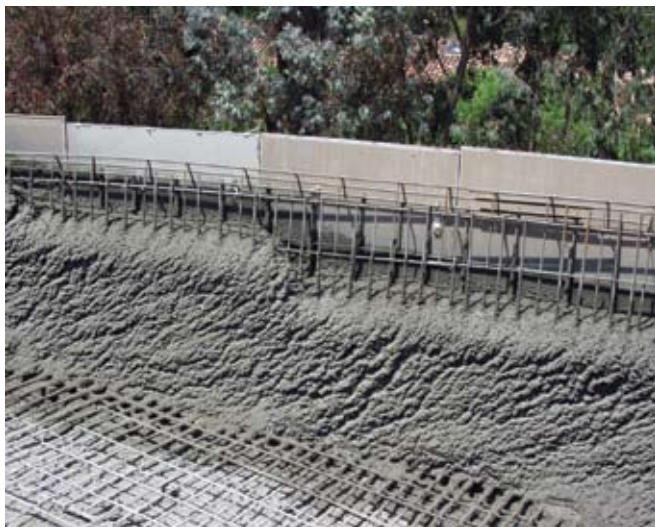
Several months ago, I ran across a brief article in a swimming pool trade publication co-authored by two shotcrete contractors who presented what they believed to be proper wet-mix shotcrete application in swimming pool construction. In every construction trade, including swimming pool construction, it's not uncommon for contractors to have different opinions as to what's the right way and wrong way to do things and often there is room for these differing opinions in trade practices. But, when we get into the realm of the backbone of the structure, which in this case is the reinforcement and concrete that make up the pool's structural shell, we must look past contractors' opinions and focus instead on standards of practice established by a recognized organization, such as the American Concrete Institute (ACI), and adopted building codes.

Although the article previously referred to was mostly accurate, several statements were made that encourage a common practice in swimming pool wet-mix application that, in my opinion, is not in conformance with proper ACI concrete placement practices. The parts of the article I want to discuss

are the statements "trimmings can be recycled if used in the right way" and "you can place trimmings in the floor." The authors made further clarification with the statement, "vibrate or properly compact it for adequate steel encapsulation." Although these statements are technically correct when discussing concrete placement in general, the required procedures necessary to permit the recycling of trimmed material from a shot wall in swimming pool construction are seldom followed in practice.

What gives me the greatest concern is that these statements could be construed to validate the common practice in swimming pool wet-mix shotcrete application of shooting the pool walls first while leaving the floor at the base of the wall open. After shooting the walls, the typical practice is to then cut the walls and allow the trimmings to fall to the unshot floor at the base of the wall where, according to the article co-authors, "trimmings can be recycled if used in the right way."

Concrete consolidation and reinforcement encapsulation are critical elements of concrete placement in structural concrete. Freshly placed



In swimming pool wet-mix shotcrete application, it is common practice to shoot the pool walls first while leaving the floor at the base of the wall open. Note the overspray, rebound, and voids under the reinforcing bar



Here's the same wall (as in the first photo) after trimming. No joint preparation or removal of overspray or rebound was done

unconsolidated concrete is in a honeycombed condition and contains excessive and detrimental entrapped air voids. If allowed to harden in this condition, the concrete will have low strength, high permeability, poor resistance to deterioration, and a lack of proper bond to reinforcement.

The major difference between shotcrete and conventional concrete in a structural application is the method by which consolidation and reinforcing bar encapsulation is obtained. Shotcrete is consolidated by the impact of the material, traveling at high velocity, on the application surface. Trimmed shotcrete, because it's been disturbed, can no longer be considered consolidated, especially after falling up to 8 or 9 ft (2.4 to 2.7 m) from its shot location and landing on the pool floor. The slump of wet-mix shotcrete is normally between 1-1/2 and 3 in. (38 to 76 mm), classified as "stiff plastic" by ACI. According to ACI 309R-05, "Guide for Consolidation of Concrete," manual methods of consolidation, that is, hand tamping, rodding, or spading, are not appropriate for stiff plastic concrete. According to ACI 301, "Specifications for Structural Concrete," Section 5.3.2.5, Consolidating, states, "Consolidate concrete by vibration." Simply stated, concrete placed in a structural application must be vibrated by mechanical means to obtain proper consolidation and reinforcing bar encapsulation.

In my many years as a licensed engineer, which includes periods as a pool builder and deputy shotcrete inspector, I've observed shotcrete placement in swimming pools all over the country. Throughout all of those observations, I have rarely seen trimmings properly processed, vibrated, or compacted to obtain the required consolidation and encapsulation of reinforcement. A common practice is to hose down the piles of trimmings with water and drag the "now over wetted" and re-tempered trimmed material to envelop the floor reinforcement. The main compaction method used is simply the shotcrete crew walking over the newly spread trimmings. The practice of incorrectly using trimmings in the floor is especially widespread in swimming pool wet-mix shotcrete construction. Because of this, it is my opinion that this practice should be discouraged unless the shotcrete crew has been trained in the requirements for proper structural concrete placement.

A fact that I repeatedly stress in the seminars I give to the pool industry on the shotcrete process is that shotcrete is not a special product; it is simply a method of placing concrete. Therefore, many of the recommended practices for concrete placement by other methods apply. Trimmed material dislodged from its shot location should be treated as conventional concrete. Based on this,



The typical practice is to cut the walls and allow the trimmings to fall to the unshot floor at the base of the wall



Trimmed shotcrete is no longer consolidated after falling from its shot location and landing on the pool floor



The trimmed concrete typically lands at the base of the wall on top of rebound and overspray



In addition to poor placement practices, proper safety practices are not being followed here



This trimmed material sat in a pile at the base of the wall for over 90 minutes. Remember, concrete consolidation and reinforcement encapsulation are critical elements of structural concrete placement

I'll offer eight reasons why the reuse of trimmings in swimming pool construction should not be encouraged.

1. In swimming pool structural design, the location in the pool where stresses are the highest is at the base of the wall where the wall meets the floor. This is the most critical location in the entire pool for proper shotcrete application. The common wet-mix practice of using trimmings where they fall, that is, at the base of the wall, places the lowest quality concrete at the location of highest stress. This is the very worst place for the placement of recycled trimmings that are not properly consolidated.
2. In real-life swimming pool wet-mix application, when walls are shot before the floor,

cut trimmings will fall the depth of the pool, often a vertical distance as much as 8 to 9 ft (2.4 to 2.7 m). The trimmed concrete does not fall freely to the floor but rolls or slides down the wall until it hits the uncovered reinforcement at the base of the wall. Section 5.4.1 of ACI 304R-00, "Guide for Measuring, Mixing, Transporting, and Placing Concrete," cautions:

"Arrange equipment so that the concrete has an unrestricted vertical drop to the point of placement or into the container receiving it. The stream of concrete should not be separated by falling freely over rods, spacers, reinforcement, or other embedded materials. If forms are sufficiently open and clear so that the concrete is not disturbed in a vertical fall into place, direct discharge without the use of hoppers, trunks or chutes is favorable."

The concrete trimmed from the wall does not fall freely into final position but is disturbed as it slides and roles down the wall. This practice is clearly discouraged by ACI 304R.

3. The trimmed concrete typically lands in a pile at the base of the wall, falling over and through the reinforcement. But, what has fallen first at the base of the wall before the wall is trimmed? Rebound and overspray! Unless removed before the trimmed concrete falls, the rebound and overspray will be incorporated into the work. This is a clear violation of proper shotcrete application. The picture used in the swimming pool trade publication actually showed the overspray on the reinforcement and the rebound at the base of the wall being covered by new shotcrete.
4. After falling, the material trimmed from the wall typically sits in piles at the base of the wall. The piled recycled concrete is subsequently dragged, pushed, or in some manner moved laterally and spread over the floor to envelop the floor reinforcement. Section 5.4.1 of ACI 304R-00, "Guide for Measuring, Mixing, Transporting, and Placing Concrete," cautions "Concrete should be deposited at or near its final position because it tends to segregate when it has to be flowed laterally into place." The lateral movement of the piles of trimmings is a practice clearly discouraged by ACI 304R. And, what about the likelihood of poor reinforcing bar encapsulation resulting from this practice?
5. Much of the concrete used for wet-mix shotcrete is delivered to the job site in ready mix trucks. The American Society for Testing Materials (ASTM) Standard Specification for Ready Mix Concrete C 94 requires that concrete be completely discharged within

1-1/2 hours of the introduction of water into the cement and aggregate. This time limit is based on the fact that concrete that is kept agitated generally can be placed and compacted within 1-1/2 hours after mixing. Further verification can be found in ACI CCS-4, "Shotcrete for the Craftsman," which states, "Wet-mix should typically be used within 90 minutes of the first water addition." In real life swimming pool wet-mix application, is it realistic that concrete will be transported, shot, attain sufficient stiffness for trimming, then be trimmed, relocated, and consolidated (vibrated) all within 90 minutes? In my opinion, the answer is no. I recently observed a wet-mix application in a swimming pool where the trimmed material sat in a pile at the base of the wall, unconsolidated and enveloping the reinforcement for over 90 minutes after trimming before the material was placed in the floor.

6. What about the bottom of the shot wall where a joint is created with the questionable trimmed material placed in the floor? In Chapter 19, Shotcrete, Section 1924.7, Joints, of the International Building Code (IBC), it states:

"Except where permitted herein, unfinished work shall not be allowed to stand for more than 30 minutes unless all edges are sloped to a thin edge. Before placing additional material adjacent to previously applied work, edges shall be cleaned and wetted."

The American Shotcrete Association (ASA) recommends that the slope referred to in IBC Section 1924.7 be no thinner than approximately 45 degrees to avoid the possibility of peeling-type delaminations.

As with the other recommended concrete placement practices I've discussed, I have rarely observed the base of a shot wall sloped, then cleaned and wetted before the material trimmed from the wall fell onto the joint. Another important point is that shotcrete is recognized for its superior bonding abilities brought about by its high impact velocity on the receiving surface. Yet, questionable trimmed material is often placed against the joint at the base of the wall rather than shot material, leaving the integrity of the bond and the joint at this most critical location in question.

7. In many areas of the country, a swimming pool must be constructed in accordance with a structural plan prepared and stamped by a licensed engineer. Preparation of swimming pool structural plans is the primary focus of my firm, and last year we provided the structural plans for almost 16,000 swimming pools. I'm also familiar with most of the



Joints standing for over 30 minutes must be cut to a 45-degree angle then cleaned and wetted before placing additional shotcrete and safety practices must be followed



Here's a typical joint that stood for over 30 minutes—notice the overspray and rebound. No cleaning and wetting took place before placing new material



Shoot the cove and the floor at the base of the wall before the wall is shot to eliminate rebound, overspray, and trimmings from becoming trapped at this critical location and practice proper safety procedures

other engineers who provide this service. Generally, the specifications on these structural plans require pneumatically placed concrete because of the unique benefits and properties of concrete brought about by pneumatic placement. As I've discussed, trimmings can no longer be considered as pneumatically placed concrete. Therefore, permission of the engineer of record must be obtained before variations from the specified pneumatically placed concrete could be used. This is just one more reason why trimmings should not be reused except for non-structural elements in the swimming pool.

8. ACI 506R-05, "Guide to Shotcrete," sums it all up where, in Chapter 7, Section 3.2, it states: "Reuse of discarded shotcrete material should not be tolerated."

What is the answer to the elimination of these poor practices that are so widely observed in the swimming pool industry? The answer is obviously education, training, and certification. Should we encourage the use of trimmings even when qualified with the statement "when properly processed" when the majority of swimming pool shotcrete applicators don't have any idea what "properly processed" means? Remember the point made in No. 1: The location in the pool where stresses are the highest is at the base of the wall where the wall meets the floor. This is the most critical location in the entire pool for proper shotcrete application. In my opinion, until a higher percentage of swimming pool wet-mix applicators catch up to the knowledge of the rest of the industry, we should not be encouraging a practice that will likely result in substandard workmanship.

In the meantime, the standard of practice for swimming pool wet-mix application should be: a) shoot the cove and the floor at the base of the wall before the wall is shot to eliminate rebound, overspray, and trimmings from becoming trapped at this critical location; b) trimmings may be reused only if still fresh and plastic but without re-tempering or the addition of water; and c) trimmings may be reused only if vibrated by mechanical means for proper consolidation and reinforcing bar encapsulation.



Ron Lacher, PE, CBP, is a well known speaker, educator, and author on proper trade practices and structural engineering in swimming pool construction. His firm, Pool Engineering, Inc., provided the structural designs for over 16,000 pools last year. With experience from prior ownership of a swimming pool construction company, he has completed over 300 forensic investigations on problem pools. He is a member of the Advisory Board of the National Pool Industry Research Center at California State Polytechnic University, San Luis Obispo, and is also a member of the American Shotcrete Association where he is on the Pool & Spa Committee. Lacher graduated from California State Polytechnic University with a degree in civil engineering and is a Licensed Professional Engineer in the State of California.