Welcome to the second installment of the Pool & Spa Corner! As mentioned in the Spring issue of *Shotcrete*, the goal of this column is to reach out to those with a stake in the pool and spa industry so that our readers can benefit from our perspectives. So let's jump in! In this issue, Ron Lacher of Pool Engineering, Inc., will share his perspectives on issues that can arise in the construction of a vanishing edge-style pool.

***Tom Norman** is a Product Manager for Airplaco Equipment Company and Gunite Supply & Equipment, two divisions of Mesa Industries. For over a decade, he has represented the company's Northeastern region based in Cincinnati, OH. Airplaco and Gunite's shotcrete equipment, including dry-mix gunite machines, batch plants, and shotcrete pumps, is manufactured at this northeast location and also distributed through Houston, TX, and Monrovia, CA, sales locations. Norman is involved in product development for Airplaco's line of shotcrete equipment, which has been produced since 1946. He served 6 years in the U.S. Army and earned an associate's degree in business from the University of Wisconsin, Milwaukee, WI. In addition to being a member of ASA and Chair of ASA's Pool and Spa Committee, Norman is a member of the International Concrete Repair Institute (ICRI) and the Association of Pool and Spa Professionals (APSP).*

Repair Procedure for Exposed or Shallow Reinforcement

by Ron Lacher

I frequently find myself involved in both common and uncommon problems relating to shotcrete application in swimming pool construction. The primary focus of my firm involves the structural and workmanship aspects of swimming pool design and construction. Because of that, I'm frequently asked to evaluate and recommend solutions to problems encountered by pool builders.

One such problem was thrown into my lap recently when one of my clients had applied dry-mix shotcrete in a vanishing edge-style pool. Because the weir wall in this type of pool is basically located between the main pool and the smaller catch pool, the weir wall is not backed by earth and must have forms on one side to permit shotcrete application. The forms are typically separated from the wall's reinforcing steel by spacers or dobies. In this case, because of vibration of the forms and reinforcing bar cage during shotcrete application, the dobies slipped out from between the reinforcing bars and

On vanishing edge pools, the weir wall and often the outer basin wall must be formed for shotcrete application. Forms are usually erected on the outside of the wall

The dobies slipped out during shotcrete application, allowing the reinforcement and formwork to come together, leaving essentially no cover over the reinforcement

the forms. This resulted in the reinforcing bars and formwork coming together, leaving essentially no cover to the reinforcement. The problem became very apparent when the forms were removed. To make matters worse, when the forms were stripped, portions of the outer surface of the shotcrete basin wall delaminated from the wall. Both of these occurrences resulted in inadequate shotcrete cover over the steel reinforcement. Unless corrected, the weir wall would be subject to ongoing problems that eventually could result in failure of the wall. We can learn several valuable lessons from this pool builder's misfortune.

The first lesson is that, when shooting against formwork, always make sure the forms and reinforcement are firmly secured against vibration and movement. Second, spacers or dobies must be secured in a manner that will prevent them from becoming dislodged. Had the dobies been secured, the pool builder would not have had to go through a difficult and costly repair process. Having mentioned these basic but important lessons, let's focus on the critical steps necessary for a lasting repair.

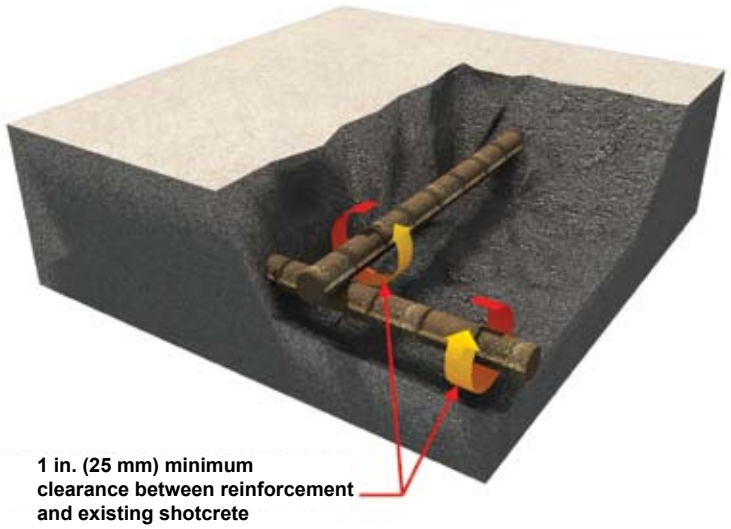
The Repair

The first problem that had to be solved was the issue of the exposed reinforcement in several areas of the weir wall. On top of that, sections of the wall had insufficient reinforcement cover. Building codes require a minimum cover of concrete (shotcrete) over the reinforcement for corrosion protection. This is also a requirement of the structural plans used for construction of the pool. But we can't just fire up the compressor and start shooting an additional thickness of shotcrete to the previously shot wall. First, there are several very critical steps necessary to ensure proper reinforcement encapsulation and bond of the subsequent layer of shotcrete.

When making repairs to concrete structures, it is recommended to follow the standards of practice established by recognized organizations such as the International Concrete Repair Institute (ICRI). ICRI recommends that when making repairs involving exposed reinforcement, all exposed reinforcement must have a minimum of 1 in. (25 mm) of clearance all around from the existing shotcrete to permit proper encapsulation of the bar by the subsequent shotcrete application. Where the reinforcement is partially exposed, the shotcrete must be removed around the reinforcement to provide a minimum of 1 in. (25 mm) clearance around the bar.

Now that we know that we must provide the minimum 1 in. (25 mm) clearance around the reinforcement, let's consider the amount of shotcrete cover needed for the reinforcement. There are a couple of options regarding the required shotcrete cover over the reinforcing steel. Building codes typically require 1-1/2 in. (38 mm) cover over reinforcement when concrete (or shotcrete) is not cast against earth (for example, shot against forms) but is exposed to earth or weather. Because of the unique exposure to moisture of vanishing edge weir walls, it is recommended

When the forms were stripped, the outer surface of the basin wall delaminated, leaving substandard cover over the reinforcement. Note the exposed reinforcement in the weir wall in the background



All exposed or partially exposed reinforcement must have a minimum of 1 in. (25 mm) of clearance all around from the existing shotcrete to permit proper encapsulation of the bar by the subsequent shotcrete application

The following is a summary of the procedures discussed in this article for applying an additional shotcrete thickness to an existing shotcrete surface for attaining proper bonding:

1. All exposed reinforcement must have a minimum of 1 in. (25 mm) of clearance all around from the existing shotcrete to permit proper encapsulation of the reinforcement by the new shotcrete application. Where the reinforcement is partially exposed, the existing shotcrete must be removed around the reinforcement to provide a minimum of 1 in. (25 mm) clearance around the reinforcement.

2. The existing shotcrete surface must be roughened by chipping or other suitable means to provide a suitable surface roughness profile. All loose, cracked, or deteriorated materials must be removed.

3. The existing shotcrete surface must be cleaned by high-pressure water-blasting or sandblasting to remove the "bruised" surface layer left behind by the chipping or other mechanical means in Step 2.

4. The existing shotcrete surface must be sound, free of defects, and clean and free of any bond-inhibiting materials (such as dust, oil, and slurry).

5. The existing shotcrete surface must be presaturated with clean water. Just prior to the shotcrete application, it should be brought to a saturated surface-dry (SSD) condition.

6. The newly applied shotcrete must be kept moist for a minimum of 7 days after application for proper curing.

Following these recommended practices will minimize problems of cracking, ensure proper bonding between the existing shotcrete surface and the new shotcrete, and provide quality results.

that both the inner and outer surfaces of these walls be waterproofed against moisture penetration. We do not consider the typical pool plaster or pebble surface coating to be waterproofing. If this waterproofing recommendation is followed, the reinforcement would no longer be considered exposed to weather and a minimum of 0.75 in. (20 mm) of shotcrete cover would be required by building codes. Where this required cover is not provided, as in the case of exposed reinforcing steel or delamination of the shotcrete surface, additional shotcrete cover must be added to provide the required cover.

When bonding additional shotcrete to previously applied work, the substrate must be prepared properly as surface preparation is critical to the success of the repair. All deteriorated concrete must be removed with either hydrodemolition or mechanical means such as light-duty chipping hammers, scarifiers, or scabblers. This would also include shotcrete removal to obtain the required 1 in. (25 mm) clearance around all exposed reinforcement. The remaining concrete surface must then be sandblasted or high-pressure water-blasted to remove the concrete "bruised" by the initial mechanical removal operation. The objective is to create a clean, sound surface with the proper surface roughness to receive the shotcrete.

After preparation of the surface, the substrate must be saturated with clean water and then allowed to dry to a saturated surface-dry (SSD) condition immediately prior to shotcrete application. Shotcrete should not be applied to a bone-dry surface, as the substrate will absorb water in the shotcrete mixture intended for hydration of the cement and this will reduce bond. Also, a bone-dry surface will tend to allow plastic and drying shrinkage cracks to form. Conversely, a surface that is wet at the time of shotcrete application will result in a high water-cement ratio (w/c) at the critical bond interface between the substrate and the shotcrete. A high w/c at the interface will result in significantly lower (or no) bond strength. A bonding agent is not required or recommended. A properly prepared substrate in a SSD condition is the optimum condition for the application of shotcrete. Bonding agents may act as a bond breaker in some circumstances, and some bonding agents have been found to re-emulsify and thus lose bond on exposure to moisture.

As with all concrete, proper curing and protection are critical. Failure to properly cure will result in lower shotcrete strengths and may cause some delaminations if drying shrinkage causes stresses that exceed early bond strength. Plastic shrinkage

cracking and "crazing" may also result from a failure to properly cure and protect the shotcrete. Moist curing is the preferred method of curing.

Finally, we recommend that the nozzleman applying the shotcrete be certified by the American Concrete Institute (ACI). Certified nozzlemen have been trained and tested on the requirements for proper shotcrete application. Requiring this certification substantially increases the probability that the desired results will be attained.

***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, CA, 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.*

As mentioned in the first installment of Pool & Spa Corner, we want your input. We want to hear your comments, suggestions, and the topics you'd like to see covered here, and perhaps you'd like to become a contributor to Pool & Spa Corner. We encourage you to contact the American Shotcrete Association with your questions and comments at: info@shotcrete.org.