Why is My Pool Cracked?

By Philip Cowles

INTRODUCTION

Swimming pools are intended to improve quality of life and be visually appealing, so no pool owner is happy to find a crack running through their investment. For liquid-containing structures like swimming pools, cracks are more than just an aesthetic nuisance. Crack control is critical to maintaining the durability and function of the structure. So why does a concrete pool crack?

The simple answer is that concrete cracks when its tensile capacity is exceeded. However, as multiple factors can contribute to this condition, this article discusses some of the reasons why concrete pools crack.

EXTERNAL LOADS

Swimming pools must resist a variety of external loads. With in-ground pools, while the primary external loads are earth and water pressures, the pool may also provide support for attached or adjacent structures such as shade canopies, grottos, and waterslides. External loads can change in magnitude during the lifetime of a pool as well — heaving or settling subgrades may increase earth pressures or reduce pool support, leading to increased stresses within the concrete (Fig. 1).

When the stresses imposed on the pool shell by external loads exceed the concrete's tensile strength, the concrete cracks. Steel reinforcement in the concrete works to resist the tension. If external loads in excess of the pool shell's resisting capacity are continually applied, the structure deflects and eventually fails.

Fig. 1: Cracks due to heavy rock structure and subgrade settlement.

FREEZE-THAW CYCLING

Concrete pools exposed to freezing temperatures may experience freeze-thaw cycling. Water absorbed by the concrete creates internal pressures when it freezes and expands. Repeated freezing and thawing cycles may cause internal pressure that causes spalling and pop-offs on the surface of the concrete and can worsen existing cracks (Fig. 2). Tile and coping are particularly vulnerable to freeze-thaw cycling since they are often exposed to the elements and become saturated. Note that cracks and pop-offs observed in these elements may be because of a failure of the mortar bed and not the underlying concrete shell.

The freeze-thaw resistance of concrete may be improved by including air entrainment, reducing the water to cement (w/cm) ratio and increasing the compressive strength. Air entrainment provides space in the concrete matrix for water to freeze. A lower w/cm ratio provides a higher compressive strength and decreases moisture ingress by reducing the permeability of the concrete.

Fig. 2: Shrinkage crack worsened by freeze-thaw cycling.

ALKALI-AGGREGATE REACTION

Alkali-aggregate reaction (AAR) refers to the reaction of alkalis and reactive aggregates in concrete. Moisture in the concrete is needed for this process to occur. AAR creates expansive forces within the concrete that cause cracking and spalling. The two forms of AAR, alkali-silica reaction (ASR) and alkali-carbonate reaction (ACR), are named after the reactive minerals found in some aggregates. ASR is more common than ACR. In general, microscopic analysis of concrete samples is required to confirm the presence of AAR.

AAR tends to be a regional issue and is not a concern for every pool. The reaction will not occur if reactive aggregates are not used. ASR may be mitigated through the use of supplementary cementitious materials (SCMs) and lithium-based admixtures. ACR cannot be mitigated so the use of reactive carbonate aggregates should be avoided.

DELAYED ETTRINGITE FORMATION

Delayed ettringite formation (DEF) refers to the crystallization of ettringite (a byproduct of portland cement hydration) in substantially hardened concrete. DEF occurs in part because ettringite was not allowed to form normally during the early stages of cement hydration due to elevated concrete temperatures. There are similarities between AAR and DEF, and the two processes may occur simultaneously. DEF requires a source of moisture and creates internal swelling pressures within the concrete. Like AAR, DEF is usually identified in a laboratory.

DEF may be prevented by limiting the maximum internal temperature of the concrete during the curing period. Concrete generates heat as it cures. The thicker the concrete section, the greater the heat increases. It is not uncommon for stairs and tanning ledges in pools to be shotcreted solid. These large concrete elements may experience elevated internal concrete temperatures that create a favorable environment for DEF. Structural foam, gravel bags, and earth forms may be used to reduce the thickness of the pool shell in these areas. A thermal control plan may be needed when large concrete sections are unavoidable.

POOR CONSTRUCTION PRACTICES

A poor but not uncommon construction practice in the swimming pool industry is the incorporation of shotcrete rebound, trimmings and overspray into the pool shell. Rebound is sometimes left in pool floors, coves, and corners. It also may be hand packed to form benches and stairs, or other elements that may lack reinforcing steel. It is no surprise then to observe cracks in these areas. Rebound is not a structural material and should be removed from the pool. Trimmings are unconsolidated concrete and likewise should not be used in the pool shell unless supplemental internal vibration is used. Tamping with a trowel or floating the surface does not consolidate the concrete.

Cracks may also occur at the interface of the pool coping and bond beam or along the waterline tile. Again, this is a location where shotcrete rebound or trimmings are hand placed to level up or correct the bond beam elevation. A better practice is to use grade stakes, wires, and forms to establish the proper shotcrete elevation and alignment and eliminate hand packing or excessively thick mortar beds.

Bricks, rocks, trash, and other construction debris should also not be incorporated into the pool shell. These materials create weakened areas within the concrete that are more susceptible to cracking. Clay bricks, rocks, and concrete masonry units (CMUs) are frequently used to support reinforcement in pool shells (Fig. 3). These supports are irregularly shaped and have a lower compressive strength than the concrete. Manufactured reinforcement supports should be used instead of bricks, rocks, and CMUs to ensure reinforcement is installed at the correct elevations and spacing.

CONCRETE SHRINKAGE

There are multiple types of concrete cracks that could be labeled as shrinkage cracks. Of primary concern for swimming pools are drying shrinkage cracks and temperature shrinkage cracks. This is because these cracks typically extend through the full depth of the pool shell (Fig. 4). If the

ABOVE
Fig. 3: Clay bricks used as bar support.

LEFT
Fig. 4: Shrinkage crack through full depth of pool shell.

LEFT
Fig. 5: Shrinkage cracks at reentrant corner.

ABOVE
Fig. 6: Shrinkage cracks in wall caused by horizontal restraint from floor.

cracks expand in width, they begin to allow water to pass through the concrete, and the structure is no longer watertight.

As concrete dries it loses moisture and experiences volume changes (shrinkage). Similar shrinkage occurs when concrete cools and contracts. This shrinkage may be restrained by a variety of factors including subgrade friction and the geometry of the structure itself. Any restraint creates tensile stresses in the concrete. As noted earlier, concrete cracks when its tensile strength is exceeded. Steel reinforcement is provided to resist the tension and keep the crack tightly closed. If the reinforcement is also overstressed, it yields (elongates) and the crack in the concrete increases in width. For many pools, the amount of reinforcement required to resist external loads may be less than that required to resist stresses from restrained drying and temperature shrinkage.

Measures may be taken during the design and installation phases to reduce restraint and shrinkage. The pool shape should be evaluated to determine areas of high restraint. It is not uncommon to observe diagonal shrinkage cracks at reentrant corners where shrinkage is restrained in perpendicular directions (Fig. 5). Providing a radius at corners may help decrease stress concentrations in these areas. A wall connected to a previously placed concrete floor is restrained horizontally by the floor (Fig. 6). Additional reinforcement may be needed near the wall-to-floor connection to control crack widths.

Installation practices and the pool environment should be assessed as well. Hot, dry, and windy conditions during concrete installation and curing lead to rapid moisture loss. This can lead to early-age plastic shrinkage cracks at the concrete surface. Proper curing is critical to delaying shrinkage until the concrete has gained strength. ASA and ACI recommend a minimum of 7 days of curing for concrete pool shells. Some conditions are unavoidable, but careful thought and planning will improve control of shrinkage cracks.

THERMAL STRESSES

The restrained temperature shrinkage noted above is a type of thermal stress, but there are other types of thermal stresses in swimming pools. Concrete exposed to large temperature gradients through the thickness of the concrete section may develop thermal stresses due to external or internal restraint of concrete contraction and expansion. Thick sections and extreme ambient temperatures increase the potential for thermal differential stresses.

Consider a wall separating a pool and spa. If the spa is heated during the winter, but the pool is not, a significant temperature differential could develop between the two sides of the wall. The conditions discussed earlier that are favorable for DEF can also create thermal stresses. For thick concrete sections, the surface of the concrete may be considerably cooler than the core of the section. Again, a thermal control plan may be needed to manage temperature gradients for thick concrete sections.

EMBEDMENTS AND OPENINGS

From skimmers to main drains to light niches to pipe, swimming pools are full of embedments and openings. Sometimes it seems the only thing in short supply is the concrete itself! Cracks are often observed around embedments and openings. Stress concentrations develop around these features due to multiple factors.

Embedments and openings interrupt the reinforcing steel and reduce the overall cross-sectional area of the concrete. If the interrupted reinforcing steel is not replaced with trim bars on either side of the opening, a weakened plane is created in the concrete (Figs. 8, and 9). This condition is worsened when multiple embedments or openings are aligned. The resulting concrete section may not have sufficient strength to resist external loads. Openings also create reentrant corners that are susceptible to shrinkage cracks (Fig. 7). Pipe embedded in and oriented parallel to the plane of the concrete member reduces the section thickness. The thinner concrete has less capacity to resist stresses due to external loads and restrained shrinkage.

Conclusion

To review, the following measures may be taken to reduce and control cracks in swimming pools:

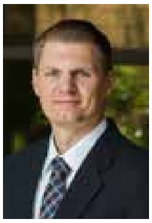
- Provide adequate reinforcement to resist stresses from external loads and restrained shrinkage. Keep in mind that the maximum stress may come from restrained shrinkage rather than external loads.
- Use concrete with air entrainment, a low w/cm ratio, and a high compressive strength.
- Avoid using reactive aggregates or develop a plan for mitigation.
- Avoid using concrete as fill for stairs and tanning ledges.
- Implement a thermal control plan for thick concrete sections.
- Do not incorporate rebound, trimmings, and overspray into the pool structure.
- Use manufactured reinforcement supports instead of bricks, rocks, and CMUs.
- Evaluate the proposed pool layout to determine areas of shrinkage restraint that may be reduced or eliminated.
- Wet cure the concrete for a minimum of 7 days.
- Maintain section thicknesses around embedments and openings.
- Add trim bars to replace reinforcement interrupted by embedments and openings.

An old adage says, there are two kinds of concrete: Concrete that has cracked and concrete that is going to crack. As can be seen, there are multiple reasons a concrete pool shell may crack. Often, a combination of factors contributes to the development and worsening of cracks. Consequently, it is perhaps unrealistic to expect a totally crack-free pool. It is reasonable, however, with proper design and construction to expect a pool to be watertight and durable. For existing pools with cracks, a design professional may help identify the causes of the cracks and make recommendations for their repair.

Fig. 7: Shrinkage crack at skimmer throat.

ABOVE
Fig. 8: Shrinkage crack at underwater light.

LEFT
Fig. 9: Pool shell distress at recessed steps.



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