

# Forming and Substrates in Pool Shotcrete

**M**any factors lead to success in building strong, durable, and watertight pools. But what is success in constructing a pool shell? Structural integrity, proper shape, watertightness, and durability are key to success. Structural integrity requires meeting or exceeding the design strength for expected loading conditions with the desired thickness and shape. Providing the desired shape requires a sound, well-defined surface to accept the impact of the shotcrete placement. Thus, formwork or a prepared substrate is key to constructing a pool shell with the required structural section, desired shape, and aesthetics.

Strength, watertightness, and long-term durability are essential to performance of all concrete swimming pools and other recreational water structures. Achieving these properties requires high-quality concrete materials, proper shotcrete equipment, and quality shotcrete placement. The receiving surface, whether erected formwork or a prepared subgrade, must meet certain performance criteria and local building codes. A solid, rigid, nonvibrating surface must withstand the high compaction energy produced by shotcrete placement, allowing maximum compaction for a watertight concrete pool shell and full encapsulation of embedded reinforcing bars.

Reinforcing steel rests against, and is often attached to, the formwork or substrate. Thus, rigidity of the formwork is important for supporting the reinforcing steel and preventing excessive vibration. This is important to both durability and strength of the shotcreted shell. Reinforced concrete is a system, where the interaction of steel and concrete provide a combined compressive and flexural resistance to those respective forces. For the reinforcing steel to be effective, it must be fully encased by the concrete. A rigid form and well-secured reinforcing steel help facilitate proper encasement.

Forming for shotcreted pool shells is one-sided, and falls into two general categories: “Against Soil” or “Installed Formwork.”

## “AGAINST SOIL” CONSIDERATIONS

- The floors of most pools rest directly on the existing soil of the project. It is a basic but fundamental requirement

that all organic materials that may decompose and reduce or expand in volume be removed with the remaining soil left in an undisturbed or properly compacted condition.

- Many times, a layer of crushed stone is applied on top of the subgrade soils to provide a well-draining, stable, workable surface, as well as a clean, dense surface for the shotcrete. The crushed stone also serves as a drainage layer beneath the pool shell. An additional benefit of the crushed stone layer is it can be used to fill in voids or remove unevenness in the excavation process, which enables the shotcrete floor to meet the designed thickness as recommended in ACI 506R, “Guide to Shotcrete.”
- In addition to being a “form” for the floor, the soil has structural significance. The soil must provide support in two directions: horizontal and vertical (that is, floors and walls). In most cases, the soil the pool shell rests on must support the combined weight of the shotcreted pool shell along with the weight of the contained water. These are very high loads and require competent soils to provide adequate support. Consider the soil loads for a pool with a 6 in. (150 mm) thick floor that goes from 3 ft (1 m) water depth to 10 ft (3 m) in depth. The vertical loads on the soil under the floor range from a low of 250 lb/ft<sup>2</sup> to a maximum of 675 lb/ft<sup>2</sup> (1200 to 3300 kg/m<sup>2</sup>).
- The supporting soil subgrade should be evaluated by a geotechnical engineer for various properties when establishing its suitability for any project. These may include: type(s) of soil, variations in the soil composition, presence of groundwater, rock, expansive soils, sloping grades, slope stability, bearing capacity, and potential for differential settlement or sinkholes. The structural engineer will use the bearing capacity of the soil in the structural design of the pool.
- When using the natural subgrade as a form, the soil must be compacted and stable before shotcreting. The geotechnical engineer should provide recommendations on methods needed to compact and test the soil for proper levels of compaction in the subgrade soils. During freezing weather, a frozen subgrade or one covered with frost must not be shotcreted upon.

- Properly stabilized soil or rock can be used as the vertical surfaces to be shotcreted on for the walls of the pool. This process can be quite effective, as it requires less time and materials spent excavating and forming, with little backfill. Loose, soft, or fractured soil or rock should be removed to give the shotcrete a stable, rigid receiving surface. Large voids in the soil can often be filled in with structural foam, or alternatively, formed so the shotcrete section is held to the designed thickness and in the desired shape.

### “INSTALLED” FORMWORK CONSIDERATIONS

- Man-made materials are commonly used for the one-sided forming of the walls. Forming may be required because the soil may be too rough, leaving large voids or undulating surfaces, or is unstable after excavation. The pool structure may need to have all or a portion of the pool built above the existing site grade, as is often the case in sloping sites or sites with very high groundwater conditions. On occasion, the pool may have been excavated without the shotcrete contractor being on site or even being consulted, and due to excessive excavation necessitate forms being built later.
  - If a forming material can conform to the desired shape, be durable, relatively rigid, and not be detrimental to the shotcrete process, it can be used to create a form surface. Rough-cut lumber, framing lumber, tempered hardboard, thin plywood, structural foam, and stay-in-place forms are common pool forming materials. Often, more than one material is used to create custom shapes or to add stability.
  - Forms must be constructed in a way that provides a rigid, stable, nonvibrating surface to receive high-velocity, high-impact shotcrete placement. With shotcrete typically being delivered at 60 to 80 mph (95 to 130 kph), the need for form rigidity is essential. If formed surfaces are weak or loose, the shotcrete crew may incorrectly reduce the force of shotcrete’s impact by reducing the volume of compressed air being delivered. In doing this, the reduced velocity of the shotcrete reduces the compaction, reduces the ability to fully encase the reinforcement, reduces the concrete’s strength, and increases the concrete shell’s permeability. Often sloping walls, bottoms of skimmers, and other areas require that forms be strong enough to carry both the impact and weight of the wet shotcrete.
  - Stay-in-place forms are often comprised of a thick-gauge welded wire covered with a heavy-duty fiberglass or water-resistant paper. This type of stay-in-place form is very useful for creating single- or double-curved profiles. However, if misused, it can create problems. An example of inappropriate use would be hanging the stay-in-place form from a wood form being used for the pool beam at the top of the pool wall, or attaching the stay-in-place forming material to the reinforcing bar cage with tie wire, but having no other support. During shooting, the impact and weight of the shotcrete pulls on the reinforcing bars and the wood forms. This can lead to many problems, and even catastrophic failure during the shoot. This type of stay-in-place form should be supported with an appropriate number and spacing of stakes, ribbing or other suitable bracing materials.
  - Sometimes soil or formwork may have extended exposure to weather and on occasion over the winter. Delayed shoots resulting from complexity or size of a pool, or because of coordination of other work on a project, may expose the soil or formwork for weeks and months prior to shotcrete placement. Other potentials for delay are pre-shotcrete placement inspection schedules and building department requirements. Under these circumstances, the exposed soil or formwork is exposed to the weather and potentially to swelling, shrinkage, cracking, or movement. In circumstances where longer-than-anticipated exposures occur, repairs must be made to restore the integrity of the soil subgrade or formwork prior to scheduling the shoot.
- In summary, whether using natural soil or installed formwork for pool construction, the shotcrete contractor must verify the receiving surface is stable, rigid, and nonvibrating; define and maintain the desired thickness and shape; and fully support any attached reinforcement during shotcreting. Full attention to the details of providing a proper surface for shotcrete placement will help to give the Owner a pool that is structurally sound, aesthetically pleasing, watertight, and will give decades of low-maintenance service.

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## Position Statements

ASA has produced position statements on the best practices for proper shotcrete placement. To date, six position statements from our Pool & Recreational Shotcrete Committee and one from our Board of Direction have been issued. These statements have also been published in *Shotcrete* magazine.