Success in Shotcreting Begins with Forming

By James Scott

In the creation of swimming pools, forming is one of the core components to building a successful shotcrete structure, and can be done in a variety of ways. Each type of forming has its pros and cons; and there usually is more than one type of forming that will work for any particular situation.

Forming for shotcrete is one-sided and has performance criteria it must meet. Stability of formwork is a major factor that allows for successful shotcreting. Form stability means forms that don't move or vibrate during the gunning process, and allows fresh shotcrete to be placed at optimal density without shifting in the finished concrete structure. Consistent high density of the placed shotcrete equates to water tightness of the pool shell, which is the whole point, after all!

Often, earth is used as the form for shotcrete in two areas: horizontal and vertical (that is, floors and walls).

- Most pools will have the floor setting on the in-place soil of the project. It is a basic, but fundamental, requirement that all organic soil and materials must be removed, with the subgrade the pool floor rests upon left in an undisturbed and compact condition (Fig. 1). Many times, a layer of crushed stone is applied over the top of the subsoil to provide a dry, stable workable surface, as well as a clean, dense surface for the shotcrete. The crushed stone also serves as a drainage layer under the pool shell. In sites with a rock subgrade, the crushed stone creates a "cushion" over the rock. An additional benefit of the crushed stone layer is that it can be used to fill in voids or remove unevenness in the excavation process—which enables the floor to be shotcreted at a uniform thickness to meet the design thickness, as dictated in ACI's "Shotcrete for the Craftsman."
- In addition to being a form for the floor, the earth subgrade has to structurally carry the high loads of the filled pool without excessive settlements. The soil will be looked at for various issues when analyzing its suitability for any particular project: soil structure and variation in the soil profile, presence of groundwater, ledge rock, expansive soils, and sloping grades. The geotechnical engineer will often use soil testing to determine the soil's competence to carry the loads. The structural engineer will consider the bearing capacity and settlement of the soil.
- I once asked an engineer, "What is the single most important thing I could focus on to lessen my risk when building a pool?" His answer was simple and telling; he simply said, "Compact the last layer of soil exposed by the machine before putting down the crushed stone." This told me that if I left any disturbed, less-dense soils under my pool, compaction would be taken care of for me by gravity with the weight of the filled pool! In a very real way, the ground must be in a stabilized, compact condition before the shotcrete process. For those in the freezing areas, be aware that a frozen subgrade has an expanded volume that

Fig. 1: The subgrade has been carved to the profile required, including trenching of plumbing lines beneath the future pool shell

will subside when thawed, and should not be shotcreted upon.

In areas with relatively stiff soils, earth can also be used as the one-sided form for the walls of the pool (Fig. 2). Historically, the residential pool has been formed in exactly this way, as an efficient means to construct a pool within the reach of the burgeoning middle class. This process can be quite effective, as it requires less time and materials spent excavating and forming, with little backfill. It does, however, require an excavator and dig crew who are experienced in this practice. Again, loose, soft, or fractured soil should be removed to give the shotcrete a solid receiving surface. Loose sands would not be appropriate for forming pool walls because they cannot stand up to create a vertical surface to shoot upon.

Other materials are commonly used for the one-sided forming of the walls. If a material is able to be shaped, and is durable and not detrimental to the shotcrete process, it probably can be used. Rough-cut lumber, framing lumber, pegboard, plywood, and Steeltex® are among these materials; and many times, more than one material is used to allow creation of curves and add stability to the form.

Forming materials are used instead of earth for various reasons. The soil may just be too rocky, leaving large voids and caved-in walls during excavation. The structure may be built above existing site grades due to design choices or building on sloping land (Fig. 3). In some cases, pools are excavated without the earth forming crew being on site, requiring forms to be built later.

The forms must be constructed in such a way as to provide a solid, stable, nonvibrating surface for the shotcrete. Once you realize that shotcrete is being shot out of the nozzle at up to 180 ft/s (55 m/s), you start to understand the need for form strength. Ironically, should the forms be weak or loose, the shotcrete crew may try and reduce the amount of compressed air being delivered, so as to "save" the form. But, in doing this, they fundamentally alter the shotcrete process with a detrimental effect on the in-place quality of shotcrete in the finished project. In some areas, the forms must also be strong enough to carry the static weight of the wet shotcrete once in place. A sloping wall or the bottoms of skimmer boxes are two examples that come to mind.

Steeltex deserves special mention. Steeltex is a brand name for a thick-gauge welded wire mesh covered with a heavy-duty fiberglass/water-resistant paper. It is commonly used in swimming pool forming and works well for creating curved profiles. An incorrect practice occasionally seen is to install a wood form for the pool beam (top of pool wall), hang the Steeltex down from the wood form, and then simply tie the Steeltex to the steel reinforcing cage with wire, but with no other support (Fig. 4 and 5). As gunning occurs, the impact and weight of the shotcrete pulls on the reinforcing bar and the wood forms above. This incorrect support of the Steeltex leads to poor shotcrete practice as the crew tries to save the forms by adjusting the shotcrete flow, which can

Fig. 2: The rocky soil has been trimmed to accept the shotcreted pool shell

Fig. 3: A significant set of wood forms, well-reinforced, for a negative-edge pool being built above grade

Fig. 4: Short pegboard forms poorly supported with undersized staking allows for movement at the top of forms during shotcreting

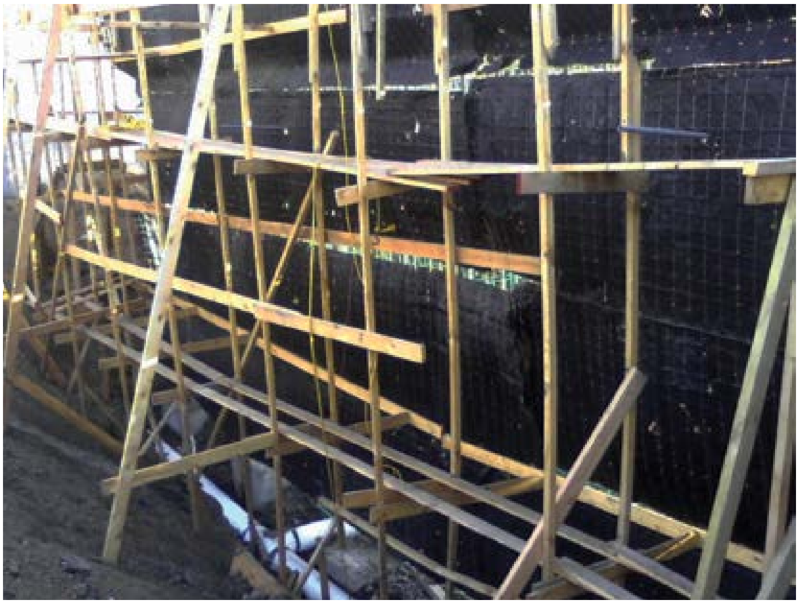


Fig. 5: A 13 ft (4 m) tall pool wall with Steeltex® hung haphazardly, with a terrible lack of support by undersized and insufficient wood forms

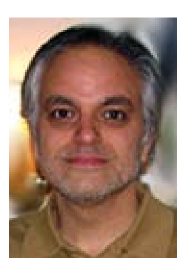
Fig. 6: Steeltex forms properly set with overlaps, wood staking behind, and plywood ribs attached to the front

Fig. 7: Proper Steeltex forming allows the shotcrete crew to focus on their placement and finish details

possibly lead to catastrophic failures during the shooting. Steeltex in itself is not bad; it simply needs to be supported with appropriate amounts of stakes, ribbing, or other forming materials (Fig. 6 and 7).

Many times, forms must hold up to extended weather and occasionally even over the winter. On complex or large pools, there may be weeks and months between forming and shotcreting, as plumbing and reinforcing steel placement take place, as well as the coordination of other work going on around the pool. In highly regulated areas, pre-shotcrete inspection schedules and building department requirements can add a great deal of time. Forms get rained on, knocked around by other trades on the job, and get snowed upon. We've even had to disassemble portions of tall forms on a negative-edge pool when high winds were forecast. So, projected timing, exposure to the elements, and job-site activity must also come into play when choosing materials.

To my way of thinking, gaining knowledge and a technical understanding of the shotcrete process is the best way to determine and understand the needs of the forming phase. As you come to understand what's happening during shotcreting and the magnitude of forces that come into play, it leads to a realization of the vital role that forming has in the success of the process and encourages appropriate techniques.



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