Monolithic Dome School Buildings

By David B. South

Just about everyone in the construction industry has been feeling the effects of the worst economic downturn since the Great Depression, but there is one sector that has been largely undeterred from moving ahead with plans for new buildings—public school districts. Fueled by bond issues passed before the crisis hit and, in some cases, federal funding, construction is currently under way on two monolithic dome school buildings. Four other school districts are nearing final approval for building a steel-reinforced, shotcrete dome in the next several months.

One of the largest of the new projects is in the Woodsboro Independent School District located near the Gulf Coast in South Texas. Construction is set to begin in fall 2009 on a 20,000 ft^2 (1858 m^2) multipurpose building that will serve as the district's gymnasium and auditorium. The dome, which will cost between \$2.1 and \$2.4 million, will host everything from band programs to graduation ceremonies. Because monolithic domes meet the Federal Emergency Management Agency's (FEMA's) standards for near-absolute protection from tornadoes and hurricanes, the building will double as a community disaster shelter when bad weather strikes.

USD 225 in Fowler, KS, recently received voter approval for a \$1.94 million bond issue that will fund construction of this monolithic dome multipurpose facility that will house a computer/technology lab, a new band/vocal room, a new gymnasium, two locker rooms, and a commons/concession area. The project is currently out for bids and, when completed, will be the first monolithic dome school in the state

Construction of the monolithic dome multipurpose facility is the final phase of the Woodsboro ISD's capital improvement program funded by a \$9.9 million school bond issue passed in 2005. But Superintendent Steve Self has also applied for grant money from FEMA to help fund the project, and he is expecting the federal dollars to come through as early as September 2009.

Self is following in the footsteps of the Niangua R-V School District in Missouri, which earlier this year completed construction on a much smaller monolithic dome building. This facility was funded by a FEMA grant. The 2700 ft^2 (251 m^2) Niangua building was financed by a FEMA predisaster mitigation grant of \$313,000 designed to cover 90% of the construction costs for a new building. Completed in April 2009, the dome is serving as the district's preschool classroom and replaces a nearby double-wide trailer that school officials concede was a tornado magnet.

Another Missouri school district that recently completed three monolithic domes is starting construction on two more of the round buildings to accommodate students in kindergarten through second grade. Valley R-6 School District in Washington County is building the two new dome structures on the same site as three existing domes. One of the new 85 ft (26 m) diameter domes will house five classrooms, whereas the other will feature three classrooms and a large library and media center. The new domes will unite students from kindergarten through grade 12 on the same campus.

The district completed two academic domes in 2002 that house a total of 11 classrooms, and a third monolithic dome multipurpose facility in 2008, which can seat 800. Construction on the two new domes is taking place in phases and will be governed by available funds. The district already has enough money in its Capital Projects Fund to finance construction of the dome shells, which is expected to cost approximately \$500,000. The interior will be completed over the next 2 or 3 years using district employees and local contractors.

In nearby Kansas, USD 225 in Fowler recently received voter approval for a \$1.94 million bond issue that will fund construction of a monolithic dome multipurpose facility that will house a computer/technology lab, a new band/vocal room, a new gymnasium, two locker rooms, and a commons/concession area. The project is currently out for bids and, when completed, will be the first monolithic dome school in the state. A second Kansas school district in Leoti, however, is working on a plan to build two large domes and one smaller one.

In Oklahoma, the state with more monolithic dome schools than any other, construction is nearing completion on a new middle school and high school in Geronimo. The project consists of five modular monolithic domes. Geronimo is among eight school districts in Oklahoma that have opted for the monolithic dome method of construction—others include Locust Grove, Buffalo, Hinton, Beggs, Okima, Texoma, and Dibble.

Although Niangua is the only monolithic dome school funded by FEMA to date, all of the monolithic dome school buildings are strong enough to serve as safe havens when severe weather strikes. Part of the monolithic domes' strength comes from the curvature of the building. While conventional walls are not strong enough to withstand the pressure of a tornado, which can push with 100 to 400 lb (45 to 181 kg) of pressure, the curved, steel-reinforced concrete walls of a monolithic dome can withstand pressure of up to 2000 lb/ft^2 (9765 kg/m^2). But the shotcrete mixture, along with the technique used to spray the shotcrete over the structure's steel reinforcing bars, also play important roles in the buildings' virtual indestructibility.

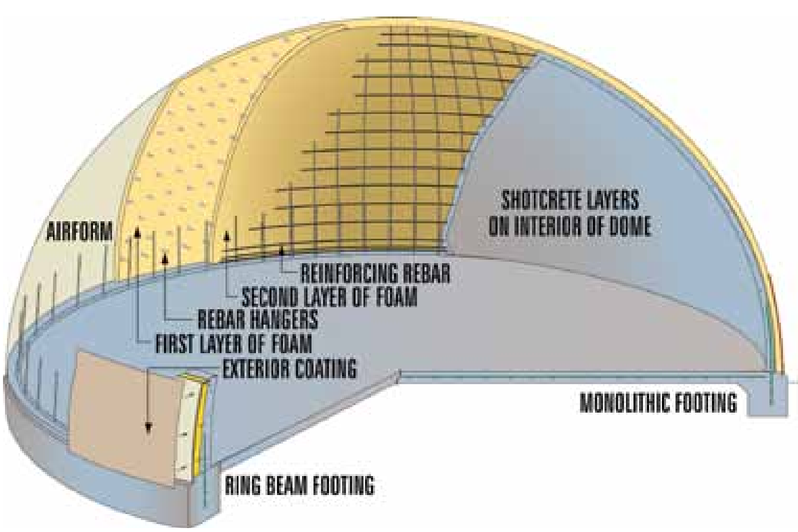
Before beginning the shotcrete phase of the construction process, crews pour a slab inside a ring beam footing. In many cases, a stem wall is then erected to give the building straight walls and a more conventional look. Next, crews attach an airform, a tarp made of tough, single-ply roofing material, which is inflated using giant fans. Once the airform is inflated, work moves to the interior where steel frames are attached to frame the windows and doors. Three inches (76 mm) of polyurethane foam is then sprayed on the rest of the airform, and a grid of steel reinforcing is attached to the foam.

At this point, the shotcrete work begins. Crews start by spraying a thick, tapered layer of shotcrete around the entire circumference at the base of the dome, up to approximately 1 ft (0.3 m) high. This ensures the concrete on the footing is not "rebound shotcrete," or aggregate (particles that separate from the air stream). Rebound does not make good concrete. Rebound and overspray also inhibit proper encapsulation if they also keep good concrete from embedding the reinforcing bar.

Once the base has been sprayed, work proceeds from the ground level up, with the first layer of shotcrete gradually thinning as it nears the top of the dome. A second relatively thin layer of shotcrete is usually applied in the same manner the next day. If the second layer is applied early in the day and the weather is warm enough to enable the concrete to set up fast, a third layer is applied in the afternoon of day two. By day three, the dome will support more weight and the layers can go on thicker. Before spraying the final layer, crews

Valley R-6 School District in Caledonia, MO, already has three monolithic dome buildings—two classroom domes and a multipurpose facility (pictured here). It is now building two new 85 ft (26 m) diameter dome structures on the same site. One dome will house five classrooms, whereas the other will feature three classrooms and a large library and media center. The new domes will unite students from kindergarten through grade 12 on the same campus

This 2700 ft^2 (251 m^2) monolithic dome preschool building in the Niangua R-V School District in Missouri was financed by a FEMA predisaster mitigation grant of $313,000 designed to cover 90% of the construction costs for a new building. Completed in April 2009, the dome replaces a nearby double-wide trailer that school officials concede was a tornado magnet



This graphic shows the various layers of the monolithic dome. The shotcrete coats the interior of the building

This is an aerial view of the newest monolithic dome school in Oklahoma. Construction is nearing completion on a new middle school and high school in Geronimo, consisting of five modular monolithic domes

check the depth to ensure that the shotcrete ranges from approximately 8 in. (203 mm) at the base to 4 in. (102 mm) at the top. A final thin layer is then applied to the dome, with crews working from top to bottom to make the shotcrete as smooth as possible.

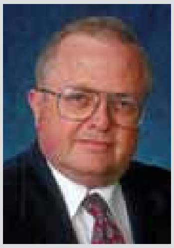
While the application process is important, the shotcrete mixture also plays an important role in the buildings' strength. Over the years, we have asked everyone, from other shotcreters to the Portland Cement Association, how to make the maximum strength shotcrete with efficiency. We have discussed how much, and what kind of, cement, supplementary cementing material, water, rock, sand, and admixtures we should use. After trying every mixture we could think of, we came to the following conclusions for construction of monolithic domes. Because of their shape, monolithic domes only need a relatively small amount of concrete, so we always use the best materials and the optimum amount of cement.

If fly ash is available—it usually is at most ready mix plants—we replace 100 lb (45 kg) of cement with 120 lb (54 kg) of fly ash per yd^3 (m^3). Fly ash makes the concrete pump easier and eventually makes the set concrete stronger, increasing the later age strengths. We also replace one bag of cement with admixtures that give us the same strength with other added benefits. These benefits include "air entrainment," easier pumping, and water reduction.

Just as importantly, we have found only very small amounts of water are needed to properly set concrete for proper concrete strength gain in a monolithic dome. Too much water is concrete's worst enemy because it weakens it and makes it crack more. Typically, crews supply the concrete with too much water to make it easier to pour. It won't stick and the worker handling the nozzle ends up wearing it. We also have to watch our crews to keep them from applying shotcrete with too little water. Too little water makes fantastic concrete, but makes it difficult to properly encapsulate around the reinforcing bar as it should.

We prefer to use natural river rock and sand for shotcrete. The best concrete has the most even gradation of its aggregate—from small (0.375 in. [9.5 mm]) down to the very, very fine rocks (1/100 in. [0.25 mm]).

Like other companies in the construction industry, we are heartened by the signs we're seeing of an economic rebound. The phones are ringing more, and inquiries are coming in for everything from our large storage facilities to our miniature monolithic cabins. But until business returns to 2008 levels, we continue to focus on the burgeoning public school market, knowing we are also doing our part to make America's children safer.



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