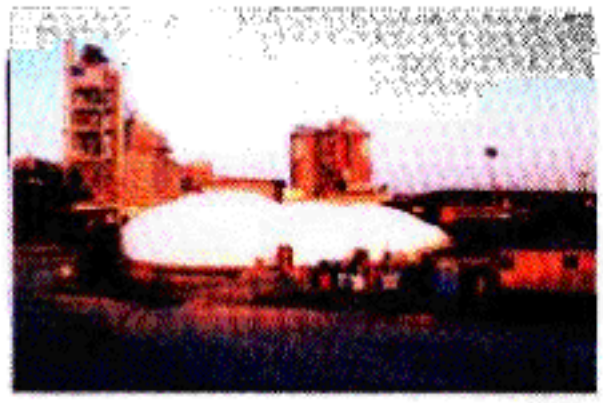
Shotcrete Domes

by Barry South



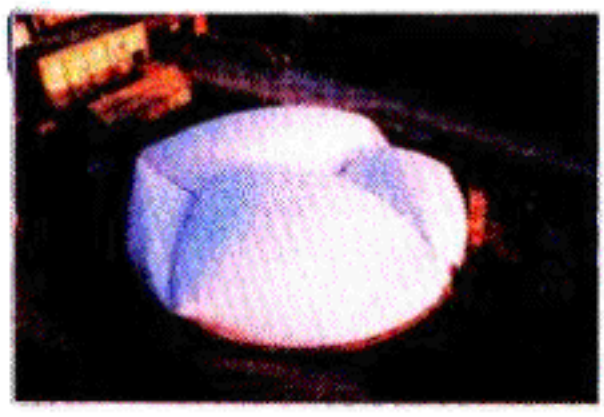


Figure 1: Inflation of the exterior skin of the dome, the air form.

Domes are durable structures that have the potential to last for a century or more. Domes are architectural symbols that represent authority. Examples are capital buildings, institutions, and museums. Domes are also symbols of religion represented by churches, cathedrals, and temples throughout the world. Domes also represent the future, and a futuristic lifestyle.

The oldest continuously used building in existence today that still has the original roof system on it, is the 143 ft (44 m) diameter half-sphere Pantheon Dome in Rome, Italy. The dome sits on a 72 ft (22 m)-high stem wall. The Pantheon was built in 126 A.D. Instead of our modern, strong portland cement concrete and reinforcing bar, the Pantheon was built with a pozzolan cement and reinforced with vitreous china rope. The natural shape of the double, compound curves gives domes their exceptional strength and durability.

Obviously, construction materials and practices have changed over time. Modern concrete domes usually fall into the category of the thin shell structures that became more popular 50 to 100 years ago. As labor and forming prices increased, the conventionally formed thin shell structures could no longer compete in price.

The domes that we build now at Dome Technology are extremely strong and energy efficient. The incredible strength comes from modern engineering, modern cement, and reinforcing bar combinations teamed up with the inherent strength of the compound curves that make up the dome shape.

The three keys to our successful dome construction are:

1. Modern fabric that can be welded into strong dome-shaped air forms that become a permanent single-ply roof;

2. Modern polyurethane that becomes part of the construction process and is also an extremely efficient permanent insulation; and

3. Modern concrete pumps that allow the efficient pumping and spraying of shotcrete.

This new technology using high-strength shotcrete and reinforcement, combined with the double curve surface of a dome, results in a new generation of domes that are extremely strong. Polyurethane foam is the best insulation known. Insulating the outside of the structural concrete protects the structure from thermal expansion, contraction, and weathering. The large concrete mass of the dome provides energy efficiency. A 50% energy savings can be expected from a Monolithic Dome. Concrete domes will not rot, nor will they burn, and they are often the last buildings standing in floods, hurricanes, and tornadoes.

Another part of the magic of Monolithic Domes is the versatility they offer for many different uses. Their beauty is exemplified by the churches and private residences that are now being built. A good example of this is the 280 ft (85 m) diameter by 70 ft (21.3 m) high Baptist Church in Birmingham, Alabama.

Their superior strength is utilized in the bulk storage industry with domes up to 250 ft (76 m) in diameter by 125 ft (38 m) high that are filled with products such as cement, grain, fertilizer, gypsum, and mine ore. A good example of this is the dome built for Holnam Cement to hold 100,000 tons (91,000 metric tons) of cement at Holly Hills, South Carolina.

Monolithic Dome construction, using wet-mix shotcrete pumped down a hose and spray applied on a flexible air form to construct a reinforced monolithic shell, is an impressive process. The first time I ever heard of spraying "concrete" I was skeptical. I would have to see it to believe it. Now I believe in it and am sold on the concept of building wonderful structures with shotcrete. Few applications can compare with its efficiency. Over 100 yd³ (76 m³) of shotcrete can be applied in an 8 h shift with just a half-dozen men working on the project. Why? Because everything in the system works well together to make it all happen.

The scaffolding generally used in large dome construction is a big crane with a man basket mounted on the end of the boom, or a similar aerial lift. The work is carried out right where it is needed with a very smooth operation. The boom carries the entire weight of the hose. The hose is fastened to the man basket so the nozzleman doesn't fight the weight of the hose, nozzle, or the thrust of the spray. Consequently the onerous manpower work is taken out of the task and it becomes satisfying to spray shotcrete — instead of being arduous. With the strenuous work taken out of spraying, it is easy to add a second nozzle. This allows twice the work to be done in the same amount of time. You have only added one more

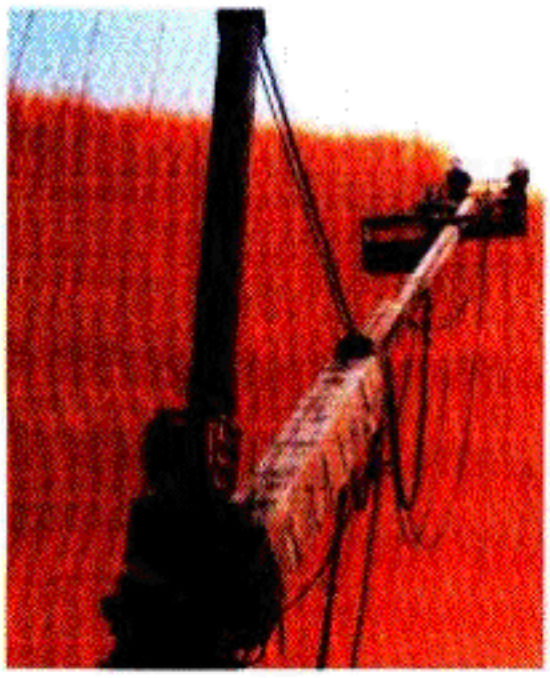


Figure 2: Placement of a polyurethane foam layer inside the air form.

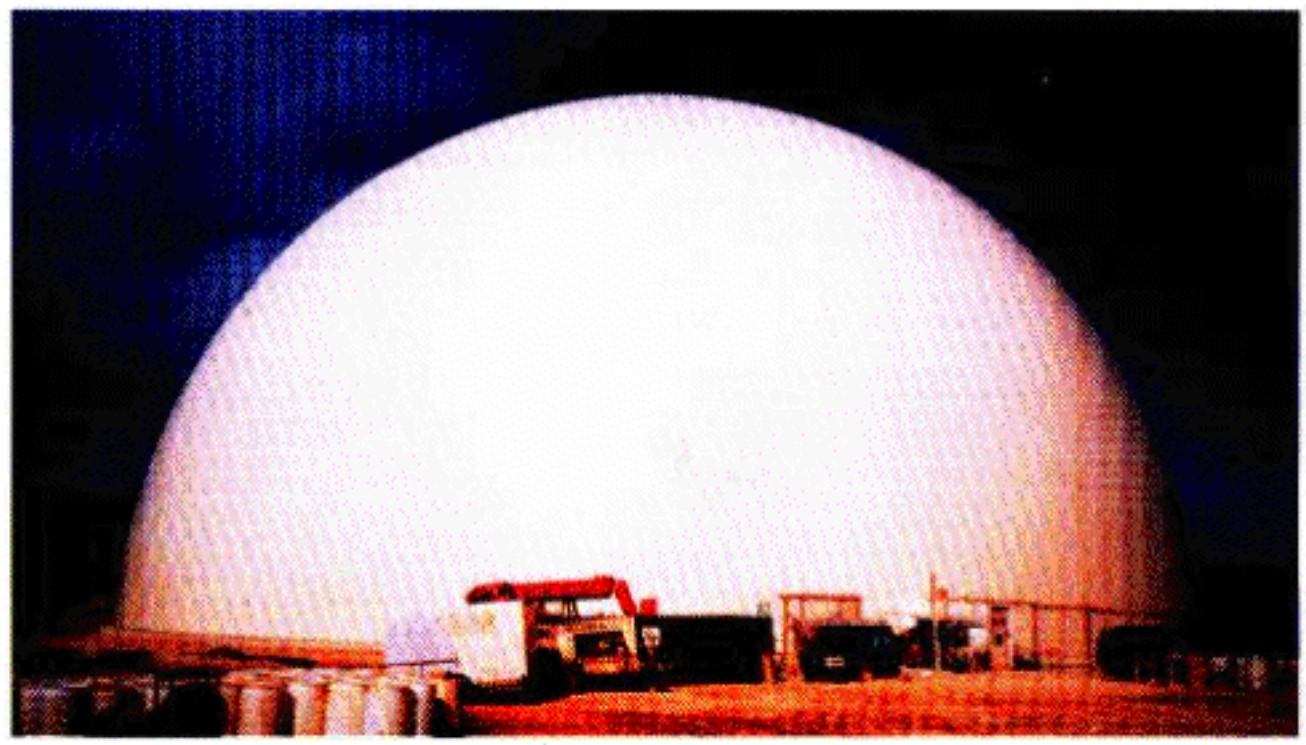


Figure 3: Holnam cement storage dome, Holly Hill, SC.

man but have increased the production twofold.

Can you think of any other application where just half-a-dozen men can place such large volumes of shotcrete in a finished manner with as much ease? We use one man as an aerial lift operator, one man as a pump operator/truck coordinator, one man to ensure the hoses don't get hung up, and two nozzlemen. Five men can do the job. It is nice to have extra men, of course, so we can eat lunch or take a break. Consistently, five men can place over a 100 yd³ (76 m³), or more, shotcrete in a day, as long as there are places to apply shotcrete. That is "efficiency" for a small trailer mounted pump.

When the shotcrete application is down low and near to the ground where the hose is not tied to a basket, the work is much different. An observer standing nearby that has never actually had a shotcrete nozzle in his hands likely would perceive the spraying as easy and simple. Hands-on it is a different story. When spraying down low on a dome, walking on the ground, without the aid of a crane to hold the hose and resist the thrust on the spray, the physical work can be intense. But even when spraying in these conditions, practice makes it easier. Skills are learned in handling the hose in ways that reduce the strain.

When the shotcrete is sprayed correctly, the reinforcing bar will be embedded properly and you will also have the best look when finished. There are many things that influence this proper "spraying." The orientation of the nozzle to the works, workability of the shotcrete, fineness modulus of the sand, type of shotcrete nozzle, distance to the substrate, and velocity, are some of the main factors. Knowing how to get these things right takes training and experience.

A nozzleman must be qualified, experienced, and committed to doing the job correctly. The nozzleman must understand how all of these factors influence the application of the shotcrete and, as a result, adjust technique to get the job done right. Perhaps the most important considerations when applying shotcrete to a dome, or for that matter any shotcrete application, are proper reinforcing bar embedment and the aesthetic look of the finished product. It takes a lot of training and practice for an individual to get to the point where he can be left alone with this responsibility. Practice and experience make a good nozzleman and a great dome.

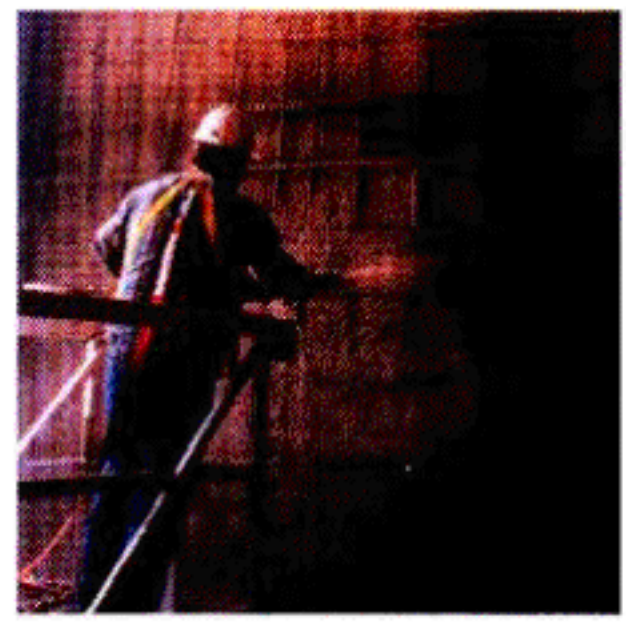


Figure 4: Close-up of rebar encapsulation.

Barry South received a degree in Business Management from BYU University and has studied engineering extensively. He is currently President and CEO of Dome Technology Inc., a worldwide construction company with satellite offices in Mexico and the UAE. He is also a member of the ACI Thin Shell Committee, 334.

South is one of the inventors and patent holders of the Monolithic Dome Patents. He invented many of the current processes used today in shotcreting domes. He has hands-on experience with over 200 of the 600 domes that have been built to date, using this patented technology. He has built domes extensively in the USA and Canada as well as in about two dozen foreign countries.