Air Forms for Building Shotcrete Domes

by Michael E. Ragen and Laurel Briggs

Concrete domes are used for both commercial and industrial applications. For example, domes have been incorporated into schools and churches. By far, however, the majority are constructed for industrial bulk storage of materials such as cement, fly ash, coal, fertilizer, gypsum, grains, and peanuts. Some of the advantages concrete domes provide include:

- Superior protection of the stored material;
- Strength and durability;
- Simple foundation requirements; and
- Superb environmental control.

Shotcrete domes today are constructed using inflatable fabric forms. The air form is an engineered fabric structure manufactured of single-ply roof membrane material. It arrives at the job site as a rolled-up single piece package. Once unrolled and spread out, it is attached to the dome's circular footing. Large blowers are used to inflate the membrane that then serves as the formwork for the shotcrete dome. Contrary to what may seem obvious, the shotcrete is seldom applied over the air form's exterior. Instead most domes are constructed by spraying shotcrete to the air form's inside surface.

Considering that the shotcrete will be sprayed on the inside, the air form membrane is designed to remain in place and serve as part of the dome's finished roof. As such, it is important to select the correct fabric that will satisfy the application's performance requirements. There are many coated fabrics to choose from. For the construction process, some of the primary issues include dimensional stability and the strength of the fabric and its seams. The owner's long-term interests usually relate more to durability, low maintenance, and appearance, including the exposed surface's ability to shed dirt and/or be cleaned. The fabric will remain as the roofing material. Several exterior top-coats, such as acrylic polymers or polyvinylidene fluoride (PVDF), are available to protect the base fabric from ultraviolet rays and enhance long-term weathering capabilities.

Several variables such as size, intended shape, and anticipated inflation pressures are considered in the selection of a specific fabric and its design into an inflatable form. Other variables like weather and fabrication tolerances can make predicting the precise inflated shape difficult, but

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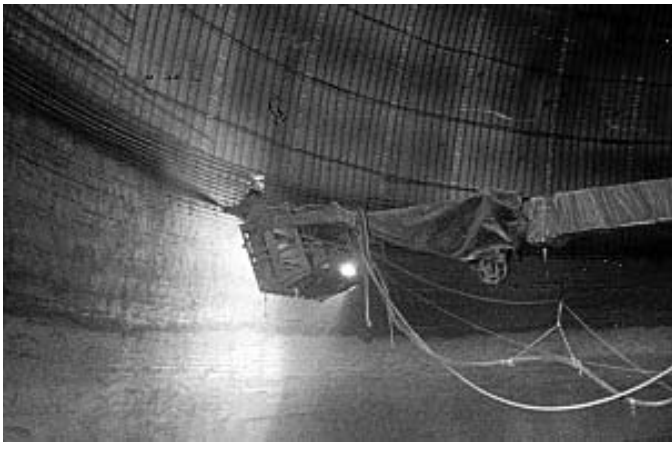
Air form being inflated



Shotcrete application inside dome

careful engineering and quality control of the fabrication lessen inconsistencies. Air form manufacturers gather as much information as possible, and they exercise care to produce forms within reasonable tolerances of the shape requested by the customer.

Shape and size are the primary variables in air form design. The most common and simplest shapes are portions of spheres, including hemispheres. Designs may also include a vertical cylindrical section producing a shape consisting of a hemisphere on top of a cylindrical base. Less common shapes are ellipsoids, or forms with barrels. The shape of the air form affects how the designer calculates the stresses on the inflated form, whereas size will determine the severity of those stresses.

Fabric selection is a major factor in the design process. Air form fabrics are chosen to meet the requirements of strength, stretch, durability, and appearance. Most of the commonly used architectural fabrics are all polyvinyl chloride (PVC)-coated polyester scrims. These fabrics provide high strengths and consistent stretch characteristics. The fabric's stretch characteristics are essential to properly pattern the air form. Fabric suppliers provide biaxial stretch test information in various ratios for their products. The stretch test information indicates the percentage of stretch that will occur lengthwise and widthwise within the fabric based on amounts of loads applied in both directions. When designing spherical-shaped forms, stretch data from a 1:1 ratio (equal loading in both directions) test is used. Cylindrical walls require using data from 1:2 ratio testing (twice the loading in one direction compared with the other).

Air forms are fabricated by heat-welding together specially patterned flat pieces of fabric that, once inflated, take on the designed curved shape. Patterning takes into account how the fabric will stretch due to stresses produced by inflation pressures. Inflation pressure is the most significant stress to be considered. Wind can also influence the inflated form's actual shape. Once at full pressure, however, wind-related stresses are minor, and any shape deformations are temporary.

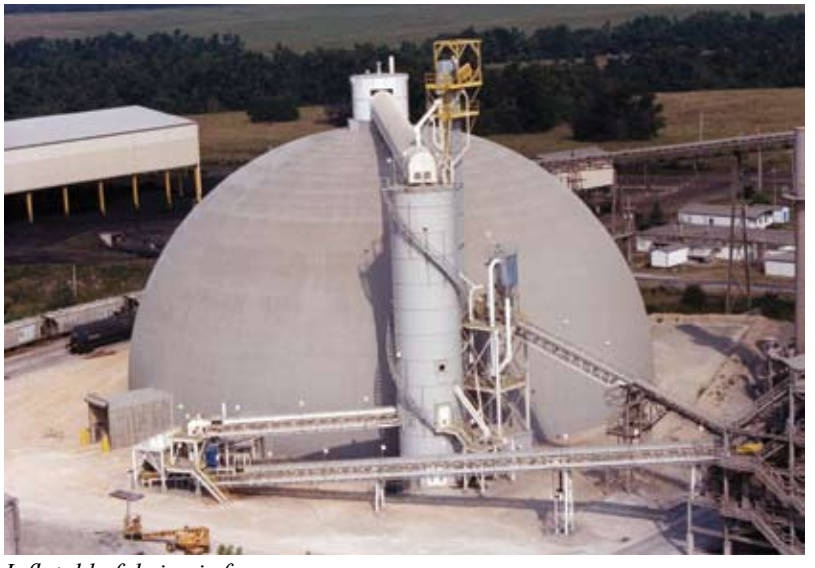
Many styles of patterning can be used to create the air form. The most common for relatively large air forms is referred to as a double panel system. This consists of pairs of vertical gores that have an equal, consistent width around the dome's base circumference and extend up to a circular piece of fabric at the form's apex. Each pair of panels has a straight center seam and curved outer seams. This style of patterning minimizes fabric waste and therefore cost during manufacture. It also provides very few horizontal seams, giving a more aesthetically pleasing final surface appearance.

Air form being rolled out

Inside the inflated air form

Outside the inflated air form

Fabric on the FIAB welder



Inflatable fabric air form

Seams between panels are created by a heat-welding process using high-frequency radio waves, also called dielectric welding. This radio frequency (RF) process is recognized as the highest quality seaming method. RF welding creates durable, watertight seams with strengths exceeding that of the fabric itself.

Fabrics can be obtained in virtually any color. Colors not regularly stocked, however, may involve a surcharge; and, in most cases, they require longer lead times for fabrication.

Inflatable fabric air forms have come a long way over the last 30 years. By selecting a strong, high-quality fabric with a durable top coat that truly is intended as a finished roof membrane and using an experienced, reputable fabricator with the right equipment and quality control practices, air forms can serve as reliable construction forms for dome builders and provide owners with low maintenance performance for many years.

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