Denver International Airport Road Sand Storage Dome

by Warren Harrison

The Denver International Airport contracted for construction of five support buildings including a new sand storage dome for use on the airport access road. The dome was a design-build structure that would store 5000 tons (4535 metric tons) of sand and salt material. The dome was designed to rest on a concrete pier foundation and was required to resist the heaving of the swelling (Bentonite) soil in the foundation. The contract specifications required that the dome have a 5.5 m (18 ft) wide by 6.1 m (20 ft) high entry door, a man door, two vents beside the access door, and two holes in the top of the dome. One top hole was for a ventilator fan, and the other hole was for filling the dome from an external conveyor.

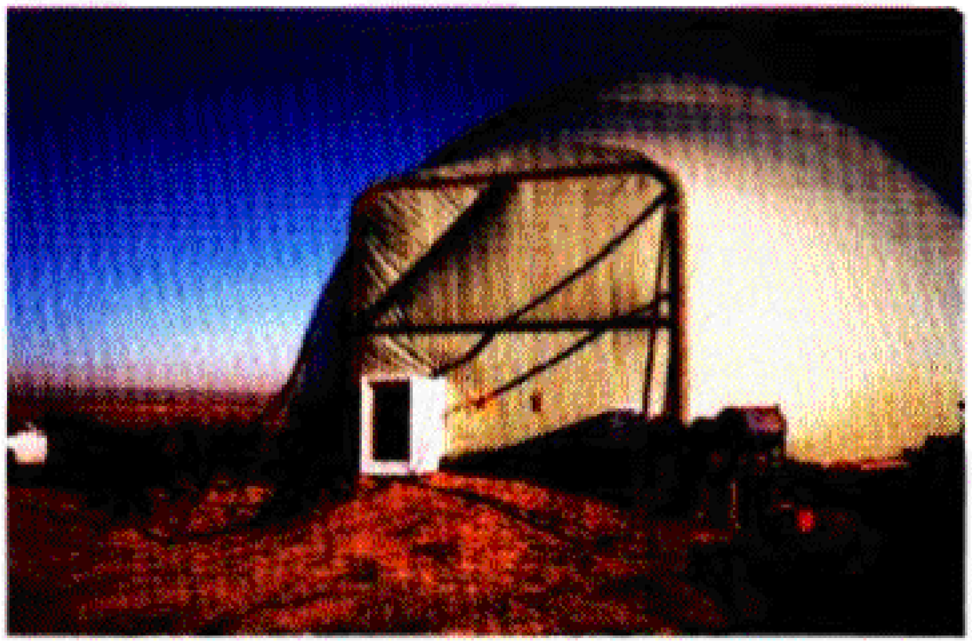

Figure 1: The set up before the full inflation.

WLH Construction and Stratispan Corporation (a joint venture) was the low bidder for the subcontract to design and build the dome. The structural design was reviewed and approved by Ground Enhancement Engineering Corporation.

By using the strength of the dome and the allowance of stacking material against the wall, the 5000-ton (4535 metric ton) capacity was met by building a 27.4 m (90 ft) diameter hemispherical dome with a height of 13.7 m (45 ft) at the center.

W. M. Brown Construction of Westminster, Colorado, the general contractor, graded the site and installed the caissons and the foundation wall. The air form was purchased from Monolithic Domes of Italy, Texas. Its color was a special shade of forest green that matches existing storage buildings.

First the epoxy-coated reinforcing steel, door frame, and a boom lift were placed inside the dome perimeter. The dome air form was then unrolled and attached to the foundation with 12.7 mm (0.5 in.) diameter anchor bolts and tie-down brackets. The form was slowly inflated using two squirrel cage fans powered by two Honda 10 hp gasoline engines. After partial inflation, a man access air lock was attached to the face of the doorway. A concrete pumping line was buried in the floor to facilitate pumping shotcrete inside the dome.

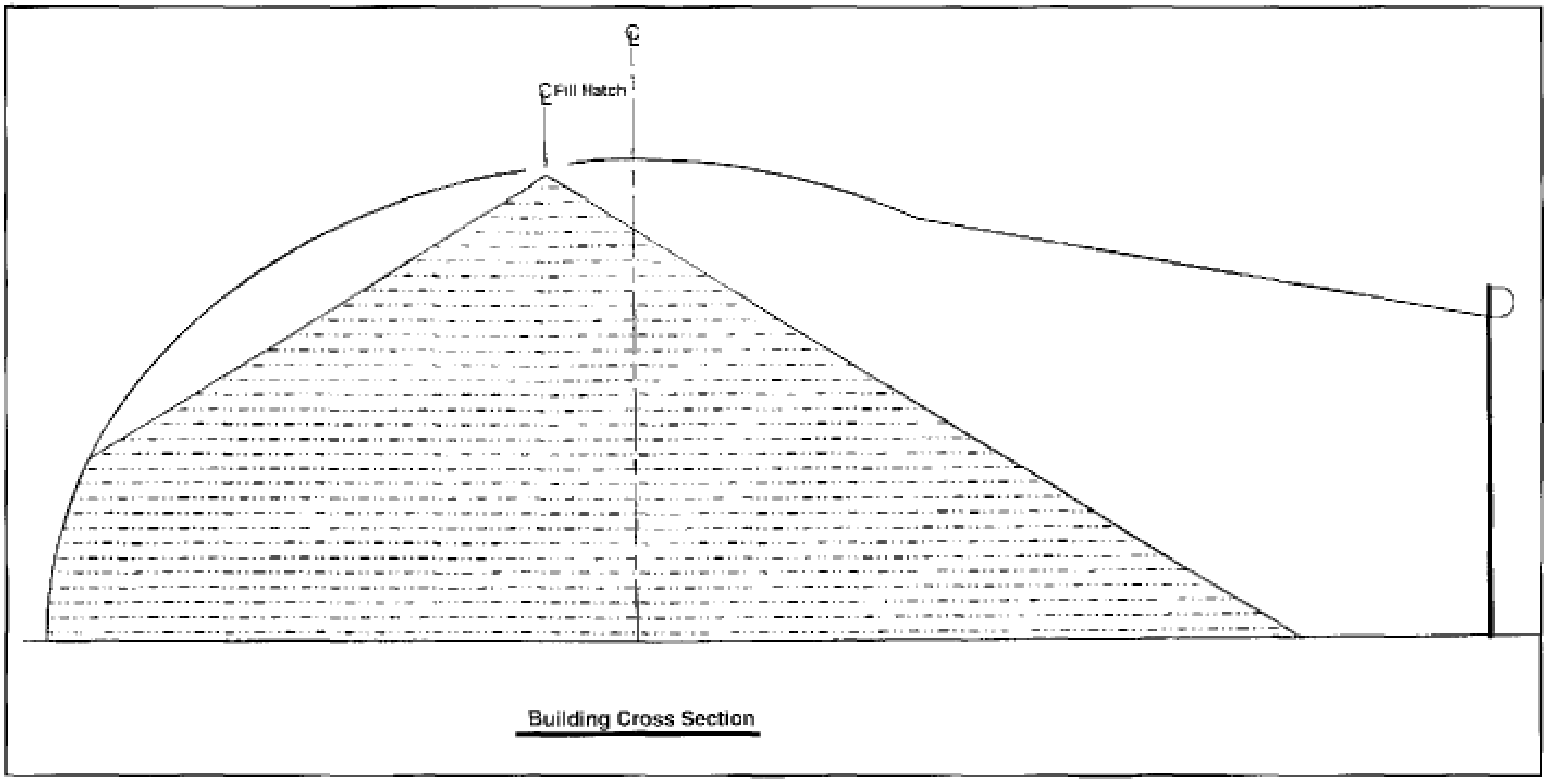

Figure 2: Denver International Airport sand storage dome cross section.

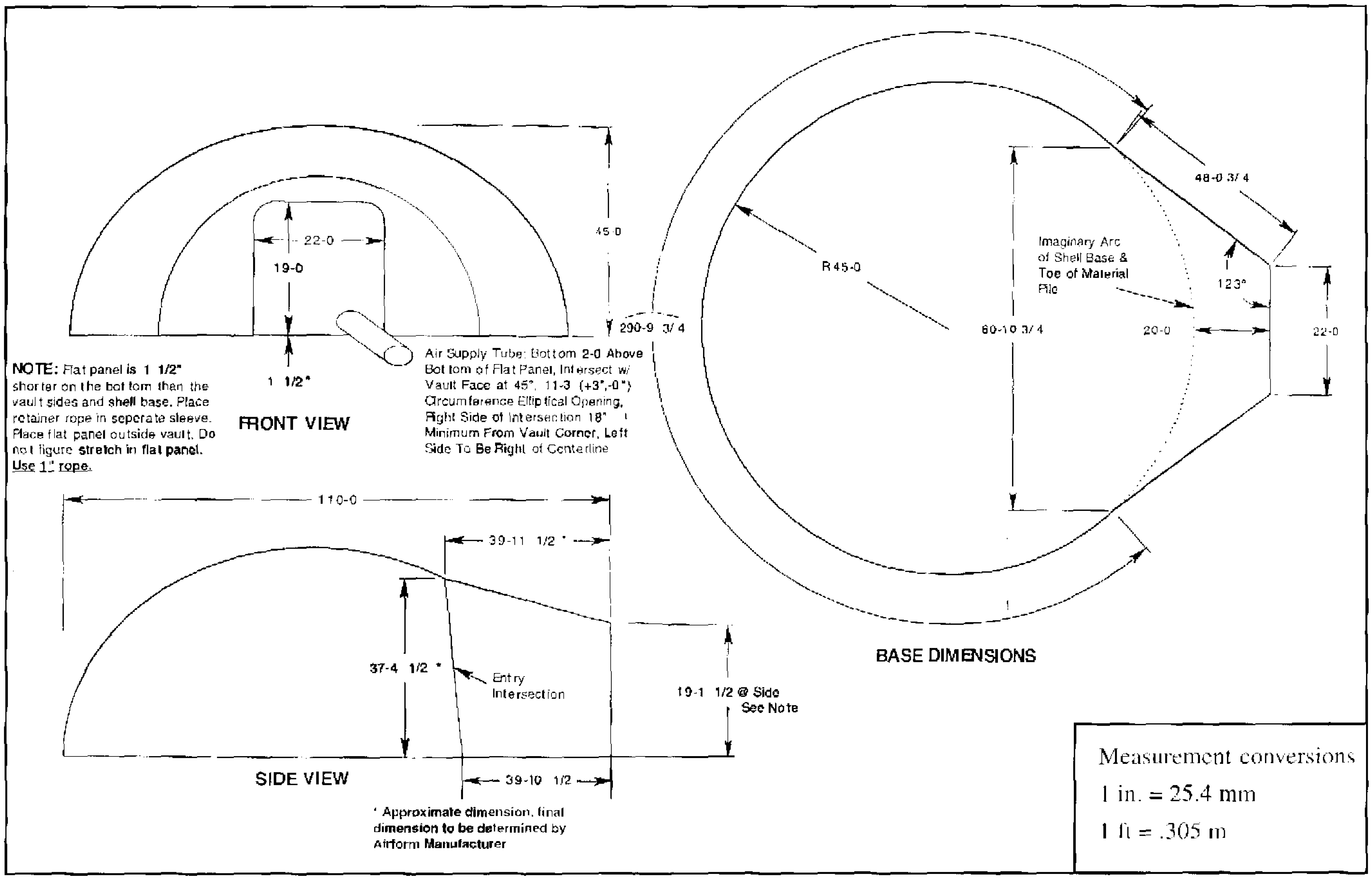

Figure 3: Denver International Airport storage dome front and side views, and dimensions.

With the air form partially inflated, the door frame was erected from inside the dome. The heavy galvanized-angle iron frame was lifted into place using the boom lift. The frame was then braced from the outside of the dome as later a reinforced shotcrete beam was shot around the door frame from inside the dome.

The air form was then inflated to the design pressure of 50 mm (2 in.) water gage. All the anchors were checked and reinforced where necessary. A 300 mm (12 in.) diameter hole was placed in the top of the dome to provide some through-flow of fresh air.

Rocky Mountain Foam of Brighton, Colorado, installed a 25 mm (1 in.) layer of polyurethane foam insulation over the interior of the dome. All opening frames for doors, ventilators, and hatches were placed during the foaming operation. The wire reinforcing bar hangers were placed in the foam to support a reinforcing steel template. The template and hangers are necessary as most of the reinforcing steel was placed overhead. With all hanger wires in place, a thin layer of shotcrete was shot over the entire inside surface of the dome. The thin layer performs two functions, reinforcing the hanger wires and providing a rough surface for attaching production shotcrete.

Reinforcing of the dome was accomplished in several stages. Number 6 bars at 75 mm (3 in.) were required in the lower section of the dome wall with the spacing increasing and bar sizes decreasing as we progressed up the wall into the overhead section of the dome (No. 3 bars at 280 mm (11 in.)). Reinforcing was placed in 2.4 m (8 ft) wide horizontal lifts and then shotcreted in place. All reinforcing above 2.4 m (8 ft) was placed using the boom lift.

By specification, the shotcrete required silica fume for the inside 50 mm (2 in.). The outer shotcrete was required to be standard shotcrete with a compressive strength of 35 MPa (5000 psi) at 28 days by design. The original specifications required only 28 MPa (4000 psi) at 28 days, but it was decided to use our normal 35 MPa (5000 psi) mix and add economy to the structure.

The shotcrete mix designs were as follows

Standard mix – 35 MPa (5000 psi) design

Material	Proportions	
	lbs/yd^3	kg/m^3
Cement	652	387
Fly ash	100	59
Sand	1991	1181
3/8 in. Agg. (10 mm)	687	408
Water	300	178
Air	10%	10%
Kelcrete	3 oz.	89 ml.

Compressive strength from test panels shot at site – 7-day average: 32.8 and 33.0 MPa (4780 and 4750 psi); 28-day average: 43.7 and 45.8 MPa (6340 and 6640 psi).

Figure 4: Installing the exterior ladder.

Figure 5: Shooting the first layer over the form.

Silica fume mix

Material	Proportions	
	lbs/cu. yd	kg/m³
Cement	752	446
Silica Fume	56	33
Sand	2048	1215
3/8 in. Agg. (10 mm)	630	374
Water	300	178
Water reducer (Polyheed 997)	24 oz.	710

Compressive strength from test panels shot at site – 7-day average: 45.8 MPa (6640 psi); 16-day average: 48.4 MPa (7020 psi).

The silica fume mix was also tested for Chloride permeability to ASTM C 1202-94 "Standard Test Method of Concrete's Ability to Resist Chloride Ion Permeability." The specimens at the time of testing were 35 days old, and their average compressive strengths were 40.8 and 46.2 MPa (5910 and 6695 psi). After 6 h, an average total amount of 1155 Coulombs had gone through the sample, yielding a rating of "low permeability" to this concrete.

These tests were required according to the specifications, but no acceptance criteria were established. The results are included in this publication for the information of the readers. The results indicate that the silica fume shotcrete is a good barrier for chloride ions.

The dome was built in Colorado in November, December 1999 and January 2000. The requirement for a second layer of different (silica fume) shotcrete made curing a construction problem. The outside temperature was almost always below freezing so the incoming air was completely dry. Where another layer of shotcrete had to be shot, a membrane-curing compound could not be applied. Water was used to wet down the surface of the shotcrete with a pressure washer each morning and evening. The test samples were kept inside the dome for the 7-day curing time to simulate the conditions of the material on the wall. This procedure confirmed that the design strength was met and exceeded. Also because of the low temperatures, the concrete seemed to cure at a slower rate. The structural shotcrete showed no cracking. The first thin layer 25 to 38 mm (1 to 1.5 in.) of shotcrete cracked, but this was probably due to the flexible form movement. In the future, fibers might be appropriate for mitigating cracking in the first thin layer of shotcrete.

After all interior shotcrete was placed and the 7-day curing time elapsed, the air pressure was slowly removed over a period of 1 day. The openings were cut and a ladder was added to the outside for access to the ventilating fan.

Warren Harrison is President of WLH Construction Company. WLH is a shotcrete and concrete repair company located in Littleton, Colorado. Warren is a member of ACI Committee 506, Shotcreting, and a charter member of ASA. He holds an Engineer of Mines degree from the Colorado School of Mines and an MBA from the University of Colorado.