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# Shaping up at Seattle

Lane Roberts, Dome Technology, USA, considers the advantages of concrete domes and highlights these with a case study at Ash Grove.

## Introduction

Thin-shell reinforced concrete domes are being considered more and more for the storage of bulk materials at ports and inland locations worldwide. Cement is now being contained in domes in Korea and Aqaba Jordan as well as in many locations in the United States. Clinker, fly ash, gypsum and limestone are ideal products which are now stored in thin-shell reinforced concrete domes.

## Bulk storage domes

Concrete domes act as a suitable structure for most bulk storage requirements. The most common structural shapes are either vertical silos or horizontal 'flat storage'. The versatility of concrete dome construction allows a shape that will meet the intended storage requirements.

The insulated concrete dome has several advantages over other types of cement storage facilities. One of the greatest advantages of building a dome structure is the speed and efficiency of the construction process, which, in turn, reduces labour costs, generally below other type of construction. Unlike silos, the dome can be constructed in almost any type of inclement weather as the construction takes place mainly inside the protected environment of the air form.

Many port locations have poor or unstable soil conditions. The dome's foundation needs are generally simple compared to those of silos. Using a

spread footing often eliminates or reduces the number of pilings needed to support the structure. The dome is forgiving with the soil's differential settlement. The ringbeam or tension ring supports the dome at its base whilst the dome's three dimensional curve gives it strength.

The superior qualities of concrete domes are evident in any setting where it is important to control temperature, humidity and air exchange. The dome's single ply roof membrane and polyurethane insulation envelope assure water tightness and virtually eliminate condensation. The insulation also prevents temperature cycling which can cause product degradation.

The dome's inherent strength allows heavy loads to be placed on the dome's apex without internal supports. A dome storage facility recently completed in Canada has conveyor and head house loads resting on its apex weighing almost 1 million lbs. The dome requires no internal supports. Its shape and high internal volume utilisation mean that conveyors can be shorter than those used with more conventional structures. Thin-shell concrete dome structures resist the forces of hurricanes and tornadoes better than conventional type buildings according to studies by Dr. Arnold Wilson. These studies show that the unique design of the dome is superior to other structural designs against the force of an earthquake and that in a realistic situation will probably be

standing when all conventional structures had failed.

As a dome is typically filled by conveying material to the top of the dome and dropping it through one or more fill openings, the product can be piled high against the dome walls. This means that a higher percentage of the dome's volume is utilised than is the case with flat structures, resulting in a correspondingly lower cost per t of storage.

## Case Study: Ash Grove's Seattle plant

Ash Grove Cement Company has elected to use the concrete dome to store increased production of cement at their plant in Seattle, Washington. The dome is a 145 ft dia. half sphere built on a 20 ft vertical cylinder wall. The concrete dome and cylinder wall are monolithic as shown in Figure 1.

The dome was selected as an alternative to conventional silos, which exert very high bearing pressures, usually warranting deep foundations. By selecting the dome, considerable cost and time savings were realised. AGI Technologies, Washington, was selected to carry out the soil testing and make recommendations on how the reclaim tunnel and dome were to be supported. A subsurface investigation was conducted which, along with existing subsurface data for the plant, was used to characterise the 175 ft thick, soft alluvial sediments beneath the site. Extensive laboratory analysis

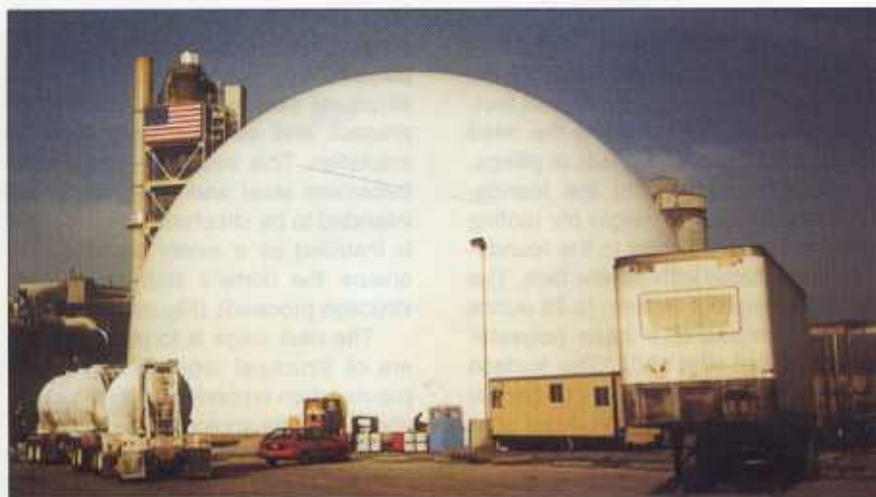


Figure 1 (left). Inflated air form. Figure 2 (right). Attaching air form to the foundation.



Figure 3. Inflating air form.

was performed at AGI's in-house laboratory, including triaxial and direct shear, consolidation, and indexing tests. The results of these tests, combined with settlement data for existing structures at the plant, were used to characterise the physical properties of the native soil deposits. The geotechnical engineering study identified several foundation alternatives, which included ground improvement, deep foundations, and a combined deep/mat foundation. The stone column was identified as the most appropriate ground improvement technology for the foundation. Nominal 42 in. dia. stone columns on 9 ft centres were designed to a depth of 34 ft below the dome floor. This concept improved foundations conditions by densification of the native sediments and provides liquefaction mitigation in the treated area by creating a drainage path for excess pore-water pressures that develop during a seismic event. High magnesium crushed limestone was used as both stone column fill and structural fill for backfilling around the bunker and tunnel.

Once the site was prepared, Dome Technology's crews began construction of the reclaim tunnel, egress tunnel, a centre bunker to support the Cambelt mechanical screw reclaim system, and the outer bunkers. The centre bunker required 146 yd<sup>3</sup> of concrete with walls 3 ft thick to support the mechanical screw to be placed on it. A large tunnel used for egress was sized to be able to easily install and maintain the pneumatic conveyors under the dome. The tunnel was built by using an air form. First, a concrete pad with 3 ft side walls was built. Then an air inflated form was attached to the side walls and inflated creating the form and framework for the tunnel. Steel rebar was ribbed around the air form and shotcrete sprayed onto it in lifts

embedding the steel rebar. As the tunnel is rounded on the top, less concrete is required to obtain the same strength as a cast in place flat roofed tunnel. The curve of the tunnel has a 5 ft radius on a 3 ft wall. The tunnel's inside dimensions are 10 ft wide and 8 ft high. The reclaim tunnel which houses Modco's pneumatic conveying system is a 15-gauge steel culvert. A formed, cast in place, round bunker is placed on the end of the reclaim tunnel with an escape ladder inside the bunker. A steel support tower will be built on the bunker to support pneumatic conveyors. When backfilling around the tunnel was completed, construction of the foundation began (Figure 2).

The ringbeam's width and depth was determined by the soils' analysis provided by AGI Technologies and the dome's structural engineering firm, SCA Engineering, located in Houston, Texas. Continuous reinforcing bars are also inserted vertically and made part of the steel grid work in the foundation. Vertical 'dowels' placed in the foundation will act to connect the dome securely to its footing. Concrete domes have the ability to maintain their structural unity even though there may be differential settlement.

In many other cases where soil conditions are poor, because of the dome's inherent strength, spread footings are utilised eliminating the need for massive foundation pads or pilings.

Upon completion of the foundation, the air form (a single ply roofing material) was attached to the foundation and inflated with inflator fans. The heavy waterproof air form (a 28 ounce fabric) is made of a base polyester fabric coated with PVC. The surface coating of the air form has exceptional resistance to degradation from ultra violet rays, colour changes, becoming chalky, erosion, dirt or mildew. The air form stays permanently in place after



Figure 4. Spraying polyurethane foam.



Figure 5. Spraying shotcrete embedding rebar.

the dome is constructed as an outside protective cover (Figure 3).

Once the air form was inflated, polyurethane foam was sprayed to the interior of the air form. The urethane foam stiffens the air form providing a secure surface to which a pre-mat of reinforcement steel is affixed. Next, a layer of shotcrete is applied embedding the reinforcement. The polyurethane foam acts both as a structural element of the construction process and as an exterior layer of insulation. This initial pre-mat of reinforcement steel and shotcrete is not intended to be structural in nature, but is installed as a safety precaution to ensure the dome's stability as construction proceeds (Figure 4).

The next stage is to place the layers of structural rebar (hung) to the pre-mat then embedded with structural shotcrete. The shotcrete is engineered to reach a strength of 280 kg/cm<sup>2</sup> (4000 psi) in 28 days. The reinforcement steel is grade 60 deformed steel

bars ranging from 6 - 40 mm (1/4 - 1 1/2 inches) in diameter (Figure 5).

When the dome shell is completed, Dome Technology will add a large concrete entry to the dome. The entry will have a large 14 ft high x 14 ft wide steel hydraulic bulkhead door to retain the cement inside the dome. The door was designed and constructed by Dome Technology. Upon completion of the entry, slab floor and concrete curbs placed on the dome's apex to support the head house and dust collector, the mechanical screw reclaim system manufactured by Cambelt International will be installed.

Retrieval of the cement is achieved using a combination of gravity discharge and mechanical reclaim. The Cambelt mechanical screw is designed to be buried fully by the cement allowing the dome to be filled almost to total capacity. The mechanical screw is designed to reclaim the cement weighing 85 pcf at a rate of 200 tph. During the reclaim operations, the stored cement gravity discharges without the use of the reclaim screw until the cement approaches its angle of repose. At this point, the mechanical screw begins to draw the cement to the centre discharge opening in the floor of the dome to a

Modco E5 100 hp pneumatic conveyor pump. The pump conveyor uses a Modco two stage, 200 hp compressed air system for the pneumatic conveyor. The cement is transferred at a rate of 120 tph from underneath the dome to truck and rail load out facilities.

Cambelt, together with Trimax Systems Incorporated, is providing Ash Grove Cement with a fully automated central control system. An Allen Bradley PLC will be used to control the Cambelt reclaimer. The PLC is interfaced with an IBM compatible PC, using 'Wonderware In-Touch' graphical man/machine interface software, to provide an easy to operate graphic control system. Other features such as alarm logging, event logging, and security protection are included.

The cement is loaded into the dome by two Fuller Kinyon pumps from two mills, each rated at 50 tph. The Fuller Kinyon pumps are powered by C300 compressors. Electrical engineering for this project is provided by Custom Controls; mechanical engineering provided by Chenathon Engineers and the control system by Vice Net. This Ash Grove plant was built in 1991 and is an FLS automation system. The plant currently pro-

duces 750 000 tpy cement.

Ash Grove Cement's plant in Durkee, Oregon, is undergoing a plant expansion. Dome Technology will be constructing a 45 000 t storage dome for cement beginning this month. This cement storage facility will be a duplicate of the dome at the Seattle plant. Cambelt is providing the reclaim system once again. Dome Technology is providing a turnkey storage facility including excavation and backfill, and installing the mechanical reclaimer.

## Conclusion

The demand for the dome as a preferred storage medium continues to grow throughout the world. Dome Technology begins the construction of the world's largest clinker storage dome located in the United Arab Emirates. The dome will store more than 115 000 t of clinker. The company currently has projects underway in Argentina, Latvia, Mexico, Canada and the United States, and has built more than 300 domes worldwide. It continues to lead the concrete dome industry in innovative ideas and new technology relating to this industry.

Enquiry no: 16

# Why A Dome?

## Strong

Withstands the forces of nature - hurricanes, earth quakes, tornadoes.

## Insulated

Insulated to minimize condensation.

## Cost Efficient

Rapid construction and inexpensive foundation requirements.

## Low Maintenance

Snow and water infect with little stress on the dome. Leaks are rare.

## Environmentally Friendly

Safer containment of dust and hazardous materials.

## Efficient Use Of Space

Superior strength allows materials to be piled higher along the walls, minimizing floor space required.



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