Bulk Storage (10,000+ tons) of Fly Ash, FGD Gypsum, Limestone and Coal at Power Stations in Concrete Domes

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ABSTRACT

This paper will focus on the benefits of storing various bulk storage materials such as coal, fly ash, FGD gypsum and limestone in concrete domes at power plants and ports. We will discuss the basic construction of domes at sites both domestic (USA) and overseas and present several successful storage projects at power plants and port sites. We will also illustrate state-of-the-art potential solutions for storing coal in capacities of over 500,000 metric tonnes. Several benefits of dome storage will be addressed as well as various mechanical and pneumatic reclaim systems including mechanical screws, stacker-reclaimers and fluidized floors.


INTRODUCTION:

Domtec International specializes in building insulated, reinforced concrete domes to the cement, mining, power and fertilizer industries for clients who want the most efficient storage option for dry bulk commodities. Domtec domes can provide the benefits of both flat storage or silo structures, or anywhere in between, at up to 50% savings in building costs while also offering the safest and most environmentally sound structures available; structures that meet or exceed the most stringent of codes including seismic requirements. Our structures will last the life of the plant protecting the materials stored therein, including against product degradation. Several methods for reclaiming the stored materials are available to choose from. For more information visit www.DOMTEC.com or view some videos of dome construction at www.vimeo.com/domtec

DESIGN/BUILD – IMPORTANCE OF CHOOSING THE RIGHT PARTNER FROM THE BEGINNING

In 2014 the largest cement manufacturer in the world set out to find the best design/build team for the storage of 60,000mt of cement in two projects in New Zealand. Their criteria were simple: they wanted to find a competent contractor with, 1.) a culture of safety, 2.) commitment to quality control, 3.) independent engineering, 4.) company culture and philosophy compatible with their own and 5.) competitive pricing. After a thorough, worldwide search, the owner selected a local general contractor and Domtec International (Domtec) as the best-for-project dome builder. Although price was a factor and Domtec was not the low-cost option, the contractor later commented that “clearly Domtec was the best choice.”

This “Early Contractor Involvement” (ECI) process allowed the owner to choose the team during the conceptual phase of the project and yielded speed to market for the project along with several value-engineering options that saved additional time and budget.

While some owners believe that “a rose is a rose is a rose” or in our industry, “a dome is a dome is a dome” using a matrix besides just price to choose your contractor yields added dividends of a long-term
relationship with a company whose values and philosophies are aligned with yours (safety, quality control and an eye for value engineering for example). The ECI approach is highly recommended to save time, money and improve quality of the project.

DOMESTIC/FOREIGN CONSTRUCTION
As a world-class international contractor, we must be flexible in the items we provide in foreign markets. Within North America, and especially the USA, it is much easier to provide a turn-key project using our own labor, materials and equipment. In foreign markets local laws and logistics limit the crew size and specialty labor as well as the equipment and material that it makes sense for us to supply. The model we’ve consistently found to be successful for building Domtec domes in foreign markets is to partner with a local contractor who will provide general labor, most of the construction equipment required, and materials such as concrete and rebar. The local partner is typically a local or regional contractor with a good reputation, usually known by the client. This symbiotic relationship allows more money to be spent in the local economy and provides good will to the community at large.

CONSTRUCTION SEQUENCING
Construction begins with a solid foundation. Crews arrive on the site after the foundation is completed and begin stockpiling rebar within the circular foundation. Crews cover sharp objects and bend over vertical rebar dowels so the air form, an industrial grade inflatable membrane can be attached to the foundation. The various pieces of lift equipment needed for dome construction are masked and driven in under the air form.

Once the air form is attached, large blower fans are used to inflate and maintain positive pressure inside the air form. These blowers also continuously replenish the air inside the dome negating concerns for air quality. Crews then spray polyurethane foam to the air form’s inside surface and subsequently hang reinforcing steel (rebar), and then begin the shotcreting process. Specialty technicians spray consecutive layers of concrete until the dome reaches its engineered design thickness.

After the dome is complete, the fans are turned off, air form membrane covering the doorway is cut out allowing for equipment to be removed. The crews then work on the apex curbs or pads that will receive the penthouse. This process all takes about four months, give or take, depending on the dome’s size/capacity, the product density and dome’s geometry.

BULK STORAGE OPTIONS IN POWER INDUSTRY:
Domes are often selected by clients for their ability to store large quantities of bulk materials on a relatively small space and for an economical cost. Due to the double curvature, domes are inherently stronger, therefore requiring fewer materials for their construction. Compared to any other type of structure designed to handle the pressures associated with stacking materials against the walls, domes are able to store the greatest volume of product for the least amount of surface area. These two main reasons: capacity and cost, are the inherent benefits of a dome:

- Domes have a lower center of gravity than silos
- Domes are monolithic reinforced concrete shells, without so many connection points as exist in typical flat storage buildings. Domes are therefore better able to resist
  - earthquakes,
  - high winds,
  - flying debris and
  - man-made disasters, such as over-filling, ...
  - front-end loaders banging and scraping and...
asymmetrical loading pressures against the walls.

- The monolithic nature of the building can allow domes to settle several inches, saving money on foundation costs. Depending on soil conditions, a spread footing may be the only foundation needed. In other cases, soil improvement can be used saving tens of thousands and in some cases, millions of dollars.
- Domes are waterproof due to the outer air form membrane this waterproofing saves the dome from
  - Salt corrosion from ocean air
  - Water seeping into the concrete and spoiling the contents
  - Freeze/thaw cycles
- Domes are insulated so interior temperature fluctuates minimally
- The dome or arch allows for heavy loading (hundreds of thousands of pounds as the case may be) on the apex, typically eliminating additional conveyor support bents and any interior columns

RECLAIM OPTIONS
- For fly ash, the best reclaim method is by aerated floor. Going back to the benefit of asymmetrical loading, fly ash is powdery and will flow like water when air is introduced at the toe of the pile. A small opening in the side of a dome with an interior sloped floor leading to that opening will allow an aerated floor to move product to the opening, avoiding the cost of subfloor reclaim tunnels. This is especially helpful in areas where there is a high-water table. SiloDomes™ are used to limit the area of the floor and costs associated with providing engineered fill for a sloped floor.
- Mechanical screw reclaim systems are also an option if the client wishes to have a flat floor on which a loader can drive, or if in the future the dome will be used for another product. Screws can move a variety of products from powder to granular.
- Hybrid. There are also hybrid options for powdery bulk product.

Some of the following case studies have appeared in past presentations but are used here for illustrative purposes.

CASE STUDY 1: HOLCIM FLY ASH
The first project Domtec took on was a 40,000MT storage dome for fly ash, in Germany in 1995. The fly ash was stored in Holcim’s cement plant for use as a raw material for making clinker/cement. The dome is 193’ in diameter and 101.5’ tall. The dome geometry was based on a Cambelt Automated Reclaim System. The reclaimer is a large mechanical screw that bears on the base of a rotating cylindrical steel column. Around the base of the column is an aerated reclaim hopper and flow control gates designed to meter product into the conveying system in a reclaim tunnel under the floor.
The aerated hopper reclaims product until it reaches its natural draw down angle of discharge. At this point, the reclaim screw is lowered to the pile surface and begins cutting into the pile, while rotating 360 degrees, drawing product into the center hopper. With each revolution or pass the screw lowers a little more, to pull another layer of product into the center feeder until eventually the screw reaches a horizontal position. Gravity helps in the reclaim process until the screw approaches horizontal at which point the screw is doing all the reclaim work. To summarize, the Cambelt reclaim system can withdraw nearly all the product in the dome through a single feeder at the center. This dome and reclaim system have been operating since 1996.

CASE STUDY 2: ARPA COAL
In 2007 Arkansas River Power Authority (ARPA) contracted to have two 6,000-ton coal storage domes built in Colorado for a new 18MW steam turbine. At that time the price of natural gas had risen to a point that it made economic sense for the plant to switch from gas to coal. Domes were selected to keep the plant clean, keeping the coal pile enclosed to avoid fugitive dust. The reclaim systems purchased were under-pile screws, one for each dome. However even before the machines were fully commissioned and operational, the price of natural gas dropped sufficiently that the plant switched back to gas as its preferred fuel source. (Peltier, 2008)

CASE STUDY 3: SEFA FLY ASH
The SEFA Group was chosen as the benefaction solution for GenOn’s Morgantown facility in Maryland. Using their STAR technology, they process upwards of 350,000 tons of fly ash per year for the local ready-mix concrete industry. To accommodate the continual supply of fly ash from the power plant and
Due to limited space on the site, a SiloDome™ was chosen as the preferred dome geometry. The dome is 120’ diameter and 127’ tall (a hemisphere integrated onto a 67’ tall cylinder). Concerns for settlement and a high-water table were challenges for this site. These concerns were allayed by hiring Hayward Baker to improve the site’s soils, increasing the soils bearing capacity and resulting in a predictable and acceptable amount of settlement. The dome then was outfitted with a DCL aerated floor with a discharge out one side thus avoiding any subgrade reclaim tunnel, with only an exterior pit for pneumatic pumping equipment.

CASE STUDY 4: FGD GYPSUM AND LIMESTONE STORAGE

At the Raven Power Plant (formerly Constellation Energy) on the outskirts of Baltimore, Maryland, a 216’ diameter by 106’ tall dome was built to store 10,000 tons of FGD gypsum with a stacker/reclaimer system that stacks the gypsum in a circular pile, and then reclaims it into an above-grade conveyor.

A smaller 142’ diameter by 48’ tall storage dome for storing 8,000 tons of limestone was also constructed at the same plant. The limestone is conveyed to the dome’s apex and discharged into a
stacking tube inside the dome. The stacking tube helps reduce dust, making it easier for front end loader operators to see as they reclaim the limestone by pushing it to a Stamler-type feeder which passes through the side of the dome’s wall.

CASE STUDY 5: PETROLEUM COKE STORAGE: STORY OF THE THREE DOMES
In 2013 Domtec was contracted to build a “replacement” dome on top of a 24’ stem wall in Louisiana.

Originally, a metal dome cover was built on the site but after several years, corrosion and hurricane-force winds the metal dome had to be decommissioned and a wooden dome was built in its place. Sometime after the wooden dome was in operation it was struck by lightning and caught fire resulting in a total loss. Domtec won the contract to build a reinforced concrete dome in place of the two previous domes. No amount of “huffing and puffing” or corrosion, or lightning will bring this dome down.

CASE STUDY 6: STORAGE OF COAL 500,000 METRIC TONNES
As environmental regulations become more stringent, a growing contingent of governments and municipalities are requiring that all coal storage must be covered. To that end, Domtec has been designing several solutions that will allow coal to be stored safely, economically, environmentally friendly, in a reduced footprint in extremely large tonnages (over 200,000 tonnes)
For coal, the best reclaim solution is a stacker/reclaimer with product stored against the walls. This allows for a smaller footprint than a large metal dome cover, and still has all the benefits of first-in, first-out reclaim, monitoring the pile for off-gassing and temperature rises as well as fire prevention. Piles can be loaded in 270- or 360-degree shapes. These domes tend to be hemispheres with little to no vertical wall.

**Concept #1: Domes with Stacker/Reclaimers**

Domes have been built with stacker/reclaimers in the past and the concept would be to build several large (90-120m or 295'–394’ in diameter) concrete domes that store product against the wall and have the product monitored and reclaimed via a large stacker/reclaimer machine in each dome.

Coal can be segregated from differing suppliers into each dome, coal can easily be blended from separate suppliers, there is built in redundancy with multiple machines and the footprint is significantly reduced.

**Concept #2: DomeSilos™ with or without Rotary Plows**

Another alternative for reclaiming coal is a “live floor” with multiple sub-floor tunnels and above-floor wedges in between the tunnels forming giant hoppers. This arrangement allows coal to free flow into the reclaim tunnels. These domes tend to look like large diameter silos with dome tops, SiloDomes™. The concept or objective for this geometry being a reduced number and length of subfloor reclaim tunnels and a less extensive matrix of wedges. The domes can be built in rows to meet the required tonnage.

While the relatively tall DomeSilos™ enhance the percentage of live gravity reclaim, because the coal is stacked higher against the walls, the stress loads to the walls are also higher. This requires additional rebar, concrete and time to build. Even so, the smaller diameter footprint and higher percentage of live gravity reclaim, along with the savings in costs for floors, tunnels and equipment outweigh the added material and time to construct.
Rotary plows can also be installed in tunnels beneath the domes. Rotary plows travel back and forth along a length of the reclaim tunnel. These plows achieve a higher percentage of live reclaim compared to a row of basic draw down hoppers. A sloped floor is constructed between the tunnels, and between the tunnel and the edge of the dome so coal will slide at its natural draw down angle into the rotary plows’ reach.

When several domes are arranged in a row with the reclaim tunnels all aligned under the entire row of domes, the same rotary plows can be used under multiple domes, thus spreading the cost of the reclaim system.

Under this concept coal is reclaimed, to a large degree, first-in, first-out (FIFO); essentially providing 100% gravity reclaim with no moving parts inside the dome. A person would rarely, if ever, need to go inside the dome. And rotary plows can easily provide all the tonnage per hour needed to supply a large power plant.

**Concept #3: LongDomes™**

LongDomes™ are longitudinal concrete flat storage buildings with a dome on each end that house a portal reclaimer like other flat-storage warehouse buildings. The building methodology is similar to other domes in that a large air form is inflated, then polyurethane foam is applied, then rebar and concrete. In theory, they can be built as long as needed to meet the required storage capacity.
Like traditional round domes, LongDomes™ are also disaster resistant, weatherproof, corrosion and fire resistant and can easily support a tripper conveyor on the interior apex. They will last for decades with little maintenance.

**Concept Conclusion:**
Each of these concepts is being developed with help from various material handling specialty companies such as Bedeschi-Midwest Conveyor, Aumund and others. To date it appears that of the above concepts the most economical overall system (ship unloader, conveyor to fill the dome, dome structures, reclaim system, conveyor to crusher) is Concept #2 DomeSilos™ with subfloor rotary plows; however, the stacker/reclaimer is still a viable solution when physically accessing the pile and blending are factors.

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<th>Description</th>
<th>Concept 1: SiloDome™ Circular Stacker/Reclaimer</th>
<th>Concept 2: SiloDome™ with Rotary Plows</th>
<th>Concept 3: LongDomes™ with Portal Reclaimer</th>
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**CONCLUSION**
Concrete domes are already a preferred storage method for large capacity bulk storage in many industries when storing large quantities of products (5,000 tonnes+ to 100,000MT+ in each dome) Domes have successfully been built in the power, concrete, mining, agricultural, fertilizer and other specialized industries. Concrete domes are now proving to be an economical and environmentally friendly storage solution for storing dry bulk materials in the coal fired power industry where large bulk storage is needed.