Deeper Understanding

Innovative Foundation and Tunnel Options

DOME TECHNOLOGY®

Introduction

Building bulk storage on a solid foundation is one of the primary steps to a successful project, and each site will possess different characteristics that impact and possibly limit which types of foundations will work. Additional considerations during the planning stages of a project are the type of reclaim and, subsequently, the tunnels necessary for processing the bulk storage. When customers choose the best tunnel system based on anticipated need, the storage facility should function better in the long term. Versatile options and innovative approaches offer economical solutions for both foundations and tunnels.

Foundations first: Conditions of the site

The qualities of the selected site dictate the type of foundation system necessary for a building's stability and structural integrity. A foundation system should be selected based on the amount of tolerable settlement and soil strength. Flat storage and silos can tolerate varying degrees of settlement, depending on site conditions. A dome can easily withstand 12 inches of settlement, and that's what allows a dome to be built on a variety of foundation systems, some of them millions less than traditional pile systems.

Domes tolerate more settlement because of their double curvature and because of their concrete construction.

Displayed on the previous page are four wood-pellet storage domes in various stages of completion. Atop this page is an image of the ringbeam foundation and three reclaim tunnels of a clinker storage dome under construction. The strength of the dome allows for various tunnel configurations that can be designed to meet the needs of diverse products and reclaim requirements.

A Geopier® foundation system is being constructed at a clinker storage dome in Romania. These foundations are among the variety of options available due to the resilience provided by the dome's form and structural composition.

The geometry and continuous shell have tremendous capacity to arch up, down, and around the circumference of the structure, providing greater stiffness and stability. Also, a dome can maximize its diameter-to-height ratio to deliver optimal storage capacity and minimize needed soil improvements.

When a structure surpasses its settlement tolerance, structural issues become apparent—beams and columns don't meet up anymore, walls separate from the roof, concrete in the foundation breaks, or the building rotates. The structure no longer functions as it should because the geometry changes. However, a dome, which might be 100 feet in diameter and 100 feet tall, can experience small movements at the foundation; these movements can be translated to the dome so that mechanical systems and the dome structure itself can continue to function properly.

Dome customers have multiple foundation options; the most common are listed here:

1. For sites with preferable or acceptable soil conditions, a ringbeam provides a shallow foundation alternative. Where applicable, the frost depth will determine the ringbeam's depth, but usually the ringbeam is placed two to four feet in the ground.

2. For sites where the top six to eight feet of ground is of questionable material, crews excavate the material, replacing it with controlled structural fill. This model allows for some settlement, but the amount will be within tolerable parameters for a dome.

3. When the top 15 to 50 feet of soil is questionable, stone columns are a workable option. First, crews use an auger to remove earth in about a 30-inch diameter hole until a more stable, soil-bearing layer is reached. Rock then fills the hole and is compacted, even laterally so the soil around it is supportive.

For areas where deeper foundations are required, other systems are available:

1. In a piled-raft system, steel or precast concrete piles are driven into the ground. A layer of crushed rock three feet thick is layered on top, along with a fabric geogrid, which stiffens the rock mat and adequately

strengthens the soil for the structure to be built on top.

2. Piles are driven and are topped with a heavily reinforced concrete pad three to four feet thick; in this model, the system is designed to bear on those piles, so the structure is essentially supported by stilts although built at ground level.

3. Soil mixing is an option when soil is questionable for as much as 30 feet of depth. An auger is used to mix the soil with cement and lime; the mixture is then compacted. For similar soil conditions, stone columns often cost less and can be installed faster.

4. In sites with high water tables, a six-inch-wide piece of plastic called a wick drain provides a way for water to escape in areas of low permeability. A wick drain is driven vertically into the ground to the desired depth, and water flows to this strip, which acts as a channel that helps remove excess water. Consolidation of this soil can be expected within about three months with a surcharge loading.

5. Dynamic compaction requires the use of a crane; a heavy weight is lifted and dropped repeatedly to densify soil.

Each of these methods requires different installation times and associated costs. Based on soil conditions, Dome Technology's team can identify early on the solutions most likely to work for a project. For a dome that doesn't require deep foundations, customers can expect to save—often millions.

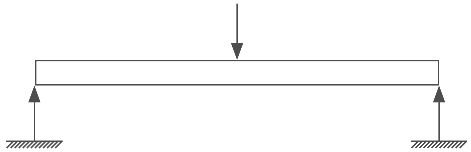
Tunnels: Construction for optimal strength

Tunnels, usually in ground, provide avenues for customers to reclaim product and analyze operations. But rather than utilizing rectangular tunnels, Dome Technology's team of engineers has pioneered a different approach, one that saves customers money and provides substantial strength to tunnel systems, adequate for bearing the stored-material's weight.

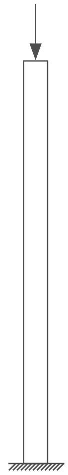
Rectangular tunnels have been chosen historically because of their ease in engineering and building; receiving competitive bids from concrete companies is straightfor-

Completed tunnel structures shown here are surrounded by the dome's ringbeam still under construction. Flexible tunnel configurations make the dome well suited for diverse material and reclaim requirements.

ward with this model. But thousands of tons of product will cause flexural stresses to a flat roof topping the tunnel. To satisfy this flexural demand, the requirement is thicker slabs, more reinforcing, and increased costs.



As a response, engineers have designed a model that takes the stacked material's force away from a flexural response and into an axial response, putting the force in the plane of the member. They've achieved this with arched tunnels that allow the majority of pressure on the tunnel to be transferred into axial loads.



To understand transferring force from a flexural response into an axial load, imagine two 2x4s; one is spanning eight feet with supports on either end, and the other is standing vertically. Both boards are then loaded with weight. The vertical 2X4 can support approximately four times the weight the horizontal, spanning board can support without sagging and ultimately snapping. This is much the same way an arched tunnel transfers loads from what would be a spanning scenario into an axial-loaded scenario; the load is transferred down the arch and into its sides, allowing it to support much more weight before being compromised. It is possible for a rectangular tunnel to support the same amount of weight as an arched tunnel; however, the materials in arched tunnels typically cost 30 percent less.

Dome Technology's team of engineers designed a system

Utilizing precast sections, like those shown here, to form tunnels helps accelerate construction.

utilizing a poured-in-place concrete foundation combined with a precast concrete arched tunnel. The foundation is interlocked with the precast arched tunnel through a patented locking system that provides a way for the tunnel to be leveled. The process also generates a decrease in both schedule time and risk in construction.

Not only are arched tunnels able to withstand heavy loads, but their construction saves customers on the cost of materials. Also, since tunnels are built with precast sections inventoried on site, their installation can be done quickly—once the earth is excavated and the foundation is poured, tunnels can be placed. In areas where tropical storms and heavy rains are common, this model mitigates the risk of having holes left open for multiple weeks.

Customizing tunnel systems

The number of and features within tunnels are determined by the following considerations:

1. Desired reclaim rate: The Dome Technology team works with customers to determine how fast product needs to move, which is dictated by costs of shipping and loading. For example, if a ship charges $10,000 a day to stay at the port for filling, customers are driven to fill quickly and will need tunnels and reclaim systems that can deliver that speed.

2. Desired means of reclaim: The way product will be removed from the dome will inform the selected tunnel system. Designers work closely with customers to design a system complementing the reclaim method.

3. Product specifics and accommodations: Agricultural products require food-safe conditions and finishes. Combustible materials must be monitored while in the dome and in transit; sensors in the tunnel analyze reclaim conditions as product moves. Necessary features are included in the dome's design to promote safety and quality assurance.

4. The necessity of "first in, first out": Systems can be designed to ensure that product is processed in the same order it enters the structure, a feature often requested for more volatile or combustible materials.

Working with a qualified team

Customers need not select the best foundation and tunnel system on their own. By working with a team of experienced engineers, economical and effective solutions can be selected. Companies interested in working out the details early in the project might consider the design-build approach, wherein an engineering team like that at Dome Technology designs not only the storage facility but also all the equipment and systems for moving product. This design takes place while a project is still in the discussion stages; engineers refine the numbers, thus helping customers determine the project's feasibility by providing a realistic preliminary bid based on hours of initial, detailed design.

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