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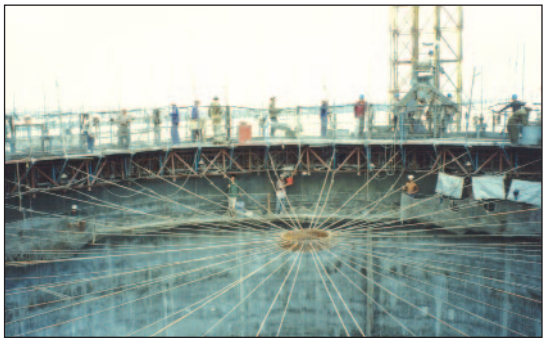
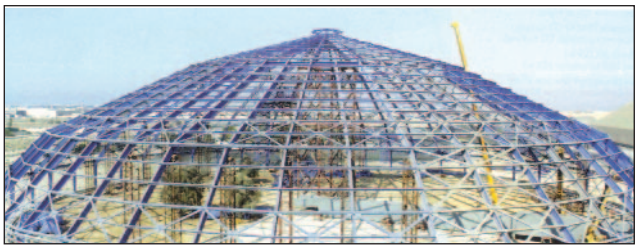
Storage System Comparison

Martin Wuerth, General Manager, Wuerth Consulting Engineers, Switzerland, looks at the different storage systems available, and compares their advantages and disadvantages.





Introduction

There is a large demand in the cement industry to store large amounts of bulk materials, such as cement and clinker. The following article provides an overview of the different storage systems available, as well as their advantages and disadvantages.

Basis for choosing a storage system

There are a few basic factors that determine what type of system is best suited to meet storage requirements in the most economical way.

- *Storage capacity*: What quantities will be stored.
- *Type of material*: What type of material will be stored.
- *On-site space*: How much space is available where the storage system will be built.
- *Soil conditions*: Soil conditions are a main factor that affects construction costs. On unstable soil, all the different storage systems require piles. On regular soil, piles are only necessary for silo structures. On rock, even large silos can be built without piles.
- *Exchange rates*: The exchange rate against the US dollar is the main factor that determines how much of the storage system can be imported (material, equipment and manpower) versus how much has to be manufactured locally. The weaker the local currency against the US dollar, the greater the reason for the system to be manufactured locally.

Other environmental factors, such as wind speed, snow, dust load and earthquake, do not usually influence a decision on which type of storage system is to be chosen.

This article describes the following storage systems:

- Flat stores.
- Silos (steel, reinforced concrete, prestressed concrete).
- Shotcrete domes.
- Steel/aluminium domes.
- Circular stores.

Flat stores

Flat stores consist of steel frames, purlins and metal sheets. This type of store is easy to design and build. However, they take up the most space and the cost for mechanical equipment to charge and discharge the material is very high compared to other solutions. Due to the missing 3-D effect, steel consumption is not optimised for large volumes.

Silos

Silos can be built with steel, reinforced concrete and prestressed concrete. For small capacities up to approximately 8000 m^3, steel silos are an economical solution. For larger capacities, up to approximately 12 000 m^3, reinforced concrete silos are usually cheaper than steel silos.

For silos over a capacity of approximately 15 000 m^3, post tensioning is necessary and if the silo is not based on rock, piles are required. The space requirement for silos is very low, but the construction costs for large silos (over 15 000 m^3) are very high, due to post tensioning, high grade concrete and slip formwork. The on-site contractor must have experience with building silos because of the use of slip formwork. For example, a silo with 40 000 m^3 capacity has approximately the same construction costs as a circular store with 80 000 m^3!

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Table 1. Comparison of storage systems					
	Flat storage	Silos	Shotcrete domes	Steel/aluminium domes	Circular stores
Space requirement	High	Low	Medium	High	Medium
Demand/difficulty for engineering	Low	Medium	Medium	High	High
Demand/difficulty for manufacturing	Low	High	High	High	Medium
Equipment costs for charge/discharge	High	Low	Medium	High	Medium
Construction costs for large capacities over 15 000 m^3	Medium	High	Medium	Medium	Low

Shotcrete domes

Shotcrete domes consists of a ring foundation and a hyperbolic shaped reinforced shotcrete cover. An inflated airform (exterior skin) gives the dome the optimal shape for the first layers of shotcrete. When the dome is finished, the structure is very strong. It can withstand wind speeds over 250 km/h and high loads on the roof, from a conveyor bridge and filter building.

The construction procedure is quite difficult for this kind of storage system. During the inflation of the airform (and applying the first few shotcrete layers) the structure is very susceptible to wind and snow.

Shotcrete consumption is quite high, due to application losses, and the material costs are higher than common concrete. Shotcrete domes must be built by specialists, and there are only a few such companies in the world. Factoring in the exchange rate (against the US dollar) these domes can be an expensive solution.

Steel/aluminium domes

Steel/aluminium domes are built with a steel or aluminium skeleton and covered with roof cladding. The side walls are made of steel or aluminium. The roof can be designed very economically with a hyperbolic or parabolic shape. The dome will require a lot of space, as steel walls cannot withstand horizontal loads from the bulk material. The bulk material is stored in a cone shape. The cost for the mechanical equipment, which loads and discharges the material is also high. The discharge tunnels below the dome have to be longer than those for a shotcrete dome or a circular store.

Aluminium domes are prefabricated single parts that must be imported and erected by specialists. Depending on the exchange rate (compared to the US dollar), this system may not always be the cheapest way to store large amounts of bulk materials.

Circular stores

Wuerth Consulting Engineers have developed a circular store system, consisting of a ring foundation, reinforced side walls and a hyperbolic shaped steel roof, covered with metal sheets. If required, the roof can be dust proof. The whole structure, foundation, wall and roof creates a 3-D effect. This makes the system very stable and allows it to carry heavy loads on the roof from the conveyor bridge and the filter building.

The system keeps construction costs very low, which are determined by the ratio between the diameter and the wall height. The ratio can be changed, but that also alters the construction costs per m^3. The space that the circular store needs is smaller than steel or aluminium domes because the reinforcement concrete walls can take the horizontal forces from the bulk material.

The main advantage of this circular store system is that it can be built with cheap construction materials including common concrete, reinforcement, segmental or climb formwork, structural steel with standard sections and roof cladding.

The whole system can be manufactured and erected by local contractors. This means that a circular store is an economical solution to store large quantities of bulk materials over 15 000 m^3, especially in countries with a weak currency.

Conclusion

The comparison of different storage systems is shown in Table 1.

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