How safe is your silo?

Every building, including the storage silo, has a lifespan, but these structures need regular maintenance and repair to extend this for as long as it is safe to do so. Wuerth Consulting discusses the management of a silo's service lifetime.

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All civil structures, whether a building, bridge or silo, have a specific lifespan. Storage silos, however, are three times more likely to collapse than bridges. There are two key reasons for this.

Firstly, while the live load of a bridge (or other civil structure) is around 50 per cent, silos have live loads of around 90 per cent – ie silos are pushed closer to their service limits than bridges.

Secondly, maintenance is different. Bridges and buildings are used by people, who often detect cracks in the structure while facility managers take care of private or public buildings. This is often not the case with silos.

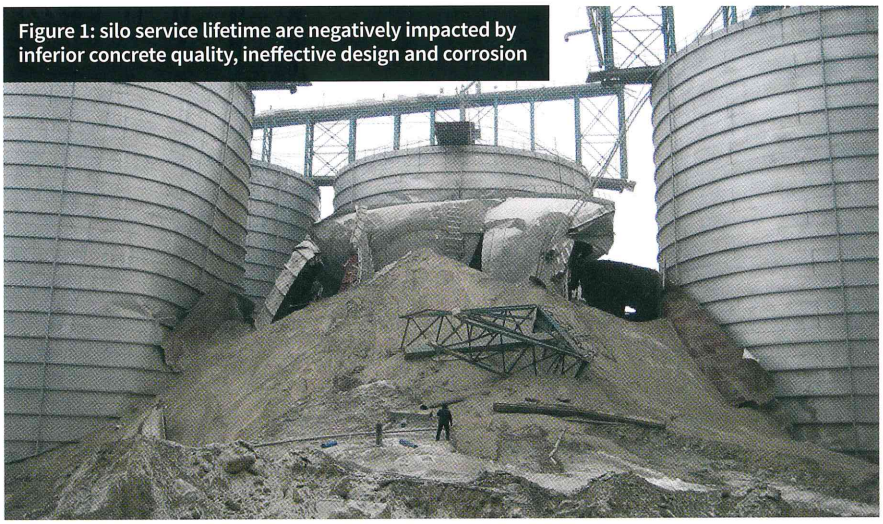


Figure 1: silo service lifetime are negatively impacted by inferior concrete quality, ineffective design and corrosion

Silo service lifetime

The service lifetime of a silo can be defined as the time during which the rebars and post positioning are able to hold back the bulk material within.

Service lifetimes are negatively affected by inferior concrete quality, ineffective design and corrosion (see Figure 1).

A well-made concrete layer over the rebar overlap ensures that the tension force in the rebars can be transferred from one to another as well as protecting the rebars from acid impacts from the environment.

The depth of carbonation in the concrete cover is an important indicator in calculating the remaining lifetime of the silo. Carbonation is the zone of concrete at the surface which has changed from a base to an acid. Air pollution, salt water and acid rain speed up this transformation. If the carbonation zone reaches the rebars, the steel corrodes until there is no iron left.

To determine the remaining service life of a silo, the structure needs to be examined. The outer surface of the silo much be checked for concrete quality, rebar corrosion, carbonation depth and concrete cover (see Figures 2-4), while the inner surface must be checked for abrasion.

Analysis of the design shows the safety factor of the structure (without erection and quality deviation or errors). Depending on the results of the investigation, the remaining service lifetime can be calculated.

Repair solutions

If the owner is not satisfied with the calculated remaining service life, the structure must be reinforced. To select the best repair strategy (see Figure 5), results from the design analysis, the concrete cover and carbonation depth are required.

If the design analysis shows unsatisfactory results, the rebars must be reinforced, possibly in combination with a concrete repair solution.

If the carbonation layer is smaller than the concrete cover, a soft or heavy solution can be achieved. However, if the carbonation layer is deeper than the concrete cover a repair solution is too expensive and a new silo must be built.

A new silo is required

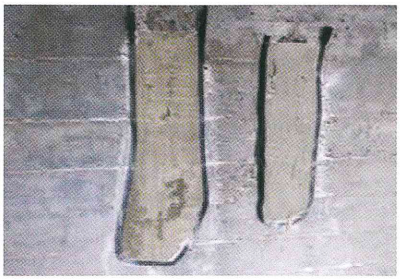
To work out an economic storage solution, several factors need to be taken into account:

Figure 2: check concrete quality

Figure 3: check concrete cover

Figure 4: check carbonation depth

Figure 5: types of silo repair



Soft repair
service lifetime: 10-15 years
civil costs: ~25 per cent

Heavy repair
service lifetime: 15-25 years
civil costs: ~50 per cent

New silo
service lifetime: >50 years
civil costs: 100 per cent

- the stored material
- the live capacity
- the local preconditions on the plant
- soil conditions (bearing capacity and settlement modulus)
- available space and settlement sensitive neighbouring buildings and equipment.

These different local conditions are the reason that there are no typical economic dimensions for different sizes, valid for all places.

Every single storage facility or silo must be adapted to the local conditions on the site, which is why silos and storage buildings are custom-made products.

Expensive construction is often due to one of these conditions. Lack of available space for the building, bad soil conditions and sensitive buildings nearby all drive expenditure up.

If there is little space available the entire heavy load of stored material plus the self-load of the building will be built on a small surface area with high pressures applied to the soil.

In this case, piles are often required because they translate the load from the soil surface to deeper soil formations with higher bearing capacities. However, the use of piles will increase building costs by 25-35 per cent.

Piles are also necessary where soil conditions are inferior. Their use helps to cut the settlement under a silo/storage building substantially.

Piles are also needed if the settlement curve is too large. The settlement curve under the silo/storage building adjusts after a few years, but the curve should not damage other buildings or equipment (columns for belt conveyor bridges are most susceptible to this effect).

Silos based on piles or rock can be designed with a small diameter and high sidewalls. Size and height has a positive effect on the horizontal loads from the bulk material. The higher the sidewalls, the smaller the horizontal bulk pressure (silo effect).

Silos and storage facilities with higher sidewalls than a certain proportion must be pre-stressed. Prestressed concrete structures have many advantages but the construction costs will rise again by approximately 25-35 per cent, especially in low-currency countries.

Another cost saving factor is the right choice of formwork for the storage. The best performance is obtained with slip formwork, but alternative climb formwork is cheaper and makes larger non pre-stressed silos possible.

Conclusion

A professional silo condition investigation provides a good return as it enables a company to plan capital expenditure and demonstrate to the public authority, staff and owner that the silo is well maintained.■

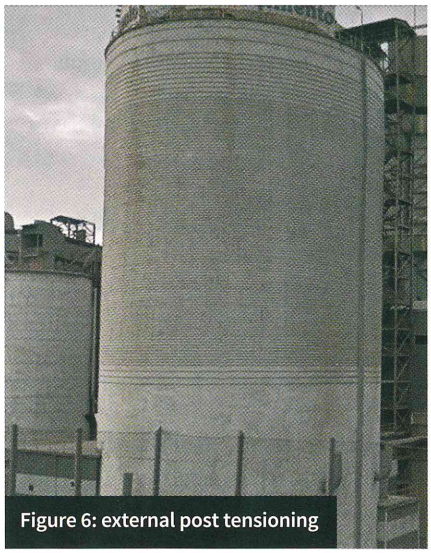


Figure 6: external post tensioning

Figure 7: vertical and horizontal steel reinforcements

Figure 8: types of silos and their applications

Steel silo
hot bulk materials or liquids, or small capacity

Concrete silo
different bulk materials or medium-sized capacity

Circular storage
bad soil conditions large capacity