Critical Nature of Wall Thickness/Diameter Ratio in Reinforced Concrete Silos

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Traditionally the design of the wall of a circular silo has been on the basis of a calculated pressure, assumed to be uniform in the horizontal plane at a given position, hence leading to a wall tension per unit height = $P. D/2$, as for a pressure vessel, where P = internal pressure and D = diameter.

Although those responsible for the design and operation of silos are aware that the pressure is not uniform, due to many reasons such as variable material properties, surges, assymmetrical outlets, etc., analytical work has still concentrated on assumed uniformity of pressure in the horizontal plane.

Even with the advances which have been made during the last twenty years, in the understanding of the mechanics of particulate solids, we seem to be still far from agreement on silo pressures and silo design. Perhaps it is for this reason that there appears to be a ground swell of opinion, judging by comments at conferences and meetings, that we should concentrate our minds more on a study of existing silos, both sound and damaged, to correlate the features of successful silos with a design method.

An interesting instance of this approach was given at a Conference in 1980 [1] when the results of an inventory of 103 reinforced concrete grain silos were presented. It was noted that for uncracked silos here was a marked correlation between the area of reinforcement (A) and the square of the diameter (D), i.e., $A \propto D^2$, whereas design on a uniform pressure basis would imply that $A \propto D$. It seems reasonable to assume that this difference is due to bending arising from uneven pressures.

It was also noted in the same paper that larger diameter bins were more likely to be cracked than those of smaller diameter.

It therefore seems that wall stiffness is of some importance in circular reinforced concrete silos and that larger silos tend to be inadequate in this respect.

If we consider a "normal" design approach for a circular silo, the pressure is first determined by whatever process the designer considers to be most reliable and appropriate, which then gives the reinforcement area.

Some designers, including the writer, reduce the reinforcement and concrete stresses for silo work, in a similar manner to the design of water retaining concrete structures, and for the same reason — to minimise cracking.

For slip-formed silos it is then convenient to divide the reinforcement area between inner and outer faces, each side of the jacking rods, giving a minimum concrete thickness of around 200 mm, allowing for adequate cover to the reinforcement.

As a consequence, one builds in a certain amount of wall stiffness and resistance to bending, even though designing nominally on pure tension in the reinforcement. However, for dimensionally similar silos, it is reasonable to assume that non-uniform distributed loading will follow the same pattern and that the resulting bending moments will increase as the square of the diameter; whereas the reinforcement will be increased only in proportion to the diameter. Hence this would lead to overstressing, if the wall thickness remains constant at the praticable minimum.

The survey quoted above gave correlation between performance and reinforcement area, but since some designers choose to increase the wall thickness and since this parameter is much easier to determine by outside observers of existing and possibly old silos, the writer suggests that it may be useful to have a co-operative program of correlating reinforced concrete silo performance, i.e., cracked, or uncracked with the ratio D/t, where t is the wall thickness.

To consider a few random examples, the writer's experience is that D/t = 35 is satisfactory (say D = 7 m, t = 200 mm)

J.E. Sadler [2] has given examples of failed silos, the ratio D/t being between 48 and 76.

D.R. Plum [3] has reported on a silo 9 m diameter, simply reinforced, where D/t = 52, which had cracked during 25 years service.

The writer would welcome comments on the possibility of such an investigation.

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References

[1] Wigram, S.: "Report on an Inventory of Swedish Grain Silos", International Conference on Design of Silos, University of Lancaster, U.K., 2—4th September, 1980.

[2] Sadler, I.E.: "Silo Problems", International Conference on Design of Silos, University of Lancaster, U.K., 2—4th September, 1980.

[3] Plum, D.R.: "Silo Strains in Working Conditions", Concrete, December, 1980