A Survey Approach of Analysis of Cylindrical Steel Silo Structure Under Seismic Condition

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ABSTRACT

Thin shell structures have given considerably attention for the at least six decades especially during the war time because of their importance in aircraft and missile applications. Shells of various shapes were investigated such as elliptical hemispherical, conical and cylindrical shells. These structures are mostly failing by bucking under external pressure. Cylindrical steel silos are tall slender structures used for storing materials like cement, grains, fly ash, carbon black, coal saw dust etc. They are special structures subjected to many different unconventional loading conditions, ranging from few tones to hundreds to thousands of tones which results in unusual failure modes. Failure of a silo can be devastating as it results in loss of the containers, contamination of material it contains, loss of materials environmental damages, and possible injuries and loss of life. Silos are subjected to normal pressure and axial compressive loads along with the self-weight. They also carry lateral loads due to wind and seismic forces.

Keywords: *Cylindrical Steel Silo Structure, Seismic Condition, Stability, Structure Analysis*.

I. INTRODUCTION

Silos are an inclusive term of all structures for the storage of bulk solids common use, may be ground-supported or elevated. Typical elevated silos generally consist of a conical roof, a cylindrical shell and a conical hopper and they could be elevated and supported by frames or reinforced concrete columns or on discrete supports. Silos are lifeline structures and strategically very important, since they have vital use in industries. Silos are special structures subjected to many different unconventional loading conditions, which result in unusual failure modes. Silos are cantilever structures with the material stacked up very high vertically. The walls of different type of silos are subject to earthquake loads from the stored mass, and these may substantially exceed the pressures from filling and discharge. The elevated silos response is highly influenced by the earthquake characteristics and is depending on the height to diameter ratio. In the earthquake analysis of such structures is to consider the silo and its content as a lumped mass and seismic effect of this mass is considered in design of the supporting frame only.

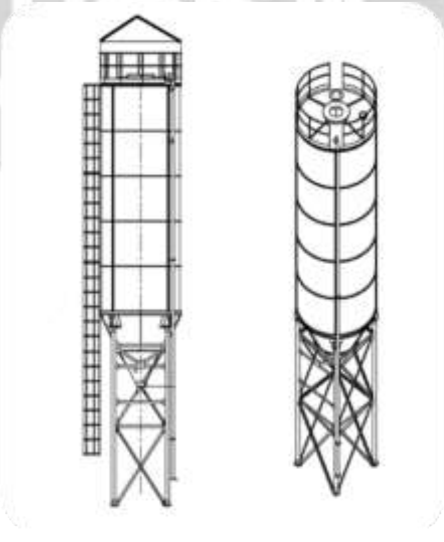

Fig 1. Elevation and 3-D view of typical silo structure

1.1 Loads Acting on Silos

Silos are subjected to several types of actions or loads. As per Indian Standard Code, IS: 875: 1987 Part I-V, the following list of loads are to be taken for silo:

- Dead load (Self weight)
- Storage load (Material load)
- Live load (Platform area, Roof and Floor load)
- Wind load
- Imposed loads and deformation load

II. LITERATURE REVIEW

This chapter presents a review of current knowledge of steel silo structures, with special emphasis on the theories for buckling and collapse in circular cylindrical thin-walled silo mixtures and the existing design criteria used for steel silo structures.

Piekarczyk et. al. (2015), presented the guidelines of the European standards on procedures for the calculation of shell structures. The analysis is illustrated with examples concerning three types of structures of the type i.e.: a chimney, a silo and a tank. The three design examples of special steel structures constructed from sheets with the cross-sections which are shells of revolution are presented. The wind load was calculated according to Eurocode in order that it provides the largest values for all the different standards. In all cases, the FEM as well as the algorithm described in standard were effectively used for the analysis of the stress state (effort) and displacements of the shells.

Gallegoa et. al. (2015), did a comparison of the results obtained in several assays conducted using an experimental cylindrical silo with those calculated using a Finite Element Model (FEM)developed by using ANSYS software package. A mid-scale test silo was used to carry out the assays, which is equipped to measure the normal wall pressures and the friction forces. The numerical pressures predicted by the FEM are quite close of those experimentally obtained, both for filling and discharge. In addition, the mean vertical pressure obtained at transition is the same for both sets of results during the filling process. Numerical model predicts higher mean vertical pressures at transition than those experimentally measured. The FEM predicts higher peak pressures than the experimental ones measured, and at a location closer to the transition than the real position of the sensor placed in the hopper to detect this peak.

Carson (2015), studied the limits of silos design codes. Numerous codes and standards are used to calculate material-induced loads that are needed to design silos. The three most commonly used of such codes do not provide users with consistent information, and many common silo design conditions are not covered. He has done a brief description of each code and its limitations is provided, and common design conditions not covered by any code are identified.

Hillewaerea et. al. (2015), Investigated the case of wind-structure interaction using three-dimensional numerical simulations. One-way and two-way simulations are presented, for a single silo and for the silo group. In the one-way, the wind pressure is applied on the structure, disregarding the structural displacements in the wind flow simulation. Two-way simulations also consider the effect of the structural motion on the wind flow. For a single silo, one-way and two-way simulations yield similar results. Silo in the group, the ovalling vibrations are significantly larger in the two-way simulations than in the one-way simulations. Aeroelastic effects and/or interactions between the wake-induced excitation and the vibration are present in the silo group for the investigated case. The aerodynamic loading and vibration amplitudes are considerably larger for silos in the group than for a single isolated silo.

Wojcik and Tejchma (2015), presented 3D results on stability of thin-walled cylindrical metal silos made from isotropic rolled plates containing bulk solids. The bulk solids behavior was described with a hypoplastic constitutive model. Non-linear FE analyses with both geometric and material non-linearity were performed with a perfect and an imperfect silo shell wherein 3 different initial geometric imperfections. The influence of a stored bulk solid during filling on the buckling strength of silos was compared with the strength of an empty silo and with the experimental results available in the literature. Numerical results indicate a clear strengthening effect of the stored solid on the silo buckling strength as in the experiments, depending upon the wall thickness, wall loading way and imperfection type and amplitude.

Ansari et. al. (2016) [23], concentrated on the study of RCC silos which are mostly used for granular materials storage. In their study they stated that concrete storage units are somewhat economical in design and cost. Also, it can offer protection to the stored materials needs little maintenance and free of hazards such as buckling or denting to some extent. For the analysis of most economical configuration of silos for volume of 125m3 they have been designed twenty-eight samples by changing the ratio of height to diameter and finally found out the most economical size. Their designs have been based on the recommendations of IS 4995-1974 (part 1-2) “criteria for design of reinforced concrete bins for the storage of granular and powdery materials" and IS 456-2000 codes. Finally, they concluded that by increasing the height by diameter ratio, the total cost of construction will also increase. In detail they concluded that increasing diameter results in high cost & vice versa and increasing height results in reduced cost of construction.

Syamili and Kottaliln (2016), studied on the influence of thickness of shell on the buckling behavior of a typical steel silo under the influence of earthquake loads. Effect of cutout in buckling was observed and it was clear that the variation of thickness around the cutout portion affects the buckling behavior of the shell structure.

Jansseunea et al. (2016), Provided partial-height U-shaped longitudinal stiffener above each support. Such stiffeners allow for a more gradual load transfer to the supports, increasing the maximum failure load. The main aim was to map the influence of the dimensions of such longitudinal stiffeners on the failure behavior of thick-walled silos. The simulations indicate that for thick-walled silos, failure will always occur plastic yielding. The failure will be in the stiffened zone of the silo just above the supports for silos with stiffeners with a small cross-section. Silo stiffened with larger cross-sections, failure occurs in the unstiffened zone just above the terminations of the stiffeners. The stiffener height only has a positive impact on the failure load when failure occurs in the unstiffened silo wall.

Zaccari and Cudemo (2016), Studied buckling failure of the real silos used in a thermal power plant to store a granular solid material (limestone) is analysed. It has long been recognized that the buckling failure of the silos is due mainly to the eccentric discharge of its stored solid. The main reason for this kind of failure is due to the difficulty, in the design phase, to characterize the pressure distribution caused by eccentric solids flow (funnelling). The pressures caused by eccentric discharge are characterized using the new rules of the European Standard EN 1991-4 that defines the "Actions in Silos and Tanks". The paper exposed the structural behavior leading to buckling during eccentric discharge and proposes a possible reinforcement design of the silos to minimize this kind of problems.

Horabik et. al. (2016), studied the influences of a filling method, seed size and seed aspect ratio on the radial distribution of the vertical pressure at the bottom of a shallow silo model. Central and circumferential filling methods were used. Horse bean, field pea, wheat, vetch and rapeseed seeds were used. The vertical pressure at the bottom was influenced by the filling methods and seed size. A significant dip in the vertical pressure near the centre of the silo radius was observed in each experimental case except the rapeseed case. Discrete element method (DEM) simulations confirmed the impact of the filling methods on the pressure distribution. The pressure increased with increasing radius for central filling and decreased with increasing radius for circumferential filling. Simulations of filling with higher particle kinetic energies showed greatest vertical pressures near the centre of the silo radius, and lowest values were located close to the silo centre and wall.

III. CONCLUSION

From the study of all literatures it is observed that, structural performance of silo depends some many factors which includes, material stored, wind interaction, type of supports, wall flexibility, staging height, stiffeners etc. The main problem in the silos structure are, they are not much safer under different loading conditions due to lack of its strength and capacity to withstand the worst conditions. Hence design a silo structure which provides much safety and strength is a challenging task for the engineers. Buckling failure is the main failure occurring in silos structure due to eccentric discharge of materials.

It is important to know that the silo structure response under various loading, and its failure arrays. Researches on the response study of silo structure under earthquakes are to be done. Studies on the stiffening of silos structure for reducing buckling are to be done.

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