Analysis of steel silos subjected to wind load with Various slenderness Ratios

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Abstract – *Steel silos are constructing in very thin shells and widely used in various industries for storing granular and powdery materials such as cement, coal, wheat etc. the present research work studied to find out the structural behavior of circular thin-walled steel silos subjected to wind load with various slenderness ratios. The study included the determination of shell stresses and deformational behavior of steel silos with proposed Load Cases WE (wind and empty silo) and WF (wind and full silo). Three silos with same capacities with slenderness ratios like slender, intermediate, and squat prepared for analysis. Its aim to know how the steel silos behave under the wind pressure and from that collect useful information for the design of steel silos. The finite element models are prepared in SAP2000 Software.*

Key Words: Steel silo, Wind load, Slenderness, SAP2000.

1. INTRODUCTION

The silos are widely used in various industries such as Food industries, Agricultural industries, Oil industries and many more for storing huge quantities of granular solids and liquids such as cement, sand, oil, molasses etc. The silos are made with materials like concrete and steel. This type of structure is not only subjected to gravity load, but also there is an effect of lateral load in this structure. The lateral load may be wind or seismic load. When a cylindrical structure having circular cross section is subjected to wind loading then there will be an ovalization phenomenon and an associated considerable deformation in the cross section of the silo wall. Various past investigations indicates that when the height to diameter ratio is less than or equal to 1 (H/D”1) then this ovalisation phenomenon does not produce severe deformation to the said structure. But, when this height to diameter ratio exceeds 1 (H/D>1) then this ovalization and deformation plays a very significant role in design of the cylindrical wall. Due to the ovalisation phenomenon the shell wall will get deformed and this deformation is totally different as compared to the beam bending deformation.

They are typically construct in circular shape because it is the most efficient way to withstand the force from the uniform pressure applied to the inside surface of silos. Generally Silos are made with steel material because they are much lighter and also puts less self loads on the foundation. They construct in thin-walled structure, hence they are prone to buckling due to horizontal wind pressure.

1.1 Steel Silos

Steel silos are widely used mostly for storing large quantity of granular or bulk solids and have been construct rapidly in many industries. The use of silos as a storage structure is very important in food industries, cement plant, power station and similar industries for effectively store the bulk material and supply all through the year. The bulk storage of material in silos has more advantages over the other forms of storage. Steel silos are commonly constructed in circular shape and may be ground supported with the degrading arm which helps to remove the stored material effectively. The structural design of steel silos consists mainly two parts; its shell wall and its foundation. The silo design is generally based on wind load and material which stored into the silo. The foundation is designed according to the moment and axial loads resulting from the shell wall and the Bearing capacity of supporting soil. The wind speed will also vary due to the surrounding area and height of silo. The increase factor of wind speeds is higher in open areas than in highly vegetated areas.

2 LOADS ON SILO WALL

The silo walls are subjected to the both horizontal and vertical load. The horizontal load due to the horizontal pressure and vertical load due to the friction between the wall surface and stored material in silo. The intensity of this pressure may be symmetric or non-symmetric and depend on whether silo is being filled or discharged. The horizontal pressure gives the circumferential tension and frictional pressure gives additional axial compression on vertical wall.

2.1 Loads on silo

Generally the silos are analyzed by using Janssen’s Theory, and it shows that the pressure distribution is influenced by the size and shape, moisture and temperature, density of the stored material also the pressure variation is changed if the slenderness ration of silo are changed when the slenderness ration is high the pressure exerted by stored material on side wall is less as compare to less slenderness ratio. For analysis of circular silos there are three types of load considered which causes by a stored material in silo.

1) Horizontal load due to horizontal pressure (Ph) acting on the side wall.

2) Vertical load due to the vertical pressure (Pv) acting on the cross-sectional area of the silo filling.
3) Frictional wall load due to the frictional wall pressure (Pw) introduced onto the wall due to the wall frication.

3 MODELLING AND ANALYSIS

Generally the diameter and height of silos usually depends upon the size of the ground area available and the volume of required to be stored. Consider S.B.C. of soil and cost of making foundation suitable for recommended height. For shell wall mild steel plates are used, the thickness of plates in bottom, shell and roof taken as per recommendations in IS codes. The joints in the plates welded by butt weld and done with smooth surface and water tight. The bottom plates shall be v- grooved and welded with butt welding, also mild steel strips 60mm width and 6mm thick provided on weld, and permissible stresses for the bottom, shell and roof of the tank shall be accordance with the IS 800-1962. Silos analyze by wind load accordance with IS 875.

For analysis of silos three models are prepared with different slenderness ratios using SAP2000 software.

The construction of silos in steel plates of IS: 2062-2006 (GRADE-E250A) plate is a low carbon steel that exhibits good strength. It is easy to machine and fabricate and can be securely welded. E250A is a common structural steel plate that can be galvanized to provide increased corrosion resistance. Tensile strength of E250A steel plate is 250 N/mm^2

Details of models:

Table -1: Parameters considered for modeling.

Parameter	Model No.1	Model No.2	Model No.3
Height (m)	42	37	32
Diameter (m)	10	15	20
Slenderness Ratio	4.2	2.46	1.6
Thickness of plate	10mm	10mm	10mm

Details of stored material:

Table -2: Properties of stored material.

Stored material	Wheat
Bulk density	850 Kg/m^3
Angle of internal friction	28°

3.1 Wind pressure assessment

The basic wind pressure, which varies along the height of the silo, has been calculated as per IS 875 – 1987 (Part III)

Table -3: Wind load parameters.

Basic wind speed (Vb)	39 m/s.
Risk coefficient (K1)	1.06
Topography factor (K3)	1.00
Reduction factor	0.7
Design wind speed (Vz)	K1xK2xK3xVb x 0.7
Design wind pressure (p)	0.60 x Vz kN/m2.

Table -4: Variation of wind pressure along the height of silo

Height up to (m)	(K2)
40	1.15
30	1.06
20	1.01
15	0.97
10	0.91

4 Result and discussion

Model No.1) Slenderness ratio-4.2

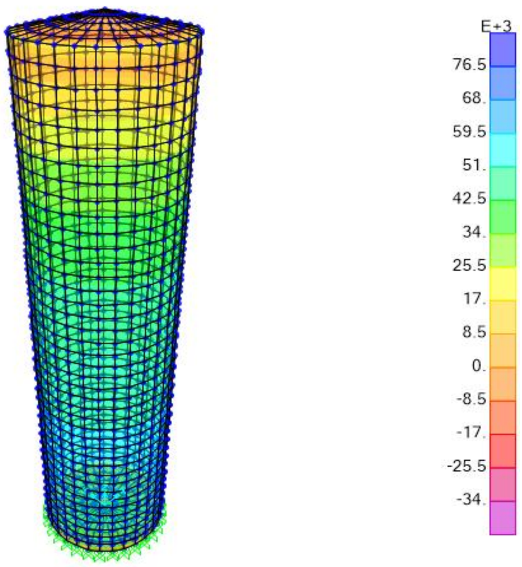

Fig -1: Stress Contour of cylindrical wall of silo

Model No.2) Slenderness ratio-2.46

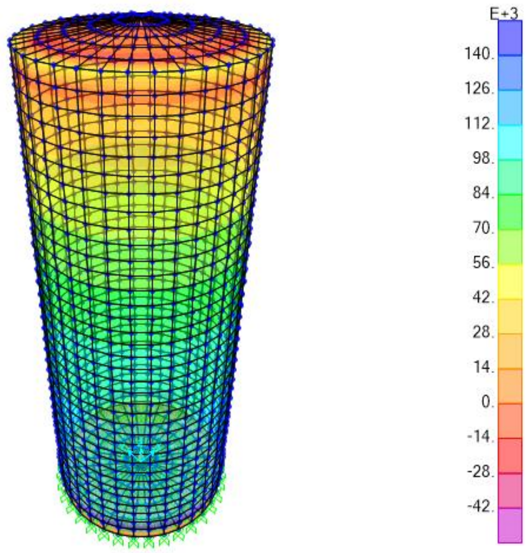

Fig -2: Stress Contour of cylindrical wall of silo

Model No.3) Slenderness ratio-1.6

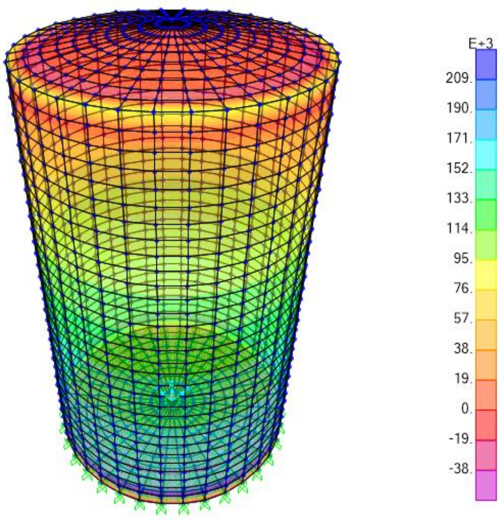

Fig -3: Stress Contour of cylindrical wall of silo

Figures show that the stress contours of a circular wall of silo which is considered for design of wall.

4.1 Silo with (WE) and (WF) condition

A) Deformation

Table -5: Maximum displacement in vertical wall

Model No.	Deformation for (WE)- mm	Deformation for (WF)-mm
Model No1	71.64	56.58
Model No2	48.43	39.43
Model No3	21.32	32.30

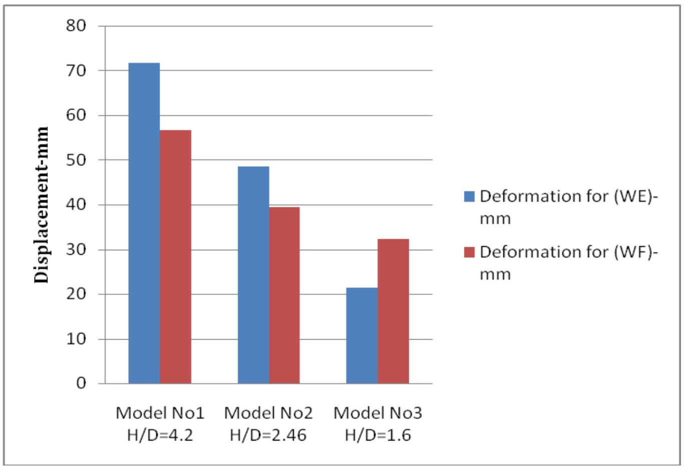

Chart-1: Maximum displacement in vertical wall

From chart no. 1 it is observed that the maximum deflection values obtained from (WE) condition with high slenderness ratio than the (WF) condition for model no. 1 and 2. Model no. 3 shows exactly opposite behavior than other models.

B) Hoop stress

Table -5: Maximum hoop stress in vertical wall

Model No.	Hoop stress for (WE)- N/mm2	Hoop stress for (WF)- N/mm2
Model No1	70.34	84.26
Model No2	98.32	170.65
Model No3	120.76	242.12

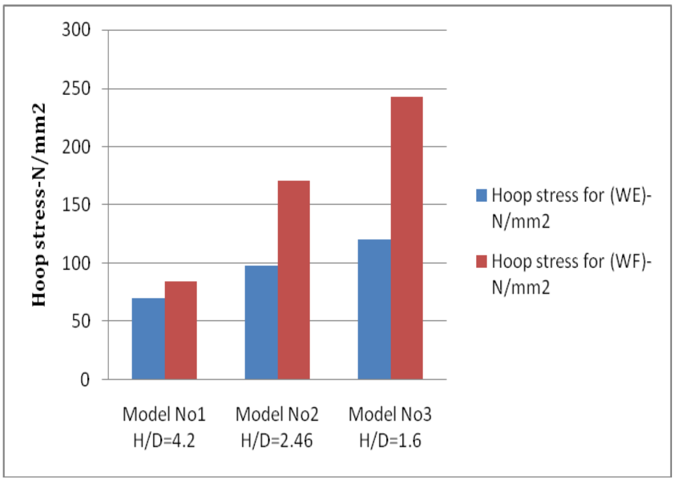

Chart-2: Maximum hoop stress in vertical wall

From chart no. 2 it is observed that the maximum hoop stress occurs in (WF) condition with less slenderness ratio than the (WE) condition.

5 CONCLUSIONS

The analysis shows that the deflection values are critical in windward side at middle half height of silo (i.e. around 0.35H to 0.70H) of the side wall when it is in empty as well as full condition. The hoop stresses are maximum at near to ground level (i.e. about 1 m high from ground level) when silos are in (WF) condition, and further they are reduced towards the top of silo. Hoop stresses are produced due to the ovalisation effect of the cylindrical wall. At the junctions of silo side wall and bottom base plate hoop stresses are large.

ACKNOWLEDGEMENT

I extend my sincerest gratitude to my parents, my Guide, head of program, head of dept., and my well-wishers who helped me in all situations whenever needed during this project completion. Also I have to express out -appreciation to the Mr. Sadanand B. Sabnis. (Shantadurga Consultants, Kolhapur) for shearing their pearls of wisdom with us during the course of research.

REFERENCES

(1) Adem Dogangun, Zeki Karaca (2009) – "Cause of Damage and Failures in Silo Structures" Journal of Performance of Constructed Facilities, Vol. 23, No. 2, April 1, 2009. ASCE, ISSN 0887-3828/2009, pp. 65–71.
(2) Arash Raeesi, H. Ghaednia (2017) - "Failure analysis of steel silos subject to wind load" Elsevier journal of 'Engineering Failure Analysis' Vol. 79, 26 April 2017, pp. 749-761.
(3)Lei Chen, J. Michael Rotter (2012)- "Buckling of anchored cylindrical shells of uniform thickness under wind load" Elsevier journal of 'Engineering Structure' Vol. 41, 26 April 2012, pp. 199-208.
(4) Luis A. Godoy (2016) – "Buckling of vertical oil storage steel tanks: Review of static buckling studies" Elsevier journal of 'Thin walled structures' Vol. 103, 2016, pp. 1-21.
(5) Qing-shuai Cao, Yang Zhao (2016) "Structural system and buckling design of cellular steel silos" Elsevier journal of 'Constructional Steel Research' Vol. 129, 24 Nov. 2016, pp. 227-239.
(6) Ru Zhang, Yang Zhao, Qing Shuai Cao (2018)- "Wind induced buckling of large circular steel silos with various slenderness" Elsevier journal of 'Thin-Walled Structure' Vol. 130, 04 May 2018, pp. 101-103.
(7) Shervin Maleki, Alireza Moazezi Mehretehran (2018)- "3D wind buckling analysis of long steel corrugated silos with vertical stiffeners" Elsevier journal of 'Engineering Failure Analysis' Vol. 90, available on 20 March 2018, pp. 156-164.

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