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Comparative study of finite element analysis of steel silos with rectangular and I stiffeners.

Estudio comparativo de análisis de elementos finitos de silos de acero con refuerzos rectangulares y en I

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ABSTRACT

Silos are used by a wide range of industries to store bulk solids in quantities ranging from a few tones to hundreds or thousands of tones. They can be constructed of steel or reinforced concrete. Steel bins range from heavily stiffened flat plate structures to efficient unstiffened shell structures. They can be closed or open. They are subjected to many different static and dynamic loading conditions, mainly due to the unique characteristics of stored materials. Wind and earthquake load often undermine the stability of the silos. A steel silo with and without stiffeners is adopted and static structural analysis and dynamic analysis is done. The analysis is done by idealizing geometry, material and boundary conditions.

Keywords: steel, reinforced concrete, silos.

RESUMEN

Los silos son utilizados por una amplia gama de industrias para almacenar sólidos a granel en cantidades que van desde unas pocas toneladas hasta cientos o miles de toneladas. Pueden ser de acero o de hormigón armado. Los contenedores de acero van desde estructuras de placas planas muy rígidas hasta estructuras de cáscara no reforzadas eficientes. Pueden estar cerrados o abiertos. Están sujetos a muchas condiciones de carga estáticas y dinámicas diferentes, principalmente debido a las características únicas de los materiales almacenados. La carga de viento y terremoto a menudo socava la estabilidad de los silos. Se adopta un silo de acero con y sin refuerzos y se realiza un análisis estructural estático y un análisis dinámico. El análisis se realiza idealizando la geometría, el material y las condiciones de contorno.

Palabras clave: acero, hormigón armado, silos.

INTRODUCTION

Silos are used by a wide range of industries to store bulk solids in quantities ranging from a few tones to hundreds or thousands of tones. They can be constructed as either ground supported or elevated. They are subjected to many different static and dynamic loading conditions, mainly due to the unique characteristics of stored materials. It is very difficult to determine the magnitude and distribution of stresses and their corresponding failure modes. Determination of loads play significant role in the design of silo (Ramakrishna et al., 2012).

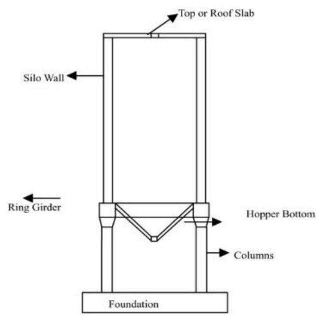

Figure 1: Terminology for parts of a typical silo

MATERIALS AND METHODS

CHARACTERISTICS OF SILO

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. 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 reduced towards the top of silo (Harshawardhan and Patil, 2019).

It is better to use intermediate slender silos than slender silos for storing bulk materials since it has greater resistance against wind (Vishnu and Priya, 2019, Nair et al., 2019) .

Buckling deformations of steel silos under large eccentricity filling are non-symmetrical, where the radial displacement in the eccentric side is much larger than that in the opposite side at the same depth. The effect of weld imperfection is also harmful to buckling resistance of silo, which is more serious for relatively slender silos than squat silos (Cao and Xhao, 2018).

The effect of the isolation system is to soften the structure by the prolongation of the fundamental period to a larger value with regard to that non-isolated. The maximum base shear force is reduced by 88% and 97% for the maximum overturning moment (Zaoui and Djermane , 2018)

Structural performance of silo depends on many factors like ensiled material, wind structure interaction, type of supports, wall flexibility, staging height, stiffeners etc. Stiffening of silos are done in order to reduce buckling (Prince and Jose, 2017).

The deformed configuration and stress contour are examined after application of wind load as point forces and some irregularities have been observed on the deformation pattern of the silo wall, which is obvious. Hence an attempt has been made to apply the same wind load as surface load after partitioning the surface of the silo wall (Ummidi and Kumar, 2016)

The silo considered is externally stiffened to stabilize the structure against the pressure of the stored material. Rings are provided along the circumference and stringers in longitudinal direction at definite intervals to carry out the reinforcing function. The effect of these stiffeners in increasing the stability of the structure is studied (Alice et al., 2015).

Steel silos with both type of bearings have similar values in Mises stress under the same loading conditions. However, steel coal bunker with profile-steel bearing has a smaller radial displacement and the total steel volumes are smaller than steel silo with cylindrical-wall bearing. Buckling analysis results indicate that the steel silo with profile-steel bearing has a better capability of buckling resistance under the same loading condition (Tang et al., 2015).

MODELLING AND ANALYSIS

A. Software Study - ANSYS is versatile finite element analysis software with many features aiding the modelling and analysis of a complex structure like silo. ANSYS Mechanical software is a FEA tool for structural analysis including linear, non-linear and dynamic studies. The software used for modelling is PTC Creo software and analysis was ANSYS R16.0. ANSYS was selected since the software is capable of solving complex structural engineering problems more effectively and complex models can be completed using this.

B. Validation Details

The journal paper taken for the validation was Lyubomir Z (2018) "Necessary height of the vertical stiffeners in steel silos on discrete supports", Challenge Journal of Structural Mechanics, 4, 153–158.. For the purpose of research, three steel cylindrical shells are modelled, using ANSYS. Their parameters are as follows:

a) Dimensions are for shell 1 – diameter D = 3 m, height H = 6 m; shell 2 – diameter D = 4 m, height H = 8 m; and shell 3 – diameter D = 5 m, height H = 10m.

b) Constant thickness of shells are t = 5 mm.

c) Shells are supported by six immovable supports with dimensions in plane 125×125 mm.

d) In order to strengthen the shells in radial direction, on 50mm above the lower edge and on 50mm below the upper edge are placed rings with section L100x8 mm.

e) The shells are stiffened with an intermediate ring with section 100x100x8 mm.

f) Material of steel – Steel 235

g) Load Details - For Shell 1 – 146874N, For Shell 2 – 348146 N, For Shell 3 – 679983 N

Wind load for the structure has been calculated as per IS 875 (part-3) - Wind speed 39 m/s, Terrain category 2.

C. Results of Validation

The results of the performed Buckling Analysis for each of shells are shown in table 1,2 and 3. The buckling of shell 1, 2 and 3 without stiffeners are given in figure 2.

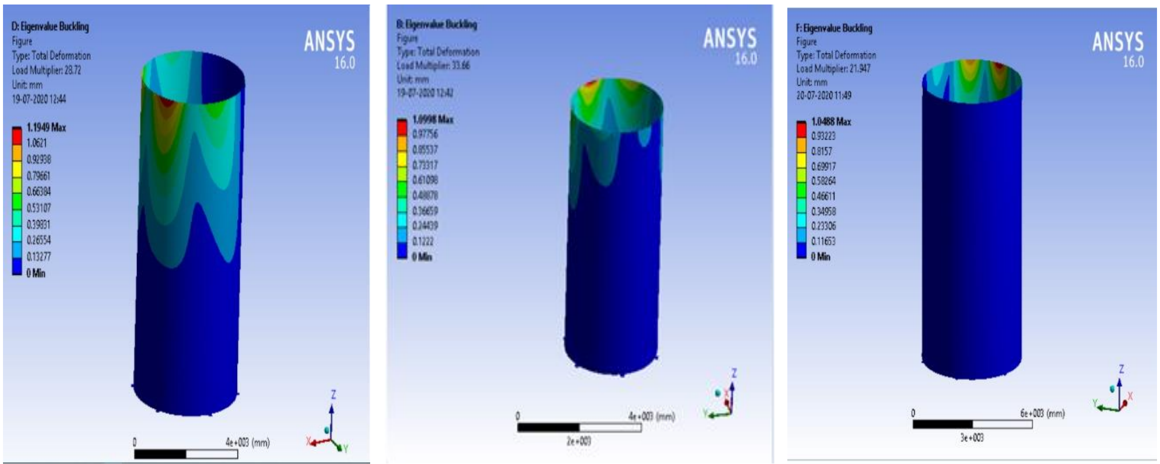

Figure 2: Buckling of Shell 1, 2 and 3 without stiffeners

Table 1 Buckling results of Shell 1 without stiffeners

Mode	Load Multiplier		% Error
	Actual	*Obtained*	
1	33.66	32.372	3.9
2	44.607	43.364	2.8
3	48.508	46.649	3.8
4	50.199	48.981	2.4

5	54.721	53.057	3.1
6	58.604	56.856	2.12

Table 2 Buckling results of Shell 2 without stiffeners

Mode	Load Multiplier		% Error
	Actual	*Obtained*	
1	28.72	27.832	3.19
2	40.112	38.544	4
3	42.37	40.845	3.7
4	48.381	46.908	3.6
5	53.727	52.185	2.9
6	55.904	54.325	2.8

Table 3 Buckling results of Shell 3 without stiffeners

Mode	Load Multiplier		% Error
	Actual	*Obtained*	
1	21.947	21.133	3.8
2	24.707	23.883	3.4
3	35.066	34.177	2.6
4	41.808	41.154	1.5
5	47.684	46.552	2.4
6	49.504	48.486	2.0

The buckling of shell 1, 2 and 3 with rectangular stiffeners are given in figure 3 and results of the performed Buckling Analysis for each of shells with rectangular stiffeners are shown in table 4, 5 and 6.

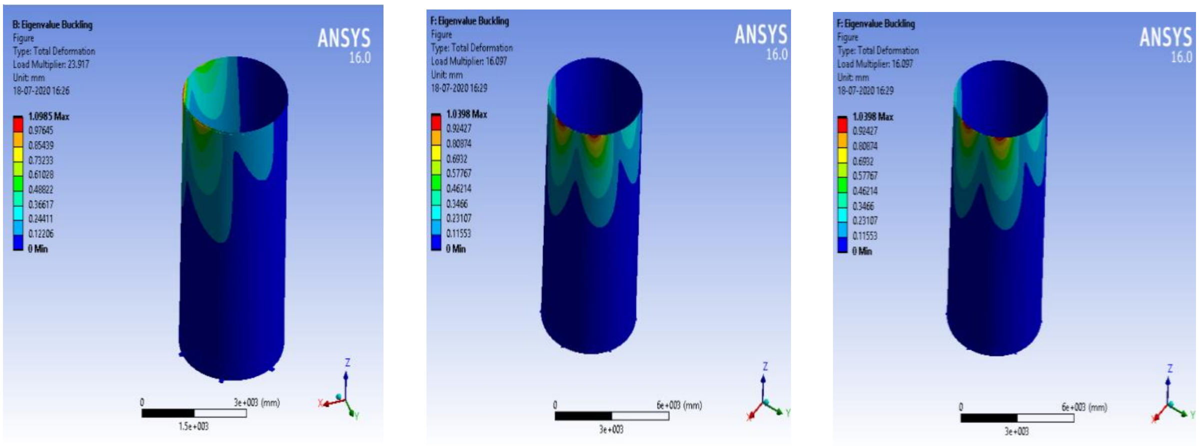

Figure 3: Buckling of Shell 1, 2 and 3 with rectangular stiffeners

Table 4 Buckling results of Shell 1 with rectangular stiffeners

Mode	Load Multiplier		% Error
	Actual	*Obtained*	
1	23.917	22.997	4
2	40.864	38.989	4.8
3	42.439	41.134	3.1
4	43.776	42.165	3.8
5	45.797	44.199	3.6
6	46.354	44.382	3.39

Table 5 Buckling results of Shell 2 with rectangular stiffeners

Mode	Load Multiplier		% Error
	Actual	*Obtained*	
1	20.308	19.824	2.4
2	34.815	33.656	3.4
3	36.77	35.695	3.0
4	40.069	38.988	2.7
5	42.726	41.453	3.0
6	43.836	42.158	3.9

Table 6 Buckling results of Shell 3 with rectangular stiffeners

Mode	Load Multiplier		% Error
	Actual	*Obtained*	

1	16.097	15.538	3.5
2	18.178	17.756	2.3
3	25.764	24.852	3.6
4	26.991	25.942	4
5	38.281	37.154	3.0
6	40.213	38.975	3.1

RESULTS AND DISCUSSION

Analysis was carried out for the 3 silo models using ANSYS APDL. The buckling of steel silos stiffened with I stiffener is studied. I stiffener with flange 100 mm, web 100 mm and thickness 8 mm is used. The buckling of shell 1, 2 & 3 with I stiffeners are given in figure 4.

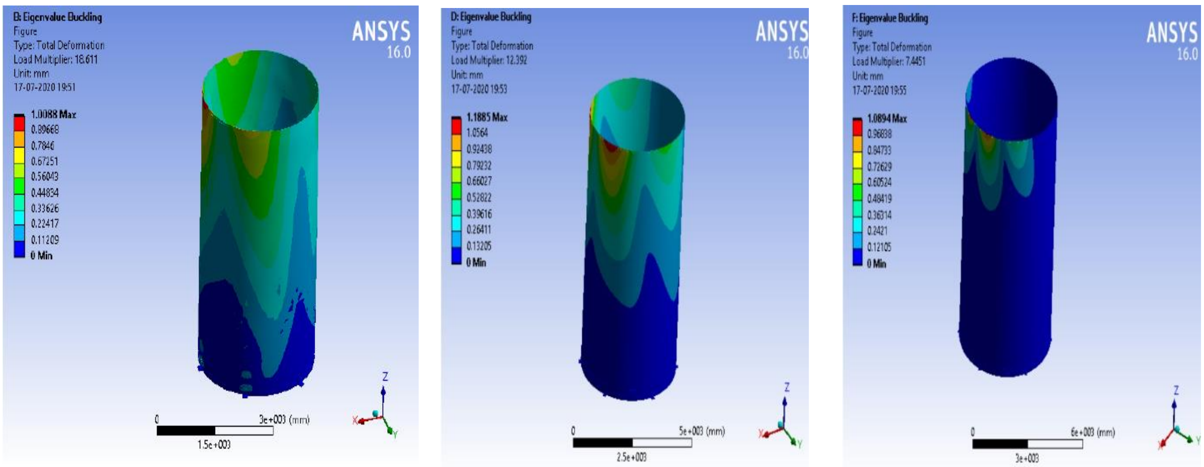

Figure 4: Buckling of Shell 1, 2 and 3 with I stiffeners

The results of the performed Buckling Analysis for each of shells with rectangular stiffeners are shown in table 7, 8 and 9.

Table 7 Buckling results of Shell 1 with I stiffeners

Mode	Load Multiplier
1	18.611
2	28.912
3	32.291
4	33.832
5	34.554
6	35.92

Table 8 Buckling results of Shell 2 with I stiffeners

Mode	Load Multiplier
1	12.392
2	26.545
3	28.803
4	32.08
5	33.548
6	36.115

Table 9 Buckling results of Shell 3 with I stiffeners

Mode	Load Multiplier
1	7.445
2	19.118
3	22.697
4	26.76
5	28.884
6	31.124

The present study focuses to determine the buckling effects on silos with the help of ANSYS software. The silos with 6m, 8m and 10m height with and without stiffeners were analysed.

From the above study, following conclusions were drawn.

• We can conclude that the silos with stiffeners shows less buckling effect compared to that of silos without stiffeners.

• The silos with I stiffener produce less buckling effect compared to that of silos with rectangular stiffener.

• Considering the peak values, the buckling effect of 6m high silos is reduced by 26.8% by the use of rectangular stiffeners. Comparing rectangular and I stiffeners the buckling effect is reduced by 24.8%.

• Similarly, for 8m high silos, the buckling effect is reduced by 28.8% with the use of rectangular stiffeners and comparing rectangular and I stiffeners the buckling effect is reduced by 25.2%. For 10m silos, it is reduced by 24.4% with the use of rectangular stiffeners and 16.73% when I stiffeners were used.

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