

# Linear Buckling Analysis of Cylindrical Steel Silos with V Type Stiffener under Wind Load

Vishnu M Nair<sup>1</sup>, Lekshmi Priya R<sup>2</sup>

<sup>1</sup>M-tech, Sree Narayana Institute of Technology, Adoor, Pathanamthitta, Kerala, India  
vishnumnair20@gmail.com

<sup>2</sup>Assistant Professor, Sree Narayana Institute of Technology, Adoor, Pathanamthitta, Kerala, India  
priya.25a84@gmail.com@gmail.com

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**Abstract** - Large cylindrical steel silos are typical kinds of thin-walled structures that are widely used to store large quantities of granular solids, cement, coal etc in the industrial and agricultural sectors. Silos are important storage structure in an industry. Since these structures are thin walled and tall, this structures are easily affected under wind and hence study on the buckling of this structures under wind load is must. In this Project three stiffened models were prepared. The prepared model belonged to slender, intermediate slender and squat categories.

The linear buckling analysis of these stiffened models under wind load was done. The deformation and load multiplication factor obtained in the silos during filling load are studied. Based on the results the stiffened models are compared. The modelling and analysis were done using the software ANSYS R15.0 and the results were noted.

**Key Words:** silos, thin walled, wind, stiffened, load multiplication factor, buckling

## 1. INTRODUCTION

Cylindrical steel silos are thin-walled structures that are widely used to store large quantities of granular solids in the industrial and agricultural sectors. They are used to store bulk materials like cement, coal, wheat etc .The diameter of Cylindrical steel silos varies from 3 to 27 m and height varies from 10 to 90 m. A cylindrical steel silo with a large diameter to thickness ratio is particularly vulnerable to buckling during filling of the silo. Filling load induced collapse has been found to result in the most catastrophic structural failures among major natural hazards such as hurricanes, earthquakes, flooding, snowfall, etc. The variation in height to diameter ratio has a significant influence on the relative magnitude and distribution of solid pressures placed on the internal surface .Ordinary steel silos without any stiffener are prone to buckling under the filling load. The filling load acting on the silo is calculated using equations from the code EN 1991.4.2006. Three models were prepared with Vtype stiffener. This models belonged to categories of slender, intermediate slender and squat silos. Linear buckling analysis gives load multiplication factor. This factor can be

multiplied with the corresponding design loads to obtain buckling load. The main novelties of this paper would be summarized as follows:

1. Conducting linear buckling analysis of the prepared models.
2. Comparing the models

## 2. DESIGN

It is worth noting that a buckling analysis of the limit state of silos depends heavily on the following working conditions: the action assessment class (Table 2.1, EN1991-4 [1]); the fabrication tolerance quality class (Table 5.1, EN1993-4-1 [2]); the consequence class (Table 2.1, EN1993-4-1 [2]), which considers effects of silo capacities, support patterns, and eccentricity during filling and discharge and weld imperfection of silo wall, as appropriate. In this study the models belongs to action assessment class 1, the fabrication tolerance quality is Q=16, the consequence class is 2 and the wall surface class as D1.

## 3. STIFFENERS

Two types of stiffeners are used vertical stiffener and circumferential stiffener. The vertical stiffener selected is a V type stiffener adopted from euro code and the circumferential stiffener from IS 9178 -2(1979).The details of V type stiffener and circumferential stiffener are provided below

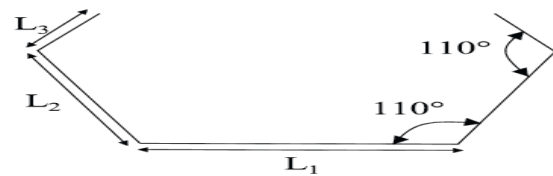


Fig -1: V type stiffener

The cross sectional details of the vertical V type stiffener used is given in the following table. The selected V type stiffener has a thickness of 5mm.

**Table -1:** Vertical stiffener details

Cross section	V5 (mm)
L1	125
L2	89
L3	35

The circumferential stiffener details is provided below. The width of this type stiffener is provided here is 100 mm. The spacing provided is 1500mm. The thickness provided varies for each model.

**Table -2:** Circumferential stiffener details

Model	Width(mm)	Thickness(mm)	Spacing
S1	100	50	1500
S2	100	50	1500
S3	100	65	1500

**4. SOFTWARE**

The software used for modelling and analysis was ANSYS R15.0. ANSYS was selected since the software is capable of solving complex structural engineering problems more effectively and complex models can be completed using this.

**5. MODELLING**

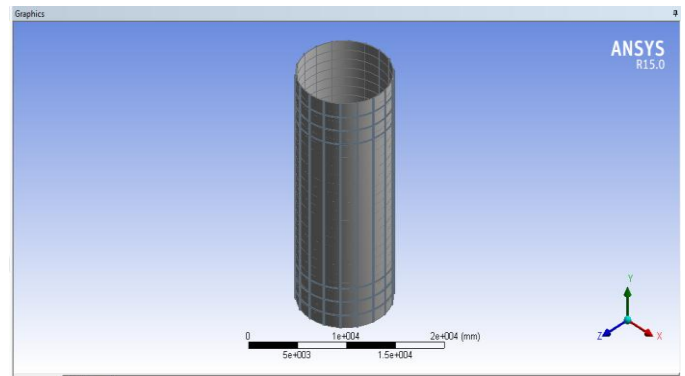
Three models were prepared of varying height to diameter ratios and belonging to slender, intermediate slender and squat categories. The modelling was done using the software ANSYS R15.0. The geometrical details of the prepared models is given in the below table.

**Table -3:** Models geometrical details

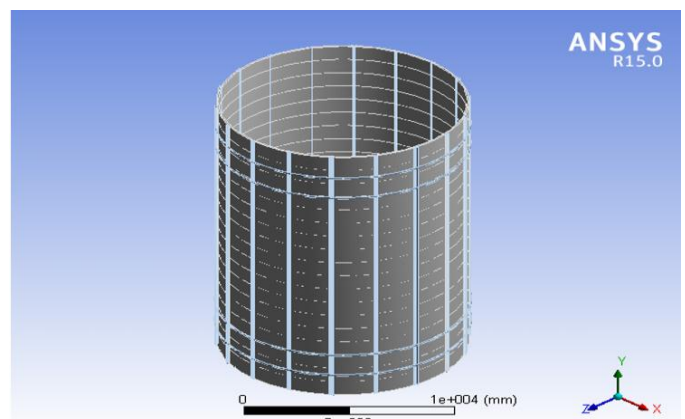
Model Name	Height H(m)	Diameter D(m)	H/D	Thickness(mm)
S1	25	10	2.5	50
S2	18	12	1.5	50
S3	12	15	0.8	65

The S1 model has a H/D ratio as 2.5 hence belongs to slender silos category, S2 has a H/D as 1.5 and belongs to intermediate slender silo category and S3 has a H/D ratio as

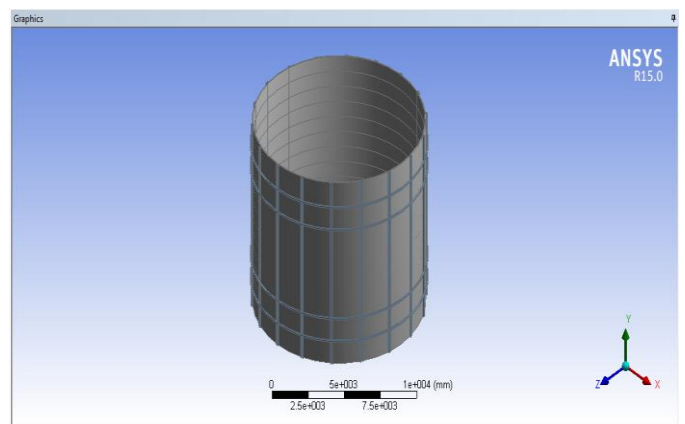
0.8 and belongs to squat silos categories. This classification is based on the the European code for design of silos.



**Fig -2: S1**



**Fig -3: S2**



**Fig -4: S3**

The above figures named S1, S2 and S3 are the models prepared. The models is stiffened using V type vertical

stiffener and circumferentially stiffened also. The details of the stiffener is provided above.

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### 6. ANALYSIS

The wind loads for the analysis were calculated from European code. The analysis was done using the finite element software ANSYS R15.0 .Linear Buckling analysis (LBA) is carried out for the designed filling loads and the load.

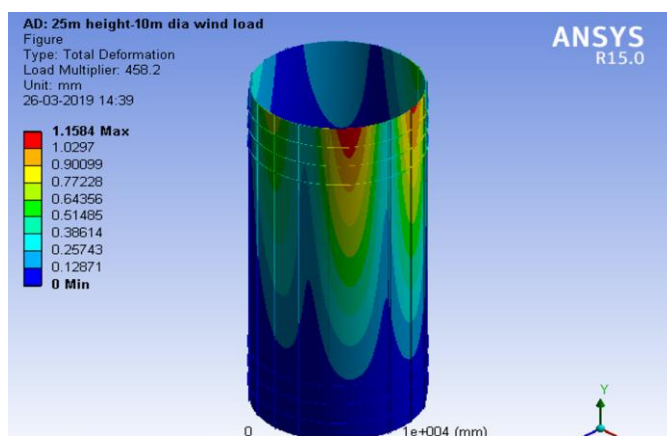


Fig -5: Analysed model S1

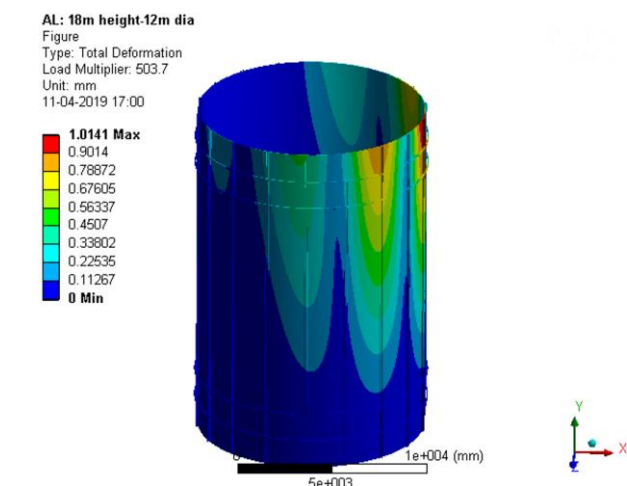


Fig -6: Analysed model S2

AQ: 12m height-15m dia  
Figure  
Type: Total Deformation  
Load Multiplier: 763.29  
Unit: mm  
13-04-2019 10:24

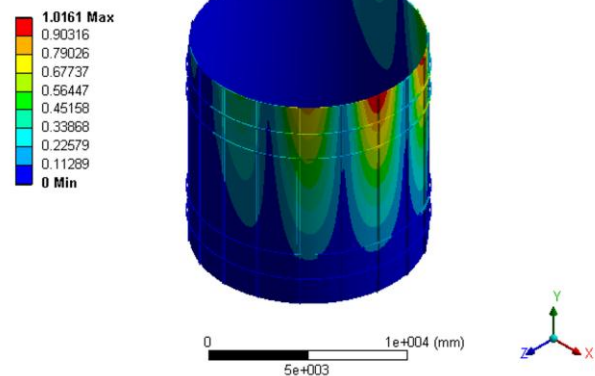


Fig -7: Analysed model S3

The above figure 5,6 and 7 shows the analysed model under filling load. The above model were done linear buckling analysis.

### 7. RESULTS AND DISCUSSIONS

After conducting the linear buckling analysis the load multiplier were obtained for each models. The model S3 has the highest load multiplier. After S3 the next model having the high load multiplier is S2.S3 has the least load multiplier. The model S1 has the highest deformation compared to other two models.

Table -4: RESULT

Model name	Load multiplier	Deformation max(mm)
S1	458.2	1.1584
S2	503.7	1.0141
S3	763.29	1.0161

The above table shows the obtained results after conducting linear buckling analysis.

### 8. CONCLUSION

After conducting linear buckling analysis the model S3 has the highest load multiplier followed by S2 and then S1.This suggests that the model S3 which belongs to the squat silos categories has more buckling resistance under wind load due to its high load multiplier. Hence it would be better to use squat silos for storing bulk materials. Also between models S2 and S1 model S2 is slightly better which belongs to intermediate slender silo category. So between slender

and intermediate slender its better to use intermediate slender silos for storing bulk materials since it has greater resistance against wind.

Also among the three models the model S3 has less deformation compared to the other two model, this shows it has buckled less under the wind load. So overall model S3 is safe and has more resistance against buckling. When it comes in case of volume the model S1 has the least volume hence less materials required.

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