International Research Journal of Advanced Engineering and Science
ISSN (Online): 2455-9024

Finite Element Analysis of Elevated Steel Silos under Seismic Vulnerability Using Different Types of Basement Techniques

Anjana V L[1], Biby Aleyas[2]
[1]PG Student, Department of Civil Engineering, Ilahia College of Engineering & Technology, Mulavoor, Kerala, India-686673
[2]Assistant Professor, Department of Civil Engineering, Ilahia College of Engineering & Technology, Mulavoor, Kerala, India-686673
Email address: [1]anjana22041995@gmail.com, [2]biby989@gmail.com

Abstract— *Silos are tall massive structures used to store bulk materials like cement, grain, coal, carbon black, etc. They may be ground supported or elevated. Typical elevated silos generally consist of a conical roof, a cylindrical shell and a conical hopper. This paper presents the seismic vulnerability of a steel silo and specific retrofitting solution has been proposed by means of different basement techniques. Modeling is done by using ANSYS 16.0. Here the natural frequency of silo under different support conditions is studied. Silos with different types of isolators and pile foundation were modeled.*

I. INTRODUCTION

Silos are tall massive structures used to store bulk materials like cement, grain, coal, carbon black, etc. They may be ground supported or elevated. Typical elevated silos generally consist of a conical roof, a cylindrical shell and a conical hopper. Most silos are steel or reinforced concrete cylindrical structures built on mat foundations. They are elevated and supported by frames or reinforced concrete columns or on discrete supports. Elevated silos are highly influenced by the earthquake forces. Seismic analysis is essential for carrying out structural design, assessment and retrofitting of structures in regions where earthquakes are prevalent. Silos generally work as storage structures between supply and demand for various goods. Thin walled cylindrical silos are highly vulnerable to seismic induced pressures, which can cause buckling phenomena of silo shell. Silos are subjected to many different static and dynamic loading conditions, mainly due to the unique characteristics of stored materials.

The walls of the silos are typically subjected to both normal pressure and vertical frictional shear or traction produced by the material stored inside the silo. The magnitude and distribution of both shear and normal pressure over the height of the wall depend on the properties of the stored material and whether the silo is being filled or discharged. Other potential loads, including seismic and wind loads, stresses created by temperature difference between the silo wall and the stored bulk solids, potential expansion of the stored material, and differential settlement of the foundation or support columns, should also be considered during the design process.

Silos are mainly used for the storage of cement, calcite, industrial materials, minerals, medical supplies, perfumery chemicals, petrochemical supplies. Used for the storage of coal, gypsum, perlite marble dust, plastic, polyethylene pellets, wood chips, activated carb. Materials used in different fields, such as carbon black and ceramic powder, suitable for pneumatic conveying and handling are also stored in the silos. Silo gives protection against any dust on the environment, bacteria and insects by forming debris shedding to the stored materials. Steel silos are easier to erect and also to install accessories like doors, ladders, samplers, etc. Steel silo structure is more flexible. Steel silos generally give greater storage capacity. Therefore they are more cost-effective because of the higher storage capacity. It is easier and more effective to do aeration in steel silos.

II. SCOPE AND OBJECTIVE OF WORK

To control the vibration of silo. To avoid future economic, life safety and environmental troubles that can be caused by the collapse of these non building structures. Specific retrofitting solution of basement such as isolator and piles. The main objectives of this study are as follows.

1) To introduce various types of isolators.
2) To study the natural frequency of silo under different support conditions.
3) To introduce pile foundation.
4) To predict the best support condition under seismic loading.

III. FINITE ELEMENT MODELING OF SILOS

A. Geometry

Three dimensional models were developed to demonstrate the behaviour properly. The models includes silo with different shapes of isolating devices and pile foundation. The dimensions and material properties considered in this thesis are fixed with reference to journal. Cross sections of elliptical shape, rectangular shape and round shape are chosen for the isolating device in the parametric study. Both static and modal analysis is done and a comparative study is carried out between the silo with bracings and grids and silo with different shapes of isolating devices and pile foundation.

The silo is made up of steel sections of density 7850 kg/m^3, Young's modulus 210000 MPa and Poisson's ratio 0.3. The height of silo is 13350 mm and height of column is 8940 mm. The outside diameter of silo is 3500 mm and thickness of

Anjana V L and Biby Aleyas, "Finite Element Analysis of Elevated Steel Silos under Seismic Vulnerability Using Different Types of Basement Techniques," *International Research Journal of Advanced Engineering and Science*, Volume 4, Issue 2, pp. 330-333, 2019.

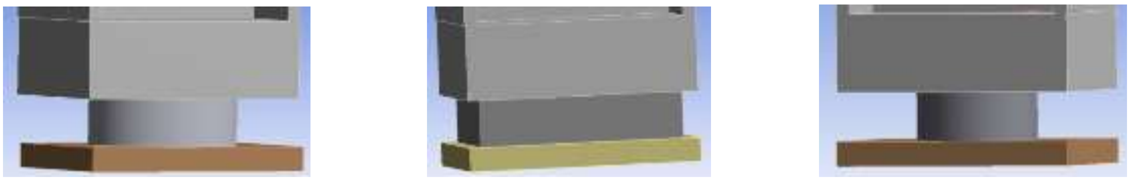
silo wall is taken as 12 mm. Isolating devices are made up of steel plates and rubber. Rubber has a density 1000 kg/m^3, Young's modulus 10 MPa and Poisson's ratio 0.41. The size of ellipse is 160 x 120 x 200 mm and size of rectangular plates above and below ellipse are 500 x 300 x 100 mm and 500 x 300 x 80 mm respectively. . The size of rectangle is 400 x 240 x 200 mm and size of rectangular plates above and below ellipse are 500 x 300 x 100 mm and 500 x 300 x 80 mm respectively. The size of round is 150 x 200 mm and size of rectangular plates above and below ellipse are 500 x 300 x 150 mm and 500 x 300 x 100 mm respectively. Pile foundation is made up of concrete. Concrete has a density 2300 kg/m^3, Young's modulus 30000 MPa and Poisson's ratio 0.18. The pile has a diameter of 900 mm and a depth of 10000 mm. Pile cap having a size of 4200x4200x1500 mm is used. The load is given as displacement as one cycle at 1 to ±100 mm to all types of silos.

B. *Material Properties*

The silo is made up of steel material. The isolating devices are made of with steel and rubber. Pile foundation is made up of concrete. Steel has a density of 7850 kg/m^3, Young's modulus of 210000 MPa and Poisson's ratio of 0.3. Rubber has a density of 1000 kg/m^3, Young's modulus of 10 MPa and Poisson's ratio of 0.41. Concrete has a density of 2300 kg/m^3, Young's modulus of 30000 MPa and Poisson's ratio of 0.18.

C. *Modeling and Analysis*

The silos are modeled using ANSYS Workbench 16.0. Different shapes of isolating devices and pile foundation is used as support condition. Fig. 1 shows the cross sections of isolating devices used for the study. Static cyclic analysis and modal analysis were performed using ANSYS software package. The properties were assigned, support and loading conditions were provided.



(a) (b) (c)

Fig. 1. Cross sections of isolating devices (a) Elliptical shaped isolating device, (b) Rectangular shaped isolating device, (c) Round shaped isolating device

Every model was modeled using 20 node solid 186 to achieve better accuracy in non linear analysis. Fig. 2 shows the model of a silo with elliptical shaped isolating device. The proposed silo where thus subjected to Non-linear cyclic analysis and equivalent Von-Misses stress and equivalent strain is calculated. Also a comparison is carried out between silo with bracings and grids and silo with isolating devices and pile foundation. The load-displacement graph is also plotted to compare the load carrying capacities of different silos. Maximum equivalent Von-Misses stress and force reaction values were noted.

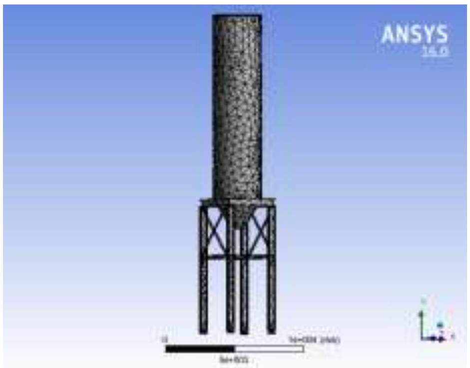


Fig. 2. Meshing on silo with elliptical shaped isolating device

D. *Results and Discussions*

After the analysis of the structures, the results are noted. The maximum equivalent Von-misses stress, equivalent strain and force reaction values are shown in table I. Fig. 3 shows the equivalent Von-misses stress of silo with elliptical shaped isolating device. Fig. 4 shows the displacement vs. force reaction graph. Table II shows the natural frequency obtained in modal analysis.

- In the case of silo with bracings and grids the natural frequency obtained is 14.096 Hz which is the highest value among them.
- In the case of silo with elliptical shaped isolating device it has an equivalent stress of 74.158 MPa and equivalent strain of 0.46577. So it has a lower strain without much increase in stress.
- In the case of silo with pile foundation it has more load carrying capacity having a value of 1308800 N.

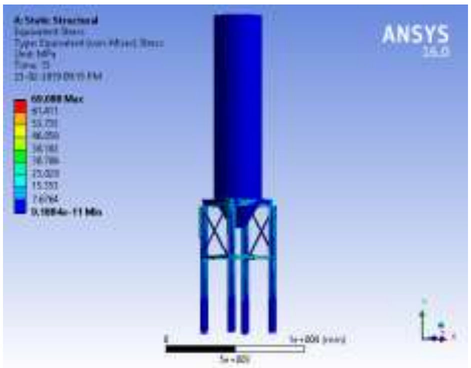


Fig. 3. Equivalent Von-Misses stress of silo with elliptical shaped isolating device

Anjana V L and Biby Aleyas, "Finite Element Analysis of Elevated Steel Silos under Seismic Vulnerability Using Different Types of Basement Techniques," *International Research Journal of Advanced Engineering and Science*, Volume 4, Issue 2, pp. 330-333, 2019.

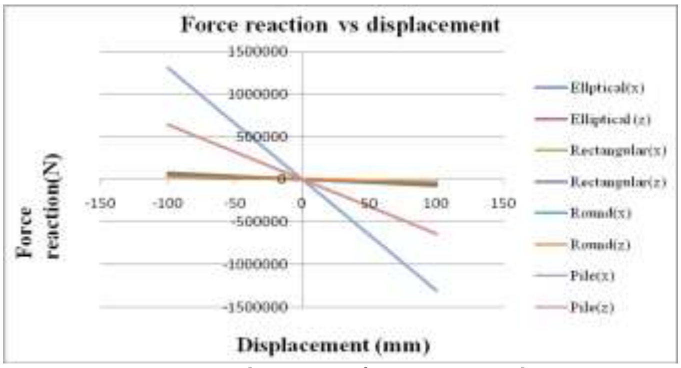


Fig. 4. Displacement vs. force reaction graph

TABLE I. Maximum equivalent Von-Misses stress, strain and force reation

Silo with	Maximum equivalent Von-Misses stress (MPa)	Maximum equivalent strain	Maximum force reaction (N)
Bracings and grids(x)	524.49	0.0048917	1289500
Bracings and grids(z)	577.93	0.0029051	601730
Without bracings and grids(x)	583.2	0.0031782	1220100
Without bracings and grids(z)	646.07	0.0032451	238440
Bracing only(x)	681.67	0.0037134	1276800
Bracings only(z)	376.06	0.0052921	644920
Elliptical shaped isolating device(x)	69.088	0.58917	56905
Elliptical shaped isolating device(z)	74.158	0.46577	45391
Rectangular shaped isolating device(x)	89.433	0.57737	80247
Rectangular shaped isolating device(z)	141.09	0.43927	59736
Round shaped isolating device(x)	57.505	066891	42915
Round shaped isolating device(z)	55.843	0.5573	36251
Pile foundation(x)	652.96	0.0041561	1308800
Pile foundation(z)	687.06	0.0049547	639360

TABLE II. Natural frequencies of silos

Silo with	Frequency (Hz)
Bracings and grids(x)	0
Bracings and grids(z)	0
Without bracings and grids(x)	13.921
Without bracings and grids(z)	14.096
Bracing only(x)	0
Bracings only(z)	0
Elliptical shaped isolating device(x)	0
Elliptical shaped isolating device(z)	0
Rectangular shaped isolating device(x)	0
Rectangular shaped isolating device(z)	0
Round shaped isolating device(x)	0
Round shaped isolating device(z)	2.3544
Pile foundation(x)	0
Pile foundation(z)	0

IV. CONCLUSIONS

Different types of basement techniques are used in silos to protect it from seismic forces. Silo with elliptical shaped isolating device carries lower stain without much increase in stress. Silo with pile foundation carries more load than any other types of silos. So it can be concluded that silo with pile foundation is better to carry load.

- Commonly all are using bracing and grid type arrangement for silos to resist seismic force.
- When we are using bracing and grid system there is not much variation in stress. Therefore it is not a good retrofitting solution for seismic protection. It is unprotected in the presence of external forces.Therefore an additional retrofitting method is introduced.
- Isolating devices with different shapes such as elliptical, rectangular and round shapes are introduced.
- Elliptical shaped isolating device provides better results. Because it has a lower strain without much increase in stress. It controls stress without increase in strain. Therefore elliptical shaped isolating device is better.
- Silo with pile foundation has more force reaction. So it is a good method.
- Result of modal analysis gives us the information that silo without bracings and grids are good in natural frequency.

ACKNOWLEDGEMENT

I wish to thank the Management, Principal and Head of Civil Engineering Department of Ilahia College of Engineering and Technology, affiliated by Kerala Technological University for their support. This paper is based on the work carried out by me (Anjana V L), as part of my PG course, under the guidance of Mrs. Biby Aleyas (Assistant Professor, Ilahia College of Engineering and Technology, Muvattupuzha, Kerala). I express my gratitude towards her for her valuable guidance.

REFERENCES

[1] Raj Kumar Janghel, R. C. Singh (2018), "*A Survey Approach of Analysis of Cylindrical Steel Silo Structure Under Seismic Condition"*, Department of Civil Engineering, RSR RCET Bhilai, INDIA, 2, 331-334.

[2] Christoph Butenweg, Julia Rosin, Stefan Holler (2017), "*Analysis of Cylindrical Granular Material Silos under Seismic Excitation*", Germany, 2017.

[3] Alper Kanyilmaz, Carlo Andrea Castiglioni (2017), "*Reducing the seismic vulnerability of existing elevated silos by means of base isolation devices"*, Department of Architecture, Built Environment and Construction Engineering, Politecnico di Milano, Italy Neapolis University Pafos, Cyprus, 477-497.

[4] Dr. Alice Mathai, Ann Stifily Steephen (2015), Elizabeth Thomas, Neethu Kumaran, Shema Sara Mathew, " *Finite Element Analysis of A Stiffened Steel Silo"*, Department of Civil Engineering, Mar Athanasius College of Engineering Kothamangalam, India, Vol. 3, Issue 1, 1-5.

[5] P. Castaldo, B. Palazzo, P. Della Vecchia (2015), "*Seismic reliability of base-isolated structures with friction pendulum bearings"*, Dept. of Civil Engineering, University of Salerno, via Giovanni Paolo II, 84084 Fisciano, SA, Italy, 80-93.

[6] Yang Zhao, Qing-shuai Cao, Liang Su (2013), "*Buckling design of large circular steel silos subject to wind pressure"*, Space Structures Research Center, Zhejiang University, Hangzhou 310058, China, 337-349.

[7] Adam J. Sadowski, J. Michael Rotter (2013), "*Buckling in Eccentrically Discharged Silos and the Assumed Pressure Distribution"*, American Society of Civil Engineers, 858-867.

[8] Adam J. Sadowski, J. Michael Rotter (2012), " *Structural Behavior of Thin-Walled Metal Silos Subject to Different Flow Channel Sizes under Eccentric Discharge Pressures"*, American Society of Civil Engineers, 922-931.

[9] Ramakrishna Vemula, K. Venkateswararao (2012), "*Design and Optimization of Silo using FEM"*, Department of Mechanical Engineering, Sir C.R.R.College of Engineering, Eluru-534007, West Godavari Distt. A. P., Vol.2, No.2, 640-647.

[10] Adem Dogangun, Zeki Karaca, Ahmet Durmus, Halil Sezen (2009), "*Cause of Damage and Failures in Silo Structures*", J. Perform. Constr. Facil., 23(2): 65-71.