ANALYSIS OF HIGH RISE SILO ON THE BASIS OF DIFFERENT LOAD WITH SHEAR WALL

Shraddha Pandey[1], Akhand Pratap Singh[2], Parmeshwar Sahu[3] , Shiva Verma[4]

[1] M.Tech Scholar, Dept. of Civil Engineering, Shri Rawatpura Sarkar University, Raipur
[2] Assistant Professor, Dept. of Civil Engineering, Shri Rawatpura Sarkar University, Raipur
[3] Assistant Professor, Dept. of Civil Engineering, Shri Rawatpura Sarkar University, Raipur
[4] Assistant Professor, Dept. of Civil Engineering, RSR Rungta College of Engineering and Technology, Bhilai

---***---

Abstract - *Shells with various shapes are being studied. B. Elliptical hemispherical, conical, and cylindrical shells. These structures usually fail by spasming with external pressure. Cylindrical steel silos are large, slender structures used to store materials such as cement, grain, flyash, soot, and coal sawdust. They are specialized structures, subject to a variety of unconventional loading conditions ranging from tons to hundreds to thousands of tons, leading to unusual failure modes. The main purpose of this work is to extend our current knowledge of silo strength and buckling/collapse. In particular, referring to the construction of steel silos on individual supports, it is to provide practical and valuable design assistance for the design and construction of future silos, and to develop new ones. Investigative aspects for further investigation. In this work, steel silo structures were considered according to literature data and different shear wall curvatures were applied. The method applied in this work is Response Spectrum Analysis, a robust dynamic analysis tool in STAAD.Pro. The current study compares the lateral analysis of steel silo structures with different model types and provides the best compared to specific structure types and literature-based structures.*

***Key Words*: silos, cylindrical shells, fly ash, shear wall.**

1. INTRODUCTION

Containers for storing bulk materials are commonly called bunkers, bunkers, silos, or tanks. Although there are no generally accepted definitions for each of these terms, shallow bins such as coal, coke, ore, crushed stone, and gravel are often called bins or bunkers, and are used to store materials such as grain and cement. Tall bins are usually called silos. In this work, silo is a generic term for all steel structures for storing bulk materials. The steel silo is primarily a much lighter structure, can be quickly assembled and dismantled, carries loads through various structural mechanisms, and deforms easily and reversibly when subjected to unbalanced loads. And unlike concrete silos, the load on the foundation is less. Steel silos are therefore widely used for short-term and long-term storage of large amounts of bulk materials and are increasingly being built in recent years in many industries such as mining, chemical, power generation, agriculture and food processing. Common steel silos [29] are usually circular in cross-section and may be above ground or elevated. A typical tower silo generally consists of a conical roof, a cylindrical shell and a conical hopper, which can be supported by a supporting apron or separate supports. The connection between vertical wall and funnel is called transition. The transition is usually provided with a rigid ring. In practice, there are many forms of support, which locally contact the shell, and which may be described as discrete supports. Columns of various widths have been widely used as supports and these may terminate below the transition junction, extend to the eaves or engage into the shell for a short distance. In this work, the term 'discretely supported silo' is used to mean that the silo cylinder is directly supported on local supports of a defined width.

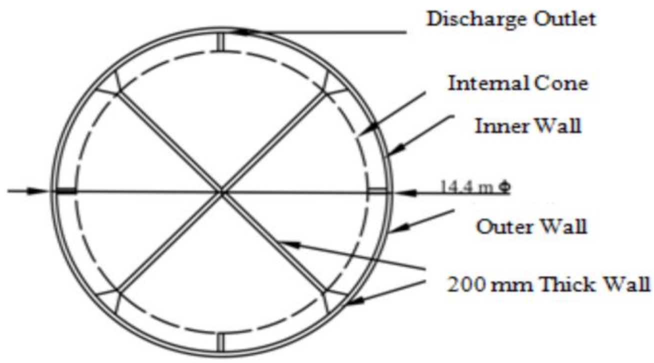


Figure 1.1 Plan of the Silo

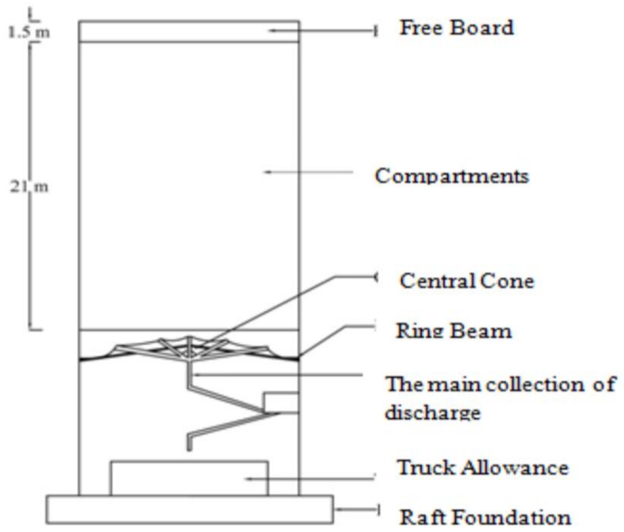


Figure 1.2 Sectional Elevation of Silo

TYPES OF SILOS:-

- **Cement Storage Silos**
- **Tower Silo**
- **Bunker Silos**
- **Bag Silos**
- **Bins**
- **Sand and Salt Silos**
- **Fabric Silos**

1.1 SUITABILITY OF STEEL STRUCTURE

Industrial buildings are generally designed as enclosures that provide functional space for internal activities that involve the use of overhead cranes and overhead equipment. Various forms of construction have been developed over the last 30 years to optimize the cost of steel construction in relation to the space provided. Moreover, their design is highly standardized around the world, which poses a difficult problem in the context of industrial risk assessments related to external hazards such as earthquakes and wind. Their dynamic response is non-trivial given the associated susceptibility to influence earthquake damage. Bulk material storage is therefore an important aspect in any industrial building. Mild steel is manufactured in workshops, which makes construction more productive. Integration into other building systems and rapid assembly at any time of the year with minimal on-site waste is achievable only with structural steel. Architects celebrate the natural beauty of steel and look forward to incorporating it into the design of structures to emphasize the elegance, slenderness, strength and transparency of the frame.

Free Expression No other frame material matches mild steel in its ability to encourage design creativity. Mild steel continues to be the most desirable material for civil engineers. Tools for steel construction are plentiful and far more advanced than tools for other systems. Full integration between analysis, design, detailing and manufacturing software is now used. Sustainability is the middle name for structural steel. Mild steel is the most recycled material on earth. Today's mild steel consists of 88% recycled products and in the future it will be fully recyclable and can be reused without further treatment. Structural steel buildings can be modified for future new applications and loading conditions, vertical expansion and changes. A typical steel column takes up 75% less floor space than a comparable concrete column.

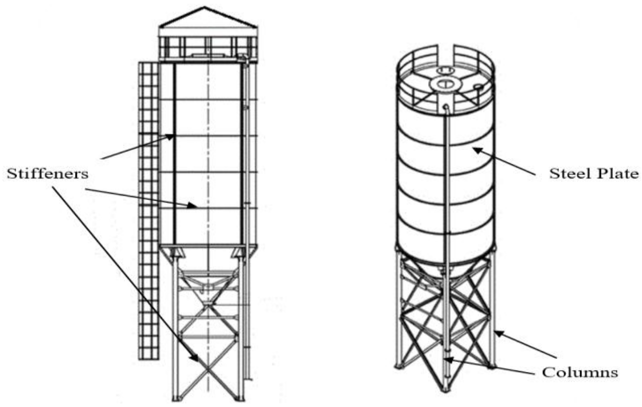


Figure 1.1.1 Elevation and 3-D view of typical silo structure

1.2 LOADS ACTING ON SILOS

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

- weight of structural material
- Storage Material Weight
- Roof and Floor Force
- Wind load
- Imposed loads and deformation load

1.3 FAILURE MODES IN STEEL SILOS
2. HEADING 2

As silos are exposed to different load conditions, different failure modes can occur. Nevertheless, a critical state of wall stress usually ultimately leads to one of the few failure modes. These can be briefly listed as follows:

For the cylindrical shell bursting

1. Buckling under axial (vertical) compression

2. Hoop (ring) buckling under compression

3. Membrane shear buckling

4. Local collapse near silo support

For the conical hopper

1. Collapse or burst of hopper body
2. Plastic collapse or burst of hopper/ring connection
3. For transition ring
4. Buckling of the transition ring
5. Plastic collapse of the transition ring
6. Direct support at local supports of defined width.

For the transition ring

1. Transition Ring Buckle
2. plastic collapsation of the transition ring.

1.4 EARTHQUAKE EFFECT ON SILO STRUCTURE

Several representative silos have been damaged or collapsed in recent earthquakes around the world. Earthquakes often cause silo damage and/or collapse, resulting in significant economic loss as well as loss of life. Seismic ground motion has three components and produces two structural loads: vertical and horizontal. The effects of vertical seismic loads on relatively heavy silo designs are usually small, while the effects of lateral loads can be significant, especially in tall silos containing heavy materials. Horizontal seismic load magnitude is directly proportional to the weight of the silo. The higher the silo height, the higher the center of gravity of the silo structure. Assuming that the horizontal seismic load is applied approximately at the center of mass, the moment arm of the lateral load and corresponding bending moment at the base will increase. The increased bending moment results in an uneven distribution of pressure on the silo floor, which can be significantly greater than the pressure due to gravity. An earthquake can also damage the top of a silo if the materials contained in the silo are allowed to vibrate inside the silo during an earthquake.

2. LITERATURE REVIEW

Rotter (1990) [1] described the results of a study on elastic-plastic collapse of axially loaded internally pressurized perfect thin cylindrical shells adjacent to the shell support. The failure mode often known as "elephant's foot" buckling which governs the design of many practical bin, silo, and tank structures were studied. The results are compared with previous design recommendations and a new simple equation is proposed for use in design.

Alauddin and Ahmad (1995) [3] did full scale analysis of circular silo having different types of supports and subjected to various loading conditions revealed that the conventional method is not adequate in predicting the values of stress resultants required for design of a silo.

Teng (1997) [4] investigated the effects of various factors on the plastic out-of-plane buckling behavior and strength of ring beam, leading to the eventual development of a simple plastic buckling approximation for design use. An annular plate ring beam at the transition junction of a uniformly-supported steel silo or tank is subject to a large circumferential compressive force derived from the radial component of the meridional tension in the conical hopper. Under this compressive force, the ring beam may fail in one of several possible modes, including out-of-plane buckling.

Croll (2006) [5] when thin cylindrical shell walls of tanks and silos are subject to combinations of internal pressure and axial compression, local form of buckling failure occur. They are axis symmetric and influenced by the end or intermediate support conditions. This paper outlines the basis of an analytical solution to the inherently nonlinear elastic–plastic buckling into axisymmetric modes.

Bischoff (2008) [6] 3-D analyses of shells comparing 3D-shell foundations, three dimensional solid elements and surface-oriented shell formulation were done. Comparison is made with theoretical formulation, finite element technology and consistency. Advantages and drawbacks of the different concepts are discussed. Distinguished the case of thin shells, were locking effect play a predominant role and the analysis of 3D structure. A dilemma appeared, it is impossible to design an element which is completely free of locking and passes the patch test at the same time.

Dash and Raju (2008) [7] studied the bucking behavior of compression loaded composite cylindrical shells wit reinforced cut-outs by ANSYS. They consider composite loaded composite cylindrical circular shells for buckling analysis. The effect of cut-outs and how their position influences the buckling strength of the shell were studied. The presence of cut outs can increase the deformation and stress concentration around it. Also, critical loading can be increased by reinforcing the cutouts.

3. METHODOLOGY

3.1 STEPS OF METHODOLOGY

- Silo data collection
- Model generation.
- Enter Geometry and Assign Properties
- Apply Boundary Conditions and Apply Loads
- Specify Analysis Type and Run Analysis
- Read, Compare, and Review Results
- Existing Designs and follow the steps above.

3.2 METHOD AND MODEL

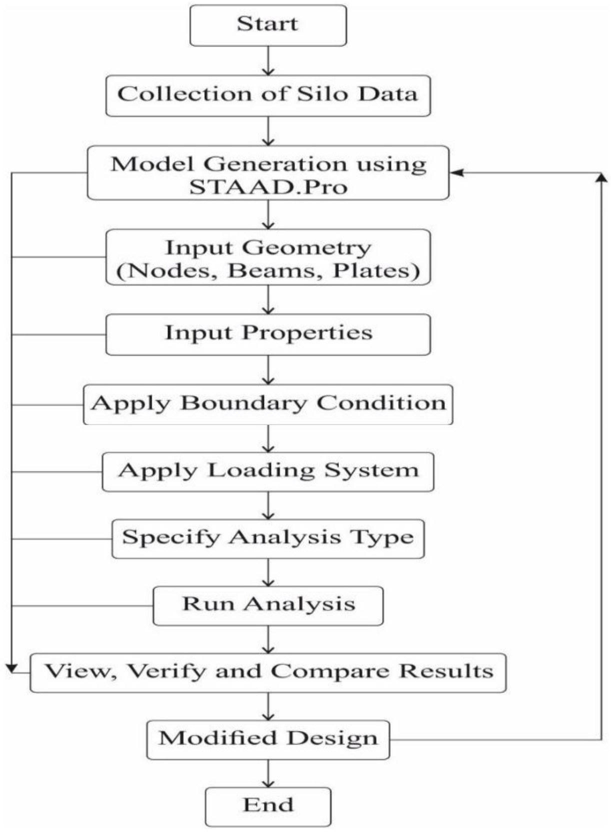


Figure 4.1 Methodology flowchart

3.3 MODELING AND ANALYSIS IN STAAD.PRO

Methods of Analysis

A. Command line editing method
B. Graphical method
1. Modeling
2. Loading
3. Analysis
• Elastic Analysis
• P-Delta Analysis
• Buckling Analysis
• Cable Analysis
4. Reading Results
• Table Results
• Graphical Results

3.4 STRUCTURE CONFIGURATION

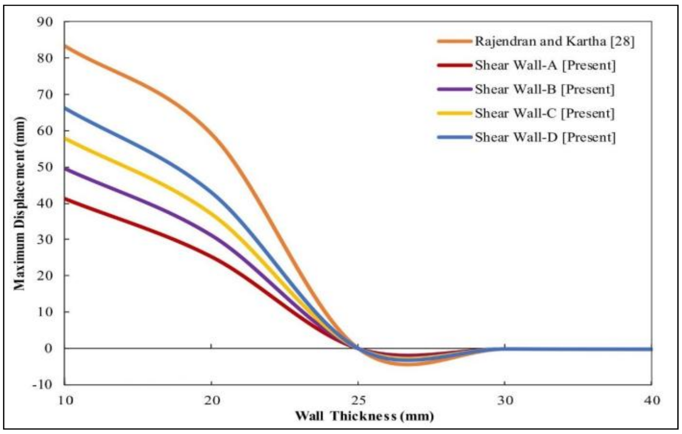
Details	Description
Cement Steel Silo Structure Capacity	100 tonne
No. of Supports (Steel pipe is fixed to the foundation)	4
Support Connected up to Height or Level (entire silo volume together with the conical hopper supporting the material)	2.2m Level
Steel Silo Wall Thickness	10mm – 40mm
Total Height of Steel Silo	11.5m
Silo Cylinder Diameter	1.6m
Behaviour of Material	Isotropic and Elastic
Young's Modulus	21000 MPa
Poisson's ratio	0.3
mass density	7800kg/m³
The loading on the structure is considered as per following calculations	
Unit weight of Iron ores	37.0 kN /m²
Diameter (d) of circular silo	7.00 m
Height (h1) of cylindrical portion of circular silo	8.05 m
Height (h2) of Hopper portion	3.50 m
Weight of Roof	18.5 kN
Size of column diameter	500mm
Stiffeners of Size ISA 70 x 70 x 8mm	0.083kN/m
Spacing of Horizontal stiffener	1.10m
Spacing of vertical stiffener are staggered with spacing	0.88m
Size of opening	500mm diameter
Weight of lining (assumed)	0.25 kN/m²
Weight of top cover with gritting	4kN/m²
Equipment load (assumed)	15 kN
Chute load (under choked condition)	10 kN
Conveyor load	5 kN
Unit weight of plate	0.628 kN/ m²
Earthquake load for the structure has been calculated as perIS-1893(Part 1):2002	
Zone (Z)	II
Response Reduction Factor (RF) For Braced Frame	4
Importance Factor (I)	1.5
Soil condition	Medium
Zone factor	0.1
Damping Ratio (DM)	0.02
Wind load for the structure has been calculated as per IS 875 (part-3)	
Wind speed	6 kmph (average)
Terrain category	2
Structure class	B
Risk coefficient (k1 factor)	1
Topography (k3 factor)	1
Temperature forces data	
Coefficient of thermal expansion α in °K of steel	12×10^{-6}
Temperature difference taken	20° C

4. RESULTS AND DISCUSSIONS

4.1 MAXIMUM DISPLACEMENT

Table 4.1 Comparison of maximum displacement results for different type of structure

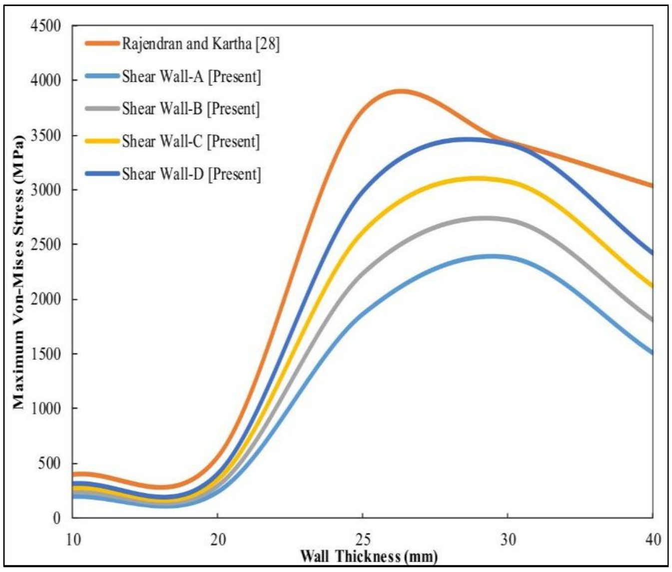
Thickness of Plate (mm)	Shear Wall-A [Present]	Shear Wall-B [Present]	Shear Wall-C [Present]	Shear Wall-D [Present]
10	41.3037	49.6479	57.9921	66.3362
20	25.3038	31.218	37.1322	43.0464
25	0.0124	0.0149	0.0174	0.0199
30	-0.0768	-0.0878	-0.0989	-0.1099
40	-0.1074	-0.129	-0.1505	-0.1721



4.2 MAXIMUM VON-MISES STRESS

Table 4.2 Comparison of maximum von-mises stress results for different type of structure

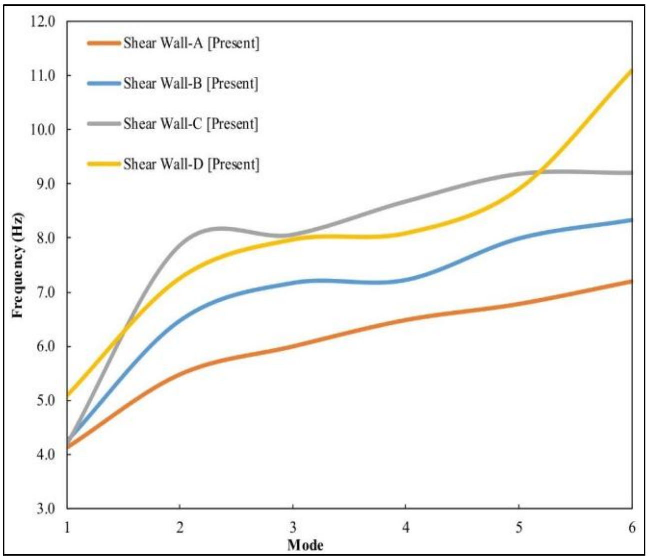
Thickness of Plate (mm)	Shear Wall-A [Present]	Shear Wall-B Present	Shear Wall-C Present	Shear Wall-D Present
10	195.11	234.53	273.95	313.37
20	238.53	294.28	350.03	405.78
25	1866.48	2238.62	2610.76	2982.89
30	2384.79	2727.93	3071.07	3414.20
40	1508.60	1811.59	2114.58	2417.57



4.3 COMPARISON OF FREQUENCY (HZ) DUE TO SEISMIC ANALYSIS

Table 4.3 Comparison of frequency (Hz) due to seismic analysis for different structure type with six modes

Mode	Shear Wall-A [Present]	Shear Wall-B [Present]	Shear Wall-C [Present]	Shear Wall-D Present
1	4.13	4.25	4.19	5.09
2	5.48	6.47	7.87	7.26
3	5.99	7.17	8.07	7.97
4	6.48	7.22	8.68	8.09
5	6.77	7.98	9.19	8.90
6	7.187	8.323	9.208	11.085



5. CONCLUSIONS

Analysis of all types of structures and discussion of all results led to the following conclusions. A structure using earthquake-resistant walls.

• From this work there is good agreement between the response spectrum analysis performed to determine the site shear wall effect on the seismic behavior of the building and the behavior of the structure.

• It is also concluded that steel silo structures with increased plate thickness also have reduced displacements from all structure types considered in this work, but from an economic point of view the cost increases with increased plate thickness. I was.

• In this study, we also found that the frequency generation of the structure was lower in Shear Wall A type for 6 different modes.

• For a 100 tonne capacity steel silo design, 10mm wall thickness and 3mm ring reinforcement, the design under consideration provides a significant increase in design stability, but Shearwall-A does not conform to the specified type and literature. Provides more reliable performance compared to The main advantage of steel silo construction compared to concrete silo is that steel silo is cheaper compared to concrete silo construction, so less time and cost compared to concrete silo construction due to the damage caused during construction. can be re-installed with.

REFERENCES

[1] Suvarna Dilip Deshmukh and Rathod S.T, “Comparison of Design & Seismic Behaviour of RCC silo”, International Journal of Science and Research, Vol.4, Issue 5, ISSN: 2319-7064, 2015.

[2] Mateusz Sondej, PiotrIwicki, Jacek Tejchmannand Michał Wójci, Critical assessment of Eurocode approach to stability of metal cylindrical silos with corrugated walls and vertical stiffeners, Thin-Walled Structures, Vol 95, no: 335-346, 2015.

[3] Marek Piekarczyk, Tomasz Michałowski, Dawid Kowalczyk, “Examples of designing steel shell structures according to eurocodes”, Technical transition, 2015.

[4] Eutiquio Gallegoa, Angel Ruizb and Pedro J. Aguadob, “Simulation of silo filling and discharge using ANSYS and comparison with experimental data”, Computer and electronics in agriculture, Elsevier, Vol 118, pp. 281-289, 2015.

[5] John W. Carson, “Limits of Silo Design Codes, Practice Periodical on Structural Design and Construction”, ASCE, Vol. 20, Issue 2, 2015.

[6] Krishna T. Kharjule1, Minakshi B. Jagtap, “Seismic Analysis of R.C.C. and Steel Silo” International Journal of Computational Engineering Research, Vol 5, Issue 7, pp 24-27, 2015.

[7] M. Wojcik and J. Tejchma, Simulation of buckling process of cylindrical metal silos with flat sheets containing bulk solids, Thin-Walled Structures, ELSEVIER, Vol 93, pp 122-136, 2015.

[8] Manfred Bischoff, “Modelling of shell with the three-dimensional finite element”, the sixth international conference on computation of shell and spatial; structure, 2008.

[9] Ramnatha Dash and Anand Raju, “Buckling behavior of compressive loaded composite cylindrical shell with reinforced cut outs”, “International journal of engineering research and application”, vol2, Issue 5, pp 2044-2048, 2008.

[10] Adem Dagungun, Z Karaca, A Durmus , “Cause of damage and failure in Silo structure ”,Journal of performance of construction facilities, Vol 23, Issue 2, pp 65-71 2009.

[11] Mueller.A, P.Knoedel and B.Koelle, “Critical Filling Levels of Silos and Bunkers in Seismic Design” in 15WCEE, LISBOA, 2012.

[12] Hamdy H.A and Abdel-Rahim, “Response of cylindrical wheat storage silo to seismic loading”, Journal of engineering science, pp 2079-2102, 2013.

[13] Yang Zhao, Qing-shuai Cao, Liang Sunand Lukasz Skotny, “Buckling design of large circular steel silos subject to wind pressure”, Thin-Walled Structures, Vol 73, no: 337-349, 2013. Ashwini Bindari and K.N.Vishwanath, “Analysis of Seismic and Wind effect on Steel Silo Supporting Structure”, International Journal of Research in Advent Technology, Vol.2, No.9, 2014.

[14] Dhanya Rajendran, “Comparison of lateral analysis of reinforced concrete and steel silo”, International journal of civil engineering and technology” Vol 5, pp 16-24, 2014.

[15] P. Iwicki, J. Tejchmann, and J. Chróścielewski, “Dynamic FE simulations of buckling process in thin-walled cylindrical metal silos”, Thin-Walled Structures, Vol 84, no: 344-359, 2014.

[16] Afzal Ansari, Kashif Armaghan and Sachin S.kulkarni, “Design and Optimization of RCC Silo”, International Journal for Research in Applied.

[17] J Michael Rotter, "Local collapse of axially compressed pressurized thin steel cylinder", Journal of structural engineering (ASCE), Vol 116, No: 7, 1990.

[18] J.W Carson, R.T Jenkyn, "Load development and structural consideration in silos design", Presented at reliable flow of particular solid, 1993.

[19] Md. Alauddin and Sobhrabuddin Ahmad "Design force and moment in circular silos based on Finite element analysis", Journal of civil engineering division, Vol CE23 No:1, 1995.

[20] J. G. Teng, "Plastic buckling approximation for transition ring beams in steel silos", Journal of structural engineering (ASCE), Vol 123(12): 1622-1630, 1997.

[21] James G. A. Croll, "Design Analysis of Tank and Silos", Journal of structural engineering ,132(2), pp. 43-49, 2006.