# FE Analysis of RC Circular Silo with Variation in Height and Hopper Angle with Constant Diameter

Arun L[1], Mamatha K.K[2]
[1] Assistant Professor, Department of Civil Engineering, Vidya Vikas Institute of Engineering & Technology, Mysuru, Karnataka, India.
[2] P.G Student, Department of Civil Engineering, BGS Institute of Technology, B G Nagar, Karnataka, India.

***Abstract***

*In this topical sprouting and industrializing era. India is methodically growing up in Steel industry. Meanwhile, India is moving astoundingly towards economic growth in steel. The competitions in India are growing up day by day, in rising industries like Ceramics , Cement , Textiles industry etc., for the storage of solid raw materials. After so many research work carried out, it is still necessary to modify and alter the requirement of storing raw materials in a modified way. "Silos" is a special Shallow or Deep Structure, usually it has no distinctive or proper definition and can be defined usually by saying that it is used for storing "Solid bulks" materials. Furthermore, in other simple way it may be termed as Bins, Bunkers, Silos, or Tanks. "Silos" may be constructed of Steel or RCC (Reinforced cement concrete).These structures becomes important as it requires throughout the year in "Material handling" and "Food processing" plants for storing granular or fine materials i.e., {grains (in use for agriculture purpose),or fermented feed known as "Silage"}.*

**Keywords -** *FEM, Silo, SAP2000.*

## I. INTRODUCTION

Finite element analysis is traditionally a numerical method, basically from branch of mechanics of solids. A numerical Finite element analysis method can be simplified by saying " A solution that "Approximate" the exact solution " and hence in simple words Finite element analysis gives approximation to exact solution.

To solve any Differential or Integral equation a numerical method finite element is assumed to be discretizing a element into piecewise approximation called "Finite elements" and obtaining the functions of parameters by reducing the errors.

In wide range of engineering problems, the finite element method is a influential tool in solving numerical solutions. Finite element method can be applied in many fields like Dynamics, Solid mechanics, Structure analysis, Electrical analysis, Aerospace, Acoustics.

Steps of formulation in Finite element by plane stress and plane strain involves "Discretization " or "Mesh" generation involved during the pre-processing. Irregular, un deformed, geometric domain and its properties, connectives, physical constraints and their loadings are to be defined. Linear system of equations are solved by applying boundary conditions. Development of Finite element analysis in new era involving, Finite element analysis of integration converted into CAD design software. During analysis the self adaptive of mesh take place. Parallel computing of nodes take place in huge size during analysis of a problem model. Physical problem is analysed from the range of microscopic to macroscopic level in a multi-scale dynamic simulation analysis.

## II. LITERATURE REVIEW

Suvarna Dilip Deshmukh and Rathod S.T [1] **:** Investigation was carried out on a industrial circular silo in Bhopal with concrete flat bottom is analysed and designed as per Indian Code provisions IS 4995 (Part 1)-1974 and also referring other Standard Codes like Euro code and ACI code. Cement is usually stored in Indian industries abundantly, thus the stored material inside the silo exerts traction force, frictional shear as well as normal pressure these parameters should be considered in design and also in consideration during seismic action. Strength design method is more speculative one. In calculating pressures, ACI codes is more speculative with other code provisions.

Dhanya Rajendran and Unni Kartha G [2] : Discussed about a comparative study on RCC and Steel silo of lateral analysis. Critical deformation are found at middle portion both in RCC and Steel silo. Steel silo shows more deformation. RCC silo shows less stress and displacement in wind load cases. Displacement decreases as the plate thickness increases meanwhile, the stress increases in Steel silo. Deformation and stresses will be more during empty condition than that of fully loading condition.

Krishna T Kharjule and Minakshi B Jagtap[3] : Discussed about Seismic analysis carried out for both RCC and steel silo. Displacement is seen maximum for RCC silo without shear wall and displacement decreases for Steel silo with shear wall by using steel plate and thus increases the rigidity of the overall structures. RCC and Steel silo with shear wall experiences less time period of structures. In Time history analysis for both RCC and Steel silo base shear increases and acceleration of silo decreases.

Hamdy H.A. Abdel-Rahim [4] : Investigation was carried out for wheat silos and its behaviour under seismic load. In earthquake areas, the ground motion effects and maximum pressure is significantly occurs at the base of silo. Slight fluctuations are obtained at tall silos. In large diameter silos, shear force and bending moment actions provoked by the earthquake ground motion. Silos are adversely affected by behaviour of earthquake by seismic response through dynamic analysis. Vibration of material increases in squat silo of larger diameter.

Riya Dey and Abhirup Bhattacharjee [5] : Discussed about the comparison of RCC and Steel hopper designs. Dead weight is more in RCC hopper, whereas steel hopper are much less in dead weights. RCC hopper is cheaper compare to steel hopper and are more durable and stable. RCC hopper gives optimal result with a thickness having 250mm when compared with steel hopper having thickness of 10mm. Steel hopper are basically long usage, cost effective and very suitable in the areas of mining.RCC is more durable and suitable for storing granular materials.

## III. SCOPE,OBJECTIVE,METHODOLOGY

- This paper represents the geometric parameters or overall geometry like
  - * Hopper angles
  - * Varying heights
  - * State of stress in cylindrical wall
  - * Effects undergone by silos with different types of materials and its varying unique characteristic behaviour in silos.
- The object and an attempt of this work is to carry out an analysis, outlined the results obtained from analysis and studying various parameters like,
  - * The effects and influences of wall pressure and stress factors undergone by different materials by keeping the wall as rigid.
  - * Stress resultant, Forces, Displacement, Base shear, are investigated and computed in graphical form.
- Two different materials with varying density along with different filling conditions i.e., fully filled, partially filled (1/4,1/2) are chosen by keeping diameter constant with varying heights of cylindrical and hopper portion.
- Analysis are done for different loads i.e., gravity and lateral loads (Static analysis) and load combinations are incorporated.

### GEOMETRIC PARAMETERS OF SILO

| Description | **Model 1** | **Model 2** | **Model 3** |
|---|---|---|---|
| Material 1 | Wheat | Wheat | Wheat |
| Material 2 | Cement | Cement | Cement |
| Volume | 600 $m^3$ | 600 $m^3$ | 600 $m^3$ |
| Density of material 1 (ρ) | 8 $KN/m^3$ | 8 $KN/m^3$ | 8 $KN/m^3$ |
| Density of material 2 (ρ) | 15.5 $KN/m^3$ | 15.5 $KN/m^3$ | 15.5 $KN/m^3$ |
| Angle of repose (ϕ) | $30^\circ$ | $45^\circ$ | $60^\circ$ |
| Diameter of silo (d) | 6 m | 6 m | 6 m |
| Hopper bottom opening | 1 m | 1 m | 1 m |
| Height of cylindrical portion | 20.65 m | 20.23 m | 19.50 m |
| Height of hopper portion | 1.44 m | 2.5 m | 4.33 m |

**Table 1: Material properties**

| | |
|---|---|
| $f_{ck}$ | 30 $N/mm^2$ |
| $f_y$ | 415 $N/mm^2$ |
| Density of concrete (ρ) | 25 $KN/m^3$ |
| Cylindrical Beam (Top & Bottom ) | 300x300 mm |
| Conical hopper Beam | 200x200 mm |
| Column | 500x500 mm |
| Bin | 200 mm |
| Column height | 8 m |
| No of columns | 6 no's |

**Table 2 : Load Combination**

- DL+LL+MAT1
- DL+LL+MAT2
- 1.5(DL+LL+MAT1)
- 1.5(DL+LL+MAT2)
- 1.2(1DL+EQ)
- 1.2(2DL+EQ)
- 1.2(1DL+WL)
- 1.2(2DL+WL)
- 0.9(1DL)+1.5EQ
- 0.9(2DL)+1.5EQ

Table 3 : Hand Calculation of Seismic base shear ($V_b$)

| | |
|---|---|
| Zone | V |
| Zone factor (Z) | 0.36 |
| Importance factor (I) | 1 |
| Response reduction factor (R) | 5 |
| Damping ratio | 5% |
| Soil type | II |
| Sa/g | 2.5 |
| Column | (0.50 x 0.50) m |
| Conical Hopper Beam | (0.20 x 0.20) m |
| Cylindrical Beam (Top & Bottom) | (0.30 x 0.30) m |
| Thickness of Shell and Hopper | 0.2 m |
| Column Length | 8 m |

| | | | |
|---|---|---|---|
| Design horizontal seismic coefficient ($A_h$) = $\frac{Z}{2} \times \frac{I}{R} \times \frac{Sa}{g}$ | 0.09 | 0.09 | 0.09 |
| Design seismic base shear ($V_b$) $V_b = A_h * W_1$ | 666.51 KN | 703.32 KN | 746.44 KN |
| Design seismic base shear ($V_b$) $V_b = A_h * W_2$ | 1071.51 KN | 1108.32 KN | 1151.44 KN |

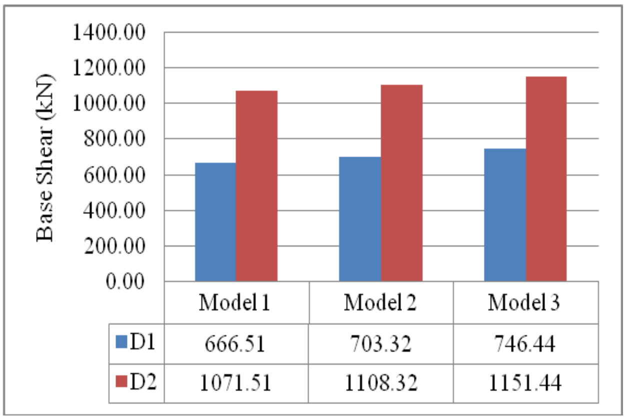



Fig 1: Combination of three cases of Seismic base shear (KN)

**GENERATED SAP2000 MODEL**

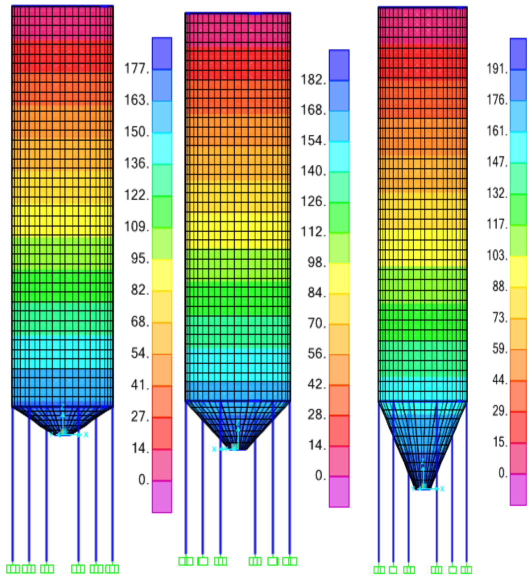
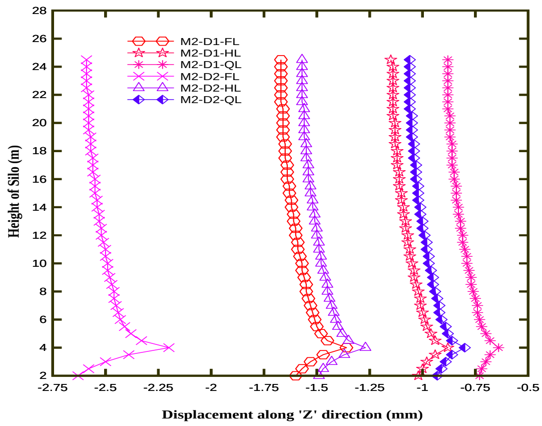


**Fig 2: Generated SAP2000 model having load intensity with variation in hopper angle(30°, 45° & 60°) with constant diameter**

## IV. RESULTS

### 1. DISPLACEMENT GRAPH FOR FULL, HALF AND QUARTER LOAD CONDITIONS



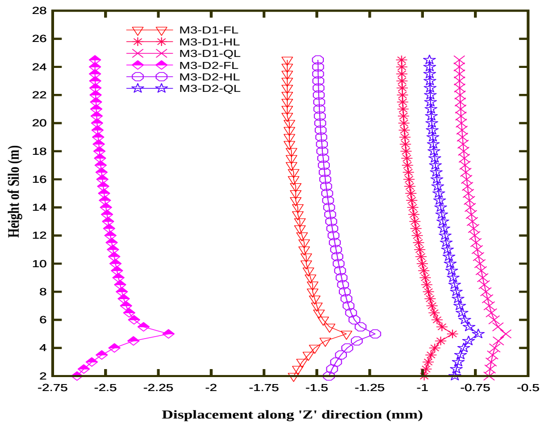



Fig 3 : Combination of Displacement graph for hopper angle 30°, 45° & 60° for full, half, quarter condition with material having different densities

2. **FORCE RESULTANT** for full load conditions for hopper angle 30°, 45° & 60° in fxx direction

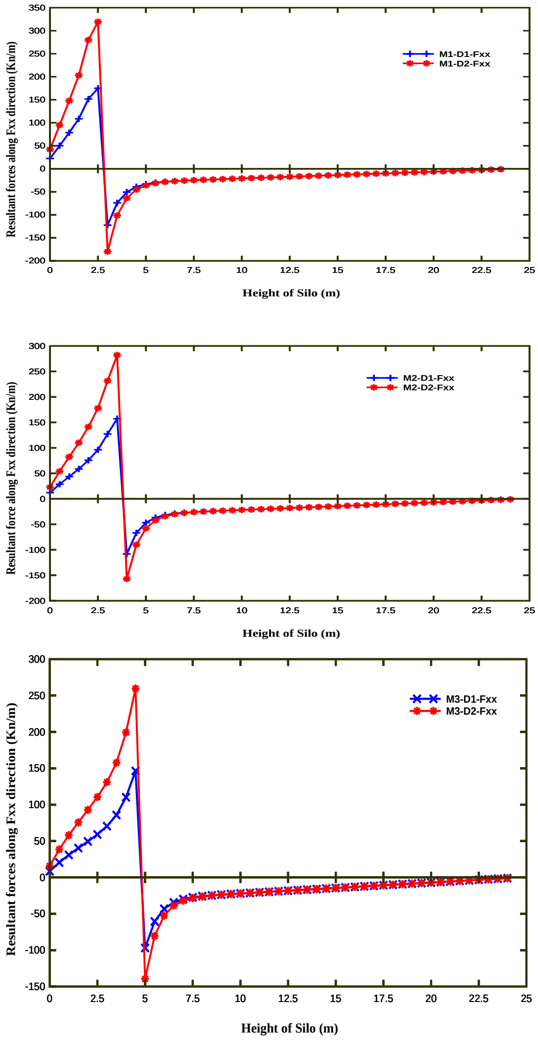
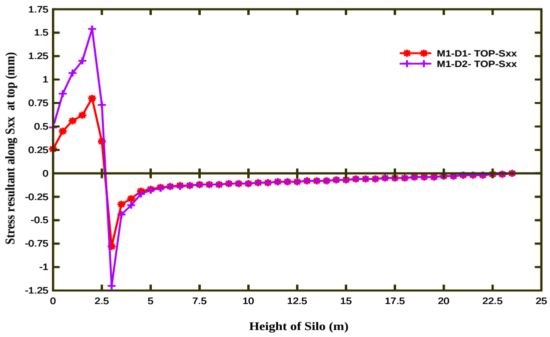



Fig 4 : Height v/s Resultant Force for hopper angle 30°, 45° & 60° for full load condition with material having different densities

3.**Shear Resultant** for full load conditions for hopper angle 30°, 45° & 60° in Sxx (Top & Bottom) direction



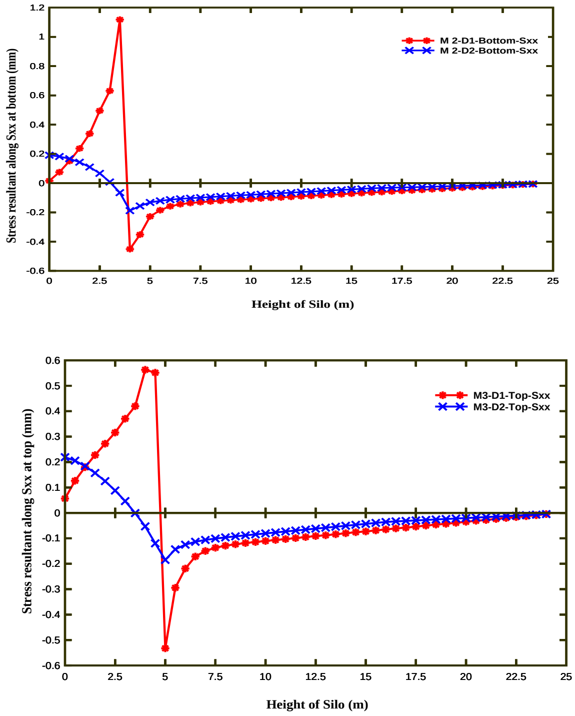




**Fig 5 : Height v/s Shear Resultant for hopper angle 30°, 45° & 60° for full load condition with material having different densities**

## V. CONCLUSION

1. 'Higher lateral displacement' are seen in silos having fully filled condition other than half and quarterly filled condition.
2. The variations is observed only in hopper portion whereas the cylindrical portion is linear, it is clearly seen that displacement following linear variations can be used for safety purpose for fully filled condition.
3. Seismic weights of the material increases due to its varying densities and has a affect on stress at junction of wall and hopper section.
4. Base shear increases up to 30 to 40 % due to the material densities.
5. Stored materials and its varying densities is directly proportional to the state of stress in cylindrical portions

## REFERENCES

[1] Suvarna Dilip Deshmukh, Rathod S.K (2015) "Comparison of design and seismic behaviour of RCC silo" International journal of science and research, volume 4, Issue 5.

[2] Dhanya Rajendran, unni kartha G "Comparison of Lateral analysis of reinforced concrete and steel silo" International journal of civil engineering and technology, volume 5, Issue 12, December (2014) pp 16-24.

[3] Krishna T Kharjule, Minakshi B Jagtap "Seismic analysis of RCC and steel silos" International journal of computational engineering research, volume 5, Issue 7, July 2015.

[4] Hamdy H.A. Abdel-Rahim "Response the cylindrical elevated wheat storage silos to seismic loading" IOSR journal of engineering, volume 4, Issue 1, pp 42-55.

[5] Riya dey, Abhirup bhattacharjee "Comparison between RCC and steel hopper designs" International journal of civil

engineering and technology , volume 6, Issue 6, June (2015), pp 114-123.
[6] K.Dharani and D. Jeyakumar (2016) "A brief review on bunkers and silos" International journal for research in applied science and engineering technology", volume 4,Issue X, ISSN: 2321-9653.
[7] Mohamed T. Abdel-Fattah, Ian D. Moore, and Tarek T. Abdel-Fattah, (2006) "Behaviour of elevated concrete Silos filled with saturated Solids", NRC Research Press Web, Vol. 227, pp (33-239).
[8] Nateghi F and Yakhchalian M (2012) "Seismic Behaviour of Silos with Different Height to Diameter Ratios Considering Granular Material-structure Interaction", Structural Engineering Research Centre, Iran, Vol. 25, No. 1, pp ( 26-37).
[9] ACI Committee 318, Building Code Requirements for Reinforced Concrete (ACI 318-83), American Concrete Institute, Detroit, 1983.
[10] ACI Committee 313, Recommended Practice for Design and Construction of Concrete Bins, Silos, and Bunkers for Storing Granular Materials, ACI Standard 313-77 and Commentary, American Concrete Institute, Detroit, revised 1983, 38 pp.