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# Dynamic Analysis of Steel Silo using Wind Load As Per Indian Standard

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***Abstract*—Structural response to earthquakes is a dynamic phenomenon that depends on dynamic characteristics of structures and the intensity, duration and frequency content of the exciting ground motion. Dynamic analysis procedures are categorized as either linear dynamic analysis or nonlinear analysis. In the present work, effect of wind load is carried out for the silo; variation along the height is studied. The Load combinations are considered as per Indian code. The results in terms of Fundamental natural period, Design Base shear, Lateral Displacements, reactions in columns are compared for the two different silo models considered in the present study.**

***Keywords*— Silo, Plates, Surface, Natural Frequency and STAAD. ProV8i.**

## I. INTRODUCTION

For steel silo, wind is considered as major source of loads. For the purpose of calculating the wind pressure distribution around a cylindrical structure of circular cross-section IS:875 Part-III, is used. To estimate such type of loads it is required to model the silo as a cantilever, fixed to the ground. In this model the wind load is acting on the exposed face of the silo to create predominant moments. But there is a problem that wind does not blow at a fixed rate always. The Indian code IS: 875(Part-III): 1987, equivalent static method is used for estimating wind loads. In this procedure the wind pressure is determined which acts on the face of the silo as a static wind load. The static wind method of load has been proved satisfactory for normal, short and heavy structures. The effect of wind on the structure as a whole is determined by the combined action of external and internal pressure acting upon it. In all cases, the calculated wind loads act normal to the surface to which they apply. The liability of a building to high wind pressures depends not only upon the geographical location and proximity of other obstructions to air flow but also upon the characteristics of the structure itself. For the purpose of calculating the wind pressure distribution around a cylindrical structure of circular cross-section, the value of external pressure coefficients given in Table 18 of Indian standard IS:875-PART-III (*clause no 6.2.2.8*) should be used provided that the Reynolds number is greater than 10000. They may be used for wind blowing normal to the axis of cylinders having axis normal to the ground plane (that is chimney and silos).

## II. OBJECTIVE

This study deals with the linear elastic analysis steel silos under wind loading. In the first part, the wind loading pattern is established and applied to the structure. Two real silos are analyzed. The linear elastic analysis of a silo will reveal the effect of wind rings along the height of silo. The wind pressure distribution is done as per Indian Standard IS: 875-part-III-1987.

### *A. METHODOLOGY*

To achieve the above objective following step-by-step procedures are followed;

- Silos are considered to be fixed at their support. Soil flexibility is not considered in the present study.
- Uniform thickness is considered over the full height of the silos.
- The wind load is taken into consideration for analysis of the silos.
- Two steel silos are considered for the analysis; one for 15m diameter and 31.5 m height and other for 18m diameter and 37.65m height.
- Carry out literature study to find out the objectives of the project work.
- Understand the design procedure of a steel silos as per Indian Standard IS.
- Analyze all the silo model using finite element analysis (STAAD Pro V8i ).
- Applying wind load on the face of the silo and check the wind pressure distribution along the height of the structure.
- Evaluate the analysis results and compare the results.
- The finite element model of the steel silo as described above are shown in fig.1and fig.2.

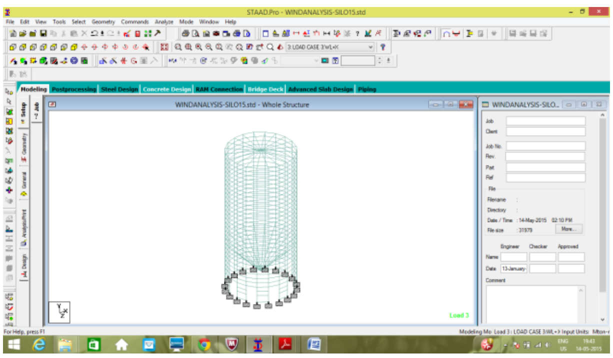

fig.1. Details of finite element idealisation (15m dia)

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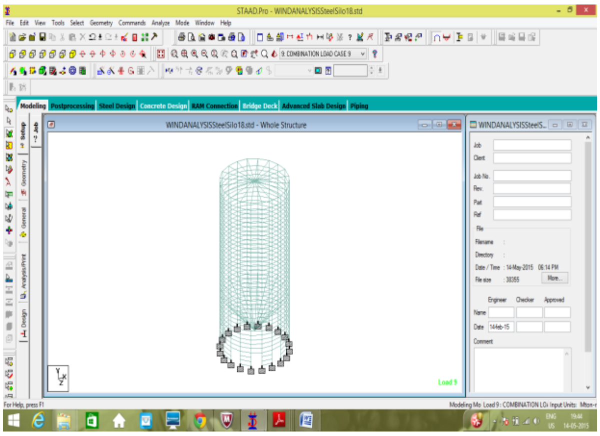

fig.2. Details of finite element idealization (18m dia)

### *B. WIND LOAD CALCULATIONS*

The Design Wind Pressure at any height above mean ground level shall be obtained by following relationship. As per IS:875 (PART-3)-1987

$$p_z = 0.6V_z^2$$

Basic wind speed of 47 m/s with risk coefficient of 1.07 is considered for wind load calculation. This is specified as category 2 in the Design Standard. The Silo is classified as class-B structure because of its maximum dimension (greatest horizontal or vertical) between 20 and 50 m. Terrain factor is obtained from table-2 of IS:875-III.Topographical factor is taken as 1 because the upwind slope is less than 3 °.The wind pressure obtained below is applied on the circumference of Silo.

TABLE I. WIND PRESSURE CALCULATION

| height | 10m | upto20 | upto30m | upto31.5 | upto37.65m | |
|---|---|---|---|---|---|---|
| Vb= | 47 | | | | | m/s |
| K1= | 1.07 | | | | | |
| K2= | 0.98 | 1.05 | 1.1 | 1.104 | 1.12 | |
| K3= | 1 | | | | | |
| | | | | | | |
| Vz= | 49.2842 | 52.8045 | 55.319 | 55.52 | 56.3248 | m/s |
| pz= | 1.46 | 1.68 | 1.84 | 1.85 | 1.91 | N/m² |

TABLE II. VALUES OF CPE

| Position of Periphery ,θin degrees | Pressure Coefficient Cpe | | |
|---|---|---|---|
| | h/d 7 | h/d 1 | h/d 2 |
| 0 | 1 | 1 | 1 |
| 15 | 0.8 | 0.8 | 0.8 |
| 30 | 0.1 | 0.1 | 0.1 |
| 45 | -0.8 | -0.7 | -0.71667 |
| 60 | -1.7 | -1.2 | -1.28333 |
| 75 | -2.2 | -1.6 | -1.7 |
| 90 | -2.2 | -1.7 | -1.78333 |
| 105 | -1.7 | -1.2 | -1.3 |
| 120 | -0.8 | -0.7 | -0.7 |
| 135 | -0.6 | -0.5 | -0.51667 |
| 150 | -0.5 | -0.4 | -0.41667 |
| 165 | -0.5 | -0.4 | -0.41667 |
| 180 | -0.5 | -0.4 | -0.41667 |

In case of structures where the cladding permit the flow of air with openings not more than about 5 percent of wall area but where there are no large openings, it is necessary to consider the possibility of the internal pressure being positive or negative .The Cpi is algebraically added to the Cpe and the analysis which indicates greater distress of the member shall be adopted. When calculating the wind load on individual structural elements such as roof and walls, and individual cladding units and their fittings, it is essential to take account of the pressure difference between opposite faces of such elements or units.

The pressure coefficients are always given for a particular surface or apart of the surface of a building. The wind load acting normal to the surface is obtained by multiplying the area of that surface or its appropriate portion by the pressure coefficient (Cp) and the design wind pressure at the height of the surface from ground.

TABLE III. CP VALUES CALCULATED

| Position of Periphery , θ in degrees | Cpe h/d 2 |
|---|---|
| 0 | 1 |
| 18 | 0.66 |
| 36 | -0.226 |
| 54 | -1.056 |
| 72 | -1.7 |
| 90 | 1.78333 |
| 108 | -1.3 |
| 126 | -0.627 |
| 144 | 0.043 |
| 162 | 0.41667 |
| 180 | 0.41667 |

TABLE VI. FINAL CP VALUES CALCULATED

| Position of Periphery ,θin degrees | Cpe | Cpi | Cp (Cpe+Cpi) | Cpe | Cpi | Cp (Cpe-Cpi) |
|---|---|---|---|---|---|---|
| 0 | 1 | 0.2 | 1.2 | 1 | 0.2 | 0.8 |
| 18 | 0.66 | 0.2 | 0.86 | 0.66 | 0.2 | 0.46 |
| 36 | -0.226 | 0.2 | -0.026 | -0.226 | 0.2 | -0.426 |
| 54 | -1.056 | 0.2 | -0.856 | -1.056 | 0.2 | -1.256 |
| 72 | -1.7 | 0.2 | -1.5 | -1.7 | 0.2 | -1.9 |
| 90 | -1.78333 | 0.2 | -1.58333 | 1.78333 | 0.2 | -1.99 |
| 108 | -1.3 | 0.2 | -1.1 | -1.3 | 0.2 | -1.5 |
| 126 | -0.627 | 0.2 | -0.427 | -0.627 | 0.2 | -0.827 |
| 144 | 0.043 | 0.2 | 0.243 | 0.043 | 0.2 | -0.157 |
| 162 | -0.41667 | 0.2 | -0.21667 | 0.41667 | 0.2 | -0.62 |
| 180 | -0.41667 | 0.2 | -0.21667 | 0.41667 | 0.2 | -0.62 |

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## III. RESULTS AND DISCUSSIONS

The wind loads are calculated as per the recommendations offered in IS 875-part-III- 1987. These are applied as direct plate pressure and the analysis is performed.

### *A.* BREIF DISCRIPTION OF LOADS

As the analysis is undertaken through the application of STAAD Ver.8i software, the following input data is provided, so as to permit the calculation of wind loads;

a) Wind speed= 47 m/s
b) Terrain category=2
c) Structure class= B
d) Risk coefficient (K1 factor)=1.07
e) Topography (K3 factor)=1

Wind load is defined as auto lateral load pattern as per IS 875 1987 in STAAD Ver.8i, then as exposure from area objects, and the Cp coefficients, calculated according to IS 875 1987, are assigned to each element at the various height of the shell structure, which is given in table below:

TABLE V. WIND LOAD PRESSURE DISTRIBUTION

| Position of Periphery ,θin degrees | height(m) | 10 | 20 | 30 | 31.5 | 37.65 |
|---|---|---|---|---|---|---|
| | pz (N/m²) | 1.46 | 1.68 | 1.84 | 1.85 | 1.91 |
| | Cp | | | | | |
| 0 | 1.2 | 1.752 | 2.016 | 2.208 | 2.22 | 2.292 |
| 18 | 0.86 | 1.2556 | 1.4448 | 1.5824 | 1.591 | 1.6426 |
| 36 | -0.426 | 0.62196 | 0.71568 | 0.78384 | 0.7881 | -0.81366 |
| 54 | -1.256 | 1.83376 | 2.11008 | 2.31104 | 2.3236 | -2.39896 |
| 72 | -1.9 | -2.774 | -3.192 | -3.496 | -3.515 | -3.629 |
| 90 | -1.99 | -2.9054 | -3.3432 | -3.6616 | 3.6815 | -3.8009 |
| 108 | -1.5 | -2.19 | -2.52 | -2.76 | -2.775 | -2.865 |
| 126 | -0.827 | 1.20742 | 1.38936 | 1.52168 | -1.53 | -1.57957 |
| 144 | -0.22 | -0.3212 | -0.3696 | -0.4048 | -0.407 | -0.4202 |
| 162 | -0.62 | -0.9052 | -1.0416 | -1.1408 | -1.147 | -1.1842 |
| 180 | -0.62 | -0.9052 | -1.0416 | -1.1408 | -1.147 | -1.1842 |

### *B. MODELLING OF LOADS*

Dead load , live load and wind loads were applied for the analysis. The application of the wind load is show below:

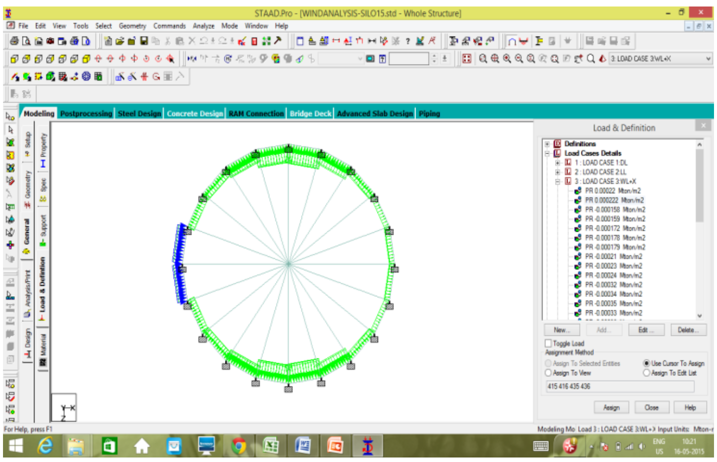

fig.3. Wind load application (top view, 15m dia.)

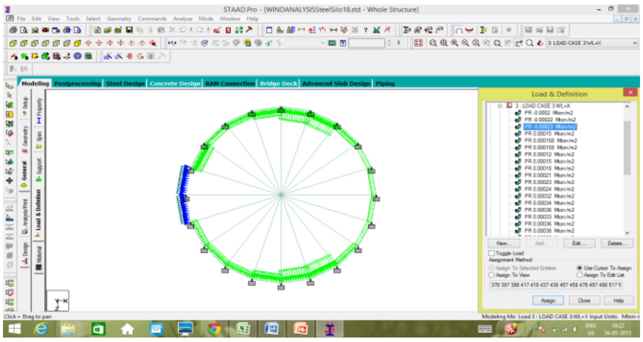

fig.4. Wind load application (top view ,18 m dia.)

The different load combinations have been noted below:
DL = Dead Load
LL = Live Load
WL = Wind Load
Serviceability Limit State
LOAD COMBINATION 4 DL + LL
LOAD COMBINATION 5 DL + 0.8LL + 0.8 WL
LOAD COMBINATION 6 DL + LL
Limit State of Strength / Collapse
LOAD COMBINATION 7 1.5DL + 1.5 LL
LOAD COMBINATION 8 1.2 DL + 1.2 LL + 1.2 WL
LOAD COMBINATION 9 1.5 DL+ 1.5 LL

Table VI. Displacement variation along height STAAD output for wind analysis

| Height(cm) | Deflection-18 m | Deflection-15m |
|---|---|---|
| 100 | 0.07112 | 0.04826 |
| 200 | 0.1016 | 0.07112 |
| 300 | 0.21082 | 0.11684 |
| 400 | 0.23876 | 0.12954 |
| 500 | 0.26416 | 0.14478 |
| 600 | 0.2921 | 0.15748 |
| 700 | 0.3175 | 0.17018 |
| 800 | 0.34544 | 0.18288 |
| 900 | 0.37084 | 0.19812 |
| 1000 | 0.39624 | 0.21082 |
| 1100 | 0.42164 | 0.21082 |
| 1200 | 0.44958 | 0.21336 |
| 1300 | 0.45212 | 0.21336 |
| 1400 | 0.45212 | 0.21336 |
| 1500 | 0.45466 | 0.2159 |
| 1600 | 0.45466 | 0.2159 |
| 1700 | 0.4572 | 0.2159 |
| 1800 | 0.4572 | 0.21844 |
| 1900 | 0.45974 | 0.21844 |
| 2000 | 0.45974 | 0.21844 |
| 2100 | 0.46228 | 0.21844 |
| 2200 | 0.46228 | 0.21844 |
| 2300 | 0.46482 | 0.22098 |
| 2400 | 0.46482 | 0.22098 |
| 2500 | 0.46736 | 0.22098 |
| 2600 | 0.46736 | 0.22098 |
| 2700 | 0.46736 | 0.22098 |
| 2800 | 0.4699 | 0.22098 |
| 2900 | 0.4699 | 0.22098 |
| 3000 | 0.4699 | 0.22098 |
| 3100 | 0.47244 | 0.22352 |
| 3200 | 0.47244 | |
| 3300 | 0.47244 | |
| 3400 | 0.47244 | |
| 3500 | 0.47498 | |
| 3600 | 0.47498 | |
| 3765 | 0.47498 | |

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It may be observed that qualitatively the trend of variation is same for two types of silos. However much larger radial displacements occur with I type silo. This is because the base of the plate structure which happens to be larger will show more displacements as compared to smaller plate structure.

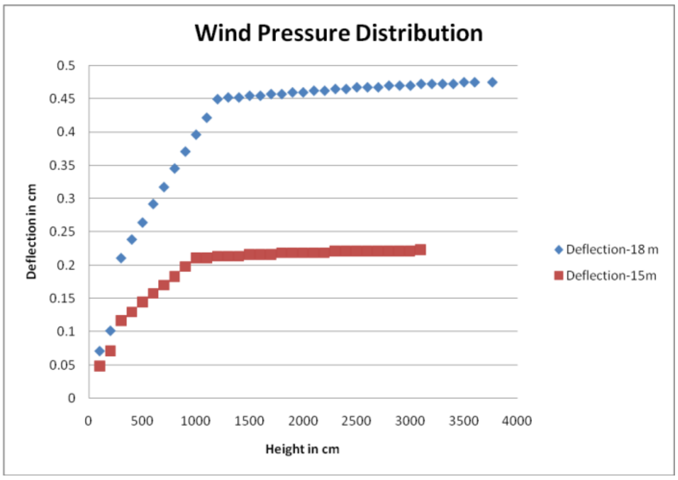


fig.5. Displacement variation with height.

## CONCLUSION

On the basis of the present study, following conclusions are made:

1. The thickness is found to be same for the entire silo.
2. The displacement of Silo with Plate element, are well within the permissible limits. The displacement increases as height increases.
3. The degree of distortion increases with height of the silo.
4. The basic wind speed is applicable to 10m height above the mean ground level for different zones of the country, which continues to grow with the height.

## REFERENCES

[1]. Indian Code of practice for design loads (other than earthquake loads) IS:875-PART-I & PART-II-1987.
[2]. Indian Code of practice for design of wind loads IS: 875-PART-III.
[3]. Indian code of practice criteria for design of steel bins for storage of bulk materials IS:9178-PART-I ;General requirements and assessment of loads, IS:9178-PART-II; Design criteria and IS:9178-PART-III; Bins designed for mass flow and funnel flow.
[4]. Indian Code of practice for silos for grain storage IS:5503(PART-I)-1969.
[5]. Indian Code of practice for general construction in steel IS : 800-2007
[6]. Analysis of steel silo structures on discrete supports by Dr. Hongyu Li.
[7]. Load development and structural consideration in silo design by J.W Carson, Phd and R.T Jenkyn, P.Eng.
[8]. Analysis of seismic and wind effect on steel silo supporting structure by, Ashwini Bidari1, K.N.Vishwanath2 *M. Tech student1 , Dept of Civil Engineering1 , DSCE , Bangalore ,Karnataka, India1 Associate Professor2 , Dept of Civil Engineering2, , DSCE , Bangalore, Karnataka, India2 E-mail: bidariashwini@gmail.com1, vishuknv@yahoo.com².*
[9]. Paulo B. Lourenco.”Types of analysis :linear static ,linear dynamic and non linear static “. www.civil.uminho.pt/masonary.
[10]. A.W Roberts “Developments in silo design for the safe and efficient storage and handling of grains”.
[11]. Adem Dogangun1; Zeki Karaca2; Ahmet Durmus3; and Halil Sezen, M.ASCE4.”Cause of Damage and Failures in Silo Structures”.
[12]. Silos theory and practice by Marcel L. Reimbert and Andre M. Reimbert.
[13]. Parametric Study On Dynamic Response Of Silo Anand Adi [1] , Hemant L. Sonawadekar [2] 1-Post Graduate Student, Department of Civil Engineering, KLEMSSCET, Belgaum, Karnataka, India, 590008 ,2-Assistant Professor, Department of Civil Engineering, KLEMSSCET, Belgaum,Karnataka, India, 590008.