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Effect of Height to Lateral Dimension Ratio on Dynamic Behaviour of Rcc Circular Silo

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***Abstract**: This research work provides an idea of effect of height to lateral dimension ratio on dynamic behaviour of reinforced cement concrete (RCC) circular silo. The various load intensity and structural parameterare calculate using Janssen's theory as per IS: 4995 (Part I and Part II): 1974. Analysis of silo done using Response Spectrum Method and Wind Analysis. The considered silos are studied for different seismic zone i.e. Zone-III and Zone-V as per IS: 1893 (Part-I):2016 and wind analysis is carried out as per IS: 875 (Part-III): 2015. The circular silo is model and analysis is carried out inSTAAD Pro. Result are obtained for the various height to diameter ratio in the form of lateral displacement and base shear. It is seen that if height to diameter ratio increases then the effect of wind load appear in critical load combination for Zone-III whereas for Zone-V earthquake load be a part of critical load combination for lateral displacement. Base shear is increases with height to diameter ratio increase and also for the higher seismic zone.*
***Keywords** -Base Shear, Circular RCC Silo, Lateral displacement, Response Spectrum Method, STAAD Pro, Wind Analysis.*

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I. Introduction

Storage structure likes bins are basically called as silos and bunkers for storing different type of material. Classification of silo and bunker is depending upon the plane of the rupture. If bin in a each way that plane of rupture is intersect the top of the surface then it is called as bunker and if bin structure in a such a way that plane of rupture is intersect the opposite site of the structure is called silos. Silos are generally taller in structure, the height of structure in greater than the diameter, diameter or breath. As per the IS code 4995(Part I):1974 Height/Diameter ratio greater than or equal to two for the reduction of lateral pressure over the large height takes place. Basic shape of silo is circular but as per requirement it could be square, rectangular or polygonal shape and it is provided with roof and bottom which may be conical, pyramidal or flat. Silos are generally supported with number of column, total structure wall, hopper bottom and column is connected by the ring beam to distribute the load. Silo basically design for both vertical and horizontal pressure. The exact pressure calculation is difficult due to the many factor acts during the emptying and filling of material.

The various load act on the silo structure, during the structural design of silo various load applied according to its intended use, size, structure type, material, design life time, location environment in order to assure life safety and to maintain it essential functions. For structural design self-weight of structure should be consider, live load on the top of roof, snow load when needed as per location, wind load as per revisedIS: 875 (Part III):2015 code cyclonic factor should be consider. Seismic load is basic requirement in structural design due to the larger mass concentrated above the slender portion and stored material load acted in horizontal, vertical direction as well as the frictional pressure should be consider. Effect of vertical seismic loads is small as compare to lateral seismic loads on the tall silos. Seismic load magnitude in lateral direction directly related to the weight of silo. In earthquake analysis increase of lateral load induces increase in bending moment results into non uniform pressure at bottom of silo which increase as compare to pressure due to gravity load.

In past many researchers worked on analysis of silo considering effect of earthquake like Afzal Ansari (2016), KashifArmaghan and Sachin S. kulkarni (2016), AshwiniBindari and K.N.Vishwanath (2014), HamdyH.A.Abdel Rahim (2014), Krishna T. Kharjule and Minakshi B. Jagtap (2015), Rajani S Togarsi (2015)and many more, but it is seen from literature survey that no one has considered the effect of cyclonic wind load which is also effective force in the analysis of silos like earthquake load.

1.1 Calculation of Bin Load:-

There are two methods suggested by IS-4995(Part I):1974 is Janssen's Theory and other one is Airy's Theory to calculate bin loads.

Janssen's Theory

The assumption that portion of the weight of the contained material is supported by friction between material and the wall, and only a small portion of weight is transferred to the hopper bottom. Due to this, Rankine's (1857) or Coulomb's (1776) lateral pressure theories cannot be directly applied. The vertical walls of the silo are subjected to direct compression as well as lateral pressure. [15]

Airy's Theory

Airy's analysis is based on Coulomb's wedge theory of earth pressure. By this theory, it is possible to calculate the horizontal pressure per unit length of the periphery and the position of the plane of rupture. [15]

II. Methodology

The aim of analysis is check the behaviour of the circular RCC silo under various force and analysis carried out by using response spectrum method and wind analysis.

2.1 Data considered

Type of silo = RCC Circular silo.
Type of material stored = Wheat (assumed)
Bulk density of material stored = 8.5 kN/m^3 (Table 1, IS: 4995 (Part-I):1974)
Diameter of Silo (D) = 6 m (Assumed)
Depth of cylindrical portion (H) = 12 m, 18 m and 24 m
Height of the conical hopper (H') = 2.5 m
Opening of hopper bottom (d) = 1 m
Height of column above plinth (h) = 6 m
Height of column below plinth (h') = 3 m
Angle of repose = 28° (Table 3, IS: 8730:1997)

2.2 Modelling and analysis

The modelling is done in STAAD Pro. V8i software with the dimension taken under consideration. The model consists of 6 columns with fixed supports, beams, plates and nodes. Figure2.1 shows the top view plan and side view plan in STAAD Pro.

2.3 Section Property

Table 2.1 various structural member sizes obtained for Circular Silo model

Sr. No.	Member	Circular Silo (H/D=2)	Circular Silo (H/D=3)	Circular Silo (H/D=4)
1	Cylindrical wall (H)	300 mm thick	300 mm thick	300 mm thick
		12 m Height	18 m Height	24 m Height
2	Hopper Bottom wall (H')	300 mm thick	300 mm thick	300 mm thick
		2.5 m Height	2.5 m Height	2.5 m Height
3	Column	550 × 550 mm	550 × 550 mm	550 × 550 mm
	Column height above Plinth (h)	6 m height	6 m height	6 m height
	Column height below Plinth (h')	3 m height	3 m height	3 m height
4	Bottom ring beam	550 × 550 mm	550 × 550 mm	550 × 550 mm
5	Top ring beam	300 × 300 mm	300 × 300 mm	300 × 300 mm
6	Plinth beam	550 × 550 mm	550 × 550 mm	550 × 550 mm

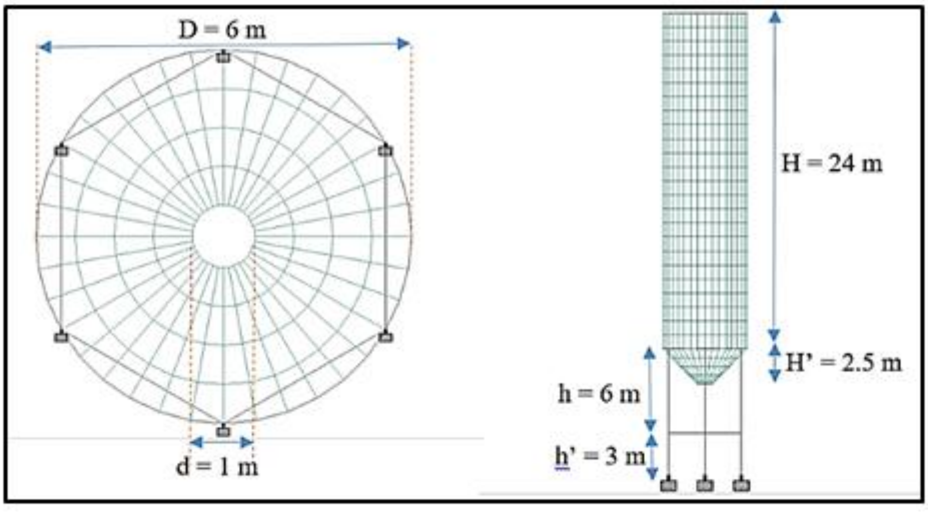

Figure. 2.1 Top view and side view plan on circular RCC silo

2.4 Load Intensity

Structures on earth are generally subjected to two types of loads such as static and dynamic. Static loads are constant where dynamic load varies with time. The structure is rarely subjected to dynamic loads. But these loads cannot be neglected as it may become cause of disaster, mainly in case of earthquake.

The various load calculated for H/D ratio 4 of silo for analysis are as follows:
Horizontal wall pressure at top of cylindrical wall (P_h) = 0.01 kN/m^2
Horizontal wall pressure at bottom of cylindrical wall (P_h) = 41.89 kN/m^2
Frictional wall pressure (P_w) = 10.13 kN/m^2
Vertical Load intensity (Pv) (applied on bottom ring beam) = 34.84 kN/m
Normal Pressure on hopper bottom (P_n) = 52.82 kN/m^2
Live Load on roof = 1.5 kN/m^2
Self-weight of structure

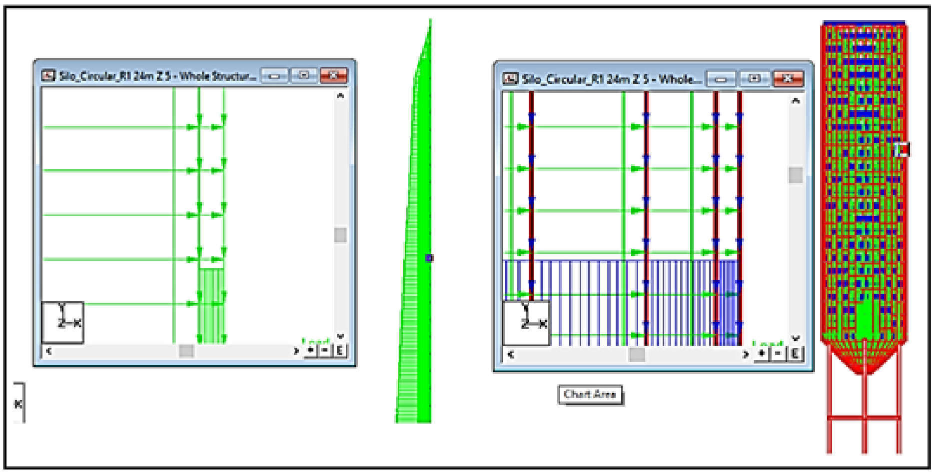

Figure 2.2 Horizontal and frictional pressure on cylindrical wall

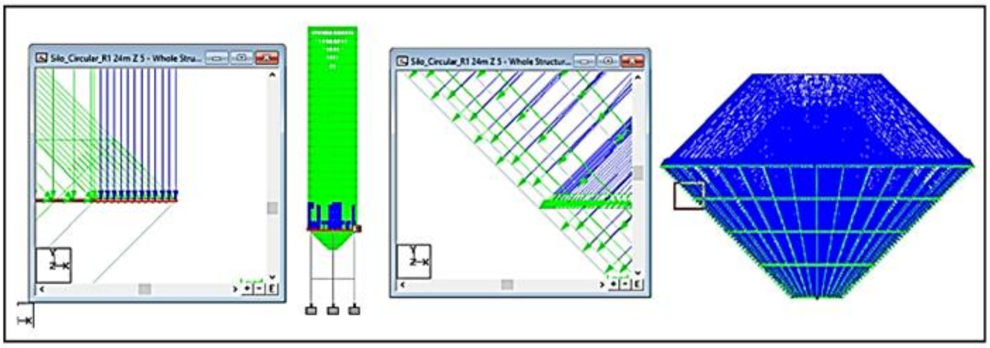

Figure 2.3 Vertical pressure on ring beam and normal pressure on hopper bottom

III. Method of analysis

Response spectrum method is carried out for two seismic zone.
Seismic load parameter details (IS: 1893 (Part-I): 2016):
Zone-III and Zone-V
Z= 0.16 for Zone-III
Z= 0.36 for Zone-V
Soil Type Hard
Important factor I= 1.5
Response Reduction Factor R = 5
Damping ratio= 0.05
Similarly to carried out effect of wind.
Wind load parameter are considered as,
Wind speed V_b = 44 m/s for Zone-III(Mumbai)
Wind speed V_b = 50 m/s for Zone-V(Bhuj)
Terrain category = 3
Probability factor k_1 = 1
Topography factor k_3 = 1

Importance factor for cyclonic region k_4 = 1.3
Terrain roughness and height factor k_2 = Change as per height

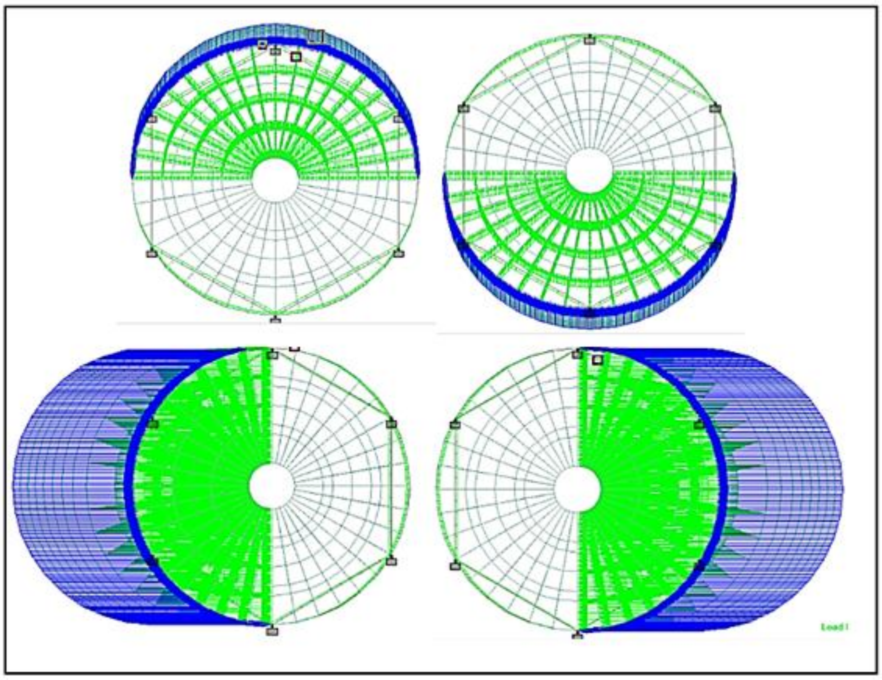

Figure 3.1 Wind pressure on silo in X and Z direction

IV. Results and Discussion

Results are obtained by using Response Spectrum Method and also by considering effect of wind silo model in the form of lateral forces on each node, base shear, maximum lateral displacement and time period.

4.1 Base Shear

Figure 4.1 shows base shear values obtained by dynamic analysis method for 6m diameter of circular silos for different H/D ratio in the form of chart.

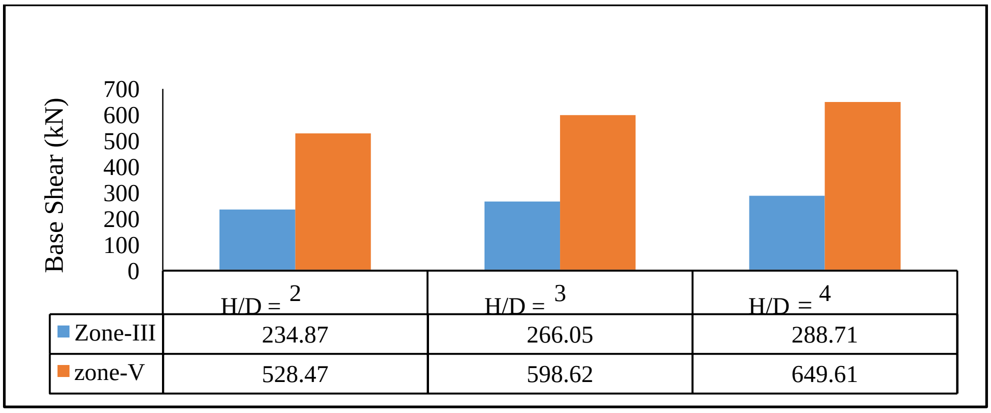

Figure. 4.1 Base Shear in Zone-III and Zone-V for various H/D ratio

Maximum ase shear value is found to be 649.61 kN for Zone-Vand for H/D ratio is 4. Base shear value is increasing with the increasing H/D ratio and also for the higher seismic zone base shear is increases.

4.2 Lateral Displacement

4.2.1 Maximum Lateral Displacement for H/D ratio 2 of circularsilo

Table 4.1 shows maximum node displacement in X and Z direction obtained for 12m cylindrical wall height of silo model for different load case, whereas Figure4.2 shows lateral displacement for the critical load combination in X and Z direction in the form of graph.

Table 4.1- Maximum Lateral Displacement in X and Z Direction for H/D ratio 2 of circularsilo

Load Case	Zone-III		Zone-V	
	X–Direction (mm)	Z–Direction (mm)	X–Direction (mm)	Z–Direction (mm)
Dead Load (DL)	0.058	0.051	0.058	0.051
Live Load (LL)	0.001	0.001	0.001	0.001
Earthquake (X)	7.629	0.013	17.165	0.029
Earthquake (Z)	0.012	7.629	0.029	17.165
Wind (+X)	6.276	0.03	8.242	0.038
Wind (-X)	6.276	0.03	8.242	0.038
Wind (+Z)	0.03	6.276	0.038	8.242
Wind (-Z)	0.03	6.276	0.038	8.242
Critical Load Combination	7.632	7.632	17.168	17.168
	1.0DL + 0.5LL + EQ+X		1.0DL + 0.5LL + EQ+X	

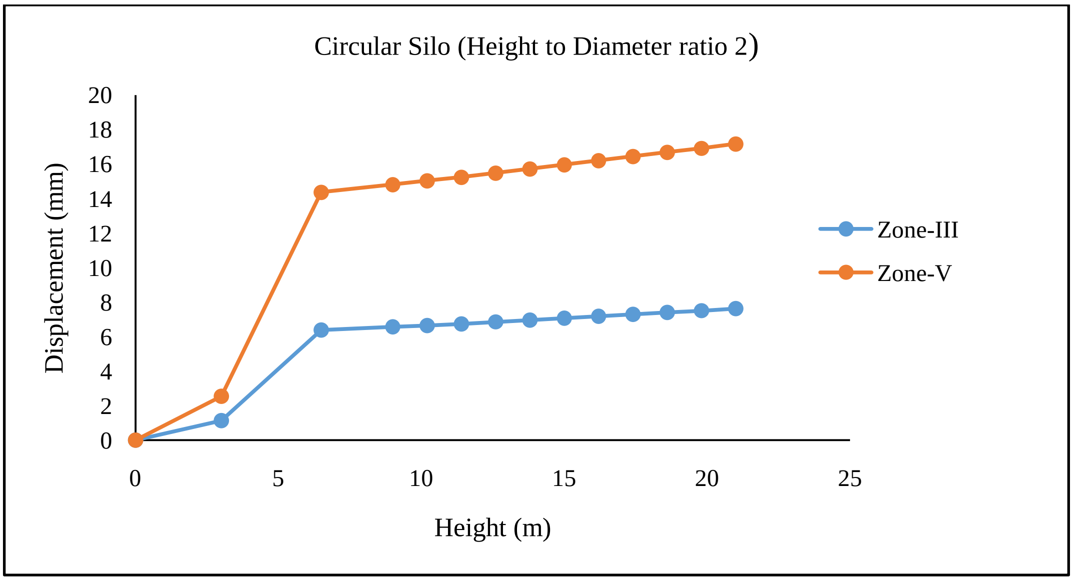

Figure. 4.2 Maximum Lateral Displacement in X and Z Direction for Critical Load Combination for H/D ratio 2 of circular silo

Maximum lateral displacement in X and Z-direction is found to be 7.632 mm at height 21 m that is at top of model in Zone-III for critical load combination 1.0 DL + 0.5 LL + EQ+X and maximum lateral displacement in X and Z-direction is found to be 17.168 mm at height 21 m that is at top of model in Zone-V for critical load combination 1.0 DL + 0.5 LL + EQ+X. It is observed that lateral displacement increases linearly with increase in elevation.

4.2.2 Maximum Lateral Displacement for H/D ratio 3 of circularsilo

Table 4.2 shows maximum node displacement in X and Z direction obtained for 18m cylindrical wall height of silo model for different load case, whereas Figure4.3 shows lateral displacement for the critical load combination in X and Z direction in the form of graph.

Table 4.2- Maximum Lateral Displacement in X and Z Direction for H/D ratio 3 of circular silo

Load Case	Zone-III		Zone-V	
	X–Direction (mm)	Z–Direction (mm)	X–Direction (mm)	Z–Direction (mm)
Dead Load (DL)	0.077	0.067	0.077	0.067
Live Load (LL)	0.002	0.002	0.002	0.002
Earthquake (X)	10.307	0.015	23.19	0.034
Earthquake (Z)	0.015	10.307	0.033	23.19
Wind (+X)	11.837	0.068	15.587	0.09
Wind (-X)	11.837	0.068	15.587	0.09
Wind (+Z)	0.068	11.837	0.09	15.587
Wind (-Z)	0.068	11.837	0.09	15.587
Critical Load Combination	11.84	11.84	23.192	23.192
	1.0DL + 0.5LL + WIND+X		1.0DL + 0.5LL + EQ+X	

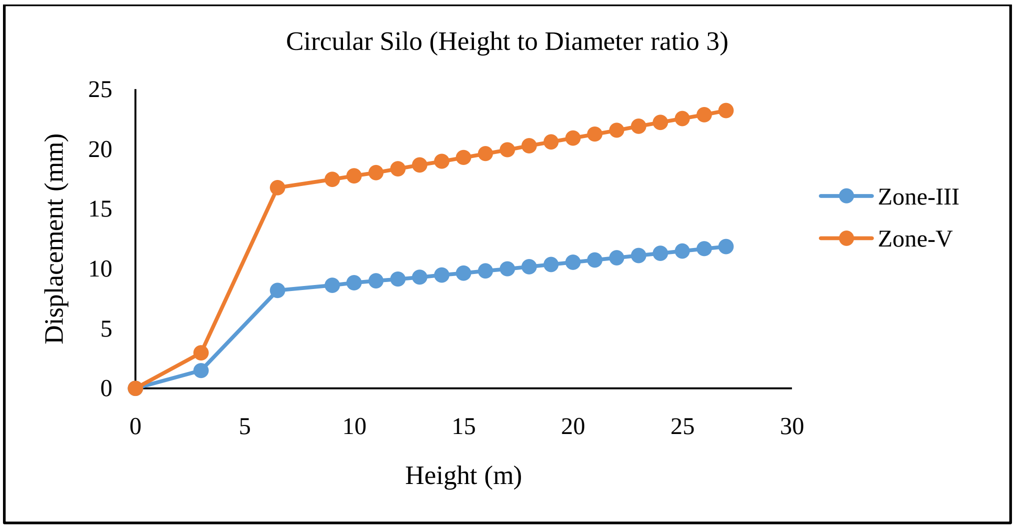

Figure. 4.3 Maximum Lateral Displacement in X and Z Direction for Critical Load Combination for H/D ratio 3 of circular silo

Maximum lateral displacement in X and Z-direction is found to be 11.84 mm at height 27 m that is at top of model in Zone-III for critical load combination 1.0 DL + 0.5 LL + WIND+X and maximum lateral displacement in X and Z-direction is found to be 23.192 mm at height 27 m that is at top of model in Zone-V for critical load combination 1.0 DL + 0.5 LL + EQ+X. It is observed that lateral displacement increases linearly with increase in elevation.

4.2.3 Maximum Lateral Displacement for H/D ratio 4 of circularsilo

Table 4.3 shows maximum node displacement in X and Z direction obtained for 24m cylindrical wall height of silo model for different load case, whereas Figure4.4 shows lateral displacement for the critical load combination in X and Z direction in the form of graph.

Table 4.3 - Maximum Lateral Displacement in X and Z Direction for H/D ratio 4 of circularsilo

Load Case	Zone-III		Zone-V	
	X–Direction (mm)	Z–Direction (mm)	X–Direction (mm)	Z–Direction (mm)
Dead Load (DL)	0.088	0.076	0.088	0.076
Live Load (LL)	0.002	0.002	0.002	0.002
Earthquake (X)	13.417	0.015	30.189	0.034
Earthquake (Z)	0.015	13.417	0.034	30.189
Wind (+X)	20.201	0.097	26.665	0.482
Wind (-X)	20.201	0.097	26.665	0.128
Wind (+Z)	0.097	20.197	0.128	26.665
Wind (-Z)	0.097	20.197	0.128	26.665
Critical Load Combination	20.204	20.204	30.191	30.191
	1.0DL + 0.5LL + WIND+X		1.0DL + 0.5LL + EQ+X	

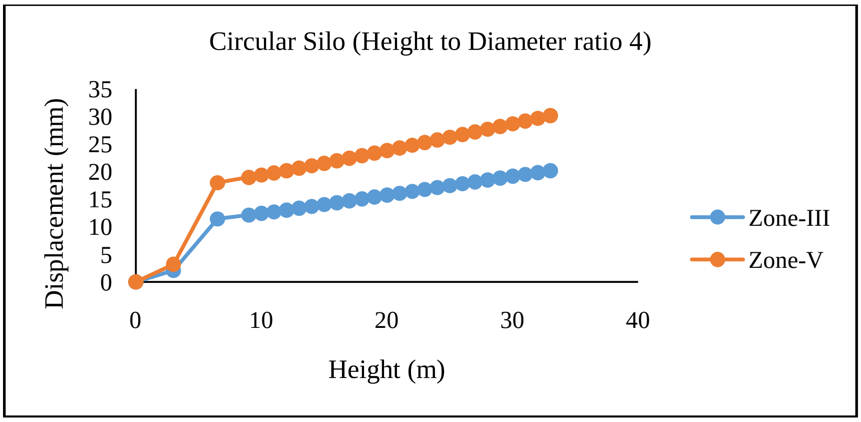

Figure4.4 Maximum Lateral Displacement in X and Z Direction for Critical Load Combination for H/D ratio 4 of circular silo

Maximum lateral displacement in X and Z-direction is found to be 20.204 mm at height 33 m that is at top of model in Zone-III for critical load combination 1.0 DL + 0.5 LL + WIND+X and maximum lateral displacement in X and Z-direction is found to be 30.191 mm at height 33 m that is at top of model in Zone-V for critical load combination 1.0 DL + 0.5 LL + EQ+X. It is observed that lateral displacement increases linearly with increase in elevation.

V. CONCLUSIONS

1. It is observed that base shear is increased with H/D ratio increase and also for the higher seismic zone.
2. Lateral displacement is increase with H/D ratio is increase.
3. As H/D ratio is increase the effect of wind load appear in critical load combination for Zone-III whereas for Zone-V earthquake load be a part of critical load combination.

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