International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 04, April-2019

A Review on Computational Behaviour Analysis of RCC Grain Silo Under Seismic Forces

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***Abstract*—RCC silos which are designed to maintain silages and to provide from the elements to improve life span of stored grains. This analysis and design gives more safety to silo during earthquake intensity. In this study circular RCC silo is analyzed and designed for various heights by both manual design and by using staad pro V8i software for influence parameters such as pressure and displacement. Also it has been analyzed for seismic forces for different zones i.e. zone III, zone IV, zone V and the variations in the displacement are studied.**

Keywords- R.C.C. Silo, displacement, Seismic forces, Wheat grains.

I. INTRODUCTION

1. Vessels of different shapes, sizes and material are required in many industries as well as in agricultural field to store granular or powdery materials which hold the same amount of material in a smaller area in terms land. Silo has the features of water tightness and protect against the moisture.
2. An elevated silo consists of conical roof, a cylindrical shell, conical hopper and could be supported by RCC columns or frames.
3. RCC silos are generally built for permanent bulk storage as it is an economical storage unit in design and reasonable cost.
4. Concrete can offer high water resistance; gives protection to stored materials which requires less maintenance and aesthetic look also it is comparatively free from bulking and damaging.
5. Silos are cantilever structures which are subjected to many unconventional loading. The various types of loads act on these are dead load, wind load, earthquake load etc.
6. The walls of silos are subjected to normal pressure and vertical and horizontal forces produced by stored material. The magnitude and distribution of pressures at different height depends on the properties of material stored silo and filling condition.
7. So the careful evaluation of silos is done for the safe design in a seismic area.

The design of silos is done generally by two methods;

1. Airy's theory
2. Janssen's theory

Airy's theory

Airy's theory is related to coulomb's wedge theory of earth pressure. By which horizontal pressure acting along its circumference and the position of plane of rupture is determined and following parameters can be studied; horizontal pressure, and vertical load and vertical pressure taken by walls.

Janssen's theory

This theory assumes that the friction between material stored and walls of silo supports large portion of weight of material store and hopper bottom supports only small portion of weight.

The walls of silo are subjected to direct compression as well as lateral pressure.

II. METHODOLOGY

The data for numerical example considered for analysis,

Type of silo = R.C.C circular silo
Total height of silo = 18.45m
Type of material stored = Wheat
Density of material stored = 7850N/m^3
Diameter of silo = 5m
Depth of cylindrical portion = 16m
Height of conical hopper = 2.25m
Opening of hopper bottom =0.5m
Coefficient of friction, μ= 0.466, μ'= 0.444
Angle of repose = 45°
Type of soil condition = soft soil
Silo has been analyzed for earthquake forces in staad pro V8i for following zones, i.e. Zone III, Zone IV and Zone V for 10 different filling conditions.
Impact factor = 1
Damping ratio = 5 %

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Description for models-

Model 1: R.C.C silo filled with wheat grains up to 2.25m from bottom of hopper.

Model 2: R.C.C silo filled with wheat grains up to 4.25m from bottom of hopper.

Model 3: R.C.C silo filled with wheat grains up to 6.25m from bottom of hopper.

Model 4: R.C.C silo filled with wheat grains up to 8.25m from bottom of hopper.

Model 5: R.C.C silo filled with wheat grains up to 10.25m from bottom of hopper.

Model 6: R.C.C silo filled with wheat grains up to 11.97m from bottom of hopper.

Model 7: R.C.C silo filled with wheat grains up to 12.25m from bottom of hopper.

Model 8: R.C.C silo filled with wheat grains up to 14.25m from bottom of hopper.

Model 9: R.C.C silo filled with wheat grains up to 16.25m from bottom of hopper.

Model 10: R.C.C silo filled with wheat grains up to 18.25m from bottom of hopper.

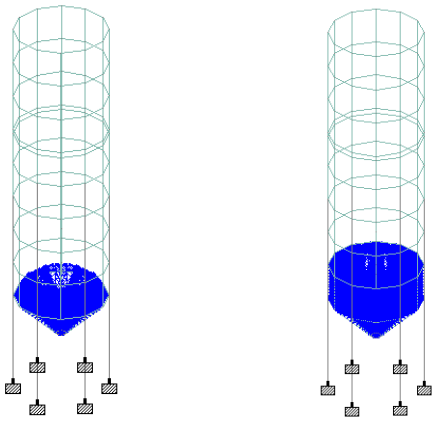

Fig. A showing Model 1 and Model 2

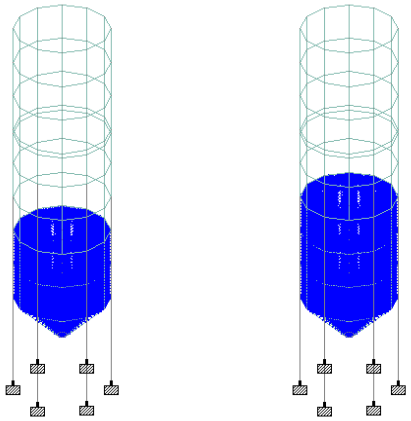

Fig. B showing Model 3 and Model 4

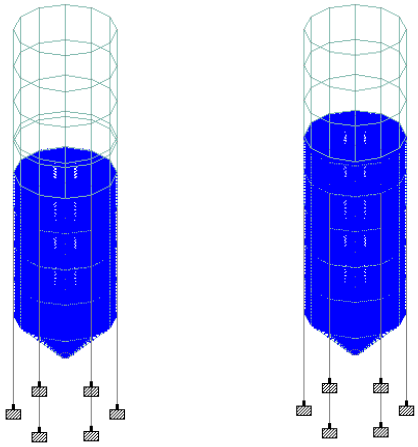

Fig. C showing Model 5 and Model 6

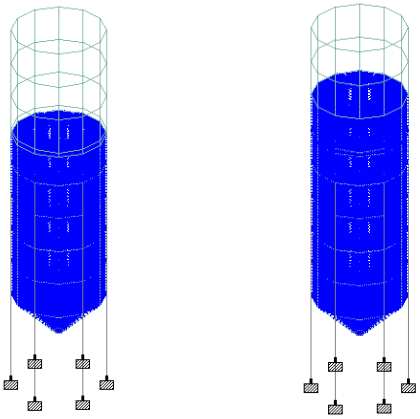

Fig. D showing Model 7 and Model 8

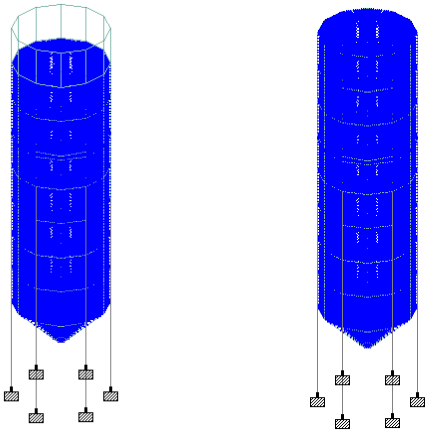

Fig. E showing Model 9 and Model 10

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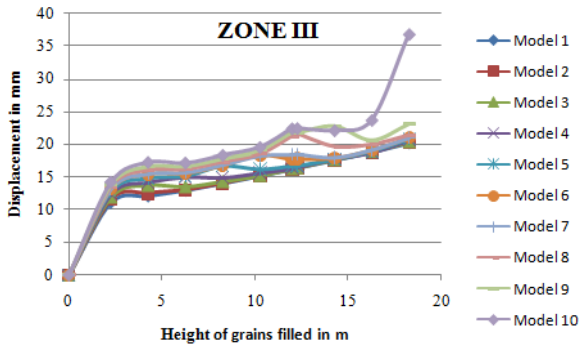
III. RESULTS AND DISCUSSION

Height (m)	Displacements in mm									
	Model 1	*Model 2*	*Model 3*	*Model 4*	*Model 5*	*Model 6*	*Model 7*	*Model 8*	*Model 9*	*Model 10*
0	0	0	0	0	0	0	0	0	0	0
2.25	11.104	11.595	11.915	12.321	12.730	13.065	13.119	13.506	13.886	14.230
4.25	12.104	12.526	13.689	14.115	14.761	15.392	15.416	16.038	16.649	17.256
6.25	12.970	13.008	13.497	14.922	15.095	15.538	15.617	16.160	16.675	17.154
8.25	14.034	14.038	14.284	14.826	16.648	16.734	16.801	17.294	17.840	18.330
10.25	15.186	15.189	15.190	15.546	16.133	18.314	18.199	18.497	19.025	19.538
11.97	16.213	16.216	16.219	16.219	16.635	17.618	18.360	21.252	21.739	22.384
12.25	16.388	16.390	16.394	16.423	16.667	17.702	18.439	21.586	21.653	22.422
14.25	17.610	17.613	17.627	17.653	17.659	17.825	17.925	19.637	22.714	22.089
16.25	18.839	18.841	18.851	18.686	18.898	19.058	19.093	19.968	20.538	23.676
18.25	20.226	20.285	20.377	20.530	20.728	20.910	20.932	21.383	23.025	36.805

Table no. 1. Results for displacements of silo under Zone III

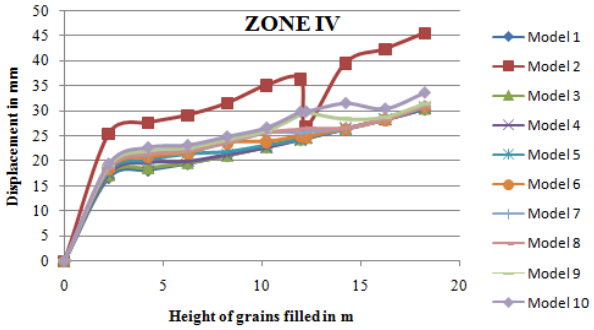


Graph no 1. Comparison of displacements of silo in zone III

1. The displacement for Model 1 at 2.25 m which is at junction where conical shape changes to circular shape is 78.03% as compared to Model 10, where in Model 10 has the highest displacement among all.
2. The displacement for Model 1 at 18.25 m is 54.95% as compare to Model 10, where in Model 10 has the highest displacement among all.
3. The displacement for Model 1 at 11.97 m is 72.43% as compare to Model 10, where in Model 10 has the highest displacement among all.
4. The variations in displacement for Model 1, Model 3, Model 4, Model 5, Model 6, Model 7 and Model 8 are almost same.
5. Model 9 and Model 10 have more displacement as compared to other models.

Height (m)	Displacements in mm									
	Model 1	*Model 2*	*Model 3*	*Model 4*	*Model 5*	*Model 6*	*Model 7*	*Model 8*	*Model 9*	*Model 10*
0	0	0	0	0	0	0	0	0	0	0
2.25	16.656	25.475	17.147	17.467	17.873	18.282	18.617	18.671	19.058	19.438
4.25	18.152	27.656	18.578	19.741	20.167	20.813	21.381	21.469	22.090	22.701
6.25	19.456	29.175	19.580	19.983	21.407	21.580	22.023	22.102	22.645	23.160
8.25	21.042	31.574	21.048	21.301	21.844	23.666	23.751	23.818	24.311	24.857
10.25	22.779	35.171	22.782	22.783	23.139	23.878	25.807	25.792	26.090	26.648
11.97	24.319	36.428	24.322	24.325	24.325	24.944	25.725	26.466	29.359	29.845
12.25	24.581	26.875	24.584	24.588	24.617	24.861	25.896	26.633	29.780	29.847
14.25	26.415	39.625	26.418	26.432	26.440	26.464	26.630	26.730	28.442	31.518
16.25	28.258	42.389	28.260	28.270	28.284	28.313	28.439	28.390	28.856	30.426
18.25	30.339	45.567	30.398	30.490	30.643	30.841	31.033	31.045	31.496	33.610

Table no. 2. Results for displacements of silo under Zone IV



Graph no 2 Comparison of displacements of silo in zone IV.

1. The displacement for Model 1 at 2.25 m which is at junction where conical shape changes to circular shape is 85.68% as compared to Model 10, where in Model 10 has the highest displacement among all.
2. The displacement for Model 1 at 18.25 m is 66.58% as compare to Model 2, where in Model 2 has the highest displacement among all.
3. The displacement for Model 1 at 11.97 m is 66.75% as compare to Model 2, where in Model 2 has the highest displacement among all.
4. The variations in displacement for Model 1, Model 3, Model 4, Model 5, Model 6, Model 7, Model 8 and Model 9 are almost same.
5. Model 2 and Model 10 have more displacement as compared to rest other models.

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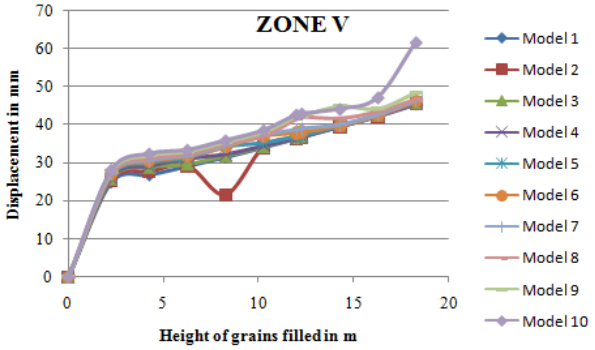
Height (m)	Displacements in mm									
	Model 1	*Model 2*	*Model 3*	*Model 4*	*Model 5*	*Model 6*	*Model 7*	*Model 8*	*Model 9*	*Model 10*
0	0	0	0	0	0	0	0	0	0	0
2.25	24.985	25.475	25.796	26.201	26.610	26.945	27.000	27.387	27.766	28.110
4.25	26.885	27.656	28.819	29.245	29.891	30.459	30.547	31.168	31.779	32.386
6.25	29.182	29.175	29.610	31.135	31.308	31.751	31.830	32.373	32.888	33.367
8.25	31.578	21.574	31.827	32.369	34.191	34.277	34.344	34.837	35.383	35.873
10.25	34.168	34.165	34.170	34.529	35.267	37.197	37.182	37.025	38.008	38.520
11.97	36.478	36.482	36.484	36.485	36.901	37.884	38.626	41.518	42.005	42.650
12.25	36.887	36.875	36.879	36.908	37.152	38.186	38.924	42.071	42.138	42.906
14.25	39.625	39.625	39.639	39.647	39.671	39.838	39.938	41.649	44.726	44.101
16.25	42.357	42.389	42.399	42.362	42.442	42.487	42.504	43.422	44.087	47.130
18.25	45.509	45.567	45.660	45.812	46.011	46.192	46.215	46.666	48.308	61.654

Table no. 3. Results for displacements of silo under Zone V



Graph no 3 Comparison of displacements of silo in zone V.

1. The displacement for Model 1 at 2.25 m which is at junction where conical shape changes to circular shape is 88.88% as compared to Model 10, where in Model 10 has the highest displacement among all.
2. The displacement for Model 1 at 18.25 m is 73.81% as compare to Model 10, where in Model 10 has the highest displacement among all.
3. The displacement for Model 1 at 11.97 m is 85.52% as compare to Model 10, where in Model 10 has the highest displacement among all.
4. The variations in displacement for Model 1 to 8 are almost same.
5. Model 9 and Model 10 have more displacement as compared to other models.

IV. CONCLUSION

1. Maximum displacements in zone III and zone V occurs in Model 10 where the R.C.C silo is filled with wheat grains up to 18.25m from bottom of hopper. Whereas in zone IV maximum displacement occurs in Model 2 i.e., R.C.C silo filled with wheat grains up to 4.25m from bottom of hopper.
2. The value of maximum displacement in comparison to all models for Zone V is 61.654mm which is 1.83 times greater than the displacements for the models of zone IV.
3. In zone III model 10 shows maximum displacement of 36.80 mm for fully filled wheat grains. In zone IV Model 2 shows maximum displacement of 45.567mm for wheat grains filled up to 4.25m from bottom of hopper. In zone V Model 10 shows maximum displacement of 61.654mm for fully filled wheat grains.
4. The Maximum displacement in zone IV occurs in Model 2 because of the variations of stiffness and mass on the walls of silos.
5. At critical height of 11.97m the variation of displacement in all models for zone III and zone V are nearly same whereas in zone IV in Model 2 the variation is more compared to other models because of the pressure intensity governed at that point.
6. It is observed that the behavior of rcc silo will change its behavior due the effect of natural period for different zones and the modes have affect on the displacements.

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