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Analysis and Design of Long Concrete Silo Having Different Height and Diameter under Earthquake Effect

Anurag Ravindra Warade[1], Dr. Tushar G. Shende[2]

[1]M-Tech (SE), Department of Civil Engineering, GHRAET, Nagpur, Maharashtra, India

[2]Associate Professor, Department of Civil Engineering, GHRAET, Nagpur, Maharashtra, India

ABSTRACT

Structures used for storing bulk solids are called bins, bunkers, silos, or tanks. There is no generally accepted definition for these terms, shallow structures containing coal, crushed stone, gravel, and similar materials are called bins or bunkers and tall structures containing materials such as grain, cement and wheat are usually called silos. Elevated silos generally consist of a conical roof, a cylindrical shell and a conical hopper and they could be elevated and supported by frames or reinforced concrete columns. Circular silos (both steel and reinforced concrete) are used to store material in various industries like cement plants (clinkers), power plants (raw coal), oil and gas industry (sulfur pellets) etc. Elevated steel and reinforced concrete circular silo for storage show performance in earthquake reinforced concrete silo stability increases by using shear wall but loss of steel silo in earthquake stability increases using steel panel on opposite side Displacement of structure decreases in case of shear wall panel and stiffness increases.

Keywords : Circular Concrete Silos, Analysis, Conventional Design and Finite Element, Shell Design of silo.

I. INTRODUCTION

Concrete silos are constructed from small precast concrete blocks with ridged grooves along each edge that lock them together into a high strength shell. Much of concrete's strength comes from its high incompressibility, so the silo is held together by steel/concrete hoops encircling the tower and compressing the staves into a tight ring. The vertical stacks are held together by intermeshing of the ends of the staves by a short distance around the perimeter of each layer, and hoops which are tightened directly across the stave edges.

The static pressure of the material inside the silo pressing outward on the staves increases towards the bottom of the silo, so the hoops can be spaced wide apart near the top but become progressively more closely spaced towards the bottom to prevent seams from opening.

Conventional methods of analysis of silos can deal well with axisymmetric loading due to gravity and stored materials. A silo, being an elevated structure, may be subjected to tremendous lateral loads due to wind and earthquake. The conventional methods cannot incorporate the effect of lateral loads in the design procedure effectively. Meridional and hoop forces developed.

Prediction of various stress resultants at critical locations by approximate conventional methods may not always be acceptable .Besides, traditional approach of analysis can not predict any type of moments at all. Despite all such approximations the conventional method of analysis has been used with considerable success in the past. Conservative design approach combined with high factor of safety can be attributed to such success. With the advancement of the versatile and powerful techniques of finite elements it has now become easy to determine more accurately all the design forces at any section of a circular silo ENTIONAL METHOD OF SILO DESIGN

Manual design worked out of silos of specific dimension to know exact design requirement of silo for static and dynamic load condition. Model of silo has made by using STAAD software and carried out its result for static analysis and dynamic analysis Model was made by using M-25 grade concrete to circular shell. And thickness of shell is 150 mm Analysis carried out after removing each column one by one. Janssen's theory used for for pressure calculations After analysis, Area of steel calculated from result of horizontal pressure, direct tension in hopper as well as cylinder.

II. STAAD MODEL AND ANALYSIS

Model of the silo has made in STAAD. There are wind and earthquake factor applied to the model of silo and designed it for sever load cases to get maximum size of section of reinforce concrete member. Wind pressure and

Earthquake forces are assigned by referring basic parameters to check the percentage of steel for static load condition, model analyse and design for static load condition.

Considering **Janssens theory** for present,

$$p_v = \frac{wR}{\mu' n}\left(1-\exp\left(-\frac{\mu' n h}{R}\right)\right)$$

$$p_h = \frac{wR}{\mu'}\left(1-\exp\left(-\frac{\mu' n h}{R}\right)\right)$$

$$n = \frac{(1-\sin\varphi)}{(1+\sin\varphi)} = \frac{(1-\sin 25)}{(1+\sin 25)}$$

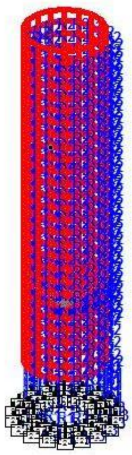
$$= 0.406$$

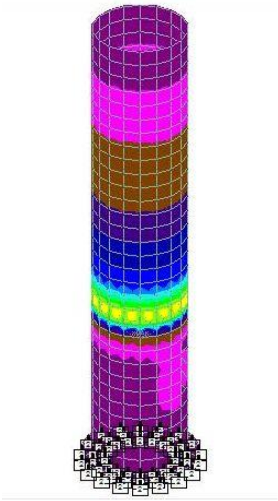
Diameter	6 m
height	20 m
Density of material stored	8 kN/m^3
coeff. Of friction b/w wall and	0.444
ratio of hor to ver pressure	0.406
Angle of repose	25 °
Grade of Concrete	20
Grade of steel	415
depth of hopper below silo	2.5 m
dia of hopper opening	1 m

	h	p_h	Pv
-1	1	3.059	1.358
-2	2	5.773	2.563
-3	3	8.178	3.631
-4	4	10.312	4.579
-5	5	12.204	5.419
-6	6	13.882	6.164
-7	7	15.370	6.824
-8	8	16.690	7.410
-9	9	17.860	7.930
-10	10	18.898	8.391
-11	11	19.818	8.799
-12	12	20.634	9.161
-13	13	21.358	9.483
-14	14	21.999	9.768
-15	15	22.568	10.020
-16	16	23.073	10.244
-17	17	23.521	10.443
-18	18	23.918	10.619
-19	19	24.270	10.776
-20	20	24.582	10.914

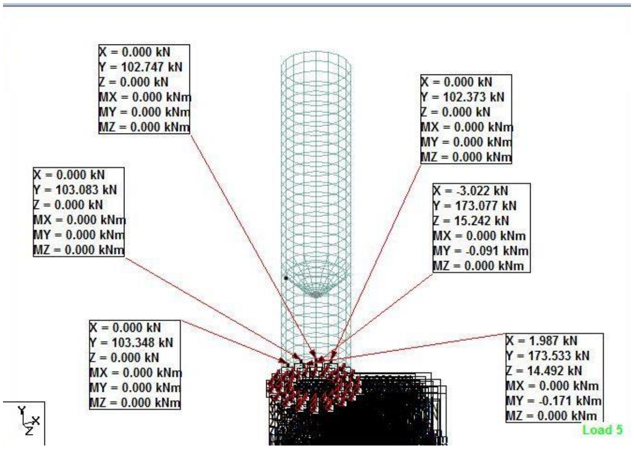
To verify result of software, Silo has designed for static load condition and it is compared with manual static design of silo.

Basic data and geometry of silo is same as it is considered in manual design. Fig Showing the geometry of silo.





Thickness of wall is 150mm. 8 m high silo supported with 4 column designed for fill condition. Pressure of wheat is considered to calculate pressure on wall of silo



From above manual calculation it is found that wall of silos required 2.81 % of steel on wall to resist pressure due to grain.

After analysing the model in STAAD with same load intensity, it is come to know that wall required 2.7 % steel to resist pressure due to grain. It is almost equal to 2.81 %.

STAAD redistribute the moments and give the optimum solution of the structural element. There for there is difference of 0.11% in between manual calculation and software analysis. Maximum Shear force in hopper element = 22 kN/m^2 And moment in hopper element is zero or negligible.

Area of steel required in hopper panel is 5 cm2 It is equal to 500 mm2 which is very near to area required of reinforcement calculated manually.

Hence, from this analysis it can conclude that manual analysis and software analysis is same so we can analyse and study the model for dynamic analysis by using STAADs software.

III. ANALYSIS OF SILO FOR WIND AND EARTHQUAKE

Load combination used for earthquake analysis and wind analysis. As per IS 1893 – 2002 and IS 875-1987 (part 3 & part 5)

1) 1.5(DL+LL)
2) 1.2(DL+LL+EL)
3) 1.5(DL+EL)
4) 0.9DL* 1.5EL
5) 1.2(DL+LL+WL)
6) 1.5(DL+WL)
7) 0.9DL* 1.5WL

Where,

DL = Dead Load

LL = Live Load

&

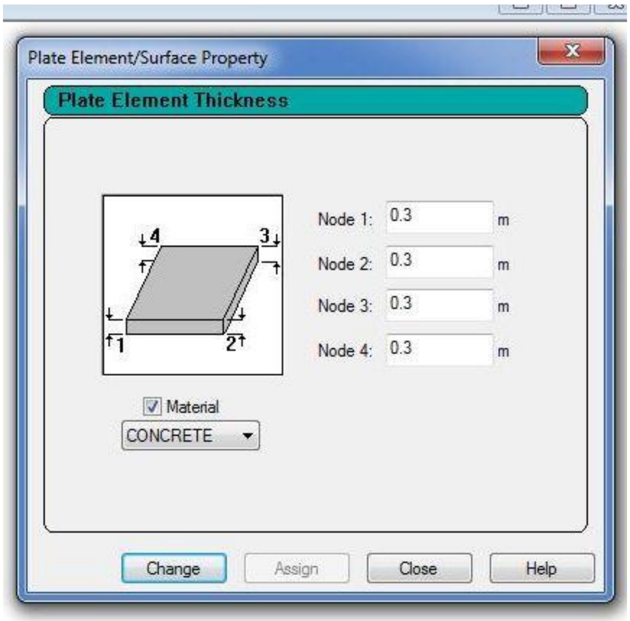
EL = Earth Load

WL = Wind load

It can be seen that axial force in very negligible in upper columns after removing column 1 at ground floor. It transferred the additional load in adjoining column. If column designed as per ductile design code, it could resist the additional load up to certain extent.

	h	vertical load	lumped VL
-1	1	2.464	0.6160
-2	2	4.928	1.2320
-3	3	7.392	1.8479
-4	4	9.856	2.4639
-5	5	12.320	3.0799
-6	6	14.783	3.6959
-7	7	17.247	4.3118
-8	8	19.711	4.9278
-9	9	22.175	5.5438
-10	10	24.639	6.1598
-11	11	27.103	6.7758
-12	12	29.567	7.3917
-13	13	32.031	8.0077
-14	14	34.495	8.6237
-15	15	36.959	9.2397
-16	16	39.423	9.8557
-17	17	41.887	10.4716
-18	18	44.350	11.0876
-19	19	46.814	11.7036
-20	20	49.278	12.3196
-20.5	20.5	50.510	12.6276
-21	21	51.742	12.9355
-21.5	21.5	52.974	13.2435
-22	22	54.206	13.5515
-22.5	22.5	55.438	13.8595

Note that these shell element internal forces are forces per unit length acting on the midsurface of the shell element. STAADS only reports the value of these forces at the shell element corner points.



Stresses for all load combination has been analysed and silo found critical in wind load case.

Maximum percentage of steel required for dynamic analysis is 3.5 % where it was 2.81% for static analysis.

In common silo design based on ACI 313 (1997) wall pressures from earthquake effects are not taken into account and the system is reduced to a cantilever beam with several point masses being situated on top of each other to calculate appropriate additional static horizontal loads, 80 percent of actual mass of stored material should be considered as effective mass for calculating masses. But Eurocode 8 part 4 (2003) considers additional horizontal pressures resulting from earthquake effects with simple relations.

Few images are displayed below which showing the failure of silos due to earthquake and wind forces. It is essential to consider wind and earthquake effect on silo.

IV. CONCLUSION

This research is carried out to check the behaviour of silos in earthquake and wind load condition. A typical model of silo taken for analysis and checked for static as well as dynamic design. For software data validation, Manual analysis is done for static analysis and checked its result with static analysis of software. Both result are same which give the idea about perfectness of software for analysis and design.

Earthquake and wind load combination taken by referring relevant IS codes such as IS 1893 and IS 456, IS 875. From the analysis it is conclude that stresses on silo is more while applying the earthquake load and wind load as compare to stresses due to static load.

To resist additional stresses during earthquake and high wind, silo shall design for additional earthquake and wind forces. Many silos fail due to lack of earthquake design as shown in above images. This analysis and design is carried out on concrete cylindrical silo. It can be check for concrete rectangular silo and steel silos too.

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