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RELATIVE EXPLORATION OF LATERAL STEEL STORAGE TOWER AND REINFORCED CONCRETE

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Abstract

This paper presents a comparison study of relative explorationi of Reinforced Concrete and Steel Silo. The silos are mostly used in agriculture and industries. They carries normal pressures and axial compressive loads due to stored materials together with the self-weight of the super structure. It also carries lateral loads due to wind or seismic forces. A finite elemental software describes the analysis and a study was conducted to compare the behaviour of Reinforced Concrete and Steel silo. From the analysis it was observed that Reinforced Concrete are more useful than Steel silo in industries. Deformations are found to be critical more for Steel silo at the middle portion of the structure than the concrete silo. Non Linear time history analysis were conducted and it shows that steel silo have more displacement and stress than concrete silo. A graph was drawn representing the behaviour of Reinforced Concrete and Steel silo structures with various thicknesses.

Keywords: Catastropic, Deformation, Final Elemental Model, Ovalisation, Pretension, Ratcheting

1. Introduction

Bunkers and silos may be classified as storage structures generally used for storing coal, cement, food grains and other granular materials. Reinforced concrete bunkers and silos have the almost replaced the steel storage structures because of their ease of maintenance and superior architectural qualities. A silo (from the Greek – siros,) is a structure for storing bulk materials. They are supported by frames or reinforced concrete columns. A silo carries normal pressures and axial compressive loads due to stored material together with the load of super structure. It also carries lateral loads due to wind or seismic forces. The silo wall deforms considerably in its cross-section and along the height when subjected to such lateral loads. For circular silo having height of wall to diameter of silo approximately equal to one (H/D=1), there is not much effect, in general. But for silo having the same ratio exceeding one (H/D>1) is subjected to deformation to greater extent, The failure of a silo structures usually leads to catastropic collapse of the entire silo. The complete structural failure results in loss of contained material and also loss of life. Silos are special structures subjected to many different unconventional loading conditions, which result in unusual failure modes. Failure of a silo can be devastating as it can result in loss of the container, contamination of the material it contains, loss of material, cleanup, replacement costs, environmental damage, and possible injury or loss of life.

Several investigators reported on the buckling behavior of Silo structures when subjected to lateral loads [1-10]. P Patra, A K Samanta, P Ray[1], studied the issue of ovalisation of circular cylindrical wall of a ground elevated RC silo in empty condition and wish to present this behavior for the entire height of the wall.

The ovalisation is found to be critical only at middle one-half height of the silo wall. It also attempts designers and practicing professionals in understanding the true deformation pattern as well stress contours of silo wall. Jorgen Nielsen, J. Michael Rotter, John D. Sorensen[2], observed that the silos are subject to several types of actions or loads. This implies that a series of design situations must be considered and the corresponding combination of actions selected. As a res ult, different load combinations are needed for different types of silos (concrete or metal, squat or slender etc.) and for silos designed for different operating conditions (flow pattern, method of discharge etc.). G.Portela,L.A Godoy[3], studied the buckling behaviour of steel tanks with a dome roof under exposure to wind. Geometric imperfections and changes in the buckling results due to reductions in the thickness were also included in the study to investigate reductions in the buckling strength of the shell.

From the study it was found that reductions in the shell thickness reduce the buckling loads. Adem Dogangan, Zeki Karaca, Ahmet Durmu s[5] studied the damage and failures of the silo. Also discussed the silo failure due to explosion and bursting, asymmetrical loads created during filling or discharging, large and non uniform soil pressure, corrosion of metal silos, deterioration of concrete silos due to silage acids, internal structural collapse and thermal ratcheting. A steel silo which is at RMC, Ernakulam is taken for analysis is shown in Figure 1. It is modeled in SAP software, analysed and the behaviour was compared with the model by changing the material by concrete. A graph is plotted, shows the displacement and stress behaviour of silo by changing the thickness with different material.

2. Computational Model

2.1 Finite Element Model

A 100 tonne capacity cement steel silo supported on 4 no of steel pipe has been modeled in SAP software is shown in Figure 3. The steel pipe is connected with the steel cylinder at a level of 2.2m, which is supporting the entire silo volume together with the conical hopper supporting the material. The steel silo wall thickness has been assumed as 10mm.The total height of the steel silo is 11.5m. The cylinder has the diameter of 1.6m.The bottom of the steel pipe is fixed to the foundation. The maximum deformation takes place at a level close to the topmost level. The deformation increases as the ratio of H/D of silo increases beyond 2. A same model is analysed by changing the material with Reinforced Concrete and a comparison is done to study the behaviour of stress and displacement when subjected to wind load or seismic load. The horizontal load on the cylinder due to wind is calculated based on wind pressure distribution as per IS 875 Part-III. The behaviour of the material (steel)is assumed as isotropic and elastic with Young's modulus = 21000 MPa, Poisson's ratio = 0.3 and mass density = 7.8e -9 t/mm3 and compared with the material(concrete) which is assumed as isotropic and elastic with Young's modulus = 25000 MPa, Poisson's ratio = 0.17 and mass density = 2.4e-9 t/mm3. The 3D silo modelled in such a way, has been analysed using SAP to get the values of deformation and stress at different directions such as in windward, leeward, and perpendicular directions due to the application of wind or seismic forces.

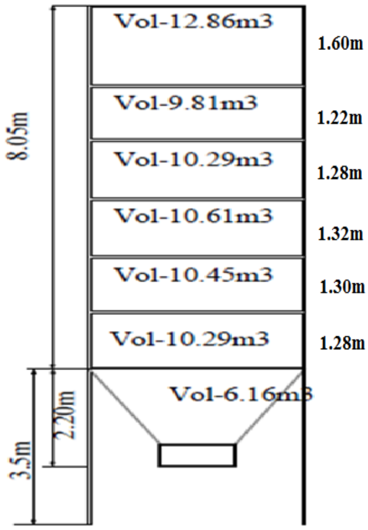


Figure 1 Steel Silo at RMC, Ernakulam **Figure 2 Silo Model in AUTOCAD**

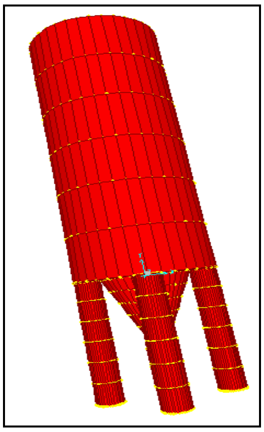
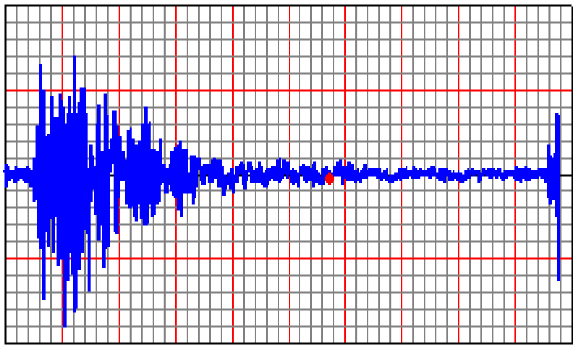


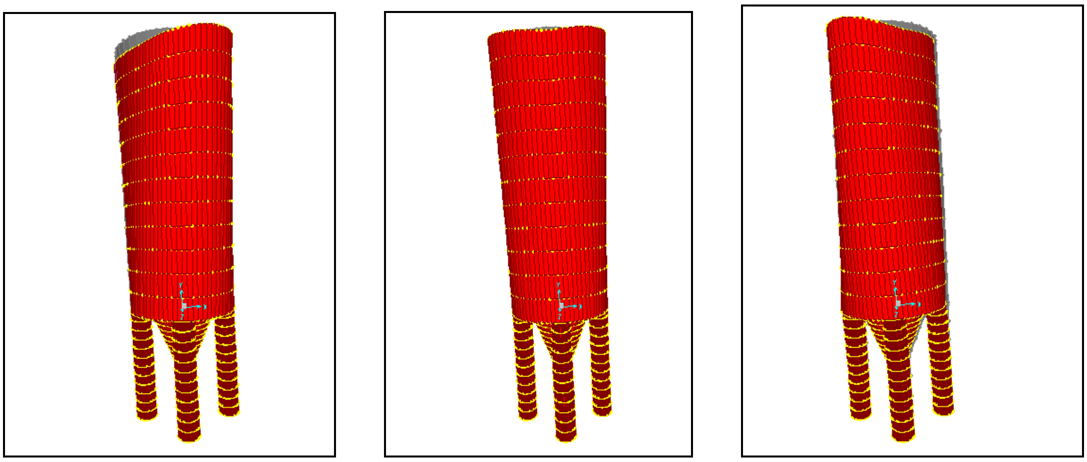
Figure 3 3D Model in SAP

3. Behaviour of Silos Under Lateral Loads

The response of structures to earthquakes is a complex, three dimensional, nonlinear, dynamic problem. There are two types of analysis procedures for representing this response. They are the linear analysis and nonlinear analysis. Analysis of the structure is conducted to determine the distribution of forces and deformation induced in the structure by the ground shaking. Linear procedure is applicable to the structure that responds in an elastic manner. Ground motion due to earthquake may cause the structure to vibrate. Static analysis can be carried out by hand or using softwares. The acting loads considered in the present analysis where self-weight and two wind load cases. In this case, the horizontal wind loads were applied perpendicular to the cylindrical face of the silo. The horizontal wind loads were calculated according to the procedures described on the IS 875 (part 3)-1987 and applied to the nodes of the cylindrical portion of the silo. The dynamic analysis can be used to provide a nominal measure of expected responses, which will ensure adequate behavior of the structure.

A linear modal analysis was performed on each model based on the stiffness at the end of the nonlinear pretension load case. Although the mode shapes and frequencies would be different if the analysis was conducted with the silo in a deformed position, this is still a useful analysis as it gives some insight into the initial behavior of the silo. Time history analysis considering all the modes of the structure is assumed to give more accurate results when compared to other linear analysis procedures. The Altadena earthquakes were chosen for the analysis. The chosen accellogram is Altadena, on June 28th, 1992 at 11:57:34,a magnitude of 7.6(6.2 MB, 7.6 MS, 7.3 MW, Depth 0.7 mi) earthquake occured 91.7 miles away from Altadena Center.



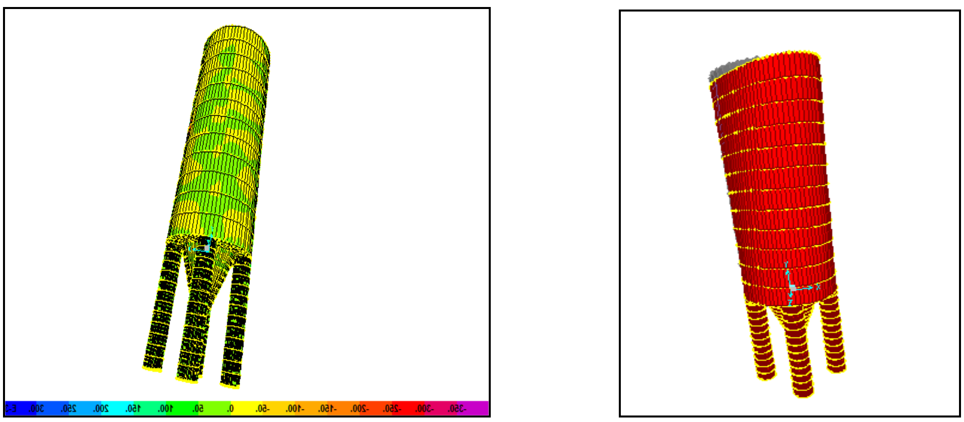


(a)Mode 1 **(b)Mode 2** **(c)Mode 3**

Figure 4 Different modes at time period (a) 0.3718 s (b) 0.14569 s (c) 0.14533 s

4. Results and Discussion

Figure 5(a) and Figure 5(b) shows the stress diagram and displacement diagram of the model in SAP due to the application of wind load without live load and Figure 6 shows the stress diagram and displacement diagram of the model due to the application of wind load with live load condition. The figure shows that during empty condition deformation and stresses will be more than that of loading condition. By comparing both reinforced concrete and steel silo structures stresses and displacement will be more for reinforced concrete silo structures. From the time history graph also it can be concluded that stresses and displacement will be more for reinforced concrete silo structures shown in the Figure 7 and Figure 8.



(a) **(b)**

Figure 5 Due to the application of wind load without live load (a) Stress Diagram, (b) Deformed Shape

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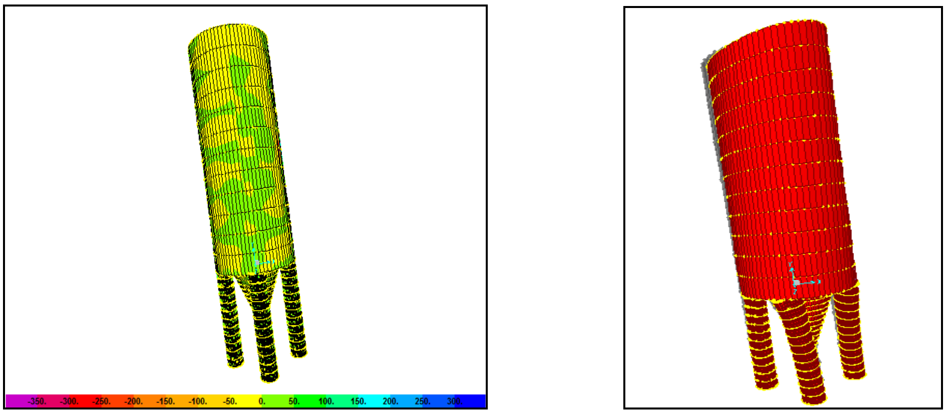

(a) **(b)**

Figure 6 Due to the application of wind load with live load (a) Stress Diagram, (b) Deformed Shape

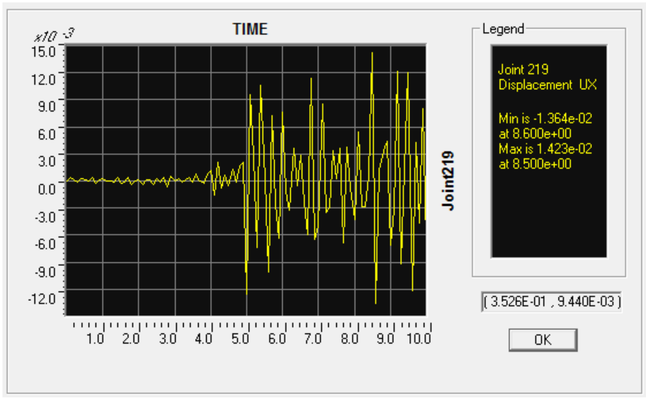

Figure 7 Time History Graph shows the displacement at the top portion of the Steel Silo

The Table 1 shows the stress values (MPa) of Steel silo structures due to the application of wind load with and without live load. Table 2 shows the stress values (MPa) of Reinforced Concrete silo structure due to the application of wind load with and without live load. The stresses will be at three directions such as in windward, leeward and perpendicular directions.

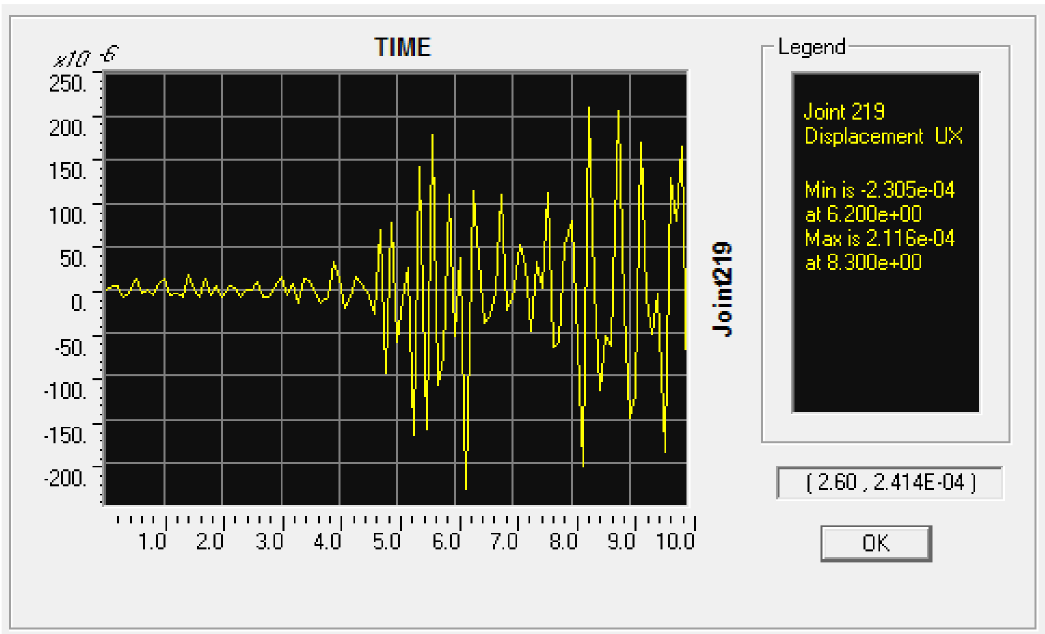

Figure 8 Time History Graph shows the displacement at the top portion of the Reinforced Concrete Silo structure

Table 1 Stress (MPa) on RMC Silo (Steel) due to the application of wind load with and without live load

WINDWARD SIDE	HEIGHT(m)	SOFTWARE (W/0 LOAD)	SOFTWARE (WITH LOAD)
	5	-0.4879	-0.6935
	8	-0.0451	-0.0641
	9	0.0452	0.091
	11.5	0.0651	0.082
LEEWARD SIDE	5	0.123	0.251
	8	0.087	0.094
	9	0.193	0.265
	11.5	0.0422	0.0744
PERPENDICULAR	5	-0.201	0.229
	8	0.4811	0.554
	9	0.548	0.788
	11.5	0.2553	0.528

Table 2 Stress (MPa) on RMC Silo (Concrete) due to the application of wind load with and without live load

WINDWARD SIDE	HEIGHT(m)	SOFTWARE (W/0 LOAD)	SOFTWARE (WITH LOAD)
	5	-0.207	-0.117
	8	-0.0173	-0.0090
	9	0.058	0.0979
	11.5	0.078	0.0941
LEEWARD SIDE	5	0.427	0.593
	8	0.093	0.0968
	9	0.206	0.323
	11.5	0.0651	0.809
PERPENDICULAR	5	-0.276	-0.105
	8	0.516	0.941
	9	0.608	0.807
	11.5	0.399	0.784

Table 3 and Table 4 show the behaviour of the structure by changing the material and it also varies with the thickness of the material. The graph is plotted representing the behaviour of steel and concrete with varying thickness which is shown in Figure 9 and Figure 10.

Table 3 Displacement and Stress behaviour of steel silo structure at various thickness

THICKNESS OF THE PLATE (mm)	DISPLACEMENT (mm)	TOTAL MAXIMUM STRESS (MPa)
10	83.4418	394.170
20	59.1418	557.508
25	0.0248	3721.611
30	-0.1105	3431.359
40	-0.2157	3029.917

Table 4: Displacement and stress behaviour of concrete silo structure at various thickness

THICKNESS OF THE WALL (mm)	DISPLACEMENT (mm)	TOTAL MAXIMUM STRESS (MPa)
10	-115.4959	0.350
20	-271.1878	0.210
25	-79.7291	0.173
30	16.1447	0.146
40	-16.3032	0.110

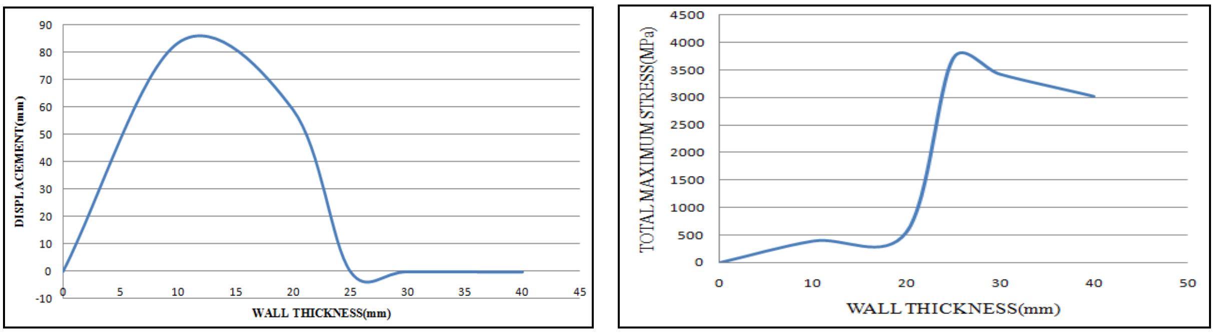

Figure 9 Graph representing the relation between Displacement and Stresses with Wall thickness of Steel silo

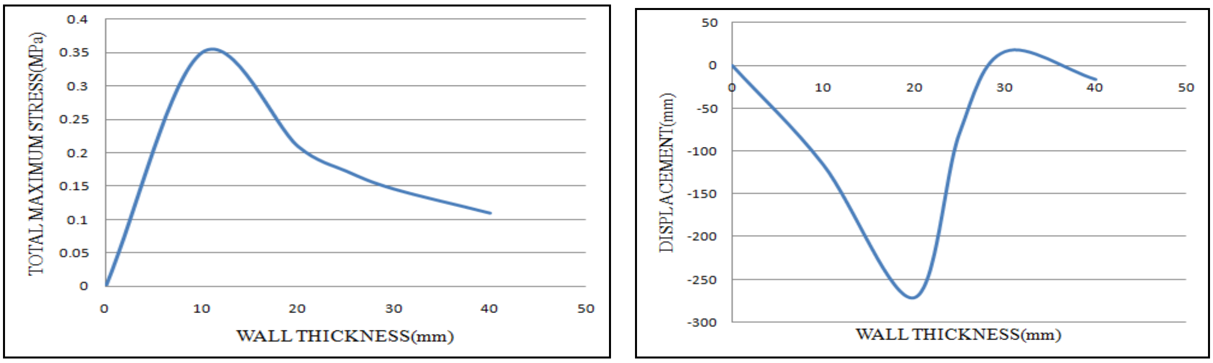

Figure 10 Graph representing the relation between Displacement and Stresses with Wall thickness of Reinforced Concrete silo

5. Conclusion

- Stresses due to the application of wind load with and without live load at different levels were tabulated for Reinforced Concrete and Steel silo.
- In the wind load case, it was found that steel silo shows more stress and displacement than reinforced concrete silo.
- Deformations are found to be critical at the middle portion of the structure in both cases but steel structure shows greater effect.
- From non linear time history analysis, it was found that displacement and stress are more for Steel silo than Reinforced Concrete silo.
- The behavior of stress and displacement of Reinforced Concrete and Steel silo with various thickness were tabulated.
- A graph was drawn representing the behavior of Reinforced Concrete and Steel silo with various thickness.

From the graph it is observed that:

- For Steel silo, as the plate thickness increases displacement decreases but stress increases but it is not economical because cost increase as the plate thickness increases.

- For Reinforced Concrete silo, as the wall thickness increases displacement increases but stress decreases.
- For Steel silo, 10mm can be provided for the wall thickness for 100 tonne capacity and by providing 3mm ring stiffeners at different intervals hence displacement and stress can be reduced.
- For Reinforced Concrete silo, 30mm can be provided for the wall thickness for 100 tonne capacity.
- One of the advantage of Steel silo is that if any failure occurs it can be reinstalled. In case of Reinforced Concrete silo, if any collapse occurs, reconstruction of the structure is necessary, hence it is expensive.

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