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Study And Evaluation Of A Compartmental Silo

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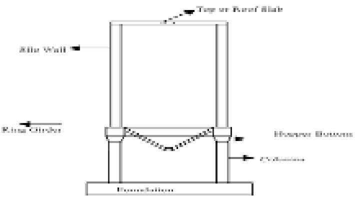
Abstract
To store different construction materials, industry need a bin-shaped storage facility so as to house various construction materials. Bins, bunkers, silos, and tanks are all terms used to describe buildings used to store bulk solids. Bins or bunkers are shallow structures used to store grains, cement coal, crushed stone, gravel, and other such identical materials. Silos are typically large constructions used to store resources like grain, wheat, cement, and other grains. The best place to store food grains, cement, or any other powdered material is in a silo. The silos are now used to store missiles because of technological advancements, in addition to holding the various materials described above. A compartmental silo (group of four silos) for storing any powdery material is taken into consideration in this work and subjected to various loading situations, including self weight, pressures of material, wind loads, seismic or earthquake loads, and variety of these loads combined. In the current research effort, the results against static loading, dynamic loading, and their combinations as well as the mode shapes and stress diagrams under different loading circumstances have been provided.

1. INTRODUCTION

The word "Silo" refers to deep bins used to hold delicate or fine material. Silo refers to tall constructions whose height is greater than their lateral dimension. Silos are storage structures, may be ground supported or elevated. Silos are crucial since they are used so frequently in various sectors. Silos are unique constructions that are subjected to a wide range of unexpected loading circumstances, leading to peculiar failure modes. Silo failure can happen for a variety of causes, including poor design, fabrication and erection, improper usage, improper maintenance, operational pressures greater than those anticipated in the design, and a combination of these and other faults.

Silo

The basic shape of a silo is circular, but depending on the situation, it may also be square, rectangular, or



polygonal. It also has a roof and a bottom, which may have a conical, pyramidal, or flat shape. To disperse the load, silos often have a number of columns, a full construction wall, a hopper bottom, and columns joined by ring beams. A silo's body and the hopper, which serves as the actual storage space, are its two main components. The hopper is a funnel-shaped structure that makes it easier to remove items from the structure. Silos are unique constructions that are subjected to a variety of peculiar loading circumstances, leading to distinctive failure modes. The earthquake has a significant impact on the elevated compartmental silos reaction. Any material that will be kept in a group or compartmental silo needs to have its features, qualities, and flow patterns understood. Along with alternate wall expansion and contraction due to daily or monthly temperature fluctuations, moisture changes, compaction, and settling may also have an impact on the forces applied by the material being stored. The "dynamic effects" are another name for these increases. However, the rise in pressure could have both static and dynamic impacts. The stability and toughness of compartmental silo walls and the supporting structure may be impacted by earthquake loads.

Figure. 1a. Compartmental Silo (3D Front View) **Figure.1b. Compartmental Silo (3D Top View)**

2. LITERATURE REVIEW

In the study of this Compartmental Silo, IS: 456-2000 Indian Standard Code of Practice for Reinforced concrete, was referred.

Krishna T. Kharjule1 and Minakshi B. Jagtap, [3] have analyzed the Elevated steel and reinforced concrete circular silos & how they perform during earthquakes and found that the stability of the reinforced concrete silos is increased by the use of shear walls, while the stability of the steel silos will be increased by the use of steel panels on the opposite side and they have identified that, when a wall panel is sheared, the structure's displacement decreases and its stiffness rises.

Sagar Belgaonkar and Swapnil Kada [4] have analyzed have examined soil types, such as hard soil and soft soil. The silos were examined for these factors, as well as for various seismicity zones and different soil types, such as hard soil and soft soil. For computing the natural period, displacements, and base shear of the silo for various circumstances, situations and to compare the results, they used STAAD.Pro for the analysis in accordance with IS 1893 (Part I): 2002. They then recommended a silo structure that would be suitable for construction based on their recommendations.

Chanchal Thomas, Surjit Singh, D. Jaishree, [5], have conducted an analysis of the silo structure after the internal cone and multiple compartments were added, and they discovered that the stresses behave uniformly throughout the structure and are also within the allowable range. They also discovered that by adding multiple compartments and an internal inverted cone to the silo, pressure is uniformly distributed throughout the structure, preventing an excessive build-up of pressure in any one area of the silo.

Anand Adi, Hemant L. Sonawadekar [6] have performed the dynamic analysis of a typical steel silo for several Indian codes using the STAAD.Pro.V8i software, using the Equivalent Static Study (ESA) and Response Spectrum Analysis (RSA) methodologies for earthquakes.

Examining the load combinations in line with Indian code, it was found that the frequency of the silo increases by 15% when a surface element is added. The addition of a surface element was also found to boost the structure's stability, particularly in areas susceptible to earthquakes or during dynamic loading. It was also discovered that adding a surface element often causes a 20% reduction in the structure's displacement.

Siva Ramakrishan, Vasanthakumar [7], have designed and estimated various-diameter circular R.C.C. and prestressed concrete silos. In order to compare the outcomes, they planned to design both pre-stress concrete and R.C.C. silos of medium diameter. They designed a silo using MS Excel programming, and when they compared the RCC and prestressed concrete designs, they found that the prestressed concrete design had walls that were 100 mm thinner than the RCC design. This result illustrated the prestressed concrete silo's material consumption efficiency. n.

Nikhil G. Magare [8], has used STAAD.Pro.V8i & performed time history analyses for circular and square R.C.C. silos using Bhuj ground motion data & has analysed at the dynamic results like, time acceleration, time velocity, time displacement, and different mode shapes and has discovered that the frequencies and period for different mode shapes show higher values for square silos, and hence concluded that circular

silos perform better.
Miss Thombare Pooja Dadasaheb, Prof. Dr. Ashok Kasnale [9], have performed analysis for the model of the circular and rectangular silos using STAAD.Pro. Natural frequency and time period, principal stresses at the top and bottom, as well as absolute, shear, and moments in the X, Y, and XY directions were all obtained for rectangular and circular silos and concluded that, relative to circular silos, more stresses and moments are developed in rectangular silos than in circular silos.
Abhilash Vishnu Gote and Prof. Ganesh P. Deshmukh [10], have modelled for both circular and rectangular geometries, among others and the STAAD.Pro software produced the findings based on the silo's variable height, the shear force, response, moment, and plate stress are the outcomes and an interactive graph was used for comparison and have concluded that, as the height rises, the displacement also rises.
F. Nateghila, M.Yakhchalian [11], have made an effort to assess the influence of granular material-structure interaction on the seismic behaviour of reinforced concrete silos, and they have come to the conclusion that, if the granular material's effective mass is taken in to account, it results in a nonlinear behaviour of the reinforced concrete silo walls under earthquakes (80% of the total mass of granular material). The earthquake impact on a RCC silo has been modelled by the ABAQUS finite element software.

3. Quantitative Analysis

Two fundamental steps involved in structural problem simulations:-

1. Pre Processing
2. Post Processing

- **Pre Processing**

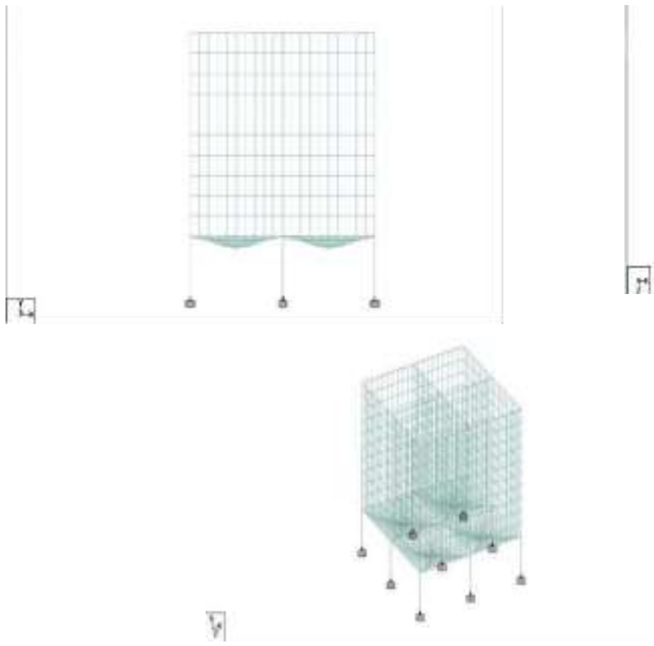


Figure. 2 STAAD.Pro.V8i Modeling

- Post Processing

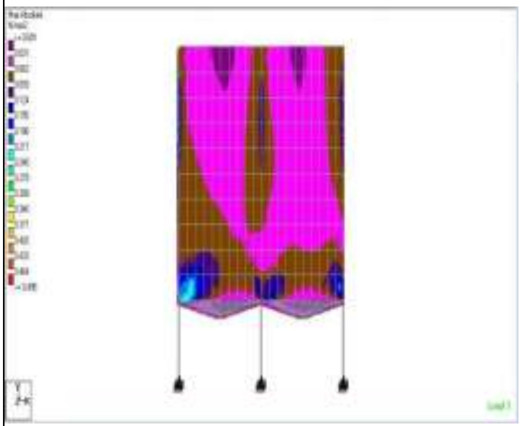


Figure. 3 Normal Stresses due to Seismic-Load X direction

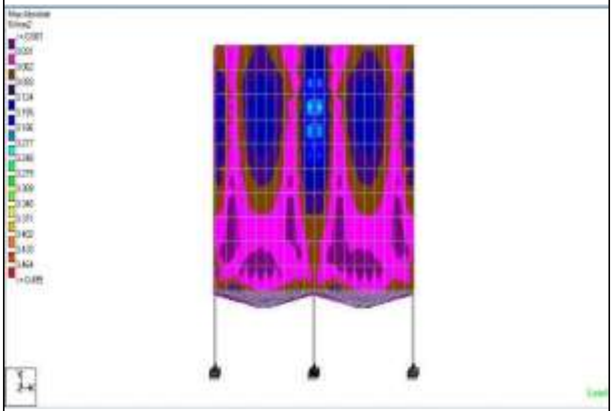


Figure.4 Normal Stresses due to Seismic-Load Z direction

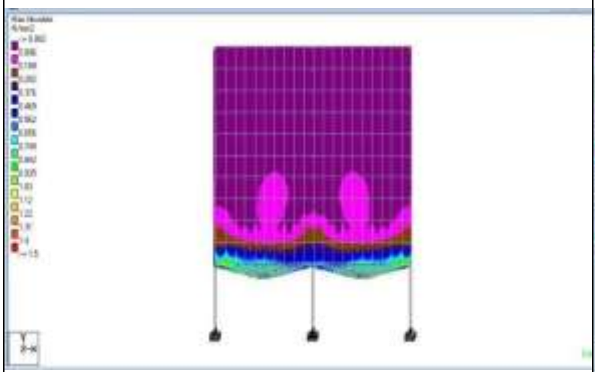


Figure.5 Normal Stresses due to Self-Weight

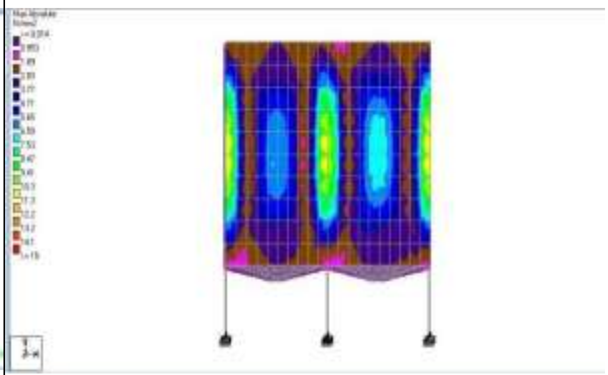


Figure.6 Normal Stresses due to Material-Pressures

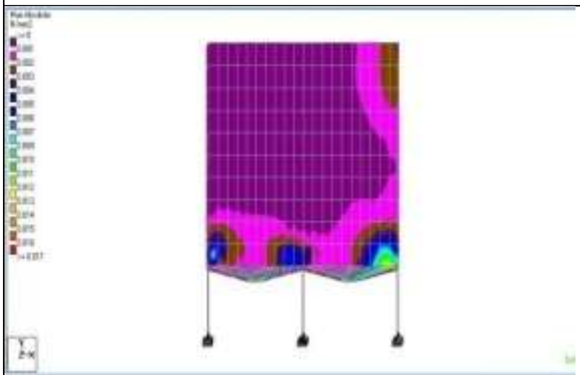


Figure.7 Normal Stresses due to Wind-Load X direction

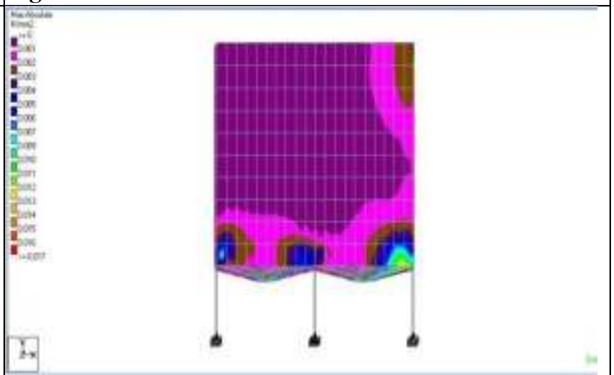


Figure.8 Normal Stresses due to Wind-Load Z direction

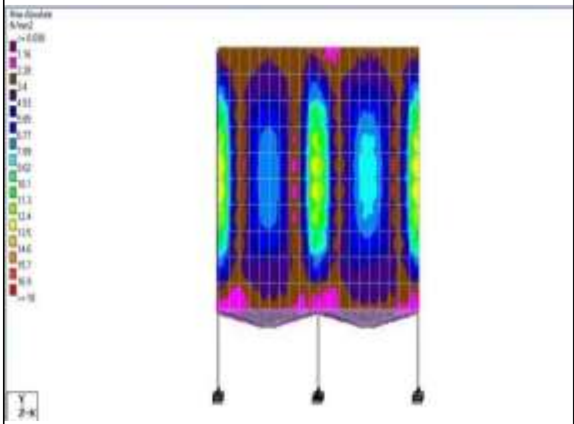
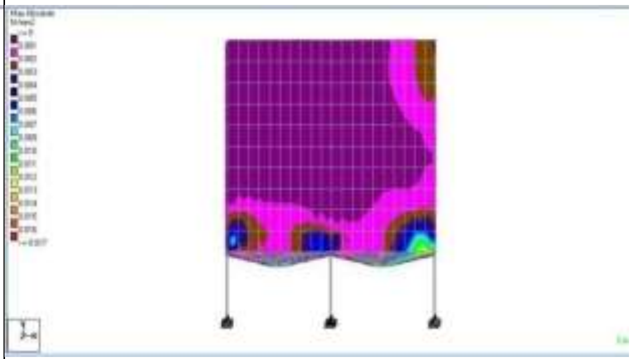
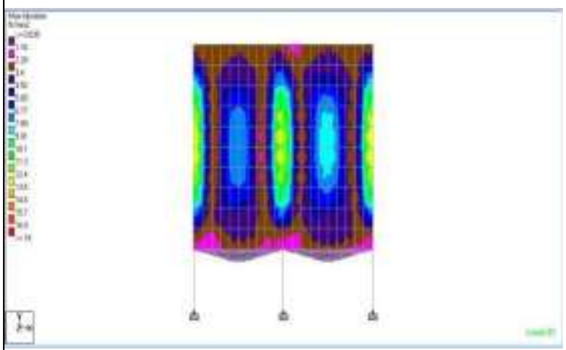
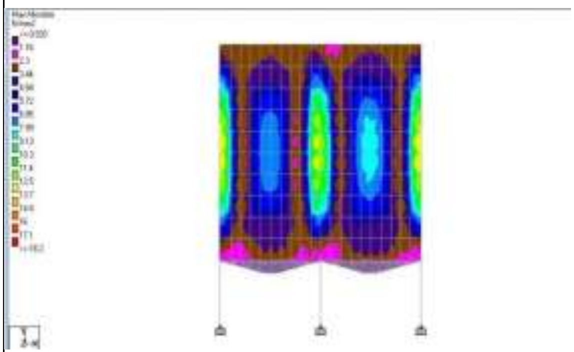
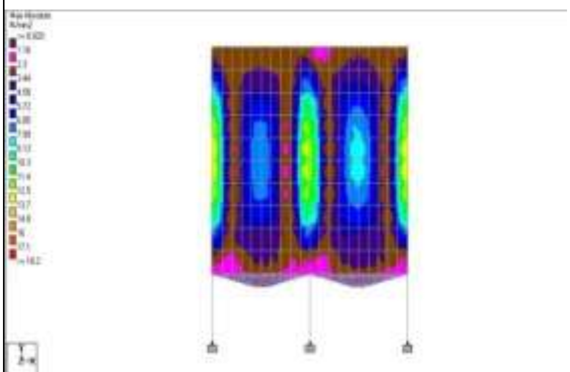
 Figure. 9 Normal Stresses due to Self Weight+Material Pressures	 Figure.10 Normal Stresses due to Self Weight+Wind Load
 Figure.11 Normal Stresses due to Self Weight+Material Pressures+Wind Load	 Figure.12 Normal Stresses due to Self Weight+Material Pressures+Seismic X
 Figure.13 Normal Stresses due to Self Weight+Material Pressures+Seismiz Z	

Table 1. Internal Pressures at various side wall heights in the silo.

S.No.	Height from top of side wall (mts)	Volume (m3)	Pressure (t/m2)
1	2000	8000	15.4
2	1900	7600	14.72
3	1800	7200	13.92
4	1700	6800	13.16
5	1600	6400	12.4
6	1500	6000	11.28
7	1400	5600	10.88
8	1300	5200	9.76
9	1200	4800	9.32
10	1100	4400	8.56
11	1000	4000	7.76
12	900	3600	7
13	800	3200	6.2
14	700	2800	5.44
15	600	2400	4.68
16	500	2000	3.84
17	400	1600	3.08
18	300	1200	2.32
19	200	800	1.52
20	100	400	0.76

Table 2. Displacements of Nodes.

	Node	L/C	X (mm)	Y (mm)	Z (mm)	Resultant (mm)	rX (rad)	rY (rad)	rZ (rad)
Max X	1787	20:COMBINAT	398.2	-12.6	-44.2	400.8	0.000	-0.018	-0.002
Min X	256	20:COMBINAT	-486.4	-13.8	-46.1	488.8	-0.001	0.019	-0.003
Max Y	1321	6:LOAD LIVE	-4.3	2.81	-5.0	7.2	0.000	0.000	0.000
Min Y	546	20:COMBINAT	-40.0	-35.5	-43.9	69.2	0.000	0.000	0.000
Max Z	1018	20:COMBINAT	-44.2	-12.6	398.2	400.8	0.002	0.018	0.000
Min Z	246	20:COMBINAT	-46.1	-13.8	-486.5	488.8	0.003	-0.019	0.001
Max rX	898	20:COMBINAT	-40.6	-11.9	65.0	77.6	0.081	0.003	0.000
Min rX	46	20:COMBINAT	-42.1	-13.3	-160.6	166.6	-0.082	-0.004	0.001
Max rY	403	20:COMBINAT	-48.0	-14.5	-235.3	240.6	-0.003	0.131	0.000
Min rY	419	20:COMBINAT	-235.3	-14.5	-48.0	240.6	0.000	-0.131	0.003
Max rZ	56	20:COMBINA	-160.6	-13.3	-42.0	166.6	-0.001	0.004	0.082

		T							
Min rZ	1667	20:COMBINAT	65.0	-11.9	-40.6	77.6	0.000	-0.003	-0.081
Max Rst	246	20:COMBINAT	-46.1	-13.8	-486.5	488.8	0.003	-0.019	0.001

Table 3. Plate centre stresses

			Shear		**Membrane**			**Bending**		
	Plate	**L/C**	**Qx** (N/mm^2)	**Qy** (N/mm^2)	**Sx** (N/mm^2)	**Sy** (N/mm^2)	**Sxy** (N/mm^2)	**Mx** (kNm/m)	**My** (kNm/m)	**Mxy** (kNm/m)
Max Qx	430	SW+LL+WL+SEISMIC	**6.4**	2.3	-29.7	-2.9	5.8	31.1	-14.4	-33.1
Min Qx	431	SW+LL+WL+SEISMIC	-6.4	2.3	-29.7	-2.9	-5.8	31.1	-14.4	33.1
Max Qy	421	SW+LL+WL+SEISMIC	0.8	3.0	14.3	2.7	-15.0	-2.2	-23.0	12.5
Min Qy	3012	SW+LL+WL+SEISMIC	-0.4	-2.9	-4.5	1.1	5.6	-57.4	-27.3	-22.3
Max Sx	2042	SW+LL+WL+SEISMIC	0.4	-0.6	29.2	-10.0	-2.1	11.0	33.4	6.8
Min Sx	1682	SW+LL+WL+SEISMIC	-6.4	2.3	-29.7	-2.9	-5.8	31.1	-14.4	33.1
Max Sy	2041	SW+LL+WL+SEISMIC	-0.5	-1.0	6.8	33.6	20.9	13.0	37.0	-6.3
Min Sy	31	SW+LL+WL+SEISMIC	-0.0	-0.2	-6.6	-51.8	-20.7	76.4	23.9	46.3
Max Sxy	30	SW+LL+WL+SEISMIC	-0.5	-1.0	6.8	33.6	20.9	13.0	37.0	-6.3
Min Sxy	31	SW+LL+WL+SEISMIC	0.5	-1.0	6.8	33.6	-20.9	13.0	37.0	6..3
Max Mx	240	SW+LL+WL+SEISMIC	4.1	-0.1	-5.8	-2.6	-4.3	**696.9**	122.2	-5.4
Min Mx	205	SW+LL+WL+SEISMIC	-0.1	0.0	-10.0	-2.3	-4.6	-384.4	-87.6	1.8
Max My	1709	SW+LL+WL+SEISMIC	0.7	-1.8	1.6	-3.1	0.1	42.6	211.6	-12.4
Min My	2057	SW+LL+WL+SEISMIC	0.1	-0.4	-3.7	-3.1	4.8	-275.0	**-131.4**	-7.4
Max Mxy	1742	SW+LL+WL+SEISMIC	-1.7	-0.1	3.3	-13.6	-5.0	-5.2	-20.2	118.6
Min Mxy	916	SW+LL+WL+SEISMIC	1.7	-0.1	3.3	-13.6	5.0	-5.2	-20.2	118.6

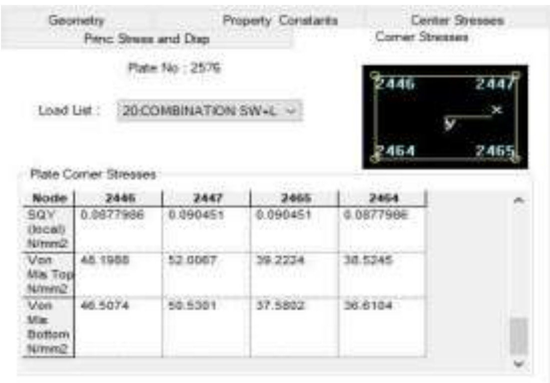


Figure.14 Principal-Stresses and Displacement.

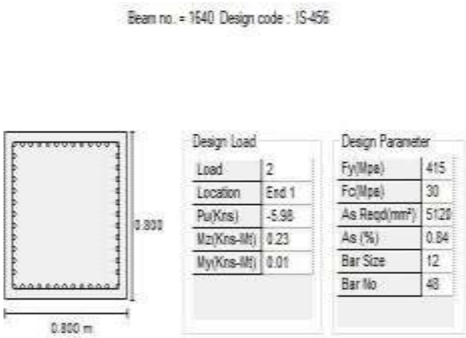
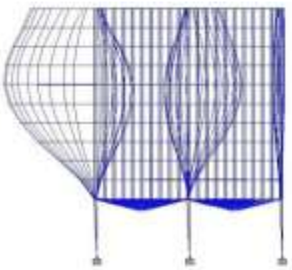


Figure.15 Column Design



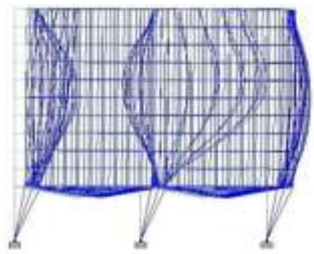


Figure.16 (a) Mode-Shape for seismic loading in x. **Figure.16 (b) Mode-Shape for seismic loading in z.**

4. Outcomes and Analysis

In this work, a group of four silos/compartmental silos of each dimension (Lenght=10m, Breadth=10m, and Height=20m) have been examined and developed for a variety of loading circumstances, such as self-weight, material pressures, wind-loads, seismic-loads, etc., as well as combinations of these loads. A 2000 tonne load capacity per compartment has been considered in the design of the compartmental silo. Fig.2. shows the STAAD.Pro modeling of compartmental silo. The material's internal pressure on the plates in the silo becomes a trapezoidal form or shape as the material moves downward. Table 1 displays the pressures at various sidewall heights.

5. Conclusions

- In the present work, a group of four/compartmental silo of each dimension (Length=10m, Breadth=10m, Height=20m) was analyzed for different loading conditions such as, self- weight, material-pressures, wind-loads and seismic-loads, as well as varied combination of these loads. The analysis and design of this compartmental silo allows it to support loads weighing 2,000 tonnes each. In Fig. 2, Compartmental Silo STAAD.Pro modeling is displayed.
- When the nodal displacements in Table.2 are observed, it is evident that the load combination results in the greatest resulting displacement, which is approximately 488.8mm, occurring for the loads combination of [Self Weight+Material Pressures+Wind Load+Seismic X].
- When stress diagrams are noticed, the critical condition, or the maximum stresses are occurring for load combination [Self Weight+Matetial Pressures+Wind Load] as seen in Figure.11. and the maximum positive moment is occurring for the load combination [Self Weight+Material Prassures+Seismic X].
- Additionally, it's interesting to see that, the intensity of stresses is almost identical for load combinations of [Self Weight+Material Pressure+Seismic X] and load combinations of [Self Weight+Material Pressures+ Seismic Z] as shown in Fig.12. & Fig.13. and as a result, it indicates that this structure is stable.
- Figure.16(a) and Figure.16(b) shows the mode shapes of the compartmental silo, for seismic loading condition.
- By effectively applying a variety of loading scenarios, including static loading, dynamic loading, and different combinations of these loads, utilizing STAAD.Pro.V8i, this study's main achievement is seen s being in favor of compartmental silo.
- Finally, it can be concluded that, the method used in this study can tackle a wide range of static and dynamic issues for intricate industrial structures.

6. Acknowledgements

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