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Analysis and Design of Reinforced Concrete Silo Structure by Considering Indian Seismic Zones- II-III-IV-V

Bogem Sasidhar[1], Dr. C. Sashidhar[2]
[1] *PG-Research Scholar, Department of Civil Engineering, JNTUA, Ananthapur, Andhra Pradesh-515001, India*
[2] *Professor, Department of Civil Engineering, JNTUA, Ananthapur, Andhra Pradesh -515001, India*

Abstract - *A wide variety of industries use RCC Silos to store bulk solids in quantities ranging from a few tones to hundreds and thousands of tones. The word silo encompasses all types in the storage system of particulate solids, which may otherwise be called a bucket, hopper, grain tank or bunker. In cement factories, silos are very demanding. Therefore RCC silos are commonly used for the storage of granular materials, which are suitable for the construction of permanent bulk storage systems, such as dry granular filling systems. In this project, we are designing the RCC silo situated in all seismic zones with the help of structural software Staad Pro. The design concept include, providing all dimensions of structural component based on trial and error method. The Analysis of silo, using Equivalent lateral force method and study the performance of structure located in all seismic regions in term of Comparison of different models of concrete silo for earthquake such as nodal displacement, stress and vertical or horizontal pressure on walls etc. The Presentation of the results is in tabular and graphical look. This method is carried out for volume of 180 m3. All the designs have been based on the recommendations of I.S 1893-2016 and I.S 456 – 2000 codes, Based on these designs, max lateral displacements obtained for the critical load case/combination for each model at different heights, the Zone V Node Displacements are 9.357 mm at 36mts height of the silo which is more compared with other seismic zones. The Maximum Absolute stresses of silo at different zones are represented as 1.67 N/mm2 in Zone V is maximum compared with other 3 zones. The Maximum Shear stresses of silo at different zones are represented as 0.841 N/mm2 in Zone V is maximum. The concrete design is done with reference to the aspects of IS 456-2000, the area of steel required for different elements in all the models were presented.*

Key Words: Rcc, Silo, Displacements, Maximum absolute stresses, Maximum shear stresses

1.INTRODUCTION

Silo is derived from the Greek word 'Siro,' a device used to storage loose materials, which is the colliery for holding an ounce. It was initially started as a storage unit for grains and content from agriculture and was then extended for storage of many other materials including cement, ash fly, etc. These silos were amended to accommodate growth of the cement industry and some changes were made to the silo to increase the stocking of materials and reduce the failure of silo.

The wide containers are referred to as containers in the handling of raw materials in every industry. Bins are storage systems used in different industries for the storage of grains, carbon, crushed materials, cement and other granular materials. The bigger compared to the lateral dimension structures whose height is high are called silo. Silo is a building in which the opposite sides cuts in the angle of rupture. The construction of silo is taken into consideration and considered as a special framework for design. Silos are usually constructed of concrete or steel. Either on steel pillars with concrete pedestals or concrete pillars, the silos can be supported. Silo design, properties such as density, determines form of stored material and its properties; silo design is influenced by lubrication of stored material. The silo is built for horizontal and vertical pressure thanks to the material that is stored.

It was initially started as a storage unit for grains and content from agriculture and was then extended for storage of many other materials including cement, ash fly, etc. These silos were amended to accommodate growth of the cement industry and some changes were made to the silo to increase the stocking of materials and reduce the failure of silo. Collapse of silo in seismic failure is the major failure; occur because of improper assumptions, wrong analysis and design. In this study consider circular flat bottom silo symmetrical about vertical axis & RCC slab Provided at the top and bottom of silo by proving small open able hole to top of silo for filling storage material in it. In this study compare various method of silo design and seismic force calculation by using different code provision like IS, ASCE, AJI, and EURO. The dividers of the storehouses are commonly exposed to both ordinary weight and vertical frictional shear or footing delivered by the material put away inside the storehouse. The size and conveyance of both shear and ordinary weight over the tallness of the divider rely upon the properties of the put away material.

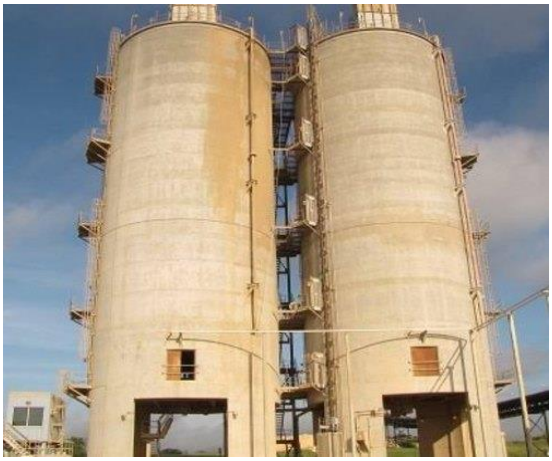


Figure 1: RCC Silo Construction

Three kinds of silos, towers, bunker silos and bag silos, are now in use. The silo industry has evolved rapidly in the pursuit of improved design and revolutionary solutions that increase silos performance and storage capacity.

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

The design of silos is done generally by two methods:

1. Janssen's Theory
2. Airy's Theory

2.OBJECTIVE OF THE STUDY

Different methodologies were carried out for the model development, load calculations, analysis, and designs. All the aspects are going to taken in according to the Indian standard code procedures, different calculations and their procedures that are done in this study are represented in a step by step representation.

The details of the silo model such as section sizes, thickness, lengths, plan and elevation views are represented, the step by step procedure for the modelling of the structure in Staad Pro software is represented.

The results from the equivalent lateral frame analysis are going to discuss along with the concrete design results, this involves the max nodal displacements for the critical load case, max absolute stresses and max shear stresses developed in each model are represented via contour diagrams, tables, and graphs, the values of minimum required Ast for beams and columns are mentioned.

Four models are going to analysed for this study depending on the different zones located in India according to the IS 1893-2016, in this each model is represented with the respective zone name, the following are the names of the models in this study.

- Base Model Zone II
- Base Model Zone III
- Base Model Zone IV
- Base Model Zone V

3.LITERATURE REVIEW

Suvarna Dilip Deshmukh and Rathod (2008)

A comparative study was made on RCC silo design and seismic behaviour. They investigated the peculiar modes and causes of failure. They evaluated and developed Euro code (EN 1998-4:1999 and EN 1991-4:2006) and ACI code in compliance with IS 4995. For the design, the stored materials and seismic loads have considered the static and dynamic strain. Based on your analysis It was concluded that the pressure due to seismic activity must be taken into account during the construction of the silo wall. In their study, they discovered that different strengthening's along the wall depth and more on the middle wall can be effective.

Indrajit Chowdhury and Raj Tilak

It proposed a method in the study of circular silos to integrate the dynamical pressure generated by earthquakes. This study was performed using the traditional Jansen method with many modifications and the dynamic pressure on the silo wall with various structural configurations was parametrically examined. In a design office environment work which did not require a detailed FEM review and could be well adapted in a tablet or shell. They insisted that a common lack of understanding of the vertical aspect of the earthquake would promote side pressure and should not especially be ignored for large silo capacities. Finally, they concluded that the silo wall design technique is significantly unknown about the seismic effect.

One researcher who developed theories which are still used today is Janssen (1895). His theory is almost universally used as the single most reliable reference point even today. This theory is the main descriptor of filling pressures within the silo. One disadvantage to this theory is that it does not take into account the surface profile in defining wall pressures near the surface. This is important in squat silo geometries. It was assumed that after filling the solid was in a Rankin active state, giving a low lateral pressure ratio, K, and leading to lower pressures, however, by the 1960's it was widely recognized that this was an underestimate of K. Some experimentalists assumed the solid changed from an active state to a passive state during discharge. This change was termed as the "switch". This theory is questioned more

recently by Rotter 1999, who believes this change is much slower and the peak pressures are much less than expected using the switch theory.

4.METHODOLOGY

Methodologies which are carried out for the model development, load calculations, analysis, and designs. All the aspects are taken in according to the Indian standard code procedures, different calculations and their procedures that are done in this study.

- Model development
- Load calculations
- Load combinations
- Analysis Procedure
- Design procedure

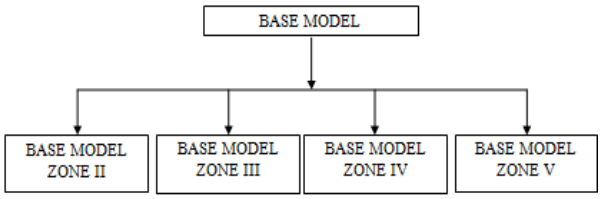
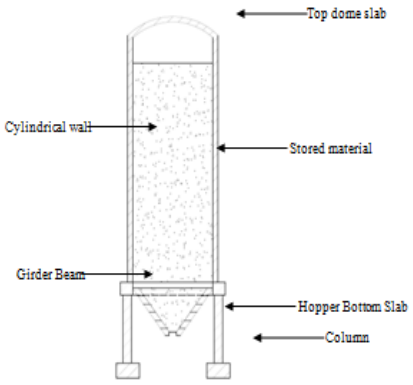


Fig 3.2.1 Model Chart

The different elements of the silo which are to be modelled are shown in the fig 3.2.2



For the analysis of the model in this study equivalent lateral load method confining to the IS 1893-2016 was employed using the Staad Pro software in order to generate all the different results of bending moments, shear forces, displacements and resultants. The detailed step by step procedure for the analysis is described in the Analysis and Design chapter.

Table 1: Material data

Material	Densities Kg/m3	Densities Kn/m3	Co-efficient of Internal angle of Friction (μ')	Angle of repose(Ø)	Parameter n
Wheat	805	8.05	0.444	27	0.4062
Coal	800	8	0.7	30	0.2709
Anthracite	835	8.35	0.51	27	0.3753
Sand	1600	16	0.577	34	0.283
Coke	450	4.5	0.839	30	0.2174

Zone	Zone Factor
II	0.10
III	0.16
IV	0.24
V	0.36

Table 2: RCC Silo model details

Element	Location	width	Breadth	Thickness
Top dome slab	Top of the cylinder wall	-	-	150mm
Cylindrical wall	Above the girder beam	-	-	300mm
Bottom hopper slab	Below the girder beam	-	-	250mm
Girder beam	Between the bottom column and cylindrical wall	350mm	400mm	-
Column	At the bottom of the slab	400mm	800mm	-
Components		**Heights**		
Radius of the cylindrical wall		3m		
Column height		5m		
Height of the cylindrical wall		30m		
Top dome height		1m		
Total height of the silo		36m		
Volume of the silo		876.5m^3		
Total number of segments divided into along vertical axis		18		

The different methodologies which are carried out for the model development, load calculations, analysis, and designs. Different calculations and their procedures followed that are done in this study are concluded.

5.RCC SILO MODELLING

Silo model such as section sizes, thickness, lengths, plan and elevation views are represented, the step by step procedure for the modelling of the structure in Staad Pro software is represented.

For the modelling of the structure Staad Pro analysis and design software have been used the structure was modelled using structure wizard input method the steps for modelling are given below

Step 1:- Initialize a project with the Meter and Kilo Newton units choose space template and select the run structure wizard tool for the input method

Step 2:- In the structure wizard tool select the plate models and select cylindrical plate

Step 3:- Enter the values of the cylinder by clicking on change property option

Step 4:- Merge the model with Staad pro

Step 5:- Using the add beam option model the circular beam at the bottom by joining the nodes and creating the beam

Step 6:- On the beam select the nodes at which the columns are be added and using the translational repeat tool copy the nodes in the negative y direction with selecting link nodes creating the columns

Step 7:- Create a hopper bottom slab by creating a reference node at the bottom and using three nodded plate generate the bottom hopper slab

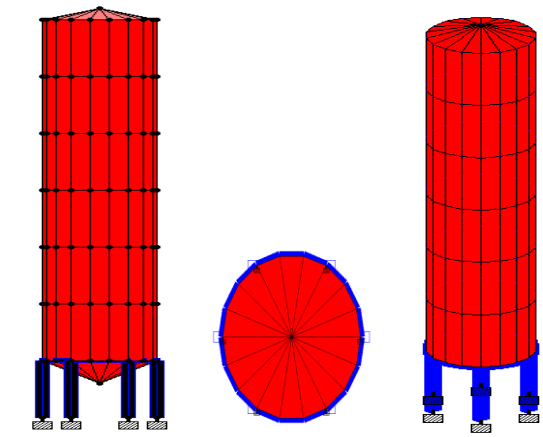
Step 8:- In the similar way create the top dome

Step 9:- Create the properties of beams columns and slabs and assign them to the respective elements

Step 10:- Check in the 3D rendered view if the model is correctly defined, if not select the elements and remodel them

Step 11:- Check the model for duplicate mode beam or plates, if any found delete them

Step 12:- Assign fixed supports to the bottom nodes.



a. Elevation view b. Plan vie c . 3d view

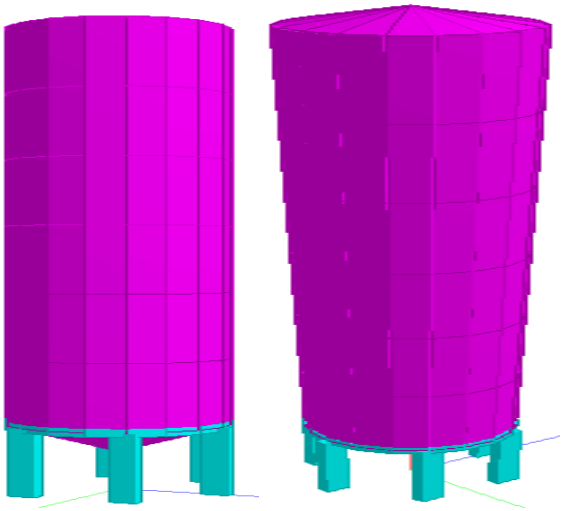
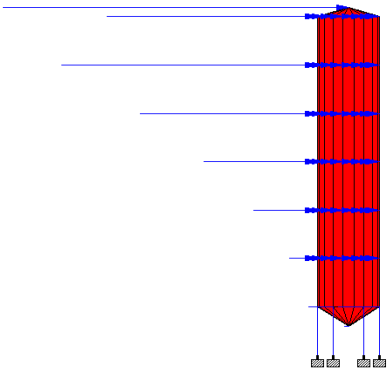


Figure 2: Silo Model views

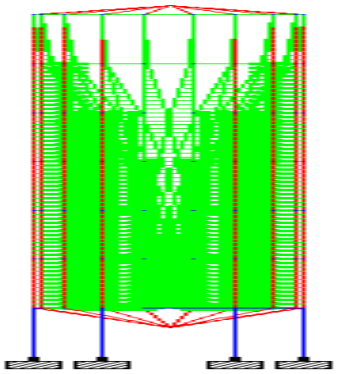
6.LOADING AND ANALYSIS

load calculations assignments and analysis procedures are given, all the loads are considered from the Indian standard codes as mentioned in the methodology, the loads which are take for this study are self weight of structure lateral load on the cylindrical wall surcharge load on the hopper bottom and finally the earthquake loads where the base model is classified into four models based on the different zones and zone factors.

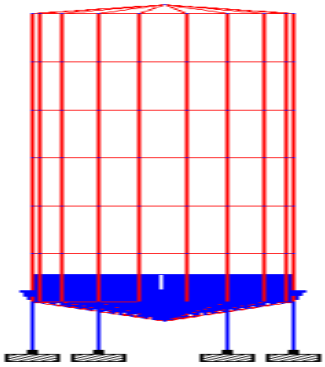
The type of analysis carried out for the structure is equivalent lateral force method via STAAD.Pro and the results are calculated for displacements bending moment's stresses shear forces and stress contours in the plates and elements the following are the steps which are to be considered while analysing the structure.



A .EQ-X load



B.Lateral load on walls



C. Hopper bottom surcharge load

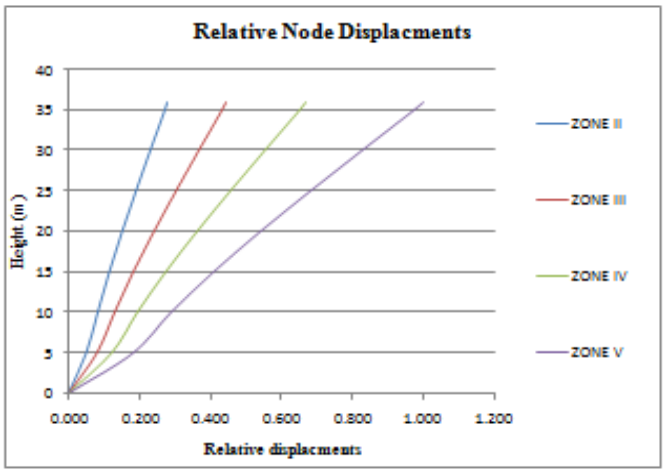
7.RESULTS AND DISCUSSIONS

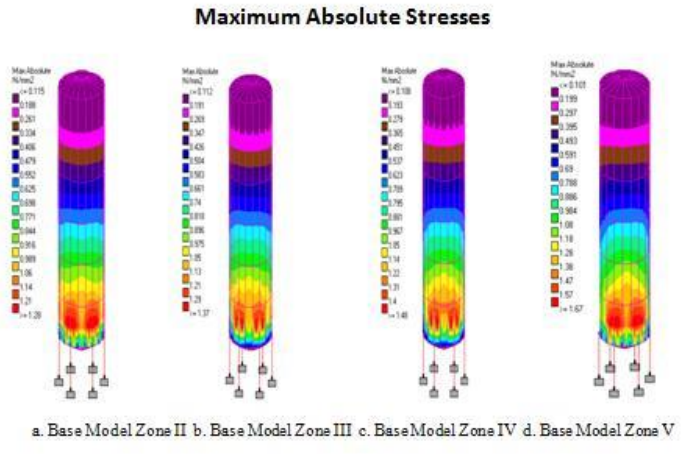
Results which are obtained from the equivalent lateral frame analysis are discussed along with the concrete design results, this involves the max nodal displacements for the critical load case, max absolute stresses and max shear stresses developed in each model are represented via contour diagrams, tables, and graphs, the values of minimum required Ast for beams and columns are mentioned

Four models are analysed for this study depending on the different zones located in India according to the IS 1893-2016, in this each model is represented with the respective zone name, the following are the names of the models in this study.

Table 3: Relative node displacements

Relative node displacements					
Node no	**height**	**ZONE II**	**ZONE III**	**ZONE IV**	**ZONE V**
127	36	0.278	0.444	0.667	1.000
109	35	0.271	0.433	0.667	0.972
91	30	0.230	0.367	0.667	0.825
73	25	0.190	0.303	0.667	0.680
55	20	0.151	0.241	0.667	0.540
38	15	0.115	0.182	0.668	0.408
19	10	0.082	0.130	0.670	0.288
1	5	0.050	0.080	0.665	0.182

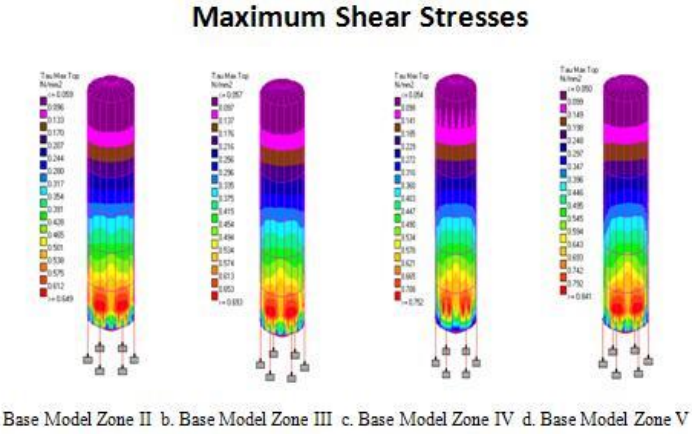




a. Base Model Zone II b. Base Model Zone III c. Base Model Zone IV d. Base Model Zone V

Table 4: Maximum Absolute Stresses

Model	Maximum absolute stresses N/mm2
Base Model Zone II	1.28
Base Model Zone III	1.37
Base Model Zone IV	1.48
Base Model Zone V	1.67



a. Base Model Zone II b. Base Model Zone III c. Base Model Zone IV d. Base Model Zone V

Model	Maximum shear stresses N/mm2
Base Model Zone II	0.649
Base Model Zone III	0.693
Base Model Zone IV	0.753
Base Model Zone V	0.841

8.CONCLUSIONS

To perform the Analysis of silo using Equivalent lateral force method and to study the performance of structure located in all 4 seismic regions. Comparison of different models of concrete silo for earthquake in terms of nodal displacement, stress and vertical or horizontal pressure on walls etc. The comparable results were obtained to assess their potentiality and suitability in understanding the true behaviour of such a structure.

- The max lateral displacements obtained for the critical load case/combination for each model at different heights, the Zone V Node Displacements are 9.357 mm at 36 Mts height of the silo which is more compared with other seismic zones.
- The Maximum Absolute stresses of silo at different zones are represented as 1.28 N/mm2 in Zone II, 1.37 N/mm2 in Zone III, 1.48 N/mm2 in Zone IV, 1.67 N/mm2 in Zone V.
- The Maximum Shear stresses of silo at different zones are represented as 0.649 N/mm2 in Zone II, 0.693 N/mm2 in Zone III, 0.753 N/mm2 in Zone IV, 0.841 N/mm2 in Zone V.
- The concrete design is done with reference to the aspects of IS 456-2000, the area of steel required for different elements in all the models were presented.

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