Analysis and Design of Reinforced Concrete Silo Having Different Heights and Diameters under Seismic Effect Zone-V

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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. In the present study the load calculations, load combinations, load assignment, earthquake parameters, and analysis have been represented, and the results from this analysis are represented and compared the result outputs of all the models are displayed, max absolute stresses and max shear stresses developed in each model are represented via contour diagrams, tables, and graphs, the values of minimum required as for beams and columns are mentioned. The Maximum absolute stresses is more for Base Model D7-H30 as 1.57N/mm² compared with D3-H30 as 1.55 N/mm² & D5-H30 as 1.53 N/mm².*

Key Words: **Silo, RCC, Maximum absolute stresses, Maximum shear stresses, Displacements.**

1. INTRODUCTION

Concrete comes in mind as the first option when we think about the construction of material storage facilities. Concrete proves to be a very useful material as it offers all the flexibilities in designing and construction of silos and bunkers which are required by any industry and foremost being in the economical limits. Silo is an upright granular material storage tank. Such structures are constructed on higher elevations with an opening created at the bottom to collect the material. The term "silo" mainly incorporates two types of structures i.e. bin and bunker. Out of these two, the first one is the deep upright container while the second one is a similar structure with relatively shallow height. In case of bins if the plane of rupture strikes the opposite wall before emerging from the top of fill, that type is called deep bins while the other case is termed as shallow bins.

Importance of these storage structures has attracted the attention of many researchers worldwide to propose different load calculation methods and design considerations. Working Stress Method IS 5503-2 (1969) is the only available guidelines, for the design of silo and bunkers. In addition to it, different researchers proposed different methods to compute the loads of moving and stacking material inside the silos and bunkers. Silos can be made of steel or reinforced concrete. Silos are mostly cylindrical or rectangular in shape but can also be made of other shapes depending on the function and storage capacity of the material.

The design of silo is based on the density and angle of internal friction of material to be stored. Silo walls are subjected to lateral and vertical pressure caused by the materials. Accurate estimation of these forces and corresponding design of these structures is one of the recent challenges which many designers are facing. These storage structures become more vulnerable when subjected to the lateral earthquake forces. Failure of these structures is highly brittle and catastrophic. Significant work has been completed in the field of designing the Silos. Most of the researchers have focused on only one of the components of Silo by using analytical and numerical methods. Dinghua and Jiping [3] researched on the lateral pressure acting on the walls of the reinforced concrete silo. The method of calculating the basic as well as the dynamic pressure acting on the wall of reinforced silo caused by the integral flow of granular material within the tower during discharge was also discussed. Zhen and Jin [4] analyzed and calculated the hoop stress in the reinforced concrete deep silo. The analysis results showed that the absolute value of hoop stress at the same height increases with an increase in height-diameter ratio but the absolute value decreases with an increase in the wall thickness. Kivanc and Baki [5] investigated the use of ferrocement in the construction of squat grain silos. It was concluded that ferrocement could be used in place of steel from the perspective of static as well as economy.

Because of high volumes and elevations, silos are highly vulnerable during earthquakes. If these structures are not properly designed, then earthquake can cause damage, and sometimes may result in complete collapse of silos. In 2001 during El Salvador earthquake, failure of silo had killed three people [6].The tall structures whose height is large as compared to lateral dimension are called as silo. The design of silos is done generally by two methods:

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

2. OBJECTIVES OF THE PRESENT STUDY

- Earthquake analysis of Reinforced concrete silo by Response spectrum method as per for IS 1893 – 2016 having different diameters and heights as:

  D3-H20, D3-H25, D3-H30

  D5-H20, D5-H25, D5-H30

  D7-H20, D7-H25, D7-H30

- Design of long Reinforced concrete silo for different diameter and height by using Staad pro.

- Comparison of different models of long concrete silo for earthquake loads in terms of stress and vertical or horizontal pressure on walls.

All the nine models are analysed for different load combinations and the concrete design for each element is done for the critical load combination, the concrete design is done with reference to the aspects of IS 456-2000.

II. Methodology:

The different methodologies which are carried out for the model development, load calculations and, analysis. All the aspects are 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 following are the methodologies which are covered during this study.

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

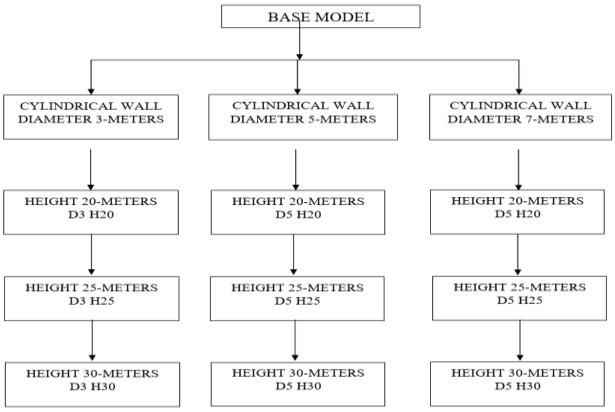

Fig 1 Model Chart

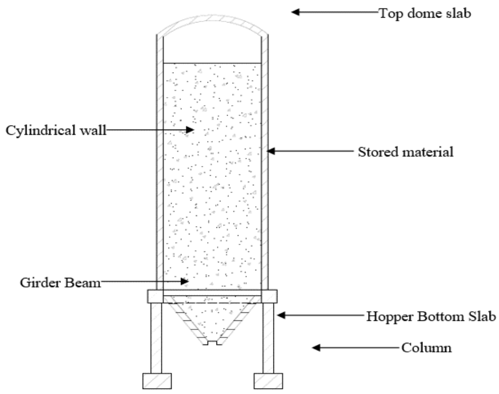

Fig 2 Silo cross section components

3. MATERIAL DATA

Table 1. Material data

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

Table 2. Different heights of the buildings considered.

Models	Height(m)
D3 H20, D5 H20, D7 H20	20
D3 H25, D5 H25, D7 H25	25
D3 H30, D5 H30, D7 H30	30

4. MODELLING

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

Initialize a project with the Meter and Kilo Newton units choose space template and select the run structure wizard tool for the input method. In the structure wizard tool select the plate models and select cylindrical plate. Enter the values of the cylinder by clicking on change property option. Merge the model with staad Pro. Using the add beam option model the circular beam at the bottom by joining the nodes and creating the beam. 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. Create a hopper bottom slab by creating a reference node at the bottom and using three nodded plate generate the bottom hopper slab. In the similar way create the top dome. Create the properties of beams columns and slabs and assign them to the respective elements. Check in the 3D rendered view if the model is correctly defined, if not select the elements and remodel them. Check the model for duplicate mode beam or plates, if any found delete them. Assign fixed supports to the bottom nodes. Below are the elevation views of the all the models.

The following table 3 represents the dimensions of each element used in the modelling of base model of reinforced concrete silo.

Table 3. Model Data

Element	location	Width	Breadth	Thickness
Top dome slab	Top of the cylindrical 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 silo	400mm	800mm	-

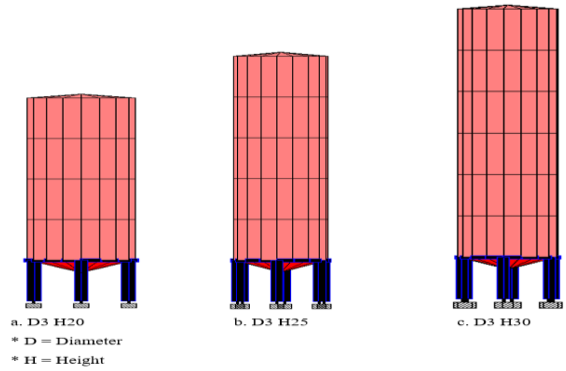

Fig 3. Elevation views of Silos D3-H20, D3-H25, D3-H30

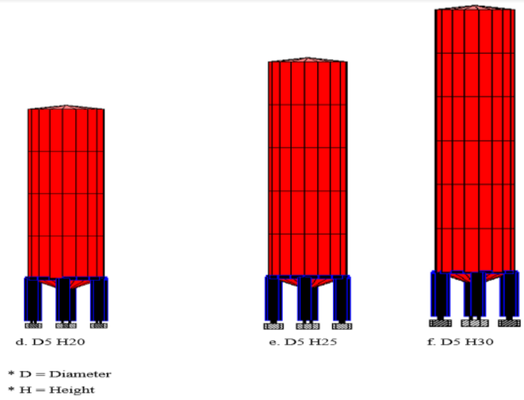

Fig 4. Elevation views of Silos D5-H20, D5-H25, D5-H30

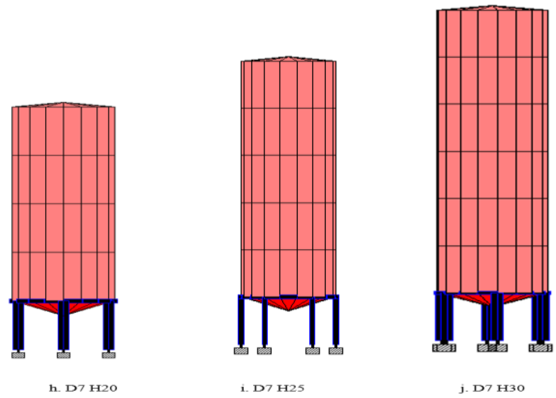

Fig 5. Elevation views of Silos D7-H20, D7-H25, D7-H30

5. LOADING AND ANALYSIS

The following are the steps to be followed while assigning the loads in staad pro

- select loads and definitions in the page setup tab
- select definition first and give the earthquake data initially
- In load case details Select the load as seismic and define loads in positive and negative x and Z directions earthquake loads will be assigned by default
- create dead load case and assign self weight
- create two live load cases for the lateral load on wall and surcharge on the bottom slab
- create plate loads for the lateral and surcharge loads
- Assign the loads to the corresponding plates by selecting the respective plates on which the load has to be applied
- Click on commands >loadings>Auto load combinations

select the Indian code and generate auto load combinations

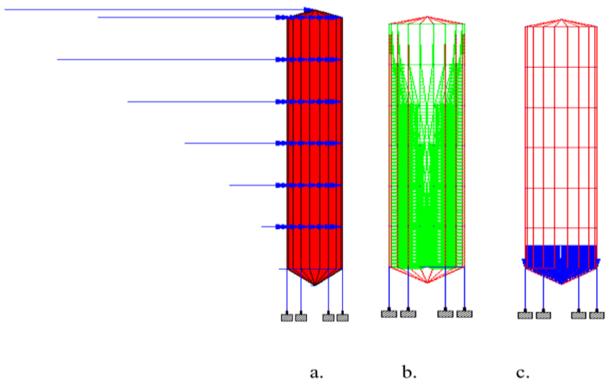

Fig 6. a. EQ-X load b. lateral load on walls c. Hopper bottom surcharge load

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 .

6. RESULTS AND DISCUSSION

(a). Maximum Absolute Stresses of D7-H20, H25, H30

The maximum absolute stresses developed for the critical load case are represented in the form of contour stress diagrams as mentioned below.

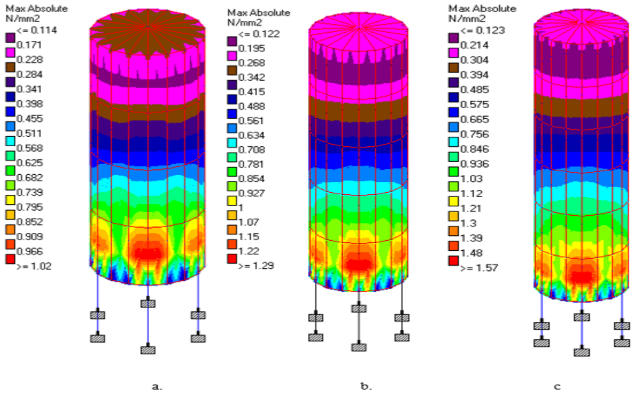

Fig 7. Maximum Absolute Stresses for D7-H20, H25, H30

a.) Base Model D7-H20 **b.**) Base Model D7-H25 **c.)** Base Model D7-H30.

Table 4. Maximum absolute stresses

Model	Maximum absolute stresses N/mm2
Base Model D7-H20	1.02
Base Model D7-H25	1.29
Base Model D7-H30	1.57

(b). Maximum Shear Stresses of D3-H20, H25, H30

The maximum shear stresses developed for the critical load case are represented in the form of contour stress diagrams as mentioned below.

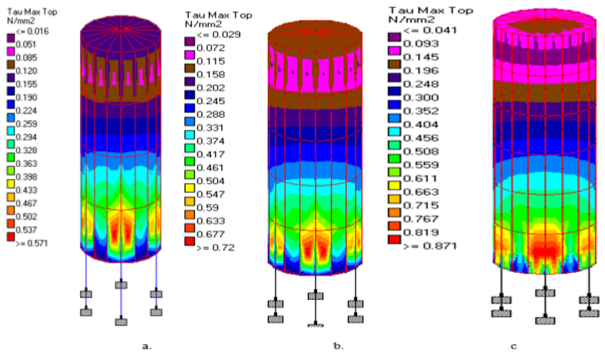

Fig 8. Maximum Shear Stresses for D3-H20, H25, H30 a.) Base Model D3-H20 b.) Base Model D3-H25 c.) Base Model D3-H30.

Table 5. Maximum shear stresses

Model	Maximum Shear stresses N/mm2
Base Model D3-H20	0.571
Base Model D3-H25	0.720
Base Model D3-H30	0.871

Maximum Shear Stresses of D5-H20, H25, H30

The maximum shear stresses developed for the critical load case are represented in the form of contour stress diagrams as mentioned below.

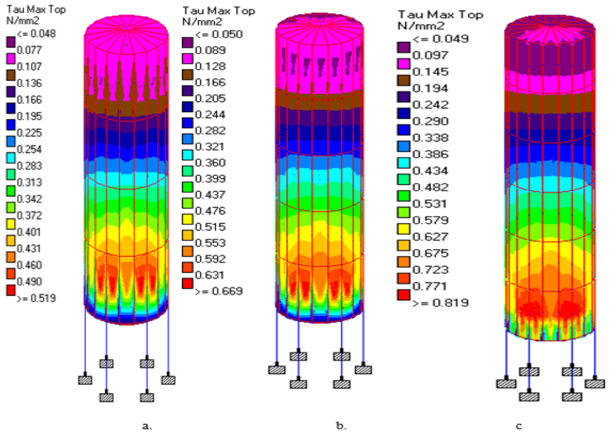

Fig 9. Maximum Shear Stresses for D5-H20, H25, H30 a.) Base Model D5-H20 **b.**) Base Model D5-H25 **c.)** Base Model D5-H30

Table 6. Maximum shear stresses

Model	Maximum shear stresses N/mm2
Base Model D5-H20	0.519
Base Model D5-H25	0.669
Base Model D5-H30	0.819

(c). Maximum Shear Stresses of D7-H20, H25, H30

The maximum shear stresses developed for the critical load case are represented in the form of contour stress diagrams as mentioned below .

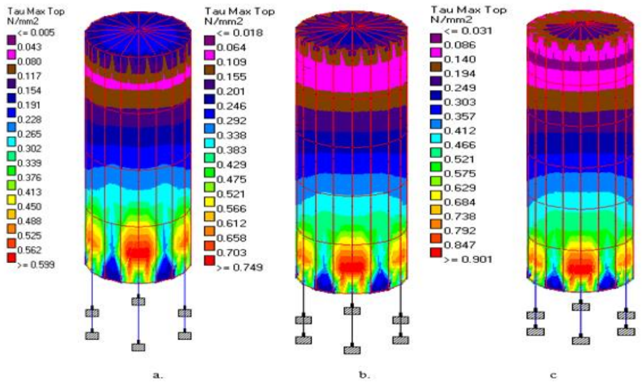

Fig 10. Maximum Shear Stresses for D7-H20, H25, H30 **a.**) Base Model D7-H20 **b.**) Base Model D7-H25 **c.)** Base Model D7-H30

Table 7. Maximum shear stresses

Model	Maximum shear stresses N/mm2
Base Model D7-H20	0.599
Base Model D7-H25	0.749
Base Model D7-H30	0.901

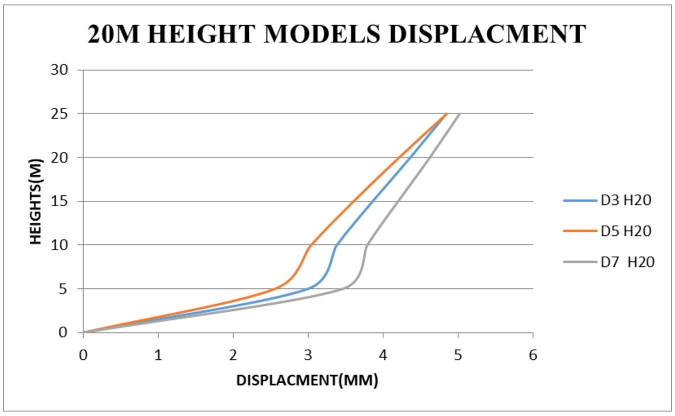

Fig 11 Node displacements of 20M Height Model

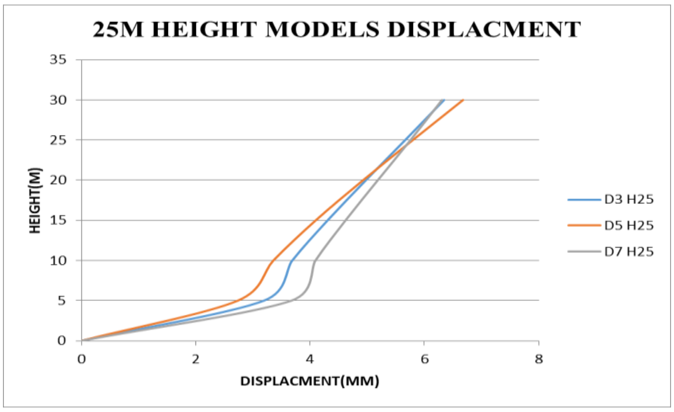

Fig 12 Node displacements of 25M Height Model

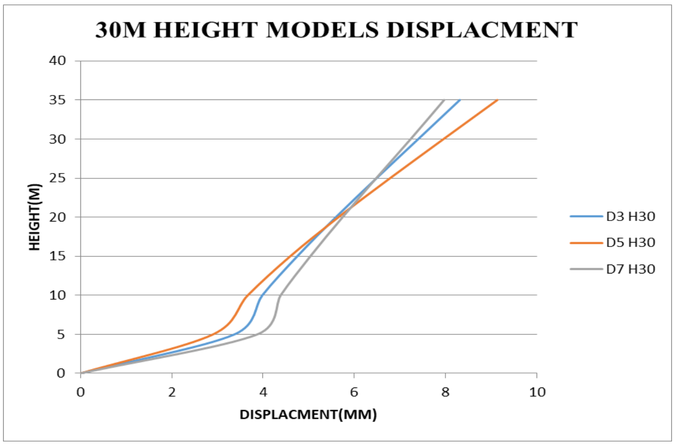

Fig 13 Node displacements of 30M Height Model

7. CONCLUSIONS

- The max lateral displacements obtained for the critical load case/combination are noted down for each model at different heights of H20, H25, H30, the following is the maximum of nodal displacements to height H30 of constant diameter of D3 as 8.311mm at nodal point 73.
- The max lateral displacements obtained for the critical load case/combination are noted down for each model at different heights of H20, H25, H30, the following is the maximum of nodal displacements to height H30 of constant diameter of D5 as 9.133 mm at nodal point 73.
- The max lateral displacements obtained for the critical load case/combination are noted down for each model at different heights of H20, H25, H30, the following is the maximum of nodal displacements to height H30 of constant diameter of D7 as 7.966 mm at nodal point 73.
- The nodal displacement for D5-H30 is maximum compared to D7-H30 @ 9.133 mm >8.311mm >7.966 mm
- The nodal displacement for D3-H30 is maximum compared to D7-H30 @ 8.311mm >7.966 mm.

- The Maximum absolute stresses is more for Base Model D7-H20 as 1.02 N/mm2 compared with D3-H20 as 0.995 N/mm2 & D5-H20 as 0.95 N/mm2
- The Maximum absolute stresses is more for Base Model D7-H25 as 1.29N/mm2 compared with D3-H25 as 1.27 N/mm2 & D5-H25 as1.24 N/mm2.
- The Maximum absolute stresses is more for Base Model D7-H30 as 1.57N/mm2 compared with D3-H30 as 1.55 N/mm2 & D5-H30 as 1.53 N/mm2.

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