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Analysis and design of reinforced concrete silo

Neha Sharma [1*], Lokendra Verma [2], Abhishek Singh [3]
[1-2] Student, M. Tech (Structural Engineering), Amity University Raipur Chhattisgarh, India
[3] Assistant Professor, Department of Civil Engineering, Amity University Raipur Chhattisgarh, India

* Corresponding Author: **Neha Sharma**

Article Info

Abstract
Silos are the structures meant for storing materials like food grains, cement, coal, ore, crushed stone, gravel, clinker etc., in large quantities. In this project planning, analysis, structural design and has been done for a concrete silo based on all Indian standard code for practice. Detailing drawings pertaining to the structural design of market building are presented. All the structural members like slabs, Ring beams, hopper, column & footing are designed using Indian Standard code IS 4995 PART I & II, IS 456-2000 and IS 875.The structural components are designed by limit state method. Materials were used as specified by National Building Code. Concrete M20 grade and Fe415 steel bars were considered for all the design. Cylindrical walls are 120 mm thick. All the dimensions are given in metric units.

1. Introduction
1.1 General
This Silos are the structures meant for storing materials like food grains, cement, coal, ore, crushed stone, gravel, clinker etc., in large quantities. In general, bunkers or bins are used to store gravel, stone and coal whereas cement and grains are stored in silos. They can be constructed as either ground supported or elevated. With the advent of green revolution, there is a need for the proper storage of huge quantity of crops for future use after it has been harvested. To fulfill this demand of storing crops and grains, the construction of silos became essential. The silo plays a vital role in agricultural, industrial and military domain for the purpose of storing materials. The materials for construction of silos comprises of steel or reinforced concrete. The silo mainly consists of bin and hopper for storing and discharging materials respectively. For the purpose of self-cleaning and emptying, the silo is supported on a number of columns. The bin is covered by a roof with suitable manhole. The foundation of the silo may be mat, raft or pile based on the soil condition.

Components of Silo: A typical reinforced concrete or steel silo consisting of a silo wall, a hopper, roof slab, ring girder, supporting columns and foundations. Hopper is a funnel-shaped chamber or bin in which loose material is stored temporarily being filled from the top and dispensed through the bottom. The column is an upright pillar that supports the silo walls. Ring girder is a support beam that is used in silos whereas the foundation is the base of silo that connects it to the ground and transfers loads from the structure to the ground. The angle of hopper is decided based upon the type of material stored and the angle of internal friction of the material.

1.2 Objective
1. To plan, analyze and design various structural elements like beams, slabs, columns & footing in an RCC structure as per Indian Standards.
2. To check the stability of the building against lateral loads
3. To analyze the building with the help of software like Auto CADD and STAAD Pro.

1.3 Literature Review
Suvarna Dilip Deshmukh and Rathod (2008)
A comparative study was made on RCC silo design and seismic behavior. 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

1.4 Codes considered in the study
Indian Standard - IS 4995: 1974. The guidelines recommended by the Bureau of Indian Standard for the design of reinforced concrete silos were explained in 'Criteria for Design of Reinforced concrete bins for the storage of Granular and Powdery materials. The silos load determination is described in Part 1 – General Requirements and assessment of Bin loads. The criteria for the design of the silo are given in Part 2 – Design Criteria. In 1968, this standard was published by considering the requirements of structural design for food grain storage bins (silos). In the year 1974, the revision was adopted to design silo for storing all kinds of materials in addition to food grains. The physical nature of the materials to be stored in the bins are taken into account and the code classified the stored materials as granular and powdery materials as shown in Table1. In this project, accumulated form of solid coal is the material which is stored in the silos.

Table 1: Classification of materials

Materials	Particle size
Granular Size	>0.2mm
Powdery	<0.06mm

The plan of the silos was achieved using AUTOCADD software. The proposed silo is 14.2 meters tall. The diameter of silo is 5.2 meters. The other dimensions are in the following:

1. Height of cylindrical portion = 9.35m
2. Depth of hopper bottom = 1.85m
3. Diameter of opening = 0.5m
4. Density of RCC (Dc) = 25 kN/m3
5. Angle of repose (Ø) = 35°
6. Typical of reinforcement = 500 HYSD bars
7. Grade of concrete = M25
8. Wall thickness provided = 120m
9. Density of coal (w) = 8 kN/m3
10. Height of the dome = 1.15 m
11. Total height of silo = 13.15
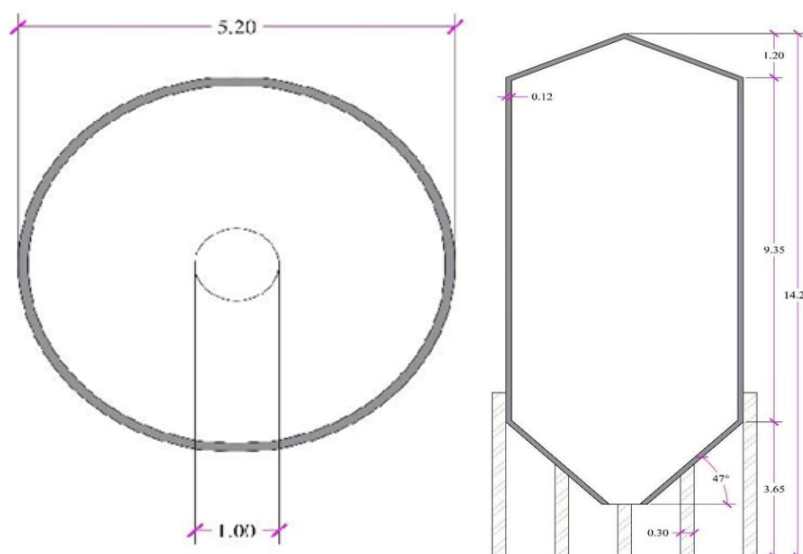
Fig 1: Sectional View of Silo

***All dimensions in the above fig 1 is in meter**
- The silo is designed in Staad Pro Software.
- Firstly, modelling is done in run wizard as shown in Fig 2 & Fig 3.
- Then section of silo is provided by giving approximate thickness.
- Columns are also provided in 3m center to center distance.
- Loads are provided which includes Dead Load, Live Load, Wind Load, Load Combinations etc.

- Then Assign fixed supports to the bottom nodes. Fig 4 & Fig 5 shows the displacement & beam stress diagram which results after analysis of structure.
- 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.
- Meanwhile, concrete design of silo is processed by choosing IS 456.
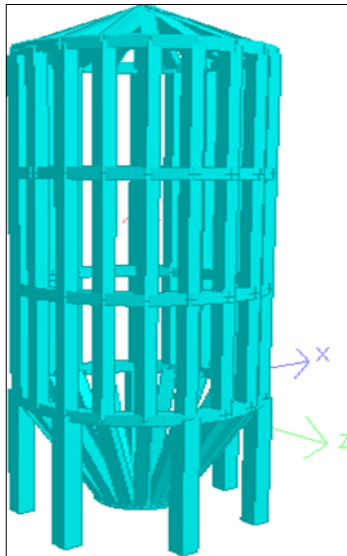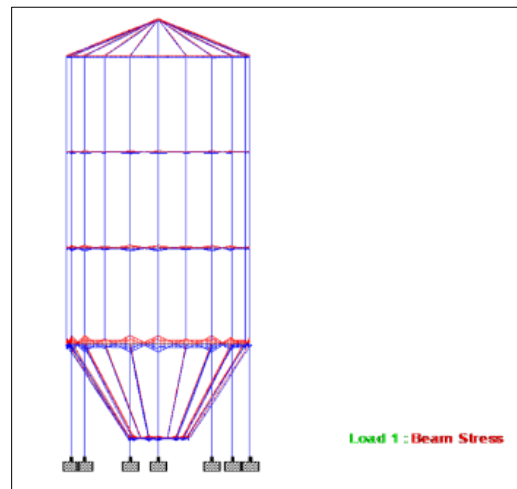

Fig 2: Rendered View
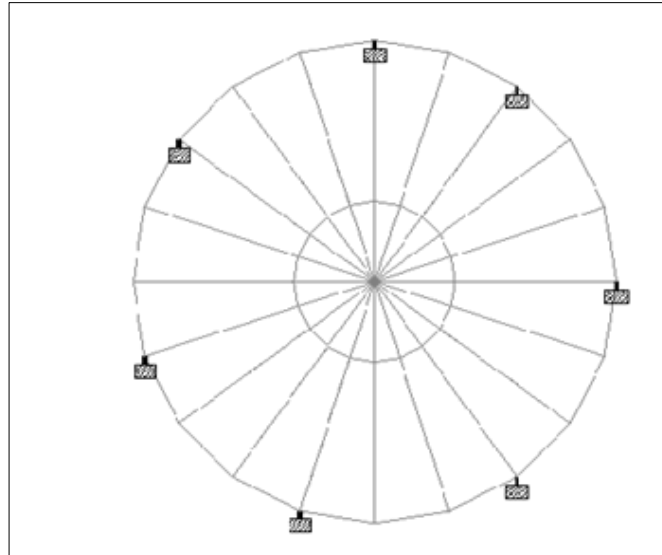
Fig 3: Top View in Staad Pro
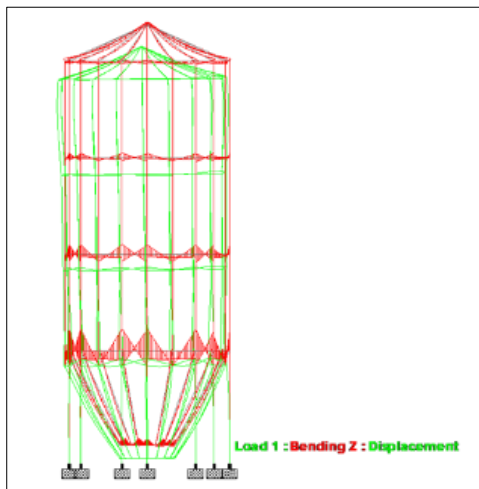
Fig 4: Bending & displacement

Fig 5: Beam Stress

Design Results

Table 2

Silo	Design Data
Dome slab	8mm @ 210mm c/c Spacing
Ring Beam (0.3Mx0.8m)	6X25T
Cylindrical Wall	8mm @ 210mm c/c Spacing
Column(0.3mx0.3m)	Main Reinforcement: 8X20t Tie bars: 8mm@230mm c/c spacing
Footing	Raft Footing: 20mm @120mm c/c spacing (top & bottom)

2. Conclusion

The planning of the silo is done using AUTO CAD and it is analyzed for all the load combinations such as dead load, live load with respective Indian Standard codes IS 456:2000, IS 4995:1974(part 1 and 2)and IS 875- 1987(part 1,2,4) using STAAD Pro. The design forces and moments are considered as per the STAAD Pro results for the design of the structures such as dome slab, ring beam, hopper, column & footing. It has been shown that the members chosen are safe to carry the expected design loads.

3. References

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