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Design & Construction Methodology for Silo in Cement Plant

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Abstract:
The following calculation report concerns the design of Silo of capacity 3500 MT. This Silo has been designed as RCC construction with Flat Slab at certain for discharging / extraction arrangement. The material considered for filling inside silo is clinker, the internal diameter of silo is 14m & of 35.40m overall height. The Staad model of silo is prepared and all the loads along with their load combinations including dead load , live loads , wind loads, seismic load , symmetrically filling load , symmetrically filling load with patch, symmetrically discharge, symmetrically discharge with patch , flow channel geometry & material loads are considered The base pressure calculation have been done on the basis of values obtained from staad , The reinforcement in raft foundation have been calculated for moments (MX and MY) for top and bottom for all elements and detailing have been done accordingly.

Keywords: Silo, Dead Load, Live Load, Wind load, Seismic Load , Symmetrically Filling Load, Symmetrically Filling With patch Load, Symmetrically Discharge Load, Symmetrically Discharge with Patch Load, Flow Channel Geometry & Material Loads.

I. INTRODUCTION

In Industry, the importance of RCC construction can not be overstressed. Keeping the longevity of RCC over Steel construction, various techniques are being sought to ensure speedy construction of RCC structures.
Silos are huge cells to store various materials e.g. agricultural products like sugar, cereals, fertilizers and industrial materials like cement, phosphates clinker, fly ash, coke powder and may more. These materials are stored in silos for preservation and for safe storing till dispatches since storing the bagged material are more expensive.
Silo have been classified into four types according to their geometry

- Slender Silo:- The Silo is defined as a slender where 2 < hc / dc
- Intermediate Slenderness Silo:- The Silo is defined as a intermediate slenderness where 1 < hc / dc
- Squat Silo:- The Silo is defined as a squat where 0.4 < hc / dc < 1.0
- Retiling Silo:-The Silo is defined as a retiling where bottom is flat & hc / dc < 1.0

Where dc is the inside diameter of silo & hc is the height of vertical walled from transition to the equivalent Surface

II. CONSTRUCTION METHODOLOGY OF SILO USING SLIPFORM TECNIQUE

1.1 General:

1.1.1 In RCC construction, the formwork involves considerable material and labor costs and involves time. Thus, the overall cost depends significantly on the formwork. It is very pronounced in case of structures of large heights. The engineers and contractors strive to rationalize the formwork to the extent possible. For many cases Slipform is considered the right solution.

1.1.2 The main benefits of this technology are:

- Total elimination of traditional scaffolding
- Dimensional accuracy
- Smooth finishing
- Minimum requirement of carpenters
- A monolithic structure is achieved without vertical or horizontal joints.
- The surface that is obtained is almost form finish and any treatment if necessary is done when the concrete is green
- Mainly depending on weather conditions, it is possible to achieve the progress of 4m to 5m in summer and 2m to 3m in winter

1.2 Slipform System:

1.2.1 The Slipform system comprises of shuttering (Steel or wooden) of height 1000mm to 1250mm connected together by transverse steel yokes at an interval of 1200 to 2500mm spacing. Walers made of wood or steel sections retain the profile of the formwork.

1.2.2 At the upper edge of the form, the working platforms are located and the scaffolds for finishing the concrete surface are suspended beneath them.

1.3 Arrangement Required Before Slipping for Mix Design

1.3.1 The design mixes should be prepared and tests conducted at site. It should be ensured that the workability of concrete is meticulously controlled. A slump of more than 100mm for hot weather conditions and around 50mm for winter concreting should be considered. Though retarder for hot weather is suggested, it is advisable to avoid since the finishing should be relatively poor when admixtures are used.

1.3.2 At the upper edge of the form, the working platforms are located and the scaffolds for finishing the concrete surface are suspended beneath them. The use of admixtures becomes necessary to avoid following problems at site:

1.3.3 Rapid setting of concrete in the form before movement of shutters

1.3.4 Retention of workability of concrete so that the concrete remains plastic till its final placement location.

1.3.5 During high ambient temperatures around 40^{o}C it is desirable to use ice or chilled water in the preparation of concrete along with cooling the aggregates before use. This would help to retain the temperature below 30^{o}C.

1.3.6 When it is contemplated to use Admixtures in concrete, the dosage should be arrived at according to manufacturer's instructions and on trial tests at site.

1.3.7 The field tests should be done on all the trial mixes with the finalized mixes and the 28days cube tests be carried out before freezing the mixes

1.3.8 The yield of the concrete should be arrived at to arrive at the consumption of the cement per cu.M. Of concrete for various grades.

1.4 Tolerances

1.4.1 **Thickness:** The variation from prescribed wall thickness should be between -10mm to +25mm at site.

1.4.2 Diameter: Variation from true circular cross section in a circular silo should no be more than +25mm or 4mm per Meter diameter of the silo whichever is lower

1.4.3 Horizontal deviation: the maximum Horizontal deviations which may consist of translational and rotational components of any point at the base of the structure should not be more than 80mm at any point in silos of 30M height nor 100mm total for silos over 30M height

III. HYPOTHESIS FOR CALCULATIONS

A STAAD model in FEM has been prepared for design of vertical wall as well as raft for this silo. Silo raft has been analyzed considering wind and Earthquake loads as per relevant Indian standard codes. The reinforcement in raft foundation have been calculated for moments (MX and MY) for top and bottom for all elements and detailing have been done accordingly. The following basic loads have been considered for the design of raft of Silo.

- Self weight of the silo structure.
- Material fill loads
- Live loads at different floors.
- Wind load
- Seismic load
- Equipment loads etc

IV. MATERIAL USED IN DESIGN

1. Concrete Grade for Silo raft M30
2. Concrete Grade for vertical walls and ring flat slab M35
3. Reinforcement Steel HYSD bars of Min Yield Strength 500N/mm^2
4. Raft have been designed for Safe Bearing Capacity of 400KN/m^2

V. METHOD OF CONSTRUCTION

The raft & flat slab of Silo will be constructed as a conventional method however the vertical walls in slip form construction.

VI. INPUT DATA CONSIDERED FOR DESIGN

1. Material = SILO (Clinker)

2. Weight of Material Stored in Storage Silo =3500 Ton

3. Thickness of RCC Wall of Storage Silo =350 mm

4. Average thickness of Top Slab of Silo = 150 mm

5. Thickness deck slab = 1500 mm

6. Elevation of bottom of deck slab above GL= 12.750 M

7. Elevation of top of deck slab above GL =14.250 M

8. Elevation of Top of roof Slab above GL = 35.400 M

9. Max. Level of Filling below Silo Top = 1.20 M

10. Height of av. Material Storage from top of deck slab= 19.950 M

11. Internal Diameter of Storage silo D = 14M

12. Angle of Repose fr = 34 ^{0}

13. Mean Angle of Internal Friction fm=34 ^{0}

14. Slenderness Ratio (hc / dc) = 1.43

15. Silo Type =intermediate silo

16. Temperature of Hot Material inside Ti =125^{o}C

17. Temperature of Outside Atmosphere T0 = 7 ^{o}C

18. Bulk Density of Stored Material= 1.8 T/M^3

19. Seismic Zone II Z= 0.1

20. Basic Wind speed =39 M/sec

21. Grade of Conc. for wall (Characteristic Strength) = 35N/mm^2

22. Elevation. Of Top of Ring Beam above GL = 12.750 M

23. Thickness of RCC Wall below deck slab bottom level= 700 mm

24. Yield Stress of Reinforcement =500 N/mm^2

25. Grade of Conc. for foundation =30N/mm^2

26. Maximum eccentricity of filling ef = 0 M

27. Maximum eccentricity of outlet e0 =5 M

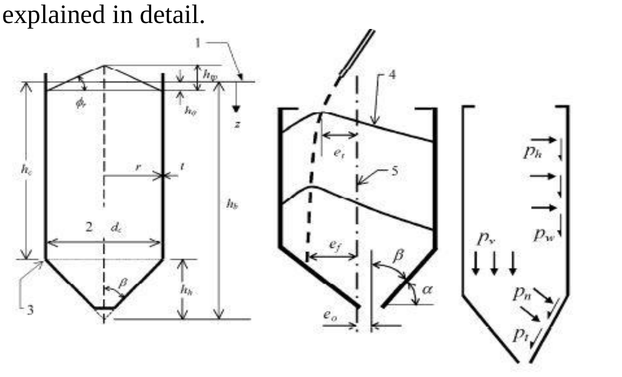
28. Top of Foundation = 4 M

29. Bottom of Foundation = 6 M

30. Outer Diameter of Foundation = 20.75 M

VII. LOADS TO BE CONSIDERED

In general, the loads to be determined & considered for designing the normal structures as per codal provisions such as Dead load, Live load, Wind load, Seismic load, Temperature load . For the design of Silo, the load due to stored materials is to be considered in addition to the loads acting on the normal structures. The loads to be considered for the design of silo are explained in detail.



a) Geometry b) Eccentricities c) Pressures and tractions

1) Dead Load Dead loads shall include the weight of all structural components such as foundation, beams, column, floor slabs, walls and other permanent applied external loads. In silos, the dead loads shall be calculated by taking the weight of the components such as foundation, shell walls, ring beams, columns, beams & slab. The unit weight of all the material & their components are available in Indian standard code standard part 1 Dead loads Unit weight of building materials and stored materials" The material loads are not to be considered in dead load until the materials are constructed permanently in position. The dead loads are static forces exerted in vertical plane and relatively constant throughout the life time. Generally the density of reinforced cement concrete to be considered for design purpose has been taken as $25KN/M^3$ & $24KN/M^3$ for plain cement concrete. In Staad model loads of roof girder on silo top, loads from intermediate reinforced concrete floor & slab have also been considered while designing.

2) Live Loads Live loads are the temporary loads which are occur on structure over the short duration of time. The imposed loads which are acting on structure produced by live loads, dust loads, operation loads, maintenance loads, erection loads, equipment loads which are placed o n the structure but they are not permanently attached to it. All the live load values depending upon the type of structure are available in Indian standard codes IS 875–1987 "Code of Practice for Design loads (Other than earthquake) Part 2: Imposed loads", the floor live loads values to be considered on different floors depending upon the importance are available in Indian standard specifications. Generally the live load on different floor have been taken $5KN/m^2$ depending upon the importance of floor. In Staad model loads of roof girder on silo top, loads from intermediate reinforced concrete floor & slab have also been considered while designing

3) Wind Load The wind loads acting on silo structure shall be calculated & according to EN 1991 – 2005, "Eurocode 1; Actions on structures. Part 1-4: General actions – Wind actions" (Eurocode (EN), 2005). In comparison to Indian standard code IS 875 - 1987 "Code of Practice for Design loads (Other than earthquake) for buildings and structures. Part 3: Wind loads", the Eurocode provides the detailed description & behavior about the wind load actions on silo wall. The wind analysis shall consider the wind direction relative to structure for external & internal pressure coefficient applied to windward sides of the structure. While doing design of structure the determination of wind action on structure depends upon location, metrological data, type of terrain, wind speed, height of structure. In staad model wind load acting on plate in such a way that the calculation on the basis of by considering angle between two element is of 8^0 & different pressure are calculated on the basis of height.

4) Seismic Load During earthquake the inertia forces are created by ground accelerations result the seismic loads. The concept of seismic loads is due to the application of earthquake generated agitation to the building structure. Seismic analysis for foundation of silo structure is determined as per IS 1893 – 2002 "Criteria for Earthquake resistant design of structures. Part 1: General Provisions and buildings" Bureau of Indian Standard "Action on Structures. Part 6: Design loads for buildings – Loads in silo bins". The seismic pressure on the walls of silo is calculated on basis of the guidelines for the calculations of seismic forces acting on the structure. The performance of seismic forces acting on the structure depending upon the building codes. The magnitude of loads depends upon the mass of building, dynamic properties, intensity & frequency of ground motions are the important factors while doing design of silo. In Staad model we considered combination of dead load 100% along with live load of 50% to determine static joint forces acting on the structure.

5) Material Load The loads due to stored material inside the silo have been considered for the designing in order to avoid unexpected loading conditions. The loads of material may vary depending upon the material properties, process of filling, process of discharge arrangements, angle of internal friction, material density, height of material filling & angle of repose etc "Action on Structures. Part 6 design loads for buildings - loads in silo bins" is the only code which is useful & helpful rules for the designers with the consideration of the load due to stored material. The load of the stored material is categorized as Symmetric load and Reference surface load which is to be determined at the filling and discharging states. The reference surface loads are defined as the load which is perpendicular to silo wall. Generally failure of silo is only due to material load is excess in comparison to loads which was considered during design. Hence material load is one of the most important loads while doing design of silo.

6) SYMMETRICAL FILLING CONDITION

Phf (z) =Horizontal pressure at depth Z=
Pho*YR (z) (T/M^2)

Pwf (z) =Wall friction traction at depth Z=
u*Pho*YR(z) (T/M^2)

Pvf (z) =Vertical pressure at depth Z
= lZv (T/M^2)

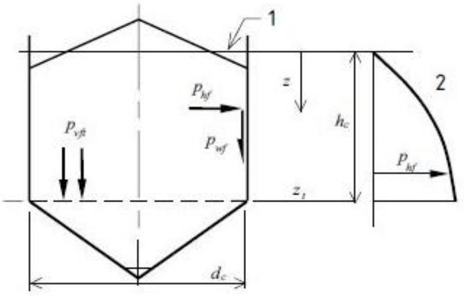
Zv = (h0-1/ (n+1)*(z0-h0-(z+z0-2h0) ^ (n+1)/ (z0-h0) ^n) m

Zo = (1 / (K*m))*(A / U) M

Pho = l*K*zo (T/M2)

YR (z) =1-((z-h0)/ (z0-h0) +1) ^n

N = (-(1+ Tanf)*(1-h0/Z0)



Key
1 Equivalent surface
2 Pressures in vertical segment

7) PATCH LOAD CALCULATION AT FILLING CONDITION

Silo Type = Thick walled circular silo

Ppf = Filling outward patch pressure

Cpf*PhfPpfi =Filling inward patch pressure = Ppf/7
Cpf =0.21*Cop*(1+2E2)*(1-e (-1.5*((hc/dc)-1)))

E = 2*ef / dc =0.00

Ef = Maximum eccentricity of surface pole during filling
= 0.0 M

Phf = Local filling pressure

Cop = Patch load solid reference factor = 0.70

S = the length of the zone on which the patch load is applied

Phf,u = Resulting symmetrical horizontal pressure for filling.

8) LOAD CALCULATION AT SYMMETRICAL DISCHARGE CONDITION

Phe (z) =Horizontal pressure at depth Z = Ch*Phf (T/M^2)

Pwe (z) =Wall friction traction at depth Z =Cw*Pwf (T/M^2)

Ch = Discharge factor for horizontal pressure = 1.15 = C0 (T/M)

Cw = Discharge factor for wall frictional traction= 1.10

C0 =Discharge factor for all solids

9) PATCH LOAD CALCULATION AT DISCHARGE CONDITION

Silo Type = Thick walled circular silo

Ppe = Discharge outward patch pressure = Cpe*Phe

Ppei = Discharge inward patch pressure = Ppe / 7

hc / dc =1.43

Cpe =0.42*Cop*(1+2*E2)*(1-exp(-1.5*((hc/dc)-1)))

E = 2*e / dc = 0.7

E =Max (ef, e0) = 5.0 M

Phe = Local discharge pressure

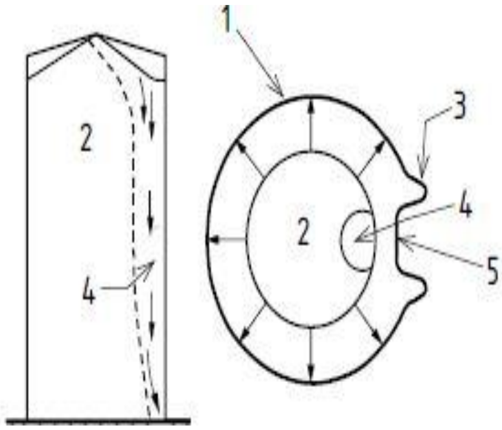
Cop = Patch load solid reference factor = 0.70

S =the length of the zone on which the patch load is applied

Phe,u =Resulting symmetrical horizontal pressure for discharge

= Maximun(0.5+0.01*(dc/t) or 1) = 1.00

10) PRESSURE CALCULATION UNDER FLOW CHANNEL GEOMETRY



1) Static Pressures
2) Static Solid
3) Channel Edge Pressure
4) Flow Channel Pressures

VIII. LOAD COMBINATIONS

There are many loads to be acting on structure which will result in the load combinations. The load combination to be calculated for the structure which contains more than one type of loads which is acting on structure. For Structure safety & their economical design all the loads & their combinations along with the factor to be considered as per the building codes. The entire Structural element i.e. raft, wall, Slab, by considering all the loads & their combinations effect which produce unfavorable effect on it. As per the Indian Standard IS 875“Code of Practice for Design loads (Other than earthquake) for buildings and structures. Part 5: Special loads and Load combinations” The Special loads & their combination are in the form of Moments horizontal & vertical due to temperature gradient shall be combined along with wind & seismic loads cases which are applicable.

IX. CONCLUSION

The design of silo by considering the bulk material handled during its loading condition. it is very important to calculate all the loads which are acting on the inside walls of silo, for safe and economical design it is very important to considered all the loads including dead load, live load, wind load, seismic load , symmetrical filling condition , symmetrical filling load wit patch, symmetrical discharge load, symmetrical discharge load with patch, flow channel geometry. It also provides the outline of the calculation of all foreseeable loads acting on the structure. During our study & design of silo by finite element method after the application of all the load cases & their combination the reinforcement in raft foundation have been calculated for moments (MX and MY) for top and bottom for all elements and detailing have been done accordingly.

X. REFERENCES

[1]. Dr. Ashok Kr. Jain, “Reinforced Concrete, Limited Status Design”

[2]. Dr. Pillai Meneon, “Reinforced Concrete, Limited Design”.

[3].M.S.Shetty, “Concrete Technology”.

[4].IS: 456 – 2000 “Code of practice for Plain & “Reinforced Concrete”.

[5]. IS:1893(Part-4):2005, “Criteria for Earthquake Resistance Design of Structure”.

[6]. IS: 875 (Part - 1) “Code of Practice for Design loads (other than Earthquake loads) for Building & Structure, Dead loads”.

[7].IS: 875 (Part– 2), “Code of Practice for design loads (other than Earthquake loads) for Building & Structure, Imposed Loads.”

[8]. IS: 875 (Part– 3), “Code of Practice for design loads (other than Earthquake loads) for Building & Structure, Wind Loads.”

[9].IS: 4995 (Part–1), “Creteria for designof Reinforced Concrete Bins for Storage of Granular & Powdery Material.”

[10].IS: 4995 (Part–2), “Creteria for designof Reinforced Concrete Bins for Storage of Granular & Powdery Material.”

[11]. SP: 16-1980, “Design Aids for Reinforcement concrete to IS: 456 – 1978”.

[12]. SP:34 (S&T)–1987, “Hand Book for Concrete Reinforcement & Detailing”.

[13].British Standard, BS EN 1991- 4: 2006 Eurocode 1 – Actions on structures Part 4: Silos and Tanks.

[14].British Standard, BS EN 1992- 4: 2006 Eurocode 2 – Design of reinforcing structures.

[15]. Eurocode (EN) (2005), “Actions on Structures, Part 1-4: General Actions – Wind Actions”.

[16].British Standard, BS EN 1991- 4: 2006 Eurocode 1 – Actions on structures Part 4: Silos and Tanks.

[17].British Standard, BS EN 1992- 4: 2006 Eurocode 2 – Design of reinforcing structures.

[18].Software Used: MS Word, MS Excel, Staad Pro, Autocad,