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Comparison of Design & Seismic Behavior of RCC SILO

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Abstract: ***Concrete flat bottom circular silos are often deployed to store material in various industries like cement plants, power plants, oil and gas industry etc. Silos are special structures subjected to many different unconventional loading conditions, which result in unusual failure modes. Failure of a silo can be devastating as it can result in loss of the container, contamination of the material it contains, loss of material, cleanup, replacement costs, environmental damage, and possible injury or loss of life. The best design of silo has helped in safe structure. In present paper an industrial silo analyzed and designed according to the Indian standards (IS 4995) and also by referring Euro code (EN 1998 -4 : 1999 & EN 1991-4 : 2006) and ACI code (ACI 313). In this study, a 450 cum capacity flat bottom silo design & analysis.***

Keywords: Flat bottom silo , pressure, seismic action, IS code, EURO code, ACI code.

1. Introduction

Reinforced concrete silo is inherently durable than steel silo. The design of silo is based on the strength design method. The design of silos is primarily governed by the type and properties of the stored material. The walls of the silos are typically subjected to both normal pressure and vertical frictional shear or traction produced by the material stored inside the silo. The magnitude and distribution of both shear and normal pressure over the height of the wall depend on the properties of the stored material and whether the silo is being filled or discharged. Design of silo considers both static & dynamic condition. Static & dynamic pressure exerted by the stored material. Other potential loads, including seismic loads, calculation of seismic load consider silo self weight and material stored in it as a lumped mass and seismic effect of this mass is considered in design of the silo wall.

2. Structure Configuration

Selected industrial silo is located in Bhopal, Madhya Pradesh, India use for storage of cement material. Consider the flat bottom silo resting on ground having capacity of 450 cu.m height 20 m , diameter 6 m & flat roof cover with small opening to store material in silo. Material stored in silo by using concentric flow. Structure situated in seismic zone II with wind speed 39 m/sec. Complete structure configuration details can be found in Table 1 as follows:

Table 1: Structure configuration details

1	Location	Bhopal, Madhya Pradesh, India
2	Capacity	450 cu.m
3	Height	20 m
4	Diameter	6 m
5	Seismic zone	II
6	Wind speed	39 m/sec
7	Wind terrain category	2
8	Wind Class	B
9	Material store in silo	Cement

3. Types of Silo

As per EUROCODE, the loads on silo vertical wall be evaluated according to slenderness of silo determined according to the following types which given in Table 2.

Table 2: Silo classification

SR. NO.	Types Of Silo	Condition
a	Slender silo	2 < hc /dc
b	Intermediate slenderness silo	1 < hc /dc < 2
c	Squat silo	0.4 < hc /dc < 1
d	Retaining silo	hc /dc < 4

4. Loads Considered

1. Dead load
2. Live load
3. Wind load
4. Earthquake load

5. Wind Calculation

Wind load calculation is done according to Indian code IS: 875(part-2)-1987-Cl.5.3, as follows in Table 3.

Table 3. Wind data

Wind speed (Vb)	=	39 m/s
Risk coefficient (K1)	=	1
Probability factor (K2)	=	1.05
Topography factor (K3)	=	1
Design wind speed (VZ)	=	K1*K2*K3*Vb
Design wind pressure (PZ)	=	0.6*(Vz)2

6. Seismic Calculation

Seismic load calculation damping & importance factor is given in table 4 & 5 respectively.

Table 4: Damping factors used in various codes

Sr. no.	Description	IS	EURO Serviceability limit state	EURO Ultimate limit state
1	Reinforced Concrete Silo	"1.2" Multiplying factor ; 2 % damping	4% damping	7 % damping
2	Prestressed Concrete Silo	"1.2" Multiplying factor; 2 % damping	2 % damping	5 % damping

Table 5: Importance Factors

Sr. no.	Description	Factor
1	Silo use to store material which is having risk to life	1.5
2	All other silo use to store material which is having risk to life	1

7. Pressure Calculation

For pressure calculation values of angle of internal friction and coefficient of friction are taken as per respective code refer table 6.

Table 6: Angle of Internal Friction and Coefficient Friction

Description	IS	ACI	EURO
Angle of internal friction	25	25	30
Coefficient of wall friction	.46	.4	.5

Pressures due to initial filling shall be computed in different code by Janssen's theory which explains below; table 7 & 8 gives pressure calculation formulas for bottom & wall of silo.

Table 7: Formulae for pressure calculation

Wall pressure	IS	ACI	EURO
vertical pressure = qv	γ A/(U μ'k)	(γ A /μ'U k) (1- e ^ (- μ'kAh /U))	(γ μ'k/2) (1+ sinϴ') h^2
horizontal pressure = qh	γ A/(U μ')	kqv	(γ kh) (1+ sinϴ')
lateral pressure ratio = k	1- sin ϴ	1- sin ϴ	1- sin ϴ
vertical friction pressure = V	γ A/U	(γh - qv) (A/U)	μ'qv (1- e^(-z/z0))

Table 8

Bottom pressure	ACI	EURO
vertical pressure = qbv	1.35qv	Cb x qv

In euro code according to the requirement of the silo the following three action assessment classes used given in table 9.

Table 9: Action class assessment

Action Assessment Class 3 (Cb = 1.6)	Silos with capacity in excess of 10000 tonnes
	Silos with capacity in excess of 1000 tonnes in which any of the following design situations occur:
	a) eccentric discharge with ec/dc> 0,25
	b) squat silos with top surface eccentricity with >0,25
Action Assessment Class 2 (Cb = 1.2)	All silos covered by this standard and not placed in another class
Action Assessment Class I (Cb = 1.2)	Silos with capacity below 100 tonnes

8. Load Combination

Load combinations include different combinations of loads according to different codes (ACI 313, IS 456 -2007) by considering strength criteria as follows in Table 10.

Table 10: Load combination

Code	IS	ACI
Load Combination	1.5qv + 1.5 qh	1.4 qv + 1.7 qh

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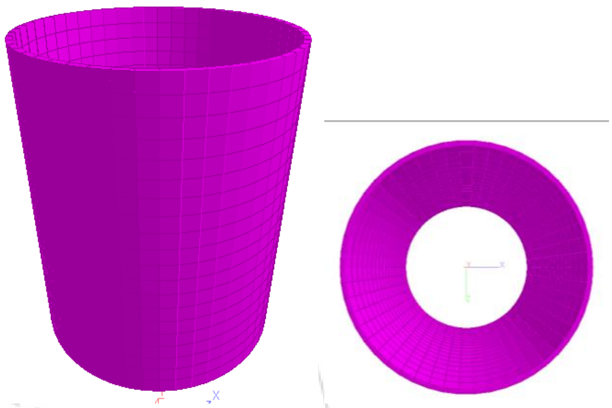

Figure 1: Staad Model for silo structure

Comparison of pressure calculation when silo in filling condition using different code, refer fig. 2.

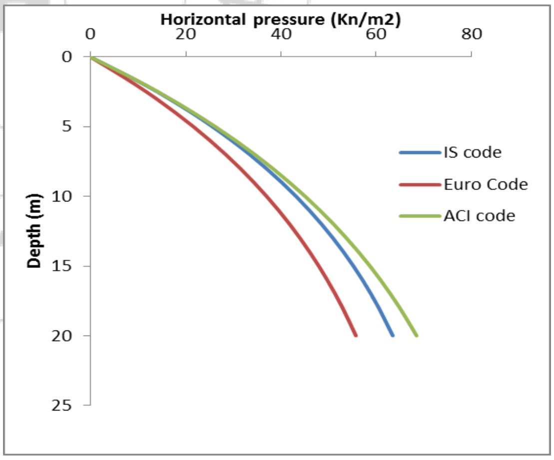

Figure 2: Pressure comparison between various codes

Table 11: Seismic parameters

Description	Value
Zone factor	0.16
Importance factor	1
Response reduction factor	3
Sa/g	2.5

Comparison of pressure calculation when silo in filling in static & dynamic condition using different code, refer fig. 3

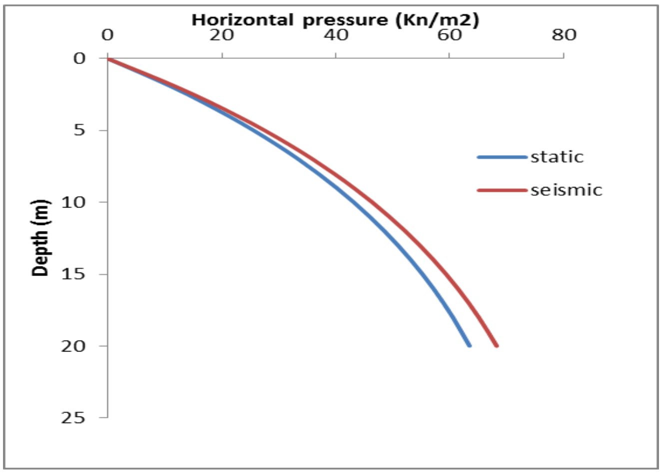

Figure 3: Pressure comparison in seismic and static condition

Comparison of pressure calculation in staad and manual by IS code refer fig. 4

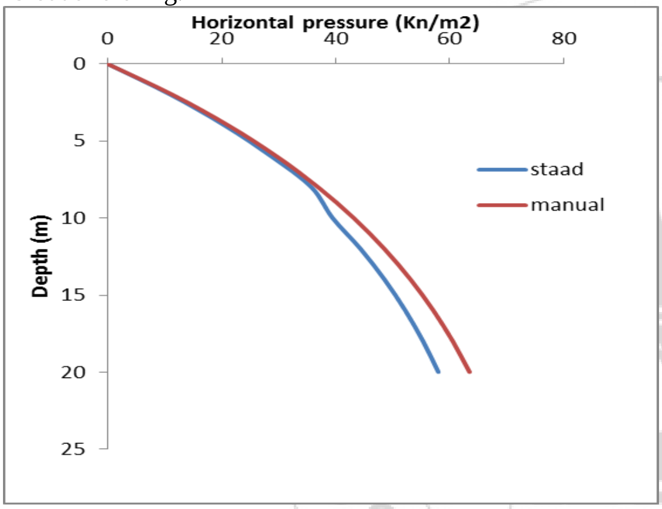

Figure 4: Pressure distribution in staad and manual calculation

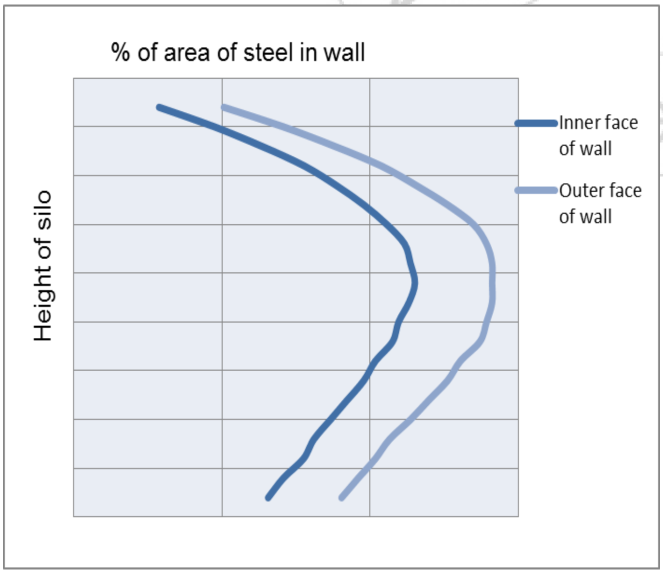

Figure 5: Comparison of steel in silo wall faces

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9. Conclusion

1. Pressure calculation given as ACI code is found to be more conservative side than other codes of practice.
2. Reinforcement is found to varying along depth of wall and found to be more on middle portion of wall.
3. Silo design & construction is based on strength design method.
4. Due to difference in value of μ and Θ; variation in pressure calculation can be seen.
5. Additional pressure due to seismic action need to be considered while designing silo wall.

Notation

H = height of hopper
T = wall thickness
A = Horizontal interior cross section area of silo
U = Interior perimeter of the silo
γ = bulk density of store material
k = pressure ratio
μ' = coefficient of friction between stored material and wall or hopper surface
α = angle of repose.
qh = initial (filling) horizontal pressure due to material
qv = initial (filling) vertical pressure due to material
V = vertical force transfer to the wall due to friction Between material & wall

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