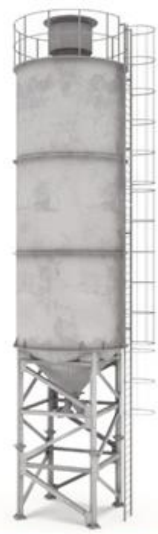
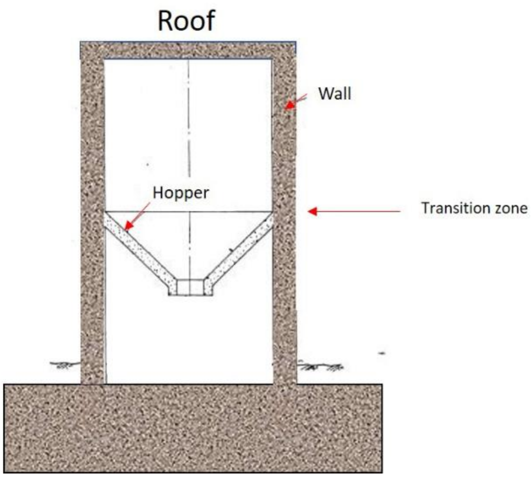
Bin structures



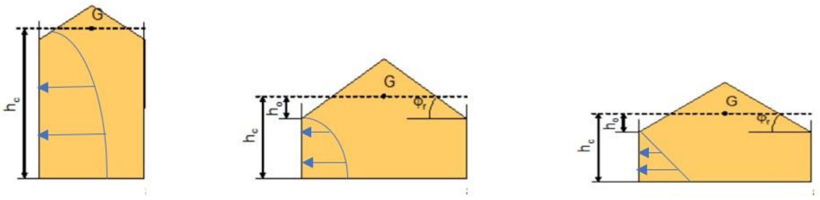
Bin structures are used for storing different materials such as granular materials like food grains, coke, coal, ores or powdery materials like flour, cement, etc. Moreover, they are also used to store fluids like water and oil or even gas. These structures may be circular, rectangular or polygonal in plan. Generally, steel bin structures may be used for small storage; however, reinforced and pre-stressed (particularly for circular shape in plan) concrete structures may be used with large amount of storage of the bins.



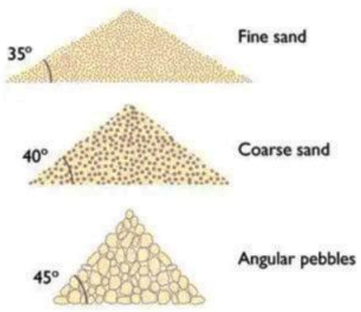
Some parts of bin structures are ignored depending on the usage purposes such as the roofs may be eliminated, or the roofs may be steel or truss structures. For fluids and gas storage bins, hopper or flat plate at the bottom are generally used since hopper is suit for flowing out materials from the bin (granular or powdery materials).

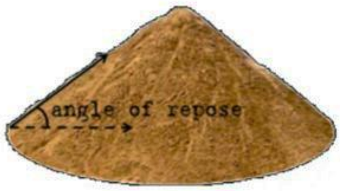
The main key for the design of a bin structure is to find the force acted by stored materials on bin wall structure. The significant parameters resulting on the design are as follows:

1. Types and shapes of bin structures

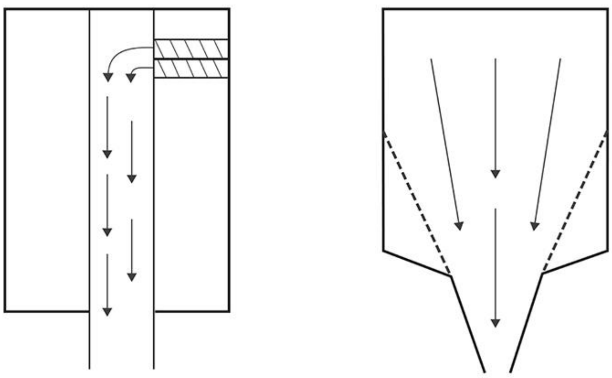


2. Types of stored materials



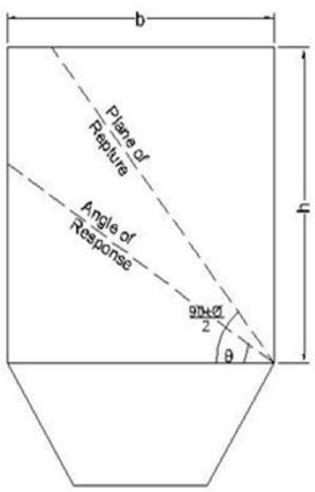
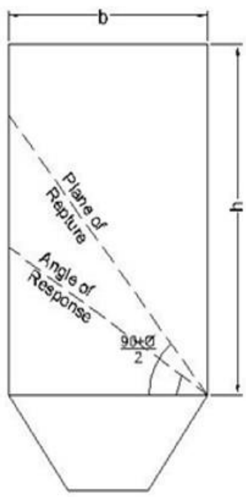


3. Filling and emptying materials



1. Type of bin (or tank) Structures

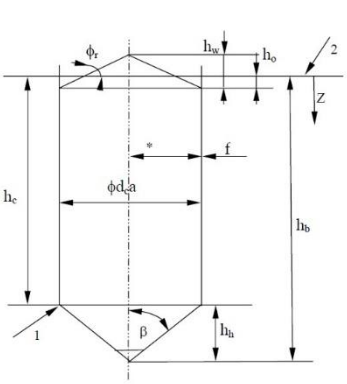
Every Code provides different specifications for finding the active force acting on tanks which are depended on the types of tanks followed by their aspect ratios (height to perimeter). The fundamental definition and theory for finding active forces acting on tank structures are shown in the figures below.

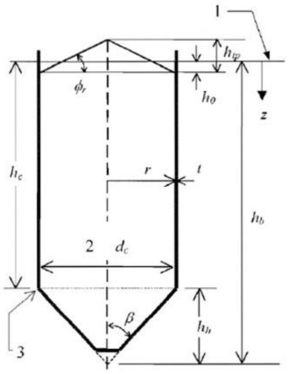
Shallow	Deep
	
Shallow Tank	**Deep Tank**
Plane of rupture is higher than plane of wall tank	Plane of rupture intersects than plane of wall tank
Weightage of stored materials act on the bottom of the tank	Weightage of stored materials is resisted by the bottom of the tank, and the friction between wall tank and stored materials respectively.
The lateral active force acting on wall tank is calculated by using the theories of Rankine and Airy.	The lateral active force acting on wall tank is calculated by using the theories of Janssen and Reimbert.

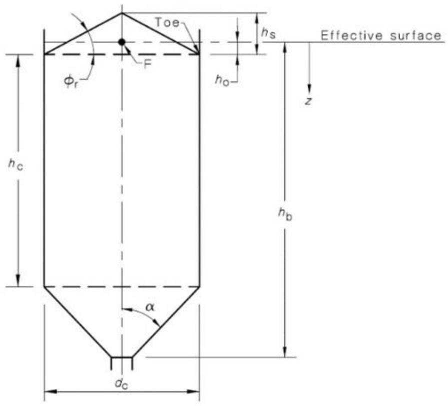
Types of Stored Materials

- Silo: Storing tank structure, normally formed as a high tank which its aspect ratio varies depending on different Codes as the following:

DIN 1055		BS EN 1991-4		AS 3774	
Slim silo	hc/dc ≥ 2.0	Slender	hc/dc ≥ 2.0	Tall	hb/dc > 3.0
Medium Slimness	1.0 < hc/dc < 2.0	Intermediate Slenderness	1.0 < hc/dc < 2.0	Medium tall	1.0 ≤ hb/dc ≤ 3.0
Low silo	0.4 < hc/dc ≤ 1.0	Squat	0.4 < hc/dc ≤ 1.0	Squat	hb/dc < 1.0
Braced wall silo	hc/dc ≤ 0.4	Retaining	hc/dc ≤ 0.4		





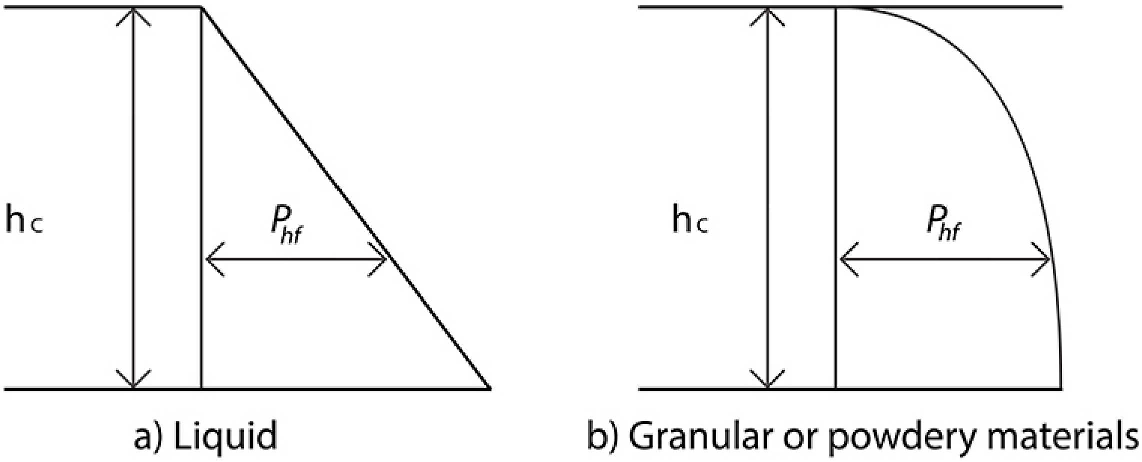


- Bunker: Storing tank structure with lower height similarly to a retaining wall structure which one or two sides are opened so that a truck or any container can get closer to collect the inside stored materials.

- Tank structure used to store fluids or gas.

2. Types of Stored Materials

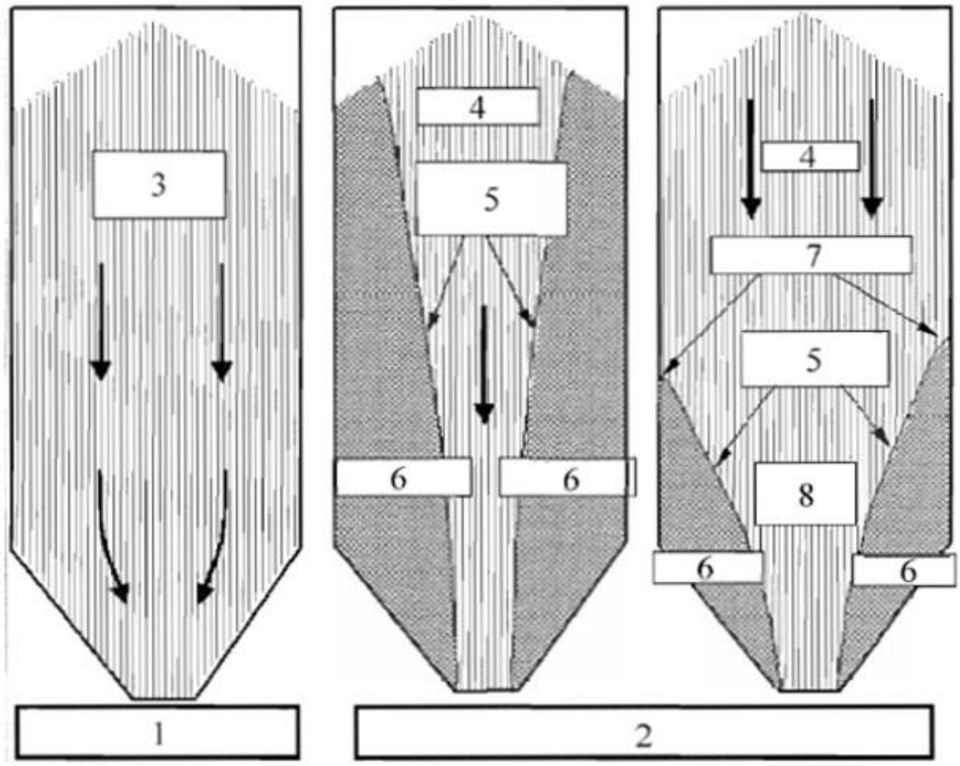
Fluids such as water or oil produces Hydrostatic Pressure, for granular, the active force acts as in the figure below.



The pressure or active force acted by granular materials can be calculated by finding some coefficients of the properties of those materials such as bulk specific gravity, coefficient of friction between materials and wall structures and the angle of internal friction (angle of repose).

3. Filling or Emptying Materials

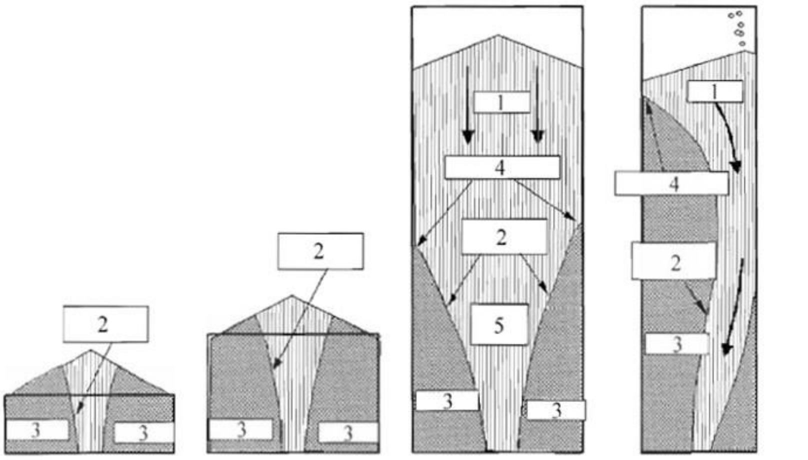
The trajectory of materials from a bin structure could lead to an eccentricity at any level in the bin so that the unsymmetrical pressures may occurred. This additional force should be added into the calculation.



a) Mass flow b) Pipe flow c) Mixed flow

Key
1. Mass flow
2. Funnel flow
3. All solids in motion
4. Flowing
5. Flow channel boundary
6. Stationary
7. Effective transmission
8. Effective hopper

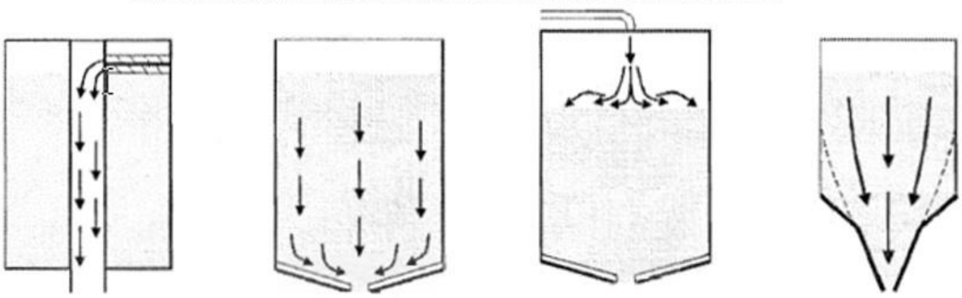
Figure 3.1: Basic flow patterns



a) Retaining silo b) Squat silo c) Slender silo d) Very slender silo

Key
1. Flowing
2. Flow channel boundary
3. Stationary
4. Effective transmission
5. Effective hopper

Figure 3.4: Aspect ratio (slenderness) effects in mixed and pipe flow patterns



a) mechanical discharge with concentric pressures

b) air injection and air slides promote mass flow

c) pneumatic filling of powders causes almost flat top surface

d) expanded flow hopper gives mass flow only in bottom hopper

Figure 3.5: Special filling and discharge arrangements

Different countries follow different Codes in the design of bin structures by standing on different hypotheses.

The Table blow shows about the comparison between Codes for the design of bin structures subjected to the previous experimental studies.

	IS 4995 - 1974	ACI 313 - 97	DIN 1055 -6: 2005 - 03	BS EN 1991 – 4: 2006
Materials stored is defined as	Granular & Powdery	Granular	Bulk material	Stored solids
Silo Classification	No	No	Based on slimness & wall thickness	Based on slenderness & wall thickness
Vital Parameters	Bulk Density W, Angle of internal friction φ, Angle of wall friction δ, Pressure ratio λ	Weight per unit volume γ, Lateral pressure ratio k, Coefficient of friction μ'	Specific Gravity γ, Coefficient of wall friction μ, Angle of internal friction ϕ, Horizontal load ratio k	Bulk unit weight γ, Coefficient of wall friction μ, Angle of internal friction ϕ, Lateral pressure ratio k
Numerical Values of Solids properties	Directly given for each materials	No values	Obtained from tests & provided as lower and upper limit value	Obtained from tests & provided as lower and upper limit
Loads during filling & discharging	Horizontal load, vertical load & Frictional load	Horizontal load, vertical load & Frictional load	Symmetric load & Reference surface load	Symmetric load & Patch load
Computation of Loads	Based on materials	Based on materials	Based on Silos	Based on Silos
Limitations	No	Effect of hot stored material is not considered	Geometric, Materials, Filling & discharging arrangements.	Geometric, Materials, Filling & discharging arrangements.
Classification of action assessment	No	No	Based on Capacity of stored material	Based on Capacity of stored material
Flow Pattern during discharge	No	Walls – Concentric and Asymmetric flow, Hoppers – Funnel and Mass flow	Mass flow, Funnel flow and Mixed flow	Mass flow, Pipe flow and Mixed flow
Applicable hopper shapes for design	All shapes	Conical and Pyramidal hoppers	Conical and Cuneiform hoppers	Conical and Wedge shaped hoppers
Pressure zone consideration	No	For calculation of wall pressure	No	No
Crack Width calculation	Check and limitations are given	Calculation given	As per DIN 1045 – 1	As per EN 1992
Particle size	No limitation	No limitation	$\not>0.03\ d_c$	$\not>0.03\ d_c$
Reinforced details, Column & Foundation design	Mentioned	Mentioned	No	No

In the design of bin structure, besides the forces occurred from stored materials, the lateral forces such as wind or seismic and the effect of temperature should also be considered.

References:

1. IS 4995, Indian Standard: Criteria for Design of Reinforced Concrete Bins for The Storage of Granular and Powdery Materials

2. EN 1991-4, Eurocode 1- Actions on structures – Part 4: Silos and Tanks

3. AS 3774, Australian Standard: Loads on Bulk Solids Containers

4. DIN 1055-6, Actions on structures - Part 6: Design loads for Buildings and Loads in Silo Bins

5. ACI 313-97, Standard Practice for Design and Construction of Concrete Silos and Stacking Tubes for Storing Granular Materials

6. S.Chithra and G.Indupriya, Contributions of Different Standards and Codes for The Design of Silo

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