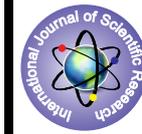


Comparative Study of Structural Design and Cost Analysis For Storage Container-Circular And Square Shapes



Engineering

KEYWORDS : Economic analysis (Structural steel, Material and Manufacturing cost) for mass flow container/bunker/silo.

Rajiv Gandhi K

Research Scholar Civil Engineering Department National Institute of Technology-Trichy

Dr. J. Karthikeyan

Assistant Professor Civil Engineering Department National Institute of Technology-Trichy

ABSTRACT

The aim of this project is to analyze the comparative study of structural design, material and manufacturing cost for same volume of containers in square and circular shapes. The economic weight of structures, material cost and manufacturing cost will be justified for commercial usage, Particularly for Bharat Heavy Electricals Limited (BHEL) – Circulating Fluidized Bed Combustion (CFBC) Boilers.

Introduction

Generally containers are used for storing bulk solids like coal, coke, ore, crushed stone, gravel, grain, cement etc. Usually containers called bins, bunkers and silos depending upon the size and shape, there is no generally accepted definition for each of these terms, shallow containers are called bins or bunkers, and tall containers are called silos. In this thesis, container is an inclusive term for all steel structures for storage of bulk solids.

Bunkers/Silos are having following different types of flow pattern:

1. Mass flow
2. Funnel flow
3. Expanded flow

The brief idea about the above flow patterns are:

Description of Flow Pattern

There are two primary and distinct types of flow of solids in hoppers, mass flow and funnel flow. There is also a special case that is a combination of these two flows called expanded flow. These flows get their names from the way in which solids move in the hoppers. The characteristics and differences between the flows are depicted in Fig 1. In mass flow all material moves in the bin including near the walls. In funnel flow the material moves in a central core with stagnant material near the walls. Expanded flow is a combination of mass flow in the hopper exit and funnel flow in the bin above the hopper (normally used in retrofit situations).

When a silo is discharged, In case of mass flow the whole silo contents, i.e., every particle, move during discharge. Mass flow is only possible if the hopper walls are sufficiently steep and/or smooth. If the latter is not the case, funnel flow prevails. In case of funnel flow, only a portion of the bulk solid in the silo moves downwards during discharge while the rest of the bulk solid remains stationary thus forming stagnant zones.

The primary difference between mass and funnel flow is that in mass flow all the material in the bin is in motion, though not necessarily all with the same velocity. In funnel flow only a core of material in the center above the hopper outlet is in motion while material next to the walls is stationary (stagnant).

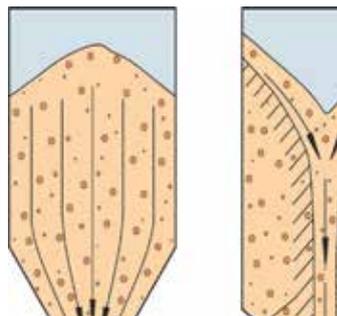


Fig. 1 Mass and Funnel Flow

Predicting Mass Flow

Many of the problems associated with bin and hopper design can be avoided by designing the hopper to operate in mass flow mode. The required cone angle from the vertical axis for mass flow to occur ranges from 40° to 0°.

Mass flow is not necessary in all cases. In some situations a mass flow hopper design is not practical due to the head room required. In most applications if you have a choice you want mass flow. But in the extreme cases or in cases in which mass flow is not really necessary then you may opt for the shorter funnel flow hopper design.

Advantages of Mass flow pattern over other flow pattern

- Total bin contents live
- Flow is more consistent
- Reduced radial segregation
- Stresses on walls are more predictable
- Effective use of full bin capacity
- First –in, first –out pattern
- Wall loads more predictable when flow pattern is symmetric

Common designs for mass flow hoppers

The Fig. 2 shows some common hoppers shapes with opening for mass flow containers

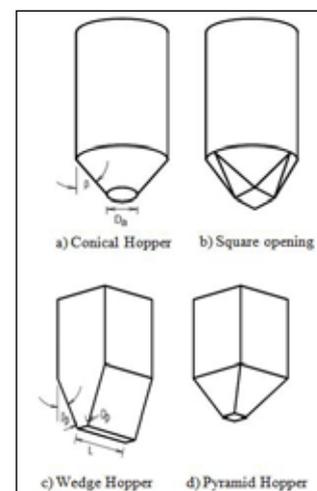


Fig. 2 Common Shapes for Hopper

Testing Bulk Solids for Mass Flow

Fig. 3 shows a hollow cylinder with frictionless walls, filled with a fine-grained, cohesive bulk solid. First the bulk solid is consolidated by the consolidation stress (σ_1). Subsequently the hollow cylinder is removed and the cylindrical bulk solid specimen is loaded with an increasing vertical compressive stress until the specimen breaks (fails). The stress failure is called compressive strength or unconfined yield strength (σ_c).

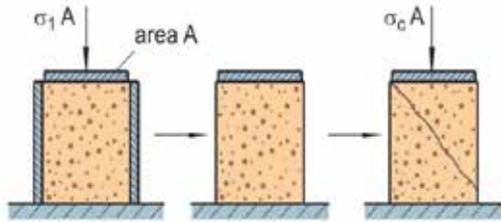


Fig. 3 Measurement of unconfined yield strength

The unconfined yield strength (σ_c) typically increases with consolidation stress (σ_1). Curve A shows the typical increase of unconfined yield strength in dependence on consolidation stress (Fig. 4). Usually the ratio (Flow Factor) ffc of consolidation stress (σ_1) to unconfined yield strength (σ_c) is used to characterize flowability numerically:

$$ffc = \sigma_1 / \sigma_c$$

The larger (flow factor) ffc is, the better a bulk solid flows. Often the following classification is used:

- $ffc < 1$ not flowing
- $1 < ffc < 2$ very cohesive (to non-flowing)
- $2 < ffc < 4$ cohesive
- $4 < ffc < 10$ easy-flowing
- $10 < ffc$ free-flowing

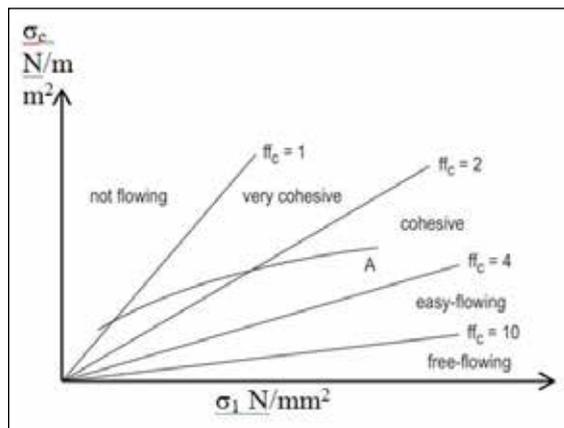


Fig. 4 Unconfined yield strength in dependence on consolidation stress; lines of constant flowability ffc .

Additionally, in Fig. 4 the boundaries of the ranges of the classifications listed above are shown as straight lines. The ratio ffc and thus the flowability of a specific bulk solid change with consolidation stress σ_1 . Therefore, for flowability measurements testers are required which make possible the adjustment of defined consolidation stresses. This is fulfilled by appropriate shear testers.

TESTING REQUIREMENTS

To design storage hoppers, the following material properties are needed:

- Internal friction coefficient
- Wall friction coefficient
- Permeability
- Compressibility

Wall friction measurement. for a bulk material to slide on a surface, friction between the two must be overcome. This friction can be measured by use of a test apparatus such as the one shown in Fig.5. First, the bulk material is placed in a retaining ring on a flat piece of wall material. Then, using weights, various forces are applied to the material in a direction normal (perpendicular) to the wall surface. Material in the ring is forced to slide

along the stationary wall material, and the resulting shear force is measured as a function of the applied normal force.

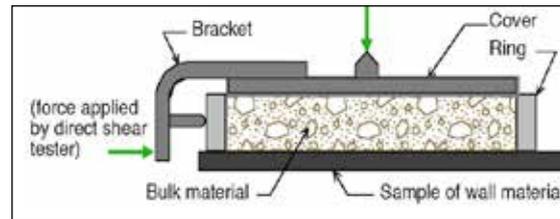


Fig.5 Typical Test setup for wall friction

Fig. 6 shows the results of a typical wall friction test. Along the horizontal axis are values of normal pressure (force per unit area acting perpendicular to surface) applied to the material, while the vertical axis represents the measured shear stresses required to overcome friction with the wall sample.

Wall friction angle, designated as ϕ' , is defined as the angle formed by a line drawn from the origin to a point on the curve. For a given bulk material and wall surface this angle is not necessarily a constant but often varies with normal pressure, usually decreasing as normal pressure increases.

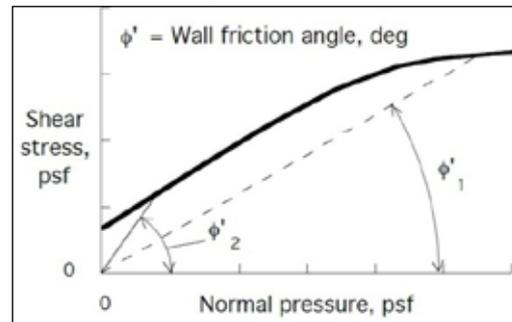


Fig.6 Typical Result for Wall Friction

Factors that influence wall friction, for a given bulk material, wall friction can be affected by:

Wall material. Generally, the smoother the wall surface, the lower the wall friction angle. As a result, less steep hopper angles are needed to ensure mass flow.

Temperature. Both the wall temperature and bulk material temperature can affect the wall friction angle that develops.

Moisture. Changes in moisture of the bulk material can affect wall friction angles. In some cases, moisture can migrate to the wall surface when warm material is deposited on cold bin walls.

Corrosion. If a hopper is fabricated from carbon steel, it may corrode, creating a more friction surface than anticipated.

Abrasive wear. As a surface wears, it often becomes polished. Then, a design based on an unpolished surface is often conservative. In other cases, the surface becomes rougher, which can upset mass flow.

Time at rest. Some bulk materials adhere to wall surface while remaining at rest under pressure. As a result, the wall friction angle becomes larger, and steeper hopper angles are needed for mass flow.

Design Description

The fuel containers/silos are plays a major role in power plant, cement plant, and commercial areas because these containers are to give the continuous supply of fuel for running the power plant. As fuel is the major part for producing steam so it should not hinder the efficiency of power plant or boiler. The hopper shapes are to be designed in such a way that mass flow occurs predominantly and the structure should be economical.

The minimum required data/input for analysis and design is taken from old executed project; using these data the pyramidal and conical shaped hopper are designed for same volume and the following Fig. 7 and 8 shows results of design weight comparison, material cost comparison and manufacturing cost comparison.

From analytical calculations the following weights arrived for square bunker with pyramid hopper and vertical cylinder with conical hopper having same volume of fuel/coal:

- Total structural weight for vertical cylinder with conical hopper =58 Tons
- Total structural weight for square bunker with pyramid hopper =116 Tons



Fig.7 Material Cost Comparison
The above Fig.7 is applicable for total structural weight comparison.

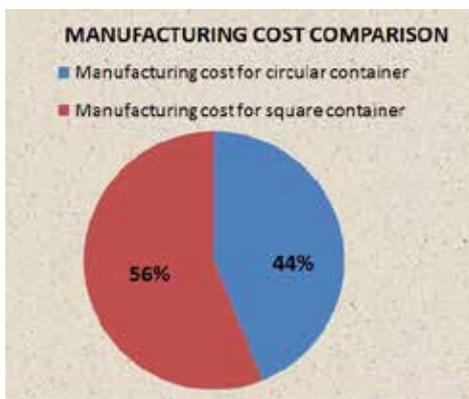


Fig.8 Manufacturing Cost Comparison

Future Scope

- Self-induced silo vibration incase flow problem
- Design validation with analysis package
- Cost comparison/analysis with other hopper shaped bunker/silos.
- Creating automation for design and detailing

Conclusion

This project investigates cost and material weight comparison. Two same volume of container with different hopper shapes geometry are taken for structural design, material and manufacturing cost comparison. The same is analyzed for structural weight cost comparison and manufacturing cost comparison and the results are shown in this paper graphically. The economical geometry is arrived cylindrical container with conical hopper, which reduces material cost by 34% and manufacturing cost by 12%. Hence cylindrical container with conical hopper can be used for forthcoming project Particularly for Bharat Heavy Electricals Limited (BHEL)-Circulating Fluidized Bed Combustion (CFBC) Boilers.

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