CHAPTER 1

INTRODUCTION

1.1 Introduction

Storage structures, either in the form of ground storage or elevated one, have been in use since thousands of years from early stages of civilization for storing grains, animal fodder etc. These were built to preserve materials and products during their abundance and withdraw them as and when necessary during lean periods to meet the requirements. These were both of temporary and semi -permanent constructions.

Industrialization led to their varied utility and also the desirability of having permanent constructions. Different forms of storage are being adopted according to the required capacity, type of material to be stored, operational requirements, convenience and economic considerations.

Storage silos are major important structures in process units like cement and other mineral based plants and also in Power Plants, Aluminium plants etc. Economy of scale has been leading to higher capacity plants resulting in demand for larger size storage silos. Circular configuration is generally chosen because of its structural efficiency.

They are very intricate in their behaviour and accordingly are safety-critical structures that demand proper understanding and assessment of stored material pressures and other actions on the structure.There are two aspects in their design:

- Functional Design
- Structural Design

As such, Silo design and construction requires highly specialized knowledge and experience.

One unique feature of these structures is that the basic structural form remains as of simple geometry for small or larger capacity silos. However, the engineering attention needed for larger silos is much more involved in comparison to the smaller ones. Large storage silos have many critical parameters to be considered during their design and construction and also the complexities involved during their loading and discharge operations. They are to be evaluated for safety against probable multiple modes of failures.

Many of these storage silo constructions extend in vertical direction, unlike other type of storages which spread on larger plan area with lesser heights. Their sizes may range from as little as one meter (m) diameter in Pharmaceutical industries to 60m or even more in the modern industrial units and their total height may reach as much as 80m to $\approx$ 100m (depending on the diameter).

Civil construction costs of silos are quite high in relation to the equipment cost. It may be as much as 80%-85%of the total cost of the installation. As such, they need proper spatial and functional considerations, correct structural analysis and, design and construction.

Several Silos have failed from time to time due to different causes. It is essential that utmost care is to be exercised in all phases of their conceptual design and physical realization. Better guide lines are available at present when compared to the state of knowledge on the design of silos available more than 50 years back. Extensive research on the material pressures that develop in silos and studies on the failed and successfully operating silos resulted in continuous improvements in the silo design codes. The current international Standards, especially Eurocode and DIN reflect them.

Nevertheless, many questions related to the material behaviour in silos under different possible situations are still not satisfactorily answered and these are still under

active research and investigation. Improvements in understanding of the magnitude of silo material pressures and various action situations are still going on. Accordingly, current silo engineering standards are likely to be further improved in future towards better understanding of the actions involved.

However, the present state of knowledge on material behaviour and its actions in silos is expected to guide towards realization of safer installations.

Table 1.1 shows an approximate idea how the silo diameters have been increasing in cement plants over the past few decades. The silo heights have also increased from approximately 35m earlier to 80m and in few cases even more, at present.

Similar developments happened in advanced countries with few years in lead.

The design and construction of the silos should ensure adequate and proper performance during their designed life. Structural collapse has to be avoided and functional utility should not be impaired. Any deterioration and defects in the structure are costlier to repair and restore their strength.

Different failure modes need to be considered for proper design of silos.

Silos resting on ground:

- Bursting of the silo wall
- Axial compression buckling of the wall
- Collapse of the bottom slab / hopper and roof slab, and supporting structure
- Foundation failure
- Excessive cracking of the walls and the roof

Silos elevated:

In addition to the above, the possibilities of failure of the elevated structure supporting the silo need to be considered.

This Book basically covers the circular silos used for storing materials in Cement and other Industrial Plants, though the basic design principles can still be applied to others for storing different materials used in other Industries or Installations as mentioned earlier.

The development in sizes of the silos in the past 50 years in India is illustrated in Table 1.1.

Table 1.1 Historical data regarding silo diameters in India.

Years	Diameter of silos
1960-70	10-14 m
1970-80	14-18 m
1980-99	18-22 m
2000 onwards	22-60 m

This book focuses on the following:

- brief historical developments in Silo design and construction
- types and classification of silos
- flow influencing properties of the stored materials
- pressures / actions that occur in silos and other loads
- load assessment and design provisions in the current codes of practice.
- foundations
- special effects in silos during their operation
- special silos
- construction aspects and precautions.
- causes of silo failures and strengthening measures
- design examples as per different Design codes.