## UNIT IV BUNKERS AND SILOS

**Introduction – Janssen's theory – Airy's theory – design parameters – design criteria – analysis of bins – Hopper bottom – design of bins.**

## 4.1 Introduction

The bunkers are large size shallow bins to store grains, coal and cement. In bunkers, the plane of rupture intersects the free surface of the stored material. Generally, steel bunkers are used to store coal at power plants and loco-running sheds. Generally, these are square or rectangular shaped. The silos are the deep bins for storage. They are circular in shape. The plane of rupture intersects the opposite side of the container. Objectives After studying this unit, you should be able to understand Airy's theory, understand Janssen's theory, know the components of bunkers and silos, design the bunkers, and design the silos.

## 4.2 Components of Bunkers

1) Main girder, 2) Cross girder, 3) Beam, 4) Sloping plates, 5) Stiffeners, and 6) Openings.

The sectional elevation and plan of the bunker are shown Fig.4.1

**Main Girders** : The main girders are provided parallel to the longitudinal sides. These are supported on cross girders**.**

**Cross Girders :** These are provided parallel to the width.

**Sloping Plates :** These are provided in the bottom portion of the bunker. The inclination is more than the angle of repose of the material for self cleaning.

**Openings :** These are provided at the bottom of the bunkers. The size is 500 mm square.

**Stiffeners :** These are provided with the inclined plates. At top, there are connected with the main - girder. At bottom, these are connected with the bottom plates.

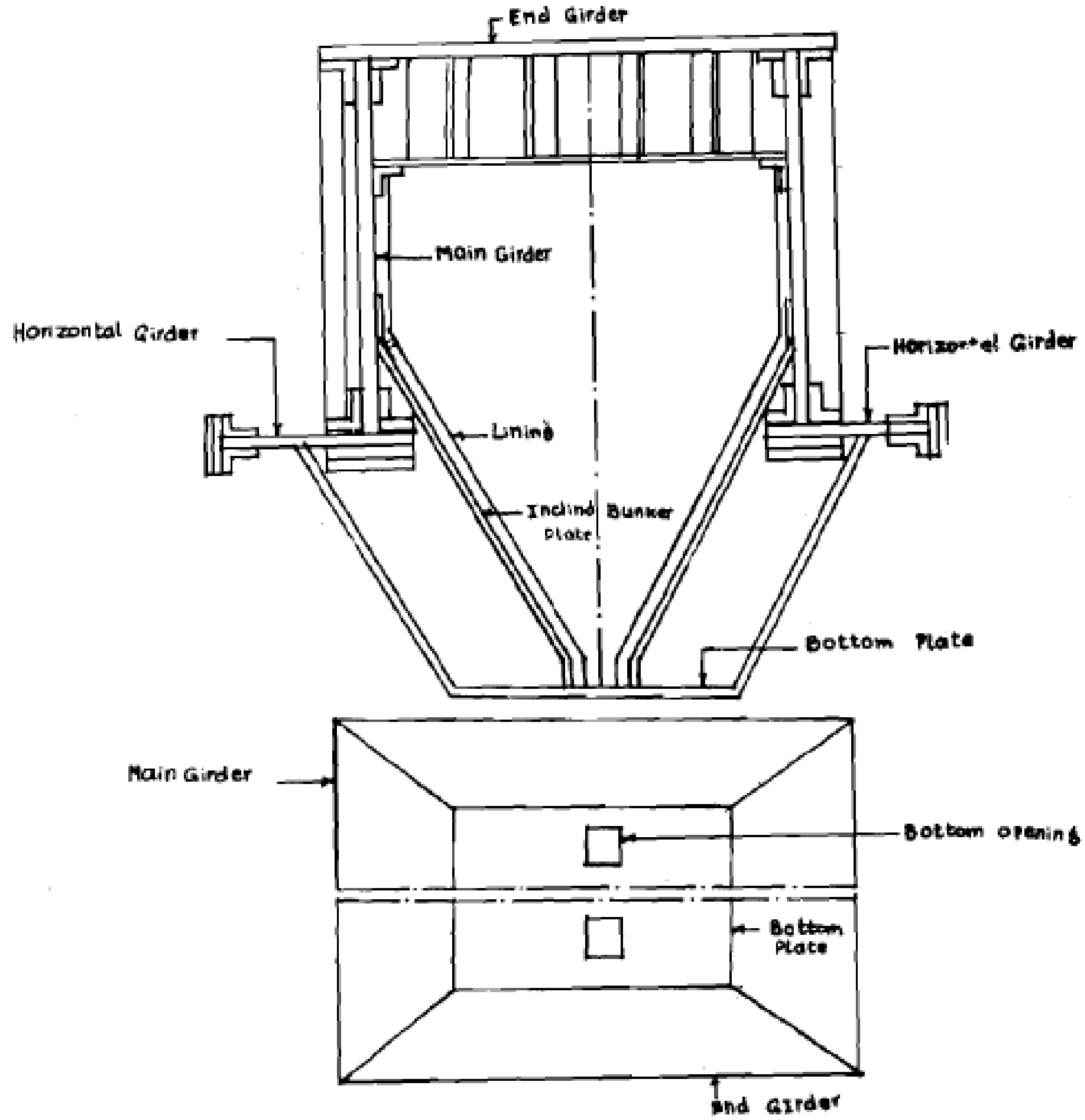


***Fig. 4.1 Section and plan of steel bunker***

## 4.3 Airy's Theory

By using this theory the horizontal pressure per unit length of periphery and position of plane of rupture can be determined. The Airy's theory is actually based on Coulomb's wedge theory of Earth Pressure.

## 4.3 Janssen's theory

### 4.3.1 Assumptions

**1)** Most of the weight of the material stored in the bin is supported by friction between the material and the vertical wall.

**2)** Weight transferred to the hopper bottom is very less. (Hence Rankine or Coulomb's lateral pressure theory cannot be applied.

3) The vertical wall of the bin is subjected to vertical force and horizontal pressure.

## 4.4 Design of Bunkers

Step 1: Force analysis

a) Calculate the vertical forces.

b) Calculate the horizontal forces using code specification.

c) Calculate the bursting forces H,1, H2, H3 and H4 Using equation of equilibrium.

d) Calculate the pressure $p_v$, $p_w$, $p_h$ on trough walls.

e) Calculate the normal and tangential pressures.

f) Calculate the normal load on trough.

Step 2: Design of trough plates

a) Span = spacing of stiffeners.

b) Considering truss-way bending, calculate the maximum bending,

$M_1 = pL^2/ (2x12)$

where, p = maximum normal pressure and L = span of trough plate.

c) Calculate the thickness required

$t = [6M_1/(\sigma_{bc}.L)]^{1/2}$ but Min. thickness = 6 mm.

Step 3: Design of inclined stiffeners in trough

a) Calculate the maximum BM and (M2) and direct tension at mid-span.
b) Choose suitable T-section with plate.
c) Calculate A, Ixx and Zxx
d) Check for tensile stress and bending stress.

Step 4: Design of plate stiffeners for trough

These are provided perpendicular to the T-stiffeners.

a) Calculate the maximum BM.
   $M_3 = pL^3/ (2x12)$

b) Calculate the section modulus Zrequired.

c) Assuming thickness (t), find the depth of plate

$td^2/6 = Z$

Step 5: Design of vertical plate

a) Calculate the maximum BM, $M_4 = pL^2/ (2x12)$
b) Calculate the thickness required
   $t = [6M_4/(\sigma_{bc}.L)]^{1/2}$ but Min. thickness = 6 mm.

Step 6: Design of vertical stifleners

a) Calculate the max. BM, $M_5 = pL^2/ (2x8)$
b) Calculate Zrequired = $M_5/ \sigma_{bc}$
c) Choose a standard T-section with plate
d) Calculate A, Ixx , Zxx
e) Check for bending stress.

Step 7: Design main (longitudinal) girder

a) Calculate the moment due to Hl at top, $M_6 = H_1L^2/8$
b) Calculate Zrequired = $M_6/\ \sigma_{bc}$
c) Choose the suitable section.

Step 8: Design of horizontal girder

a) Calculate the moment due to $H_3$

$$M_7 = H_3L^2/8$$

b) Calculate Zrequired.

c) Select the suitable section.

## 4.5 Design of Silos

Generally, the Silos are circular in shape and is shown in fig 4.2. These are designed similar to bunkers.

### 4.5.1 Design Procedure

Step 1: Calculation of horizontal pressure

By using the codal provisions, find the horizontal and vertical pressures at different depths at some intervals say 3 m, 4 m/5 m.

Step 2: Calculation of max. hoop tension

HOOP tension, $H_1 = (p_h)$ max .D/2

Step 3: Design of wall plate

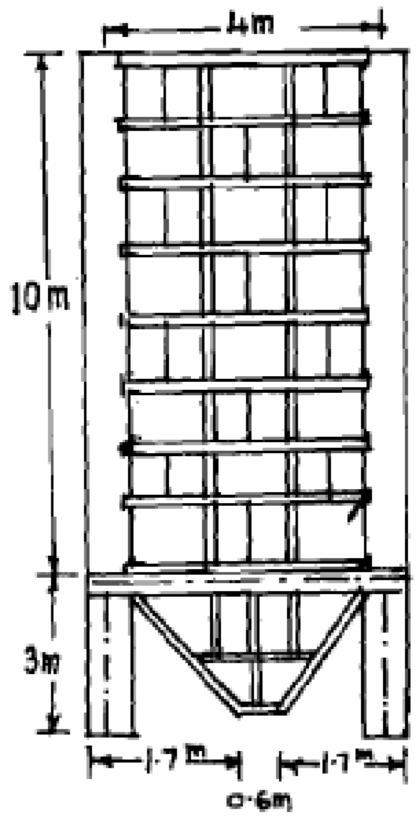


*Fig.4.2 Sectional elevation of Silo*

Calculate total vertical load, self weight, weight of lining, weight of top cover.

Calculate the vertical load.

Calculate thickness of plate from combined loading.

Step 4: Design of hopper

Calculate the total vertical load.

Calculate the direct tension.

Calculate the thickness = Direct tension/($\sigma_{at}$ x 1000 mm)

Step 5: Design of ring beam

Calculate the weight of stored material, self-weight of silos lining cover, platform.

Calculate the reaction, SF, BM, torsion and compression.

Calculate $\sigma_{ac,}$ $\sigma_{ac,cal}$ , $\sigma_{bc}$ , $\sigma_{bc,cal}$

Check for combined stresses.