Optimization of RCC Silo for Granular Material - 1

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Abstract— RCC Silos are used by a wide range of industries to store bulk solids in quantities ranging from a few tones to hundreds or thousands of tones. Silos are very demanding in cement industries. Hence RCC silos are widely used for storage of granular materials as they are an ideal structural material for the building of permanent bulk-storage facilities for dry granular like fillings. In the past, design of silos was based only on static pressure (BIS code), with no allowance to the pressure difference due to material flow, which creates bending stresses on the silo wall in filling area. Euro code gives guidelines to take care-of these wall stresses for designing RCC silos. In order to structurally design a silo, an engineer must determine all loads that are likely to be applied to it. These include, among others, wind, seismic, external, and loads induced by the stored bulk solid. Numerous codes and standards specify means to calculate the latter.

In this investigation, the diameter to height ratio is varied and has been designed and finally, the most economical size is found out. All the designs have been based on the recommendations of British Standard BS EN 1991-4:2006 and EN 1998-4:2006.

Index Terms— Optimization, RCC silo, ANSYS Workbench, Eccentric silo, Weight optimization.

I. INTRODUCTION

Silos are designing structures broadly utilized as a part of enterprises and ranches to store, nourish and process mass solids that is fundamental to horticultural, mining, mineral handling, synthetic, delivery and different businesses. Silos are for the most part worked from solid, steel and aluminum. Regardless of broad test and hypothetical investigations of Silo issues, Silos come up short with a recurrence substantially higher than the rate of auxiliary disappointment of other mechanical structures.

In a silo vertical walls are considerably taller than the lateral dimension resulting in tall structure. Consequently, the plane of the rupture of the material stored meets the top horizontal surface of the material. Due to high ratio of height to the lateral dimension, a significant portion of the load is resisted by friction of the total weight of the material acts on the floor of the structure. For a structure to be classified as silo,

$H > B \tan\left(\frac{90+\Phi}{2}\right)$

Where, B = Breadth

H = Height of the structure

Types of Silos as per Eurocode

As per EUROCODE the silos are divided by their Height to Diameter ratio. Slender silos and squat silos are widely used in industrial area. On other hand the retaining silos are used in farms to store, feed and process bulk solids that is essential to agricultural.

SR. NO.	Types of Silo	Condition
a	Slender silo	$2 < h_c/d_c$
b	Intermediate slenderness silo	$1 < h_c/d_c < 2$
c	Squat silo	$0.4 < h_c/d_c < 1$
d	Retaining silo	$h_c/d_c < 4$

II. LOAD CALCULATION

Fig.1 shows the Excel input interface for optimization of steel lattice tower. There are some blank boxes in the interface. The user has to fill geometry data, material data and shape optimization constraints.

1. Symmetrical discharge load:

For silos in all Action Assessment Classes, the symmetrical discharge pressures Phe and *Pwe* should be determined as:

$P_{he} = C_h P_{hf}$

$P_{we} = C_w P_{wf}$

Where,

Ch is the discharge factor for horizontal pressure

Cw is the discharge factor for wall frictional traction.

$P_{hf}(z) = P_{ho} * Y_J(z)$

$P_{wf}(z) = \mu * P_{ho} * Y_J(z)$

$P_{vf}(z) = \frac{Pho}{K} * Y_J(z)$

In which,

$P_{ho} = \gamma * K * Z_0$

$Z_0 = \frac{1}{K\mu}\frac{A}{U}$

$Y_J(z) = 1\text{-}e^{\frac{-z}{z0}}$

2. Wall pressures under eccentric discharge:

The pressure on the vertical wall in the flowing zone depends on the distance *z* below the equivalent solid surface and should be determined as:

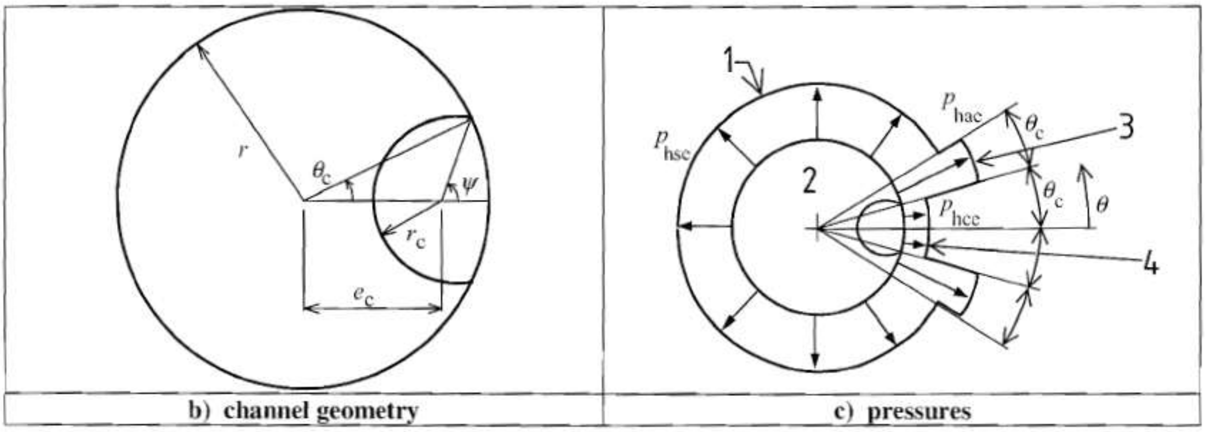


Fig. Eccentric Discharge pressure

$P_{hce} = P_{hco}\,(1 - e^{(\frac{-z}{z0})})$

and the frictional traction on the wall at level z as:

$P_{wce} = \mu\, P_{hce}$

in which:

$P_{hco} = \gamma\, K\, Z_{oc}$

where:

μ = the wall friction coefficient for the vertical wall;

K = the lateral pressure ratio for the solid.

III. DATA IN ANSYS STUDY

A. *Geometry Data*

Geometry data contains overall height and the diameter of the silo. Which is various with different Model. But from the Eurocode for Granular material different data to be provided in the Ansys workbench.

B. *Material Data*

Material data contains allowable stress, modulus of elasticity and density of RCC. This data is added to the Ansys. Here the Granular material Wheat is considered and the data should be taken from Eurocode EN-1991 Part 4.

Wall surface category considered	D3
Modification coefficient for lateral pressure ratio (a_k)	1.14
Modification coefficient for wall friction coefficient (a_μ)	1.24
Mean value of lateral pressure ratio (k_m)	0.53
Mean value of wall friction coefficient (μ_m)	0.53
Modification coefficient for internal angle friction (a_φ)	1.14
Mean value of internal angle friction (φ_m)	31
Patch load solid reference factor (C_{op})	0.5

C. *Optimization Constraint*

Optimization constraint is added in the Response surface optimization in ANSYS workbench. Here, user can limit the minimum dimensions i.e. Height and Diameter of the silos.

The constrained conditions are as follows:

1. Thickness (t) in mm

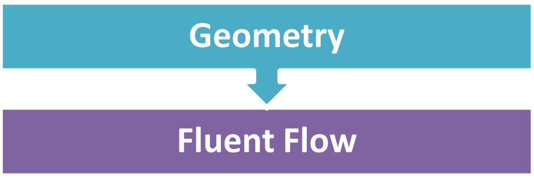
   $t \geq 100$ mm
2. Outer diameter and inner diameter

   $0\ \text{m} \leq D_i, D_o$
3. Direct Hoop tension

   $\sigma \leq \sigma_\theta$ Allowable

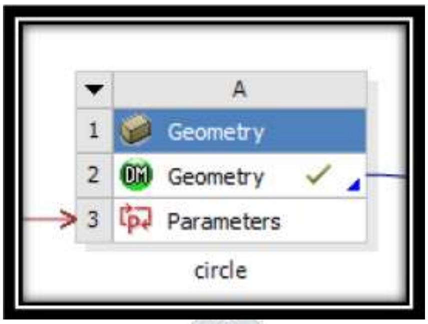
IV. CURRENT MODELLING IN ANSYS WORKBENCH:

In the ANSYS® Workbench, the geometry was prepared and after that fluent flow calculation and deflection are carried out for different points in the response surface optimization. Interpretation of result can be done with the help of response graphs as well as from the candid points.



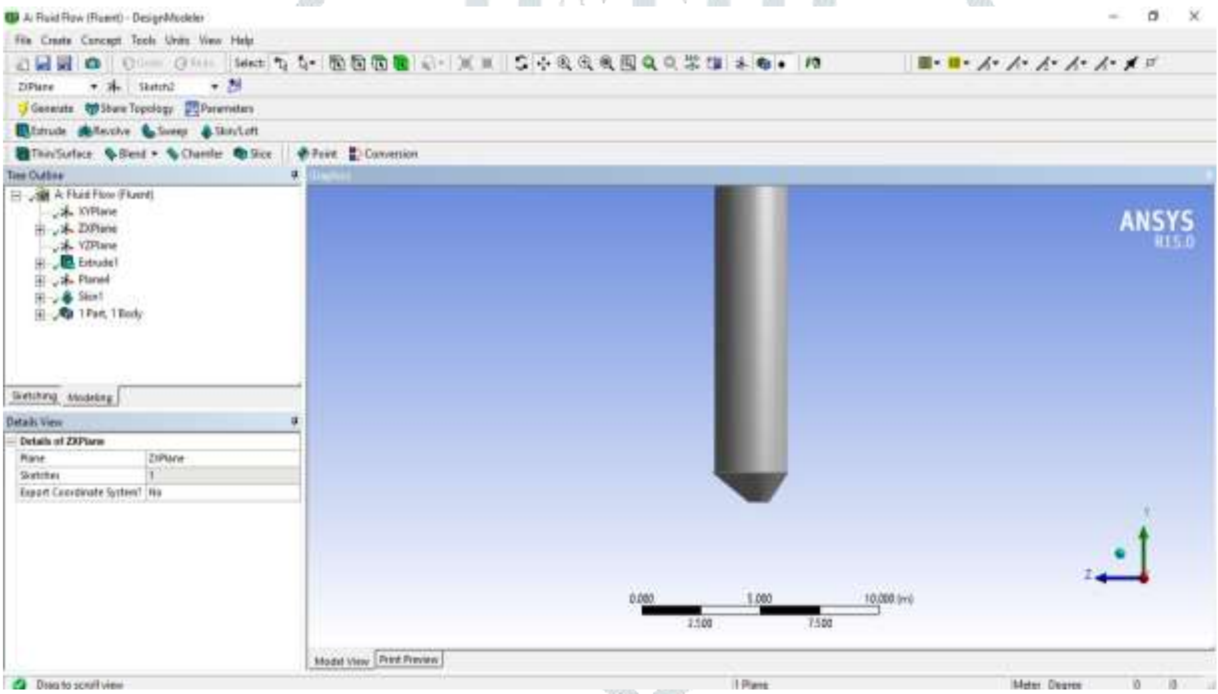
Step 1: Geometry

In this step first of all geometry section is added to the working window.



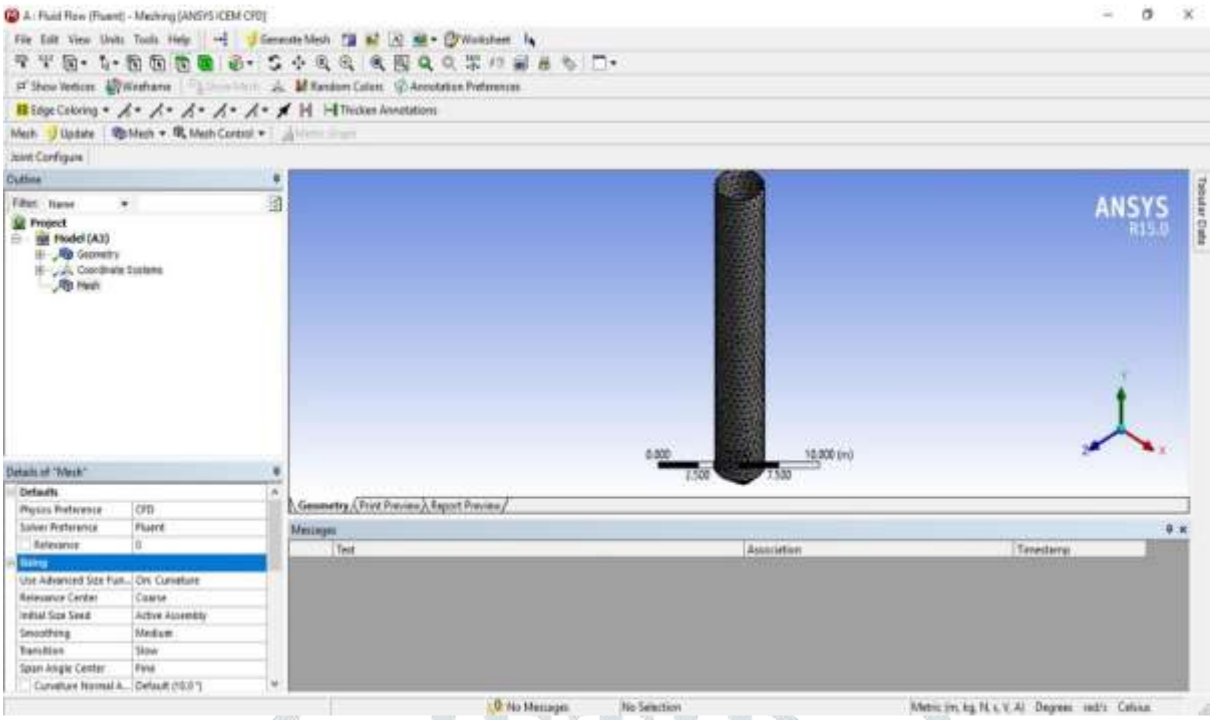
After that in the Design Modular (DM) geometry is prepared. The new plane is prepared at the height desired for our height of the structure. The desired shape is drawn at both of our plane and appropriated dimensions are given.

After that, with the help of skin final geometry is prepared as shown below.



Step 2: Fluent flow

After that, in the model sub-component mesh is generated.



Then after the Physical properties of Granular materials are setup in the fluent flow. First of all, applied velocity in downward direction.

In Multiphase model applied Eulerian Multiphase model with Dense Discrete Phase Model. And in Viscous model apply K-epsilon model with standard wall function. Apply the Group injection above the silo for Granular material and define the Granular material properties.Run the calculation with Phase coupled Simple solution method and we will got the pressure on the wall silo surface.

Here, Concrete and steel are not connected to each other. So, applied Stell APDL command and Concrete APDL Command for both and then after connect in the Static solution field via Pre processor command.

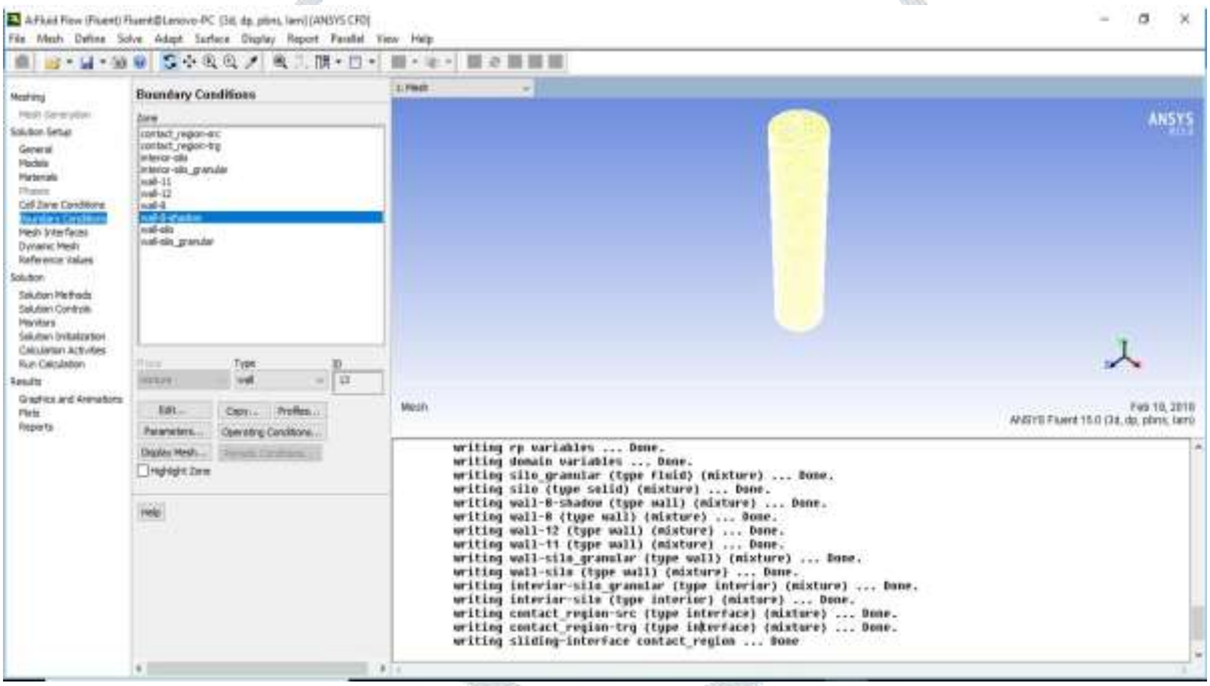
<u>CONCRETE COMMANDS:</u>

```
ET,MATID,SOLID65
R,MATID,0,0,0,0,0,0
RMORE,0,0,0,0,0

MP,EX,MATID,29250
MP,PRXY,MATID,0.2
MPTEMP,MATID,0

TB,CONCR,MATID,1,9
TBTEMP,22
```

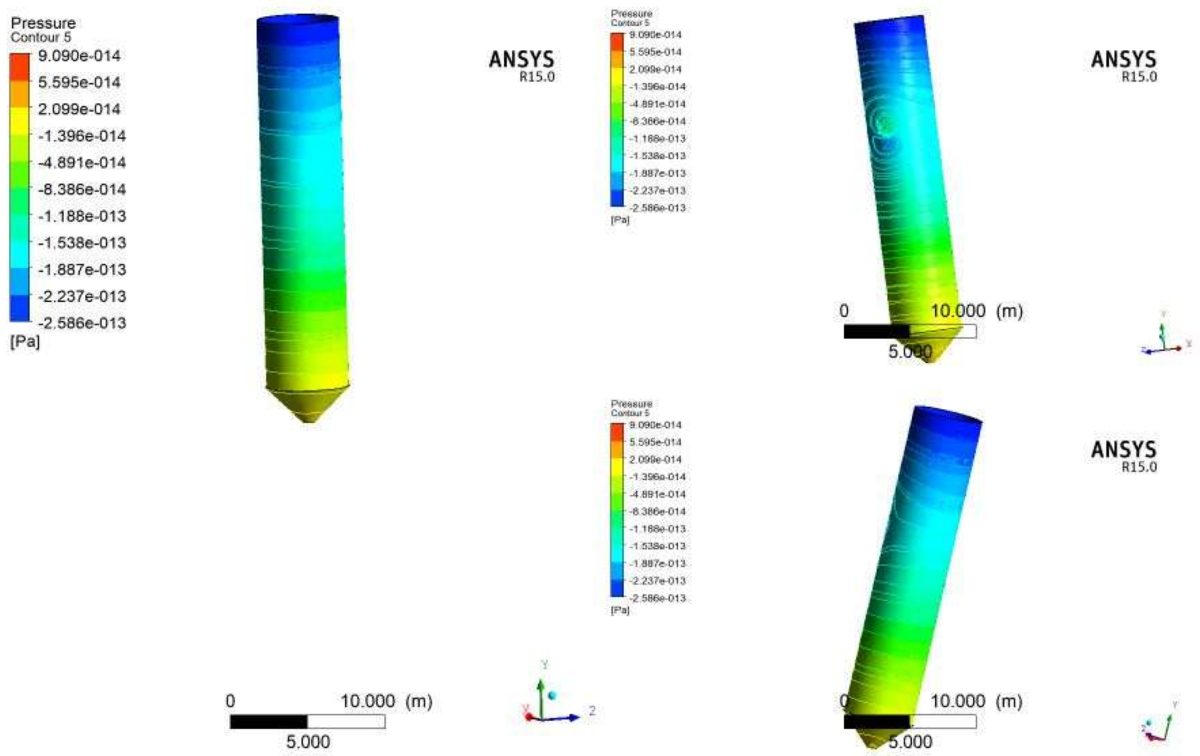
TBDATA,1,0.3,0.8,1.5,25

REBAR COMMANDS:
ET,MATID,LINK180
MPDATA,EX,MATID,,2e5
MPDATA,PRXY,MATID,,0.3
TB,BISO,MATID,1,2
TBDATA,,460,2100
R,MATID,12,,0
PRE PROCESSOR COMMANDS:
/PREP7
ESEL,S,ENAME,,65
ESEL,A,ENAME,,180
ALLSEL,BELOW,ELEM
CEINTF,0.001,
ALLSEL,ALL
/SOLU
OUTRES,ALL,ALL

Set Material and Physics in fluent flow:
Set the material and the boundary condition of the silo as per the data, which is gives the velocity and the pressure distribution of the silo.



Step 3: CFD-Post:
In CFD post we got the pressure variation and velocity with particle tracking.



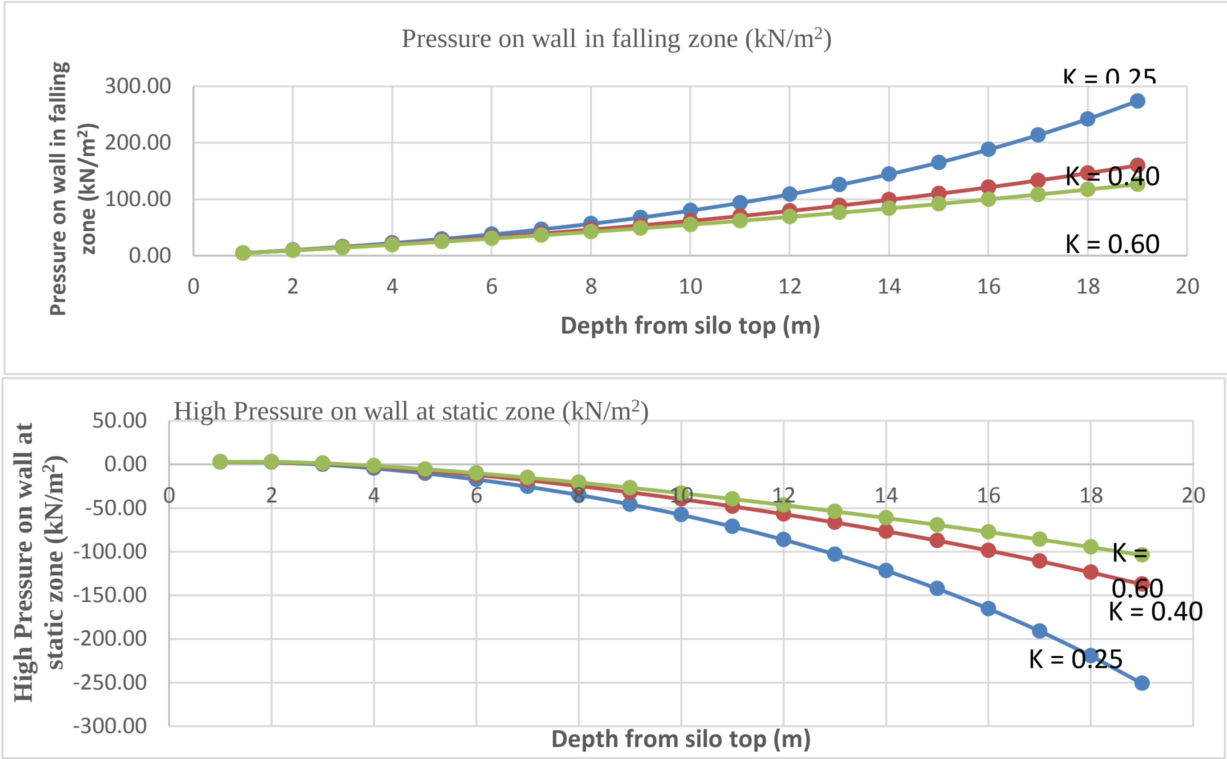
V. NUMERICAL EXAMPLES

Material property and section database is kept same for all examples.

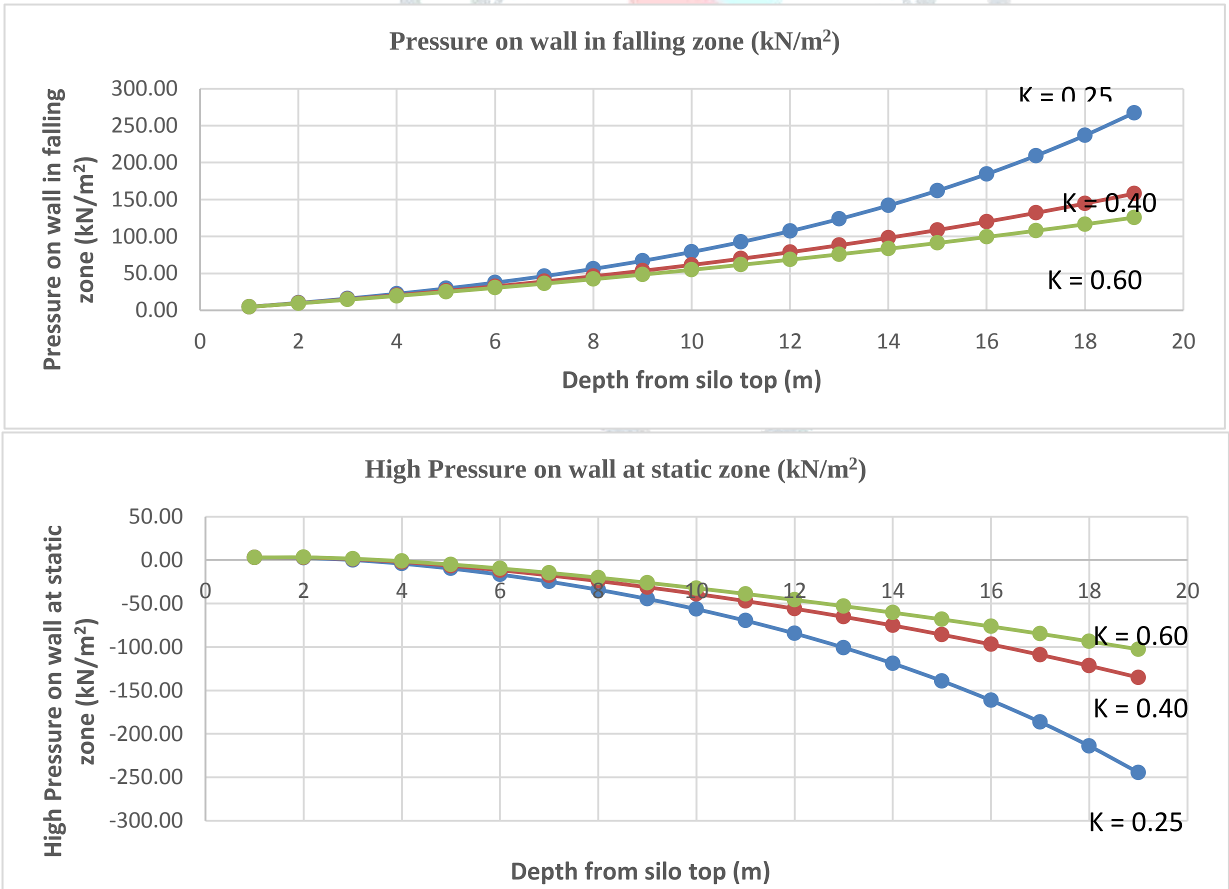
As described above, total 24 models of different height and diameter are considered in thesis work. The details of all the models are described below:

Sr.No	Height of cylindrical portion (m)	Top dia (m)	H/D Ratio	Height of frustum cone (m)	Bottom dia of hopper (m)	Volume of cylindrical portion (m^3)	Volume of frustum cone (m^3)	Total volume (m^3)	Eccentricity
1	19.9	2.8	7.11	1.15	0.5	122.53	2.86	125.39	0%, 25%,40%, 60%
2	19.2	2.85	6.74	1.18	0.5	122.48	3.03	125.51	0%, 25%,40%, 60%
3	16.1	3.1	5.19	1.3	0.5	121.51	3.88	125.40	0%, 25%,40%, 60%
4	14.1	3.3	4.27	1.4	0.5	120.59	4.69	125.28	0%, 25%,40%, 60%
5	12.5	3.5	3.57	1.5	0.5	120.26	5.60	125.86	0%, 25%,40%, 60%
6	9.1	4.05	2.25	1.78	0.5	117.23	8.70	125.93	0%, 25%,40%, 60%

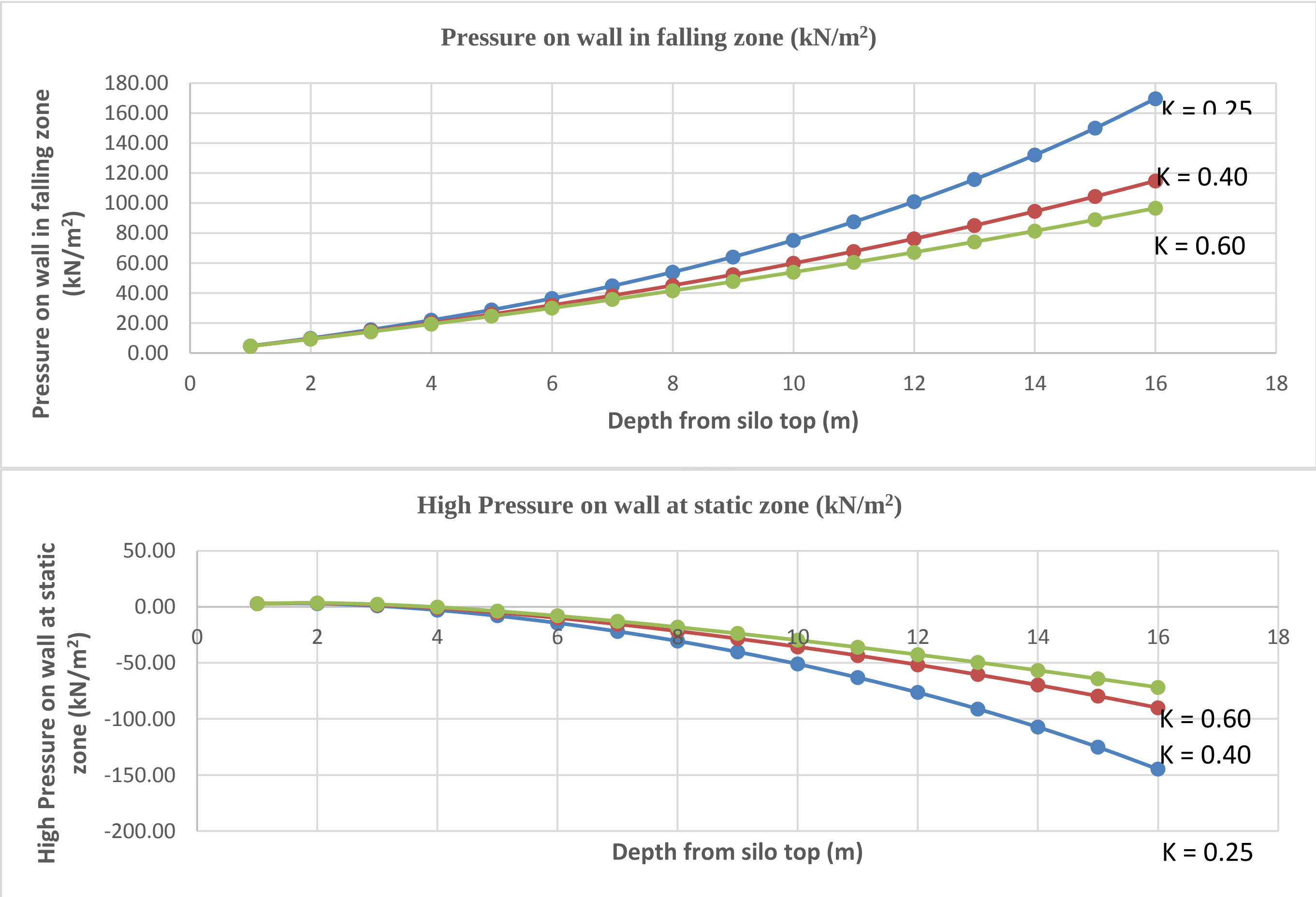
VI. Result



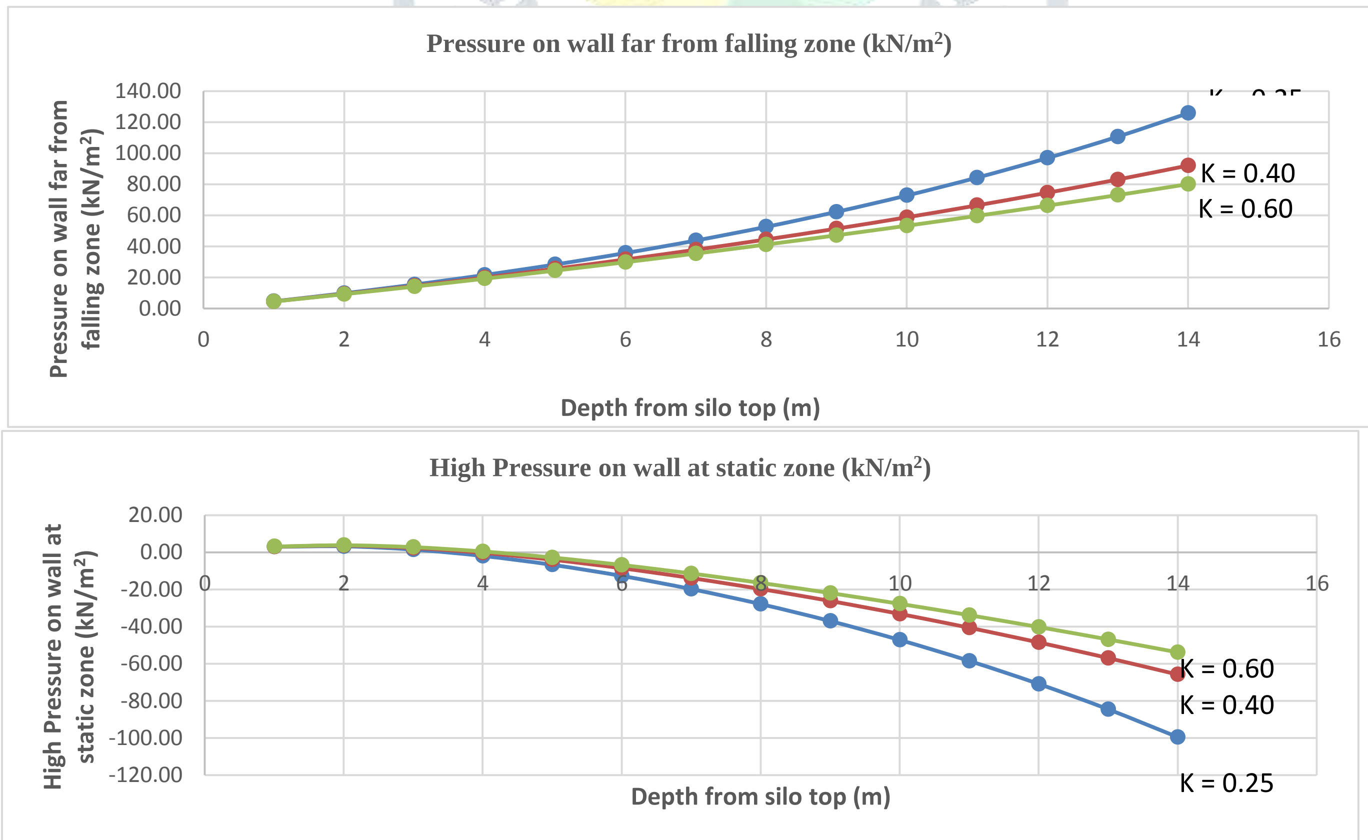
Pressure diagram for CASE 1 where the Height to Diameter ratio is 7.11.



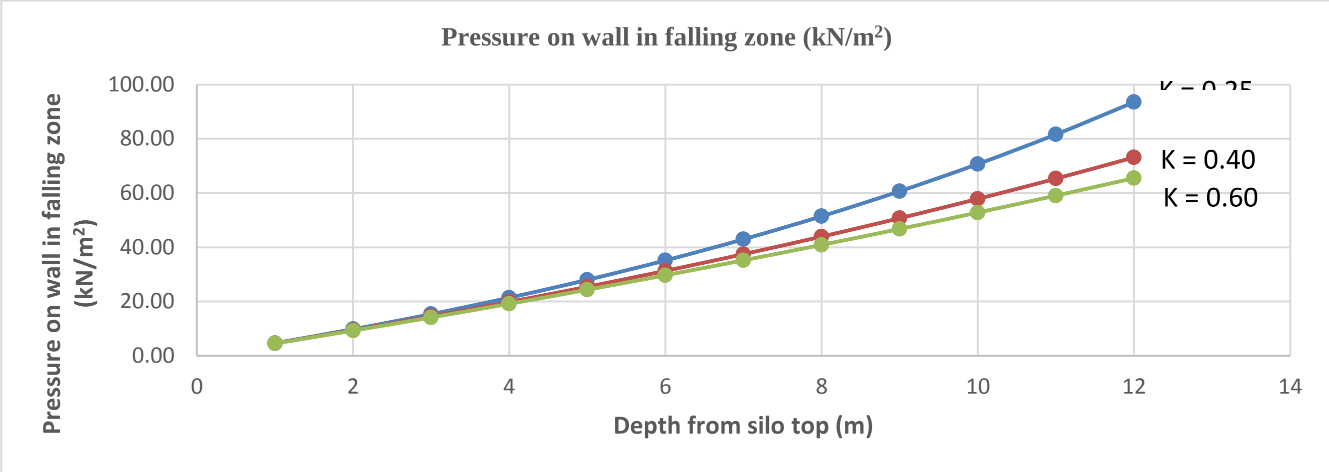
Pressure diagram for CASE 2 where the Height to Diameter ratio is 6.74.

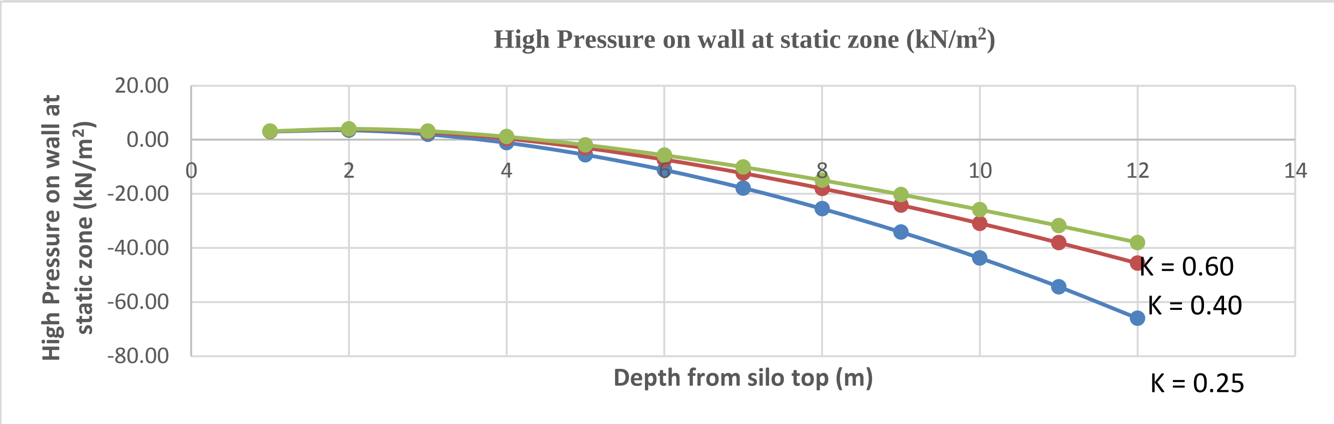


Pressure diagram for CASE 3 where the Height to Diameter ratio is 5.19.

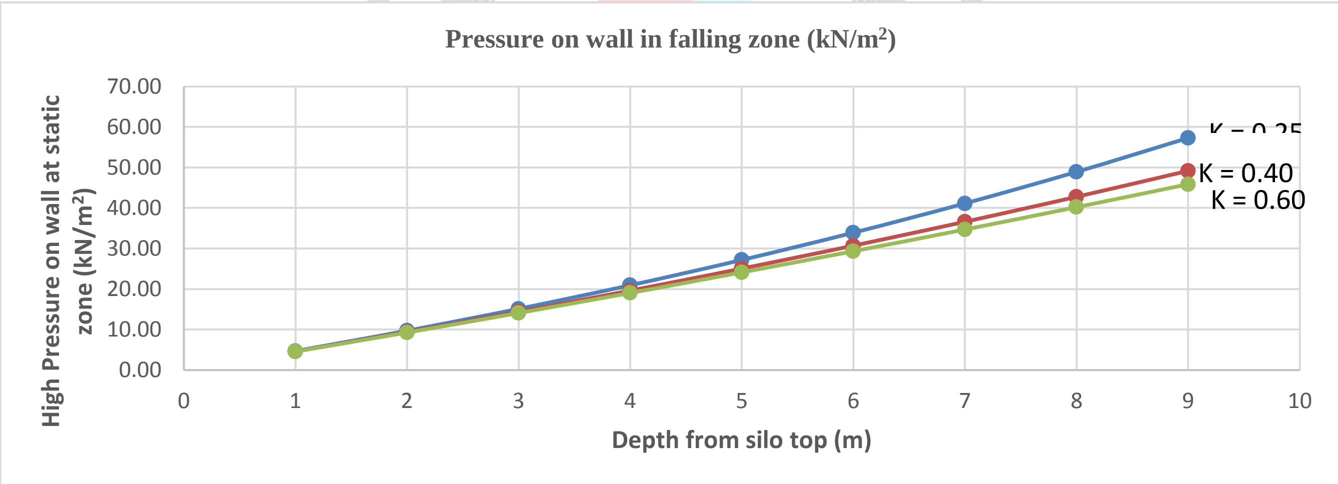


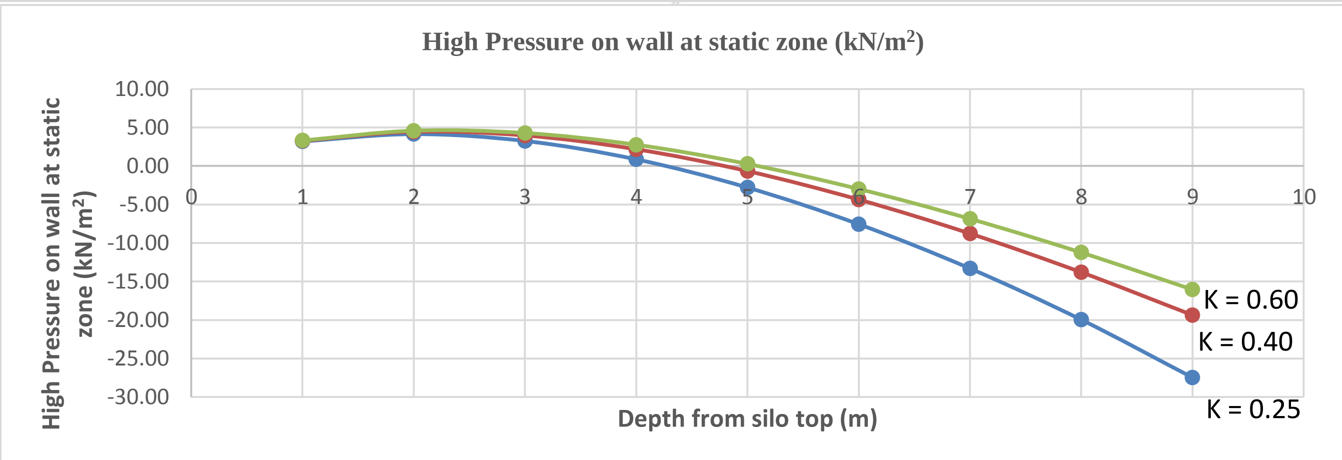
Pressure diagram for CASE 4 where the Height to Diameter ratio is 4.27.





Pressure diagram for CASE 5 where the Height to Diameter ratio is 3.57.





Pressure diagram for CASE 6 where the Height to Diameter ratio is 2.25.

VII. CONCLUSION

Here, Total Six cases are considered for the different Height to Diameter ratio of the silos. The Eccentricity of the silos are considered as 25%, 40% and 60% in the outlet diameter of the hopper. So that it was considered as Outlet Eccentricity and the difference in the pressure are observed in the ANSYS workbench.

The conclusions achieved from present work are:

1. When the depth of silo is increased the pressure is also increased it is independent from the eccentricity of the Silo.
2. Pressure on wall in falling zone is continuously decreasing when the Eccentricity of the Silo is increasing from 25 percent to 60 percent, on different cases of silos these pressure is gradually decreasing when the Height to Diameter of Silo is decreasing.
3. High pressure on wall at static zone is continuously increasing when the Eccentricity of the Silo is increasing from 25 percent to 60 percent, on different cases of silos these pressure is gradually increasing when the Height to Diameter of Silo decreasing.

In the present work, there pressure are applied to the Static Structural in ANSYS workbench for the Optimization of RCC Silos.

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