Comparative Study of Different Shapes of RCC Silos By Dynamic Analysis

Prof. Dr. Ashok Kanse[1], Miss Thombare Pooja Dadasaheb[2]
[1]Associate Professor, Dept of Civil Engineering
[2]Dept of Civil Engineering
[1, 2] Dr. D. Y. Patil School of Engineering and Technology, Lohegaon, Pune, India

Abstract- *In order to reveal the dynamic response mechanism of silo-storage-foundation system under seismic wave loading, the silo is simplified as a thin-walled cylindrical shell structure with fixed bottom and free upper part. Thinking about geometric nonlinearity, dynamic flexible modulus, damping and different elements, the nonlinear vibration differential conditions of the storehouse under powerful stacking are set up. The vibration differential conditions and the clear conditions with arrangement thoughts are given. Hence, the dynamic activity arrangement of cylinder upheld strengthened solid storehouses is examined by utilizing the shaking table test strategy. The closeness hypothesis of storehouse model test is developed, and the trial model of the storehouse stockpiling establishment communication framework with the geometric proportion of 1:20 is built up, where three seismic waves in the appropriate building foundation are chosen to do the shaking table test. The acceleration peak value at different heights of the model is measured, and the dynamic amplification factor of the silo model along the height direction is studied under different seismic intensity and different material condition. The seismic performance of the prototype structure is studied, which provides the theoretical basis and practical guidance for the design of silo system and the operation and management of silos*

I. INTRODUCTION

Silo, bins, or bunker are container used for storing bulk solids. Although no specific definition for all these terms, shallow structure use for storing coke, coal, crushed stone, gravel, ore & other similar material are usually called bunkers & bins. Tall structures use for storing grains, cement is often called silos. Most of industries used silos to store bulk solids, quantity ranges from a thousand tones to hundred to few tones. Power station, cement plant, gas work in many more short and big establishments where storage of bulk material is necessary, for the purpose of storing material silo is used.

Silo structure may be elevated or rest on ground have circular, square or rectangular in shape. Rectangular or Square silos usually have single outlet with pyramidal bottom, but sometimes a trough bottom is used with a single elongated outlet or two or more circular or square outlet. Silo which is in circular shape have flat bottom or conical bottom with single outlet. Material used for construction of silo may be RCC & reinforced concrete.

Governing factor in design of silos are the type of material stored in it and there properties. Bulk material density, frictional properties & pattern of material flow varies generously, the applied loads and load caring system different in structure like silo than other traditional structure. Silos are designed as special structure & also design is based on the strength design method.

Storage container & silo fails because of many reason. Failure of silo categories depend on silo failure causes which are as follows,

- Failure due to design
- Failure due to construction
- Failure due to usage
- Failure due to maintenance

Collapse of silo in seismic failure is the major failure; occur because of improper assumptions, wrong analysis and design. In this study consider circular flat bottom silo symmetrical about vertical axis & RCC slab provided at the top and bottom of silo by proving small open able hole to top of silo for filling storage material in it. In this study compare various method of silo design and seismic force calculation by using different codal provision like IS, ASCE, AJI, and EURO. The dividers of the storehouses are commonly exposed to both ordinary weight and vertical frictional shear or footing delivered by the material put away inside the storehouse. The size and conveyance of both shear and ordinary weight over the tallness of the divider rely upon the properties of the put away material. Calculation of seismic load consider silo self-weight and material stored in it as a lumped mass and seismic effect of this mass is considered in design of the silo wall

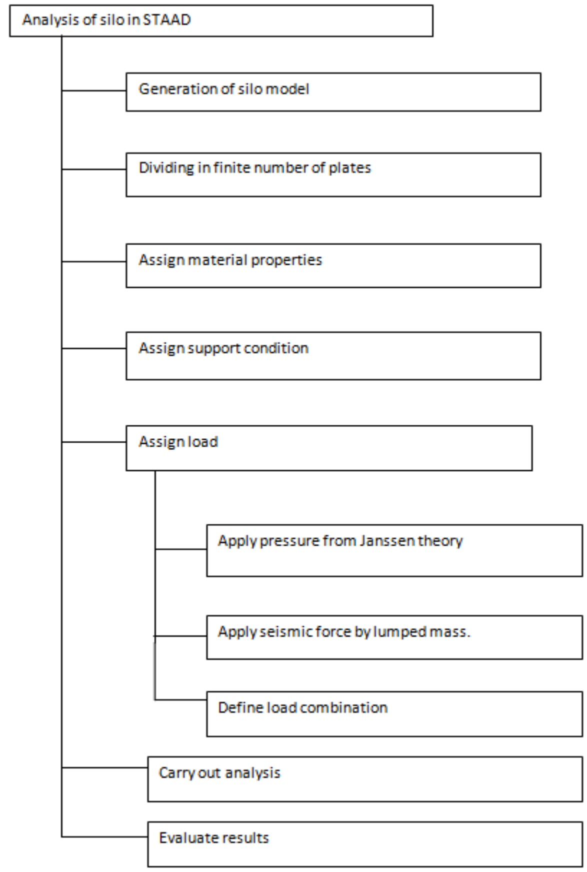
Fig. 1 Partial collapse of grain silo during 1974 Lima, Peru earthquake

II. METHODOLOGY

Dynamic analysis and seismic behavior of RCC silo and avoid failure of RCC silo during earthquake seismic force calculated by using IS code. Results will cross check by using structure design software.

1. Calculation of pressure acting on the wall of silo using height to diameter ratio and angle of internal friction by using Janssen's theory.
2. Design of silo using IS specifications.
3. Modeling and analysis of different shapes of silo by using software..
4. Calculation and comparison of natural frequency, time period and displacement for different mode shapes.
5. Calculation and validation of natural frequency, time period using Rayleigh ritz method.

2.1 General STAAD procedure



2.2 Theory of Silo:

2.2.1 Terms

1. Silo: - A storage structure, circular or polygonal in plan & intended for storing bulk material in vertical direction. The line of rupture start from bottom edge of bins intersects the wall it is called silo.
2. Bunker: - The line of rupture start from bottom edge of bins intersects the top surface of the material it is called Bunker or shallow bunker.
3. Bins: - Bins is common name for bunker & silos.
4. Silo Loads: - Loads exerted by a stored material on the wall of silo.
5. Pressure: - Force per unit area normal to wall of silo.
6. Initial pressure: - Pressure exerted by bulk solids on the walls of the silo during & after charging, but before any withdrawal of the material.
7. Strain energy: - The energy of a flowing mass of solid which could be recovered by a relaxation of boundary forces & displacement
8. Wall friction: - Force per unit area along the silo wall (vertical or inclined) on account of friction between the bulk material and the silo wall.

9. Flat bottom: - The internal base of silo, when it has an inclination to the horizontal less than 5 degree.
10. Even burden proportion K: - An esteem which determines the connection between the mean flat burden following up on the vertical storehouse dividers, and the mean vertical burden at this position in the mass material
11. Mass material: - A term used to depict a granular material running from a residue like to a huge grained assortment with and without union, which contains pores notwithstanding also, in the middle of the individual strong material particles that might be loaded up with air or dampness.

2.3 Types Of Silo

2.3.1 Flat Bottom Silos

Utilized for long haul stockpiling of huge amounts of grain, seeds and granular items.

Utilized for Storage of grains (oats, seeds, vegetables, mechanical items and different items) that Requires uncommon capacity conditions.

2.3.3 Truck load silos

This are used for the storage and subsequent delivery of bulk products

Fig. 4 Truck load silo

2.4 Load Consider For Silo Design

Loads should be applied to the structural design of a silo according to its intended use, size, structure type, materials, design lifetime, location and environment, in order to assure life safety and to maintain its essential functions.

The applied loads should be as follows, and their combinations should be defined considering the actual probability of occurrence.

(i) Dead loads
(ii) Live loads
(iii) Snow loads
(iv) Wind loads
(v) Seismic loads
(vi) Impulse and suction because of substance sloshing, and weight because of substance.
(vii) Thermal stresses
(viii) Shock,
(ix) Fatigue loads
(x) Soil and water pressures
(xi) Others.

Dead Loads: - Dead loads are the sum of the weights of the silo, its associated piping and equipment and other fixed appurtenances.

Live Loads: - Live loads should be considered forces from stored material (including overpressures and under pressures from flow), floor and roof live loads

Snow Loads: - Snow loads should be defined by considering the location, topography, and environment, density of the snow, snow accumulating period, and the shape and temperature of the tank.

Wind loads: - Wind burdens ought to be characterized by thinking about the state of the tank, its basic Characteristics, the area, and condition.

Seismic Loads: - Design seismic loads for above-ground storage tanks should be calculated by either one of the following methods:

(i) Seismic Coefficient Method, or
(ii) Modal Analysis

Thermal loads: - Thermal loads include those due to temperature differences between inside and outside faces of wall.

Shock loads: - Shock load including those due to crane movement, crane use for storing material in silo.

Soil and water load: - If silo situated below the ground then soil load act on silo and water load act on silo depend on water table available.

Other loads: - Other loads include equipment connecting to silo.

III. DESIGN OF SILO

Silos and their supports should be designed to contain all applicable loads taking into account the properties of stored materials, the shape of the silos, methods of material handling. The state of the storehouse ought to be as basic as could be allowed, be symmetrical about its hub, and ought to have auxiliary individuals which are proportioned to give sufficient quality.

In silos the weight of material stored is supported by bottom of silo and side wall of silo resulting reduction in lateral pressure. Vertical weight carried by wall causes direct compression in wall.

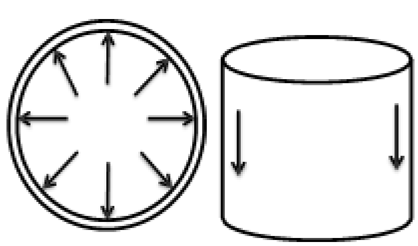


Fig. 5 Plan of silo showing horizontal pressure acting on the silo wall and
Fig. 6 Elevation of silo showing vertical pressure acting on silo wall

3.1 Seismic Pressure In Silo

Theoretical approach is given by IndrajitChowdhury and Raj Tilak in which conventional Jansen's method has been modified to develop the additional dynamic pressure due to seismic force. estimated the acceleration the silo is subjected to base on its first two fundamental time period the same can be fitted into Jansen's theory. We take here a strip of the material stored in silo of depth dz and apply the applicable forces as shown in the figure below. The distinction here is the extra power applied on the divider because of the seismic power produced by the put away material is likewise included.

3.2 Software Simulation

Finite element Analysis tool STAAD-PRO V8i is used for simulation. In analysis following assumption are made:

1. Base of silo is assumed to be fixed.
2. Pressure applied is based on Janssen Theory.
3. Stored materials is uniformly distributed throughout silo depth.
4. Silo is having flat bottom having cylindrical shape.

After analysis following result is obtain to understand behavior of silo.

1. Lateral Deflection along depth of silo wall.
2. Membrane stress S_Y along depth of silo wall.
3. Bending Moment M_X along depth of silo wall.

The STAAD plate limited component depends on half and half limited component details. A total quadratic pressure circulation is accepted. For plane pressure activity, the accepted pressure circulation is as per the following

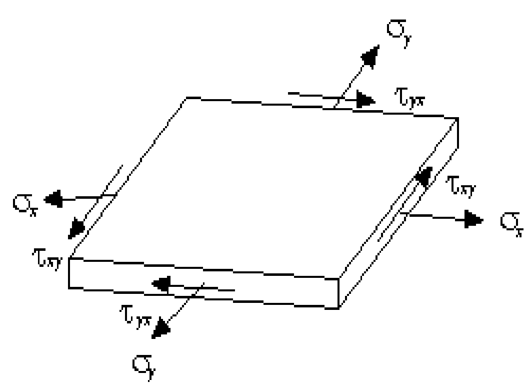


Fig.7 Complete assumed plate stress distribution

$$\begin{pmatrix}\sigma_x\\ \sigma_y\\ \tau_{xy}\end{pmatrix} = \begin{bmatrix}1 & x & y & 0 & 0 & 0 & 0 & x^2 & 2xy & 0\\ 0 & 0 & 0 & 1 & x & y & 0 & y^2 & 0 & 2xy\\ 0 & -y & 0 & 0 & 0 & -x & 1 & -2xy & -y^2 & -x^2\end{bmatrix}\begin{pmatrix}a_1\\ a_2\\ a_3\\ \vdots\\ a_{10}\end{pmatrix}$$

a_1 through a_{10} = constants of stress polynomials.

The following stress distribution is assumed for plate bending action:

$$\begin{pmatrix}M_x\\ M_y\\ M_{xy}\\ Q_x\\ Q_y\end{pmatrix} = \begin{bmatrix}1 & x & y & 0 & 0 & 0 & 0 & 0 & 0 & x^2 & xy & 0 & 0\\ 0 & 0 & 0 & 1 & x & y & 0 & 0 & 0 & 0 & 0 & xy & y^2\\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & x & y & -xy & 0 & 0 & -xy\\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & x & y & 0 & -x\\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 1 & 0 & -y & 0 & x & y\end{bmatrix}\begin{pmatrix}a_1\\ a_2\\ a_3\\ \vdots\\ \vdots\\ a_{13}\end{pmatrix}$$

a_1 through a_{13} = constants of stress polynomials.

ollowing are the things incorporated into the ELEMENT STRESS yield.

SQX, SQY - Shear stresses (Force/unit length/thickness.)

Sx, Sy, Sxy - Membrane stresses (Force/unit length./thickness) Mx, My, Mxy-Moments per unit width (Force x Length/length)

(For Mx, the unit width is a unit remove parallel to the nearby Y hub.

For My, the unit width is a unit separate parallel to the nearby X hub. Mx and My

cause bowing, while Mxy makes the component curve out-of-plane.)

Smax ,Smin Principal worries in the plane of the component (Force/unit zone)

TMAX Maximum shear worry in the plane of the component (Force/unit zone)

Angle Orientation of the principal plane (Degrees)

V_{ONT}, V_{ONB} Von Mises stress, where

$$VM = 0.707\sqrt{(SMAX - SMIN)^2 + SMAX^2 + SMIN^2}$$

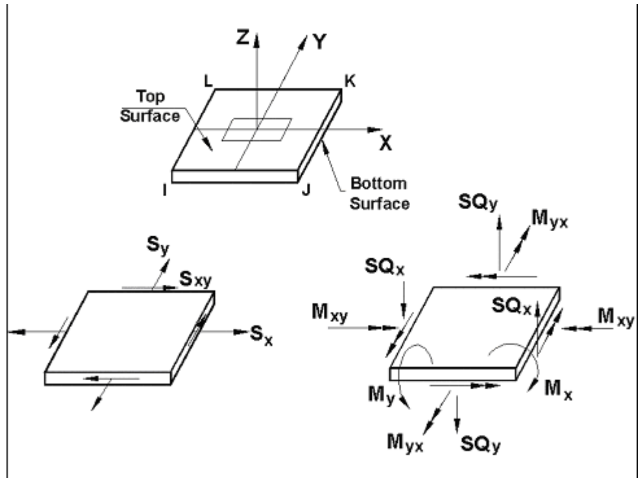


Fig. 8 Graphical representation of stresses on plate element

3.3 Problem Statements

In this paper RCC single hopper silos and double hopper silo is analyzed using STAAD-PRO V8i.

1 Self weight
DL=VolumexDensity =25x0.02=0.5 kN/m^2

2 Load on vertical walls
$P_h = \gamma hk$
=25x3x0.4
=30kN/m^2
Where k is 0.25 ≤k≤ 0.6(Ref. Jansson'stheory)

3 Earthquake load
Zone-III
Zone factor-0.16
Soil Condition-Medium
Time Period-Ta=0.09h/$\sqrt{d}$=0.5sec
Sa/g-2.5
Damping Ratio=0.05
Type of support-Fixed support

3.4 Analysis Of Silo

For calculation of static pressure on silo wall parameter consider for silo design as per IS code. While calculation done for seismic force parameter used for calculation of seismic force will varies with their respective code condition that parameter.

Following data consider for calculation of silo pressure

Type	RCC silo	RCC silo
Purpose of silo	Storage of cement	Storage of cement
Configuration	A single free standing rectangular shape	Double free standing rectangular shape
Height of silo	12m	12m
Length	3m	1.5m
Width	3m	1.5m
Thickness of silo	20mm	20mm
Storage product density	15.50kN/m³	15.50kN/m³
Angle of internal friction	25	25
Friction coefficient of tank wall	0.46	0.46
coefficient of wall friction(ɜ)	tan φ	tan φ
Seismic zone	III	III
Grade of RCC	Fe500	Fe500

3.5 Validation Of Model

Single hopper silo is verified using single degree of freedom system. Natural frequency and time period of silo is compared against values of STAAD-Pro (Refer Table no.)

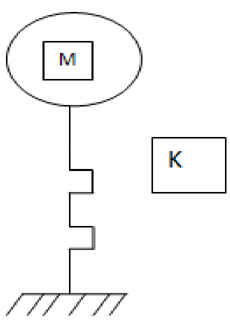


Fig.9SDOF MODEL OF SINGLE HOPPER SILO

3.6 Stiffness matrix

The total number of columns having the same size in each storey =6

Therefore, $k = 6(12EI/h^3)$
Where, $E = 2.05x10^5 N/mm^2$
Stiffness of column=$9.269x10^3$
Mass of silo=7.53Kn

Mode Shapes Equations (characteristic Equation)

$$(k - \omega^2{}_n m)\,\phi_n = 0$$

The right hand side of the equation is zero.

$$\text{Either } \phi_n = 0 \text{ or } [k - \omega^2{}_n m] = 0$$

But ϕ_n cannot be zero because it leads to trivial solution implying u=0, which means no motion.

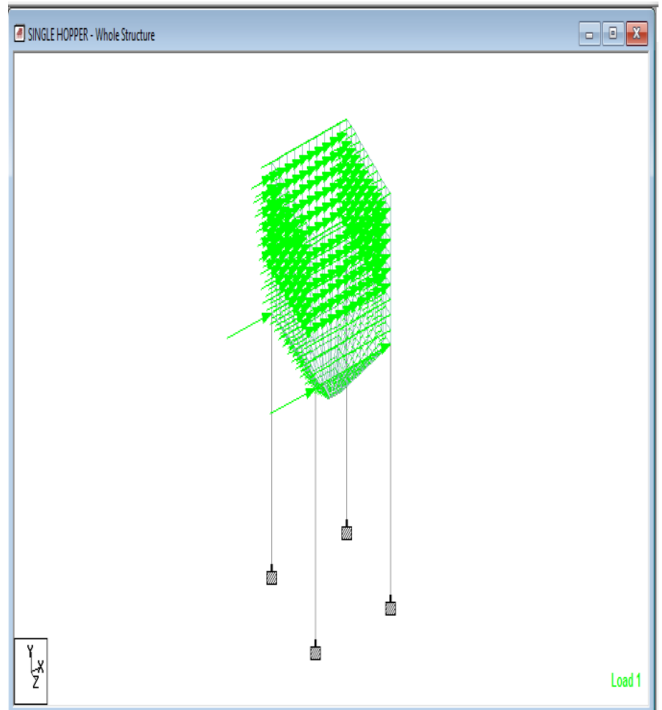


Fig.10 Vertical load

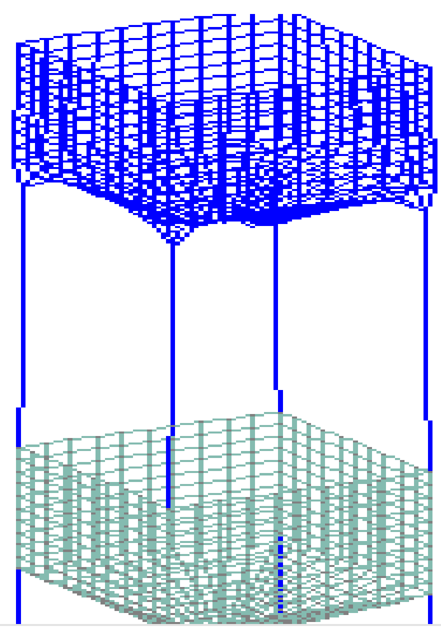


Fig .11 Mode Shape No.1

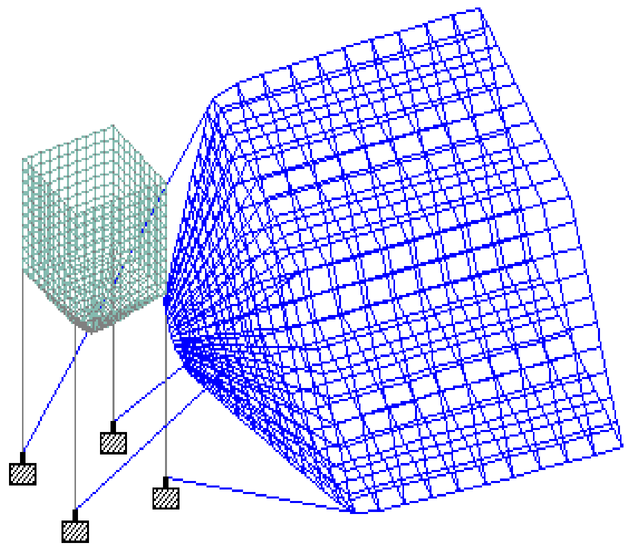


Fig .12 Mode Shape No.2

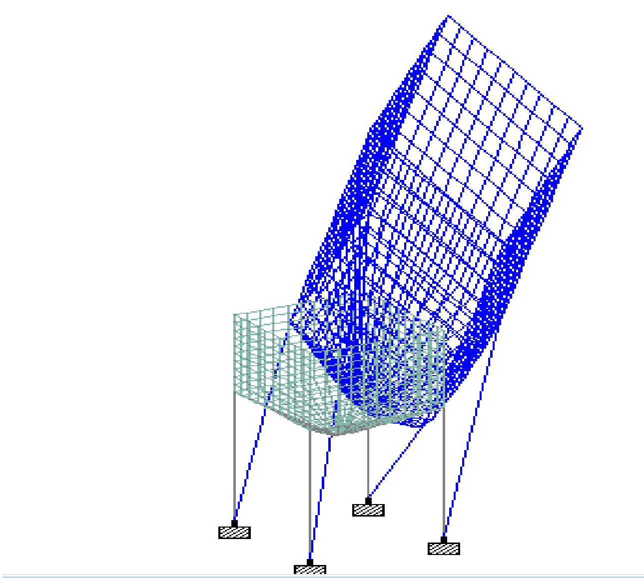
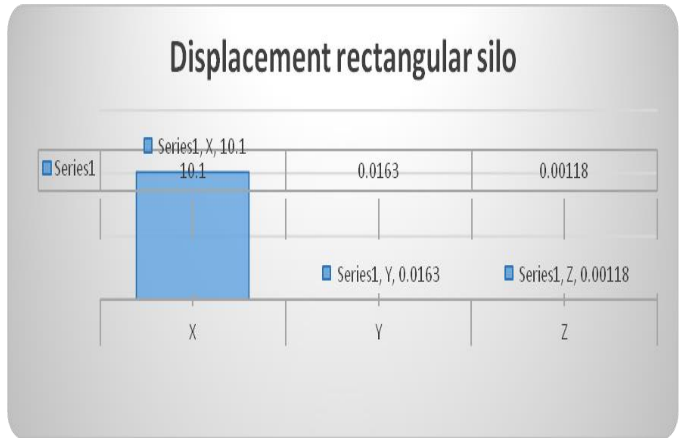


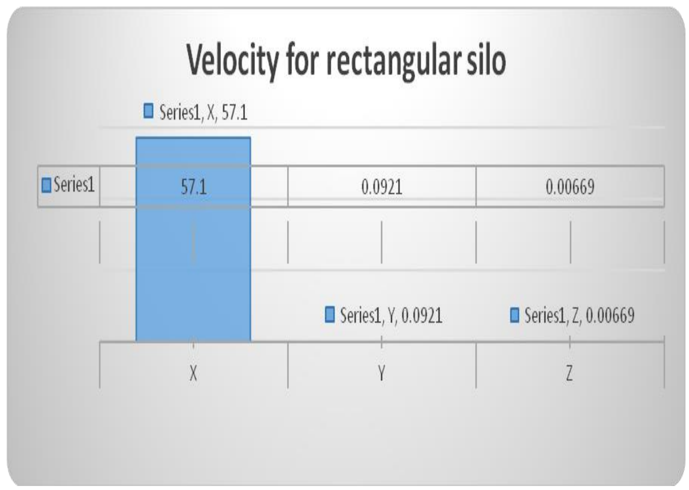
Fig.13 Mode Shape No.3

IV. RESULT AND CONCLUSION

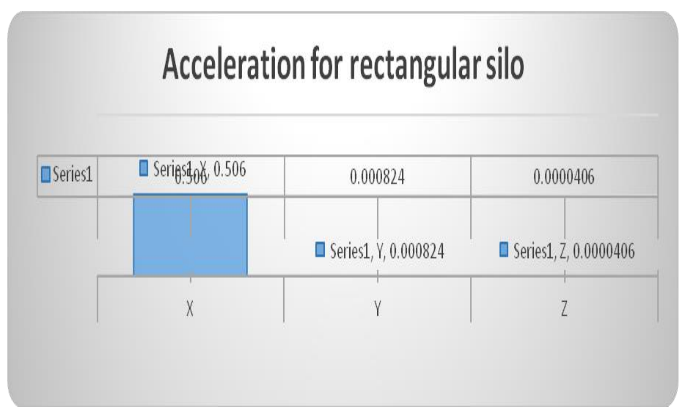
4.1 Graphical representation of rectangular silo for empty condition



Graph.1 (Displacement for rectangular silo)

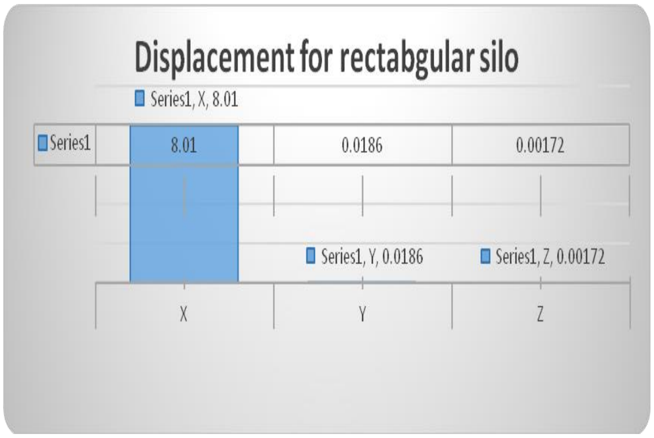


Graph 2 (Velocity for rectangular silo)

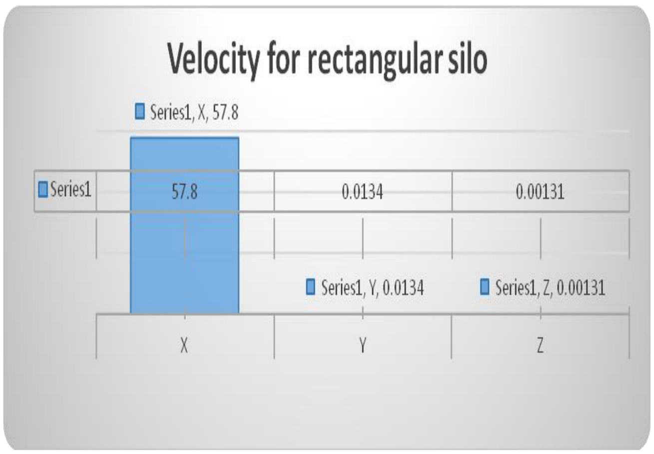


Graph 3(Acceleration forrectangular silo)

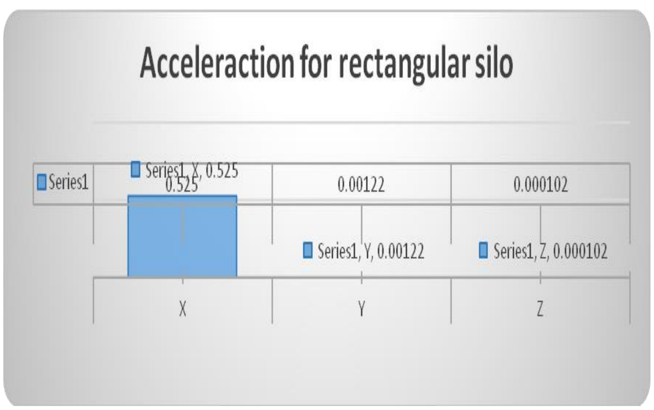
4 .2 Graphical representation of rectangular silo for full condition



Graph 4 (Displacement for rectangular silo)

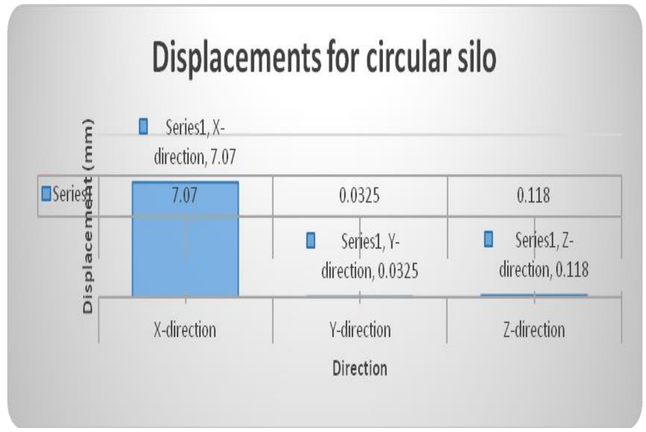


Graph 5 (Velocity forrectangular silo)

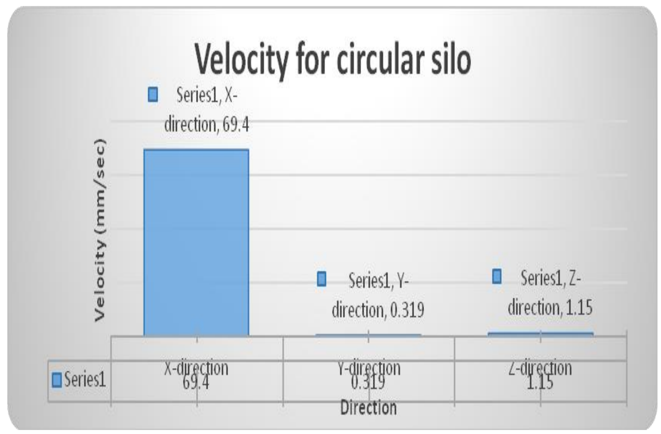


Graph 6 (Acceleration for rectangular silo)

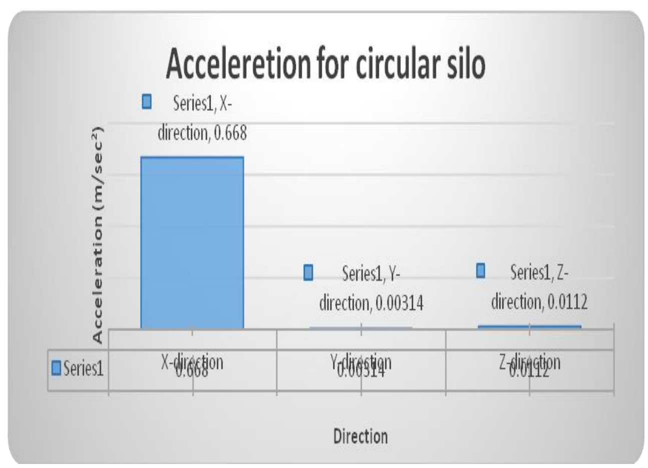
4.3 Graphical representation of circular silo for empty condition



Graph 7 (Displacement for circular silo)

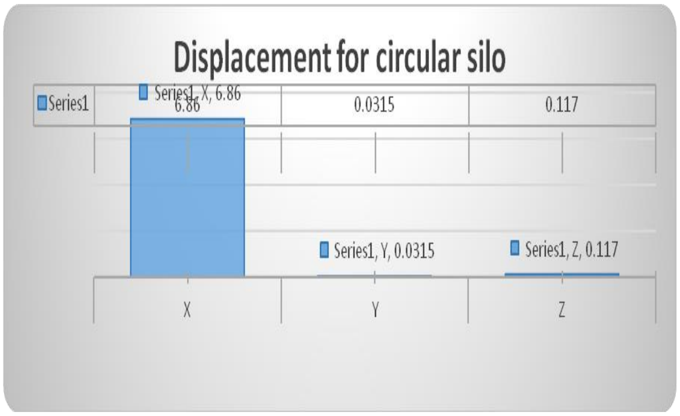


Graph 8 (Velocity for circular silo)

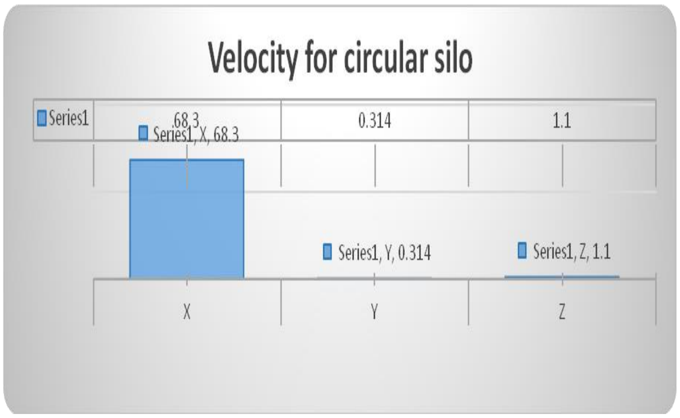


Graph 9 (Acceleration for circular silo)

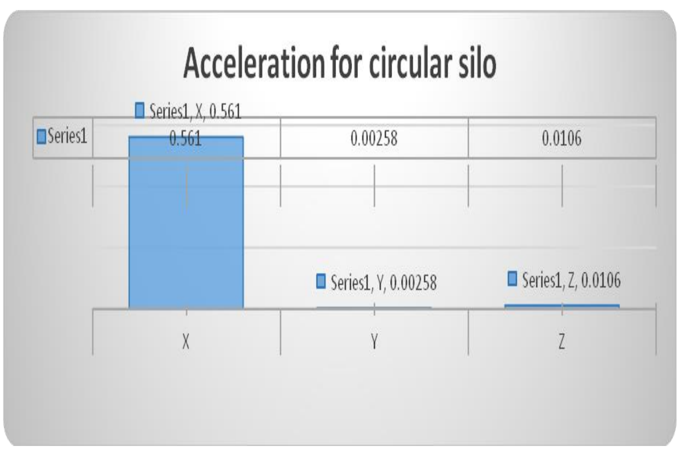
4.4 Graphical representation of circular silo for full condition



Graph 10 (Displacement for circular silo)

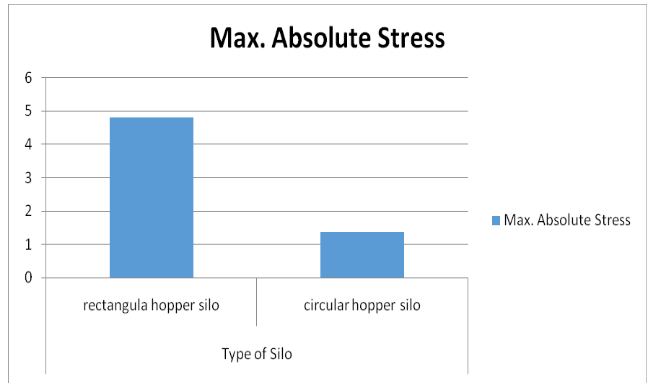


Graph 11 (Velocity for circular silo)

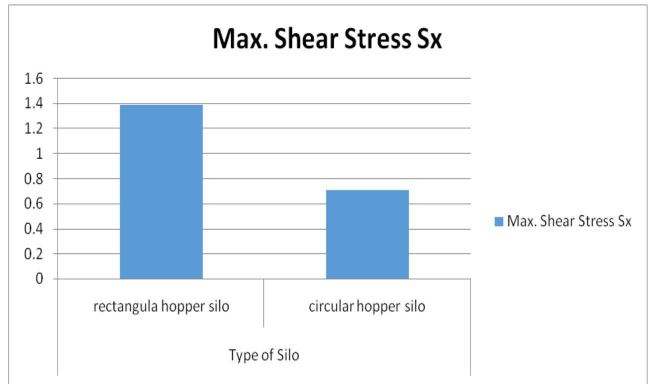


Graph 12 (Acceleration for circular silo)

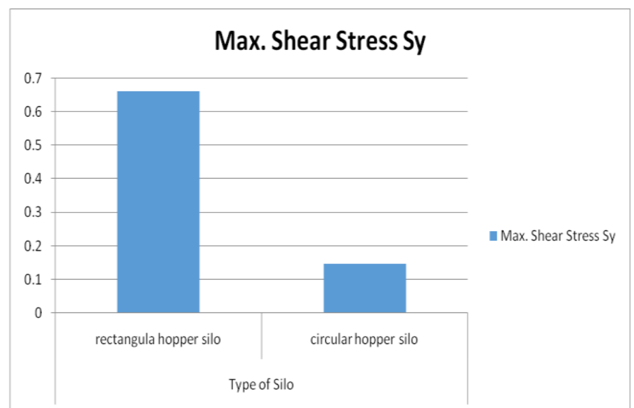
COMPARISON BETWEEN RECTANGULAR HOPPER AND CIRCULAR HOPPER



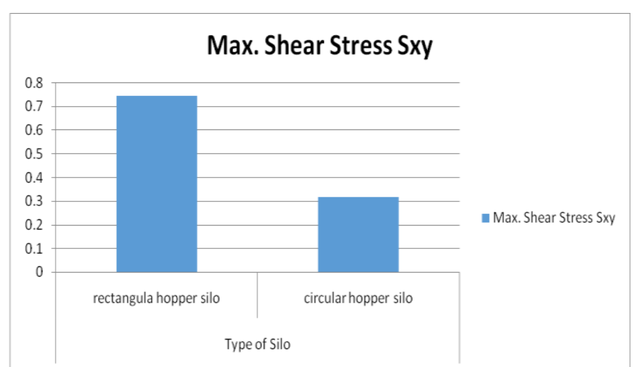
Graph No.15 Max. Absolute Stress



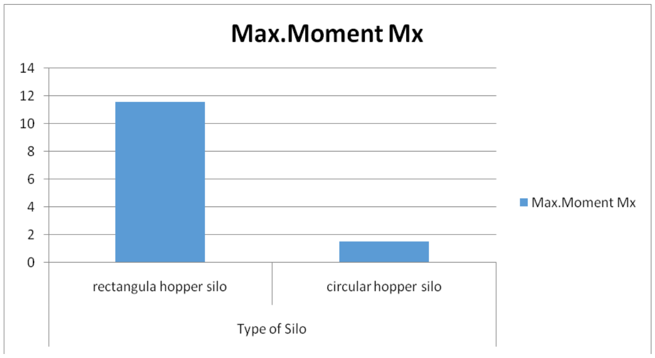
Graph No.16 Max. Shear Stress S_X



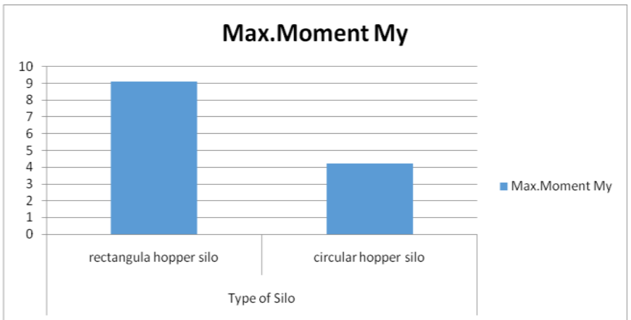
Graph No.17 Max. Shear Stress S_Y



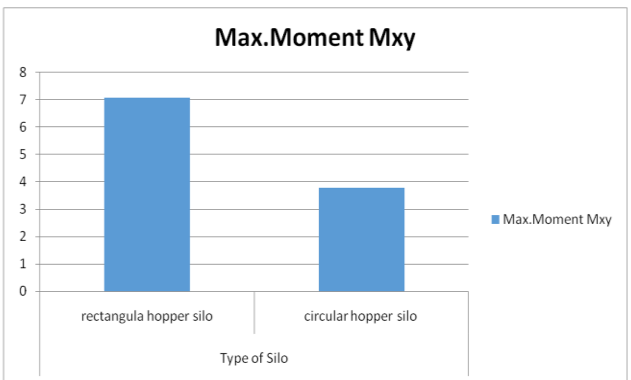
Graph No.18 Max. Shear Stress S_{XY}



Graph No.19 Max. Moment M_X



Graph No.20 Max. Moment M_Y



Graph No.21 Max. Moment M_{XY}

V. CONCLUSIONS

1) In this study single and double hopper steel silos is analyzed under the influence of self weight, pressure on vertical wall and seismic load.
2) It was observe that maximum displacement along X-direction and Z-direction is reduced by 15-20% in single hopper silo.
3) But displacement along in Y-direction i.e. along gravity direction 20 % less in double hopper silo as compare to single hopper silo
4) However nodal rotation are remain nearly same indicates that the torsion movement due to accidental eccentricity will be same in both cases.

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