A Comparative of Steel Silo Subjected To Specified Ground Motion

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Abstract-*Silos are containers used for storing bulk solids. Although there is no generally accepted definition for these terms, shallow structures containing coal, coke, ore, crushed stone, gravel, and similar materials. Silos are special structures subjected to many different unconventional loading conditions, which result in unusual failure modes. In this present study pressure calculation is carried out by STAAD-Pro and Janseen's theory for dynamic condition and additional pressure due seismic action is calculated by Theoretical approach. Base shear force generated at bottom of silo is compared with IS 9178 Part-2 and seismic conditions using IS 1893-2002. Calculation is completely based on respective codal provision applied to Indian seismic zones, site condition etc.*

Keywords-SSilo, silo failure, action of forces, seismic behavior, Staad-Pro

I. INTRODUCTION

1.1 General

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 is 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 shorter 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 steel & reinforced concrete.

Governing factor in design of silos are the type of material stored in it and their 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.

Fig.no-1(steel silo)

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. The walls of the silos are typically subjected to both normal pressure and vertical frictional shear or traction produced by the material stored inside the silo. The magnitude and distribution of both shear and normal pressure over the height of the wall depend on the properties of the stored 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.

An earthquake analysis effective components acting on silo due to structural loading are the two horizontal and one vertical direction. Silos have effect of seismic vertical loads is small, compare to lateral seismic loads on the tall silos storing heavy material. Seismic load magnitude in lateral direction directly related to the weight of silo. In earthquake analysis increase of lateral load bending moment also increases result of this non uniform pressure at bottom of silo increase as compare to pressure due gravity load.

1.2 Types of Silos

a) Flat Bottom Silos
b) Hopper Silos
c) Truck load silos

1.3 OBJECTIVE OF STUDY

- Analysis and design of silo by using Janseen theory
- To perform dynamic analysis in STAAD PRO software for steel silo of various hopper diameter using time history analysis
- Validate results of STAAD PRO software using IS 9178 part-2 i.e. Jansen theory.
- To compare natural frequencies, time period for different mode shapes.
- Additional pressure due seismic action is calculated by theoretical approach and comparison made with IS 1893-2002

1.4 LOADING ON SILO

Static Load

- Dead load
- Live load
- Seismic load
- Wind load

Dynamic Load

- El-Centro

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

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

1.4.3 Seismic Load - 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

1.4.4 Wind Load- Live loads should be considered forces from stored material (including overpressures and under pressures from flow), floor and roof live load

II. LITERATURE REVIEW

Marek MAJ & KAMINSKI-Experiment on silo model & free standing silo. In this Study they evaluate temperature effect; silo wall pressure & both these act on silo simultaneously. They placed sensor in bottom and wall of silo also as sounder for material stored in silo. In research include evaluation of strength parameter of silo wall. Parameter which investigated was random variable parameter. Data collected such as temperature, pressure and strength coefficients is important significance, in the study Marek many times measure all these loads. The data collected from these studies can be used for designing similar silos.

S. Silvestri, T. Trombetti and G.- An innovative methodology for the seismic design of flat-bottom silos containing granular, grain-like material. In the general issues concerning the actions provoked by earthquake ground motion on the walls of flat-bottom grain silos, the assessment of the horizontal actions seems to be of particular interest. Up to date, the horizontal actions due to the seismic event are usually evaluated under the hypotheses (i) of stiff behavior of the silo and its contents and (ii) that the grain mass corresponding to the whole content of the silo except the base cone with an inclination balanced by the horizontal actions provided by the walls (supposing that the seismic force coming from the base cone is balanced by friction and does not push against the walls). The analyses reported here, which are developed by simulating the earthquake ground motion with constant vertical and horizontal accelerations, lead to the subdivision of the ensiled material into three different portions depending on the interaction with the container, by means of plain dynamic equilibrium considerations with reference to the above mentioned accelerations. Two portions push into the silo walls, while the third one does not push into the silo walls. The findings indicate that, in the case of silos characterized by specific (but usual) height/diameter slenderness ratios, the portion of grain mass that interacts with the silo walls turns out to be noticeably lower than the total mass of the grain in the silo.

Indrajit Chowdhury and Raj Tilak- Dynamic pressure on circular silo under seismic force. Circular silos (both steel and reinforced concrete) are often deployed to store material in various industries like cement plants (clinkers), power plants (raw coal/coke), oil and gas industry (sulfur pellets) etc. Technology that is in vogue for earthquake analysis of such structures is to consider the silo and its content as a lumped mass and seismic effect of this mass is considered in design of the supporting frame only. No effect of this seismic force is considered on silo wall when the content is subjected to seismic vibration. Procedure has been suggested wherein the additional dynamic pressure due to earthquake can be incorporated in analysis of such circular silos. While carrying out this analysis, conventional Jansen¡¦s method has been modified to develop the additional dynamic pressure due to seismic force and a parametric study has been done to study the effect of this dynamic pressure on the wall of silo for different structural configuration.

Alan W. Roberts- An overview of developments in silo wall load analysis and design over the period commencing with the 1880¡¦s to the present. The pioneering work of Janssen (1995) in establishing the basic theory of silo wall loads under static filling conditions and the important contributions by Jamieson (1902-1903) in identifying the overpressures during symmetrical discharge and the non-symmetry of the wall loads during eccentric discharge are given. The identification of the basic flow patterns of discharging bulk solids and the linking of these flow patterns to specific bin and silo geometries is reviewed. The associated bin wall loads that are linked to the flow patterns is studied. Particular mention is made of the complex loading problems that are associated with eccentric discharge and multi outlet bins. The problems of grain swelling due to moisture increases and silo wall expansion and contraction that accompany temperature variations are outlined. The application of anti-dynamic tubes for controlling wall loads in tall grain silos is illustrated. In the case of rapid discharge of bulk solids which gives rise to impact loads which must be considered in the design of bin an its support structure. Brief mention is made of the loads on structural members that are buried in bins, bulk storage sheds and stockpiles.

F. Ayuga Téllez- Analysis was made of a series of variables involved in the static pressures generated in agricultural silos with an eccentric hopper using the commercial ANSYS 5.5. Program based on the FEM. The most significant conclusions are summarized below. According to the FEM, the pressure curves corresponding to the cylinder wall until the Silo-hopper junction is approached follow the same tendency as calculation methods proposed by existing standards, but are lower than those proposed by the Euro code. The FEM, in agreement with the Euro code, situates greatest pressures at the silo-hopper Junction, unlike the French and DIN norms, according to which these correspond to inside the hopper.

According to the FEM, hopper eccentricity does not affect pressures on the cylinder wallUntil areas close to the silo-hopper junction are approached. Maximum normal pressures on the silo walls correspond to the silo-hopper junction, on the opposite side to the displacementof the outlet for any eccentricity, increasing at this point as hopper eccentricity rises. According to the FEM, the K factor is not constant throughout the silo, unlike the case Described in the Euro code, in which it is subject to a variation in height for the same Eccentricity and a further variation according to the eccentricity of the hopper, for different eccentricities.

Nian Tingkai- In this paper, a large diameter silo was established by three-dimensional finite element. Static wall pressures and wall pressure at the end of filling were studied. Two lamination ways to simulate filling process was studied. And the influence of mechanical parameters of bulk solid to wall pressure was studied. The following conclusions can be drawn from the results of the generated finite-element model:

- Silo scale has heavy influence on wall pressure. It is not feasible to compute wall pressure oflarge diameter silos with methods based on small diameter silos. It is important to study on large diameter silos.
- Yong’s modulus, Poisson’s ratio, grain-wall frictional coefficient and internal friction angle have heavy effect on static wall pressure while dilatation angle and cohesion have little influence to static wall pressure. The value change of Yong’s modulus has no effect to wall pressure at the end of filling.
- Wall pressures of large diameter silos at the end of filling were much larger than static wall Pressures near silos bottom. Wall pressure of filling should be considered in design of large diameter silos. There is little system research on large diameter silo currently. Study in this paper has heavy theoretical significance and provide an important basis for the large diameter silo design.

Sivabala. P- The frequency of the silo increased from 19.995 Cycles/sec to 35.995 Cycles/sec on the addition of extra plates between the supporting columns. This increase accounts for about 80 percent. Thus providing plates in between the columns increases the stability of the structure especially in earth quake prone areas or under dynamic loading. The stresses in the structure decreased from about 20 to 62 percent due to the addition of plates between columns. The displacement of the structure is generally found to be reduced from about 23 to 57 percent on addition of plates between the columns. The mode shapes of the silo with and without plates are found to be entirely different. Hence the deflection and failure pattern are also found to be different.

Suvarna Dilip Deshmukh- Pressure calculation given as ACI code is found to be more conservative side than other codes of practice. Reinforcement is found to varying along depth of wall and found to be more on middle portion of wall. Silo design & construction is based on strength design method. Due to difference in value of μ and Θ; variation in pressure calculation can be seen. Additional pressure due to seismic action need to be considered while designing silo wall.

Anand Adi- The frequency of the silo is increased providing surface element. This increase accounts for about 15%. Thus providing surface element increases the stability of the structure, especially in earth quake prone areas or under dynamic loading. The displacement of Silo with Plate element, bracing element and Surface element are well within the permissible limits. The displacement increases as zone increases. The displacement of the structure is generally found to be reduced from about 20% on providing surface element. The Surface element as shear wall gives the economical results compared to bracing element.

III. PROBLEM STATEMENT

Model No.1 Rectangular Silo

Purpose of silo	**Storage of cement**
Type	Steel silo
Configuration	A single free standing, rectangular shape
length	3M
width	3M
Thickness of silo	0.1M
Storage product density	15.50KN/m3
Angle of internal friction	25
Friction coefficient of tank wall	0.46
coefficient of wall friction (ვ)	TanΦ
Seismic zone	III
Grade of Steel	Fe500

Model No.2 Circular Silo

Purpose of silo	**Storage of cement**
Type	Steel silo
Configuration	A single free standing, rectangular shape
Diameter	1.7m
Thickness of silo	0.1M
Storage product density	15.50KN/m3
Angle of internal friction	25
Friction coefficient of tank wall	0.46
coefficient of wall friction (ვ)	TanΦ
Seismic zone	III
Grade of Steel	Fe500

IV. FEA MODELS IN STAAD-PRO

In this chapter 3 parametric models of silos are modeled using FEA tool STAAD-Pro. For dynamic condition El-Centro data is used.

4.1 Rectangular silo

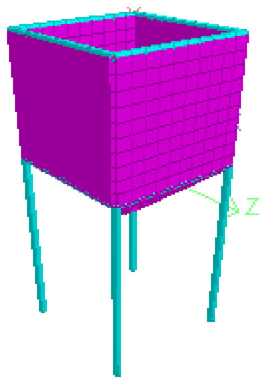

Fig.no-2(STAAD-PRO model)

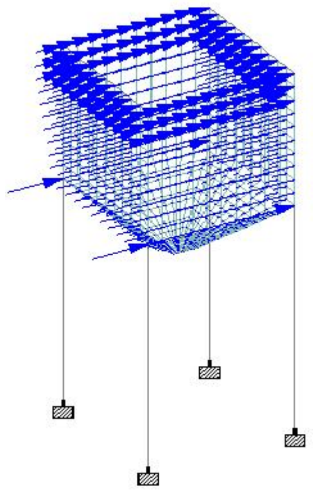

Fig.no-3(EQ+X)

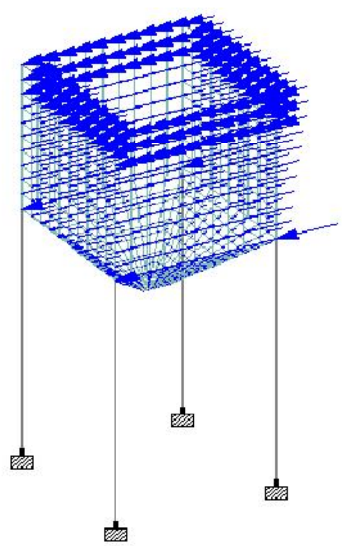

Fig.no-4(EQ-X)

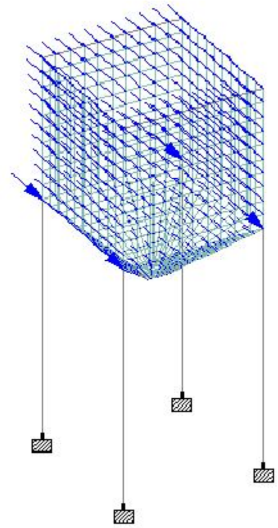

Fig.no-5(EQ+Z)

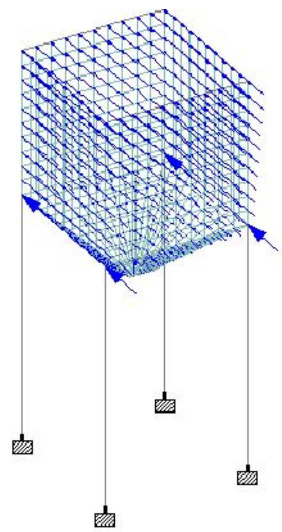

Fig.no-6(EQ-Z)

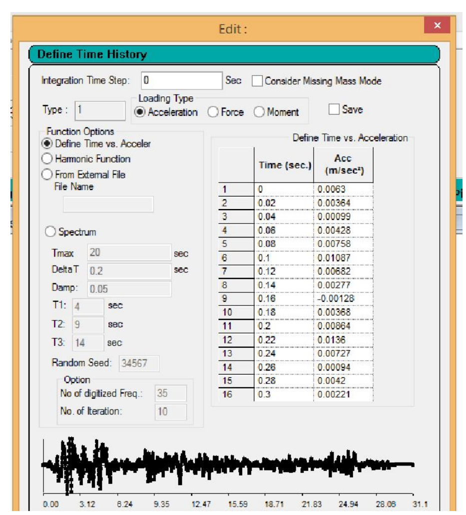

Fig.no-7(EL-Centro)

4.2 Circular silo

4.2.1 Time – Displacement

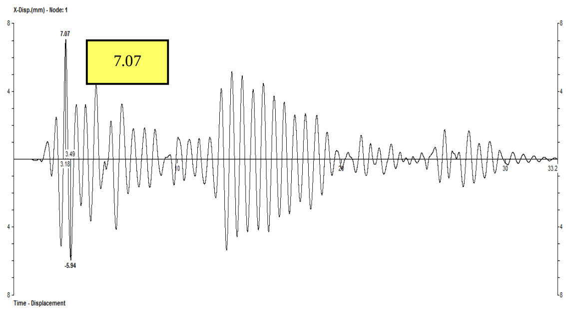

fig.no-8(X-direction)

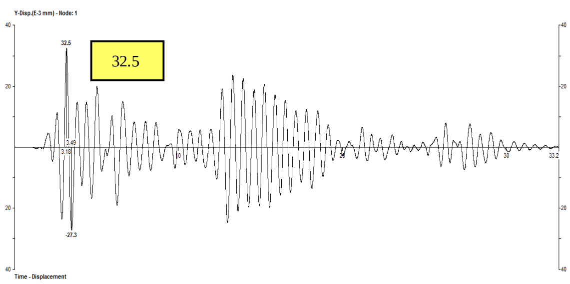

fig.no-9(Y-direction)

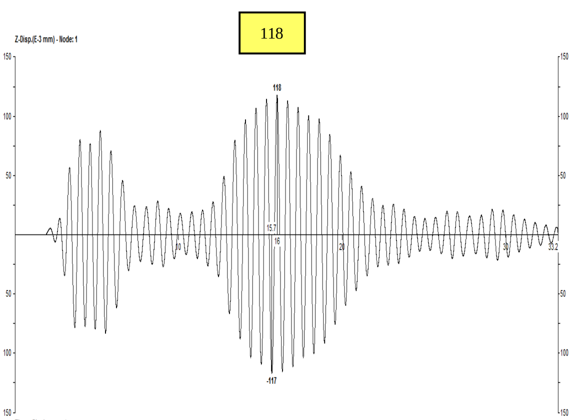

fig.no-10(Z-direction)

4.2.2 Time - Velocity

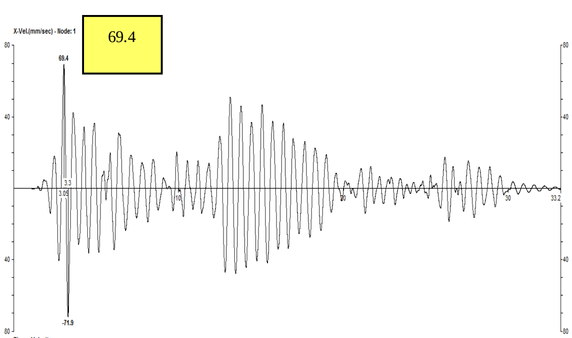

fig.no-11(X-direction)

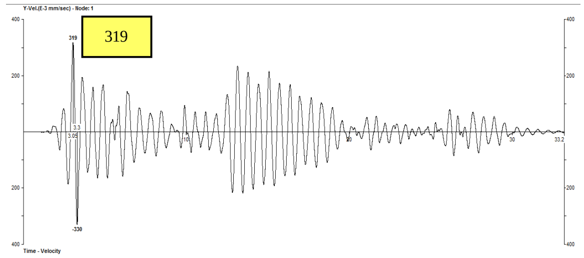

fig.no-12(Y-direction)

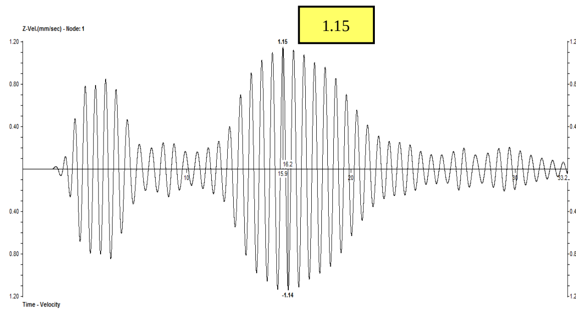

fig.no-13(Z-direction)

4.2.3 Time – Acceleration

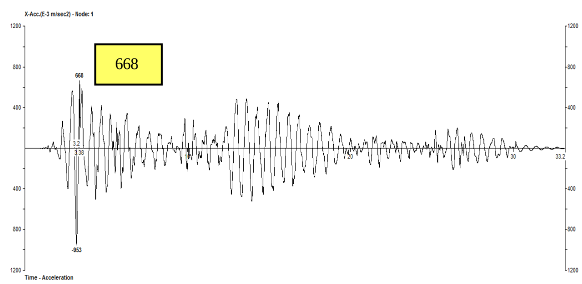

fig.no-14(X-direction)

fig.no-15(Y-direction)

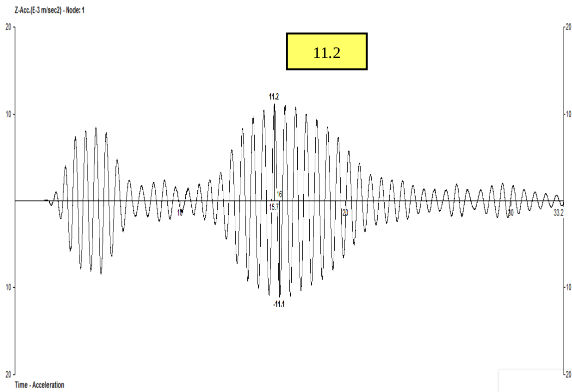

fig.no-16(Z-direction)

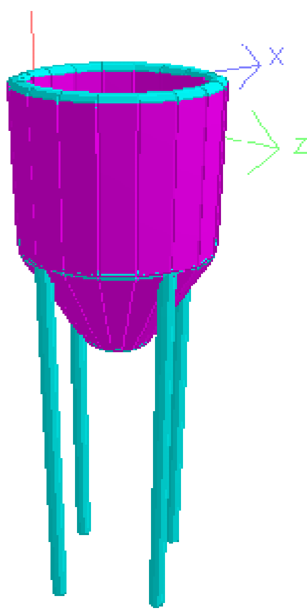

fig.no-15(STAAD-Pro model)

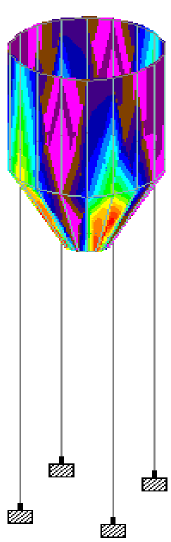

Fig.no-17(Plate stress contour)

V. CONCLUSION

In the first stage of study circular and rectangular parametric model of steel silos were studied in accordance of Janseen's theory Later using FEA tool STAAD-Pro linear static and dynamic analysis of steel silos is performed using IS 1893:2002 and El-Centro data respectively and following conclusions can be drawn

1. Displacement in circular silo along X-direction is 17% more than rectangular hopper silo
2. Displacement in circular silo along Y-direction is 5% more than rectangular hopper silo
3. Displacement in circular silo along z-direction is 20% more than rectangular hopper silo
4. Silo drift is observed larger in circular silos as compared to rectangular silos for same base shear

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