International Journal of Engineering Science Invention (IJESI)
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org ||Volume 8 Issue 10 Series. II || October 2019 || PP 09-13

Compressive Behaviour of steel silos under Dynamic Loading

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Abstract: *Reducing post harvest losses is considered as a major step towards food security. In India it amounts to more than 20 million tons per year which is approximately 10% of total food grain produced. In our country where 20% of the population is undernourished, post harvest losses of 20 million tons annually are a substantial avoidable waste. Hence, proper storage to save food grain is a burining issue. Storage implies preserving. It is the process of carrying surplus production for future consumption. Here is lies the significance of improved storage structure and scientific Storage of grains. The study has carried out in the village level of Akbarpur Taluka of Ambedkar Nagar in eastern Uttar Pradesh of India. Functional and structural aspects for silo under dynamic loading of it, has evaluated. This was found that for 1,35,730 Kg of wheat seed the diameter and height of silo as 8.94m and 13.41m was needed. But for a convenient height ten bins have designed for the above capacity for easy handling. Lateral pressure as 493718.95 kg/m^2, vertical pressure as 1818782 kg/m^2 were calculated for which compressive stress on vertical wall of silo was found as 0.27, as well as the compressive stress due to load transfer at the base of silo as 29236 kg/m^2. Stress due to self weight has calculated as 32160 kg/m^2. To strengthen design of silo the stress due to wind moment has also evaluated as 589958.75 kg/m^2. All these compressive stress on submission has evaluated as 662074.91 kg/m^2 (662.07 kg/m^2). Since the allowable stress of steel is 710 kg/ cm^2, the proposed structure under dynamic loading was very safe.*

Keyword: *Loading; Stress; Strain; Structure; Design; Pressure.*

Date of Submission: 20-10-2019 Date of acceptance: 03-11-2019

I. Introduction

In the rural areas of India, where farmers make a living from agriculture have little opportunity to diversify incomes through additional employment in non-farming activities. At the same time it is seen that food grain production has been steadily increasing because of advancement in production technology, but the inappropriate storages results in high losses of food grains. Annual production was 116 million tonnes in 1975-76, which has increased to 253.16 million tonnes in 2016-17. However there has been a marginal increase in the structure for food grain storage. According to the World Bank estimate (1999), post harvest losses in India amount to 17 to 15 million tonnes of food grains per annum, which can nourish one – third of India’s poor masses. Food grain losses due to contamination is influenced by the types of storage structure, humidity, temperature variations and moisture present in the food grain etc. Past harvest losses also cause resource wastage because natural resources, human and physical capital are committed to produce processes, handle and transport food that no one consumes.

The occurrence and number of stored grain the insect, pests are directly related to climatic and geographical conditions. Due to lack of proper storage in Eastern Uttar Pradesh of India, the harvest as collateral to access credit (Sample et. al. 1988; Tefera et. al, 2011) . It is therefore, crucial that appropriate, affordable storage technologies are readily available to the farmers for them to safely store and maintain quality of their produce (Thamga- chitja et. al.; 2004). Safe storage at the rural level also is crucial, as it directly impacts on poverty alleviation, food and income security of the small holder farmers,

The metal silo technology has proven to be effective in protecting the harvested grains from attack not only from the storage insects but also from rodents and pests (Tefera et. al. 2011). The objectives of this paper were to assess the effectives of metal silo storage technology in view of comprehensive behaviour under dynamic loading, for safety.

II. Material And Method

In the study progressive farmers from the village Bangaon of Akbarpur Taluka of Ambedkar Nagar district in Eastern Uttar Pradesh, India has selected. Land areas of cultivars have found from the revenue records and the average yield by crop cutting samples from individual farmers. The total production of wheat found by multiplying the average yield to the wheat area shown in the village under study. It was decided to design steel silo structures which are being commonly used to large grain storage for longer periods under insured safety against heat, moisture, insects and deterioration in quality. The structural aspect of design based on shape of silo, weight of grain and anticipated load of the grain on the silo. Grain load pressures are found by the Rankine's and Janseen's theories which are commonly used to determine the pressure exerted by grain on the silo walls. However these classical theories do not consider the effect of movement of grain during filling and emptying operations.

The loads applied to the structural design of a silo according to its intended use, size, structure types material, design, lifetime, location and environment, in order to assume life safety and to maintain its essential functions. The applied loads as dead load, live load, snow load, wind load, seismic load, pressure load due to content, thermal stresses, shock and fatigue loads along with their combination be defined and considering the actual probability of occurrence. Because when a silo fails it can be devastating , in more ways than one including loss in container, contamination of material it contains, loss of material, clean – up, replacement costs and most importantly possible injury or loss of life.

Silo design primarily governed by the type and properties of stored material, walls of the silo are typically subjected to normal pressure and vertical frictional shear produced by material stored inside the silo. Depending upon the relative dimension i.e. height and diameter a shallow structure is one which has a relation $h < 1.5d$, where h and d is the height and diameter of the structure. Lateral pressure has calculated by using Rankine's formula i.e. $PL = w.h [(1 - \sin\Theta) / (1 + \sin\Theta)$, where PL is the lateral pressure, w = bulk unit weight, Kg/m^3, h = depth below the free surface and Θ = Angle of repose of the wheat grain stored. The vertical pressure on the bottom of silo is also calculated by Rankine's formula i.e. $Pv = w.h$, where Pv is the vertical pressure in kg, w is the bulk unit weight, kg/m^2 and h, is the depth below free surface, m. The compressive stress has calculated by dividing the vertical load by base area of silo. Stress due to self weight of silo has obtained by height of steel silo to the unit weight of steel per sq meter. Wind load has assumed to act at the middle of the total height of the silo, which causes the bending of the structure and produces tensile stress at one edge of the silo and compressive stress at the other edge at the base of silo. The moment of Inertia (MI) = $\Pi / 64 [(\text{External diameter})^4 – (\text{Internal diameter})^4]$ is used to calculate stress due to wind moment, by formula (Moment of wind pressure / MI) x External radius of silo. The sum of addition of compressive stress, stress due to self weight and stress due to wind moment gives the maximum compressive stress of the silo structure. If this maximum compressive stress is less than allowable working stress of steel, then the designed structure shows it is safe or vice-versa.

III. Result and Discussion

The mechanical behaviour of AISI-416 stainless steel under compressive loading is investigated in this paper. Silos are special structures subjected to different static and dynamic loading conditions, which cause unusual failure modes. The designing comprises of calculation for diameter and height of the structure, lateral and vertical pressure on the structure, wall of the Steel structure etc. The details are described as under:

The weight of wheat to be stored = 135730 kg.

The volume of wheat to be stored= Weight of wheat /Density of wheat

$$= 135,730 \text{ kg} / 1070 \text{ kg/m}^3$$
$$= 126.85 \text{ m}^3 \text{ i.e. } 127\text{m}^3.$$

Design for diameter and height of the structure:

Since, grain storage structure is a shallow type, which has a relation between height and diameter as $h < 1.5d$

Now,

$$\text{Volume of structure} = \Pi / 4d^2h + 1/3 \text{ X } \Pi / 4d^2h$$
$$= \Pi / 4d^2h + \Pi / 12 \, d^2h$$
$$= (3 \, \Pi d^2h + \Pi d^2h)/12$$
$$= 4 \, \Pi d^2h / 12 \text{ m}^3$$

Volume of structure = Volume of wheat

$$4 \, \Pi d^2h / 12 = 126.85 \text{ m}^3$$
$$4 \, \Pi \, d^2h = 126.85 \text{ x } 12$$
$$d^2h = (126.85 \text{ x } 12) / 4 \, \Pi$$
$$d^2 = 80 \text{ m}^2$$

Diameter of structure from $d^3 = 17759/220$

$$d = 8.94 \text{ m}$$

Height of structure from the relation, $h = 1.5 \text{ x } 8.94$

$$h = 13.41 \text{ m}$$

Since the volume of wheat to be stored is large quantity (i.e. 127 m^3) which will give an inconvenient height and diameter of the hopper type bin. Hence, ten bins volume of 33.78 m^3 have taken for design consideration.

Lateral pressure on wall on the structure:

On the basis of Rankine's formula,

PL = w.h [(1 - sinΘ) / (1 + sinΘ)
PL = 135.730 x 13.4 [(1 – sin35^o) / (1 + sin35^o)]
PL = 135,730 x 13.4 [(1 – 0.573) / (1 + 0.573)]
PL = 493718.95 kg/m^2
Vertical pressure on the bottom of structure:
Pv = w.h = 135,730 x 13.4
= 1818782 kg/m^2
Estimation of Compressive stress to the load transfer:
The ratio of compressive stress can be found out by the following equation:
Compressive stress = (Load transfer on vertical wall of structure) / (Load transfer at the base of structure)
= 493718.95 /1818782
= 0.27
Compressive stress due to load transfer:
= (Vertical load of the wheat at the base of structure) / (Area of the base of structure)
= [181782 / (Π/4 (8.9)^2)]
= 1818782 / 62.21
= 29236.16 kg/m^3
Hence, 27% of the total pressure in supported by vertical wall and 74 % of the total pressure is supported by bottom of the structure.
Estimate of stress due to self weight of the structure:
This stress is found by multiplying the height of structure to the weight of concrete.
Therefore, stress due to self weight = 13.4 x 2400 kg/m^2
= 32160 kg/m^2
Estimation of wind load:
The stress due to wind load 5m height of the structure at 100 kg/m^2
= 100 x 5 x 55.03 = at 100 kg/m^2
= 26515 kg
In the design wind load has been assumed to at the middle of the height of structure which will cause binding of the structure and produces tensile stress at one edge and compressive stress at the other edge of the structure.
Therefore, Moment of the wind pressure about the base of the structure.
= 26515 x 5
= 132575 kg-m
Moment of Inertia of Wall section
= Π / 64 [(9.30)2 – (8.90)^2]
= 0.356 m^4

Stress due to wind moment,
= (132575) x (8.9/2)
= 589958.75 kg/m^2
On adding all the calculated stress, the maximum compressive stress is found as :
= 29236.16 kg/m^2 + 32160 kg/m^2 + 589958.75 kg/m^2
= 662074.91/1000
= 662.07 kg/cm^2
Since the allowable working stress of AISI – 416 is 710 kg/cm^2, the proposed structure is very safe.

Several research studies are reported in the literature on the mechanical behaviour of different grades of stainless steel under dynamic loads. Lee and Yeh (1997) have investigated the deformation behaviour of various grades of steel. the results shows that the flow stress increases with increase in strain rate. Reimbert theory and Janseen's theory is used for pressure calculation by Ajay Chaubisa (2018) also. The study under taken by them to know the displacement of silo along x – direction by using software. Indrajeet chawdhury and Raj Tilak (2010), has worked for circular steel silo by ignoring the seismic effect. The geometry of the silo considered as diameter of silo as 10m and height also 10m. column height of 8m at 4m each with column cross section 0.5m x 0.5m. The pressure distribution along the wall of the silo, using Janssen's formulation and is being compared with the increase or decrease in pressure on the walls. They found the result in corroboration to the results in the present study.

The Spanish research team, F. Ayuga et. al. (2005), tried t o provide relevant results related to silo. They gave the activity of filling and discharge phenomena of silo, as much as eccentricity influence are simulated to better understanding for the silo behaviour. The accurate simulation of the mechanical behaviour of the bulk solid, the silo wall, the contact between them and the dynamics of the phenomena. Tatko, Radoslaw and Kobielak, Sylwester (2008), have carried out laboratory test in the steel flat bottomed silo model fill with sand, subjected to external dynamic loads. Horizontal pressure-time curves were used to analyze the influence of subsoil vibrations on the distribution changes due to these pressures. They concluded that a stable increase or decrease of pressures, horizontal pressure depends on the silo wall displacements which is in corroboration to our study.

Xie, Yu (2015), conducted a research to determine the structural behaviour of silo and lateral displacement of corrugated sheet under grain load. The finite element model developed in this study was used to optimize the silo structure. The grain load equation as developed was also validated using a field full scale silo structure. A series of conclusions were made like (i) The maximum lateral displacement of the wall occurs at the height of 1.47 m from the top of the foundation. (ii) Janssen's equation was found to be able to accurately predict the horizontal pressure load on the side wall. (iii) Hoop strain always remains positive and (iv) Vertical strain of the side wall became negative when silo is fully filled. This indicates that the side wall is under compression in the vertical direction, which is similar with the study. Kishore B. Vanghela and Hiten J. Shah (2017) worked on the analysis and design of large cylindrical steel silos composed of horizontally corrugated sheet with stiffeners. They concluded that the increase in the horizontal pressure of silo is directly proportional to the height of grain storage.

The research work carried out by Yong Hongwu (1990), for the prediction of bulk material pressure on the silo walls and the internal stresses in silo shells under both static and dynamic conditions. A finite element method formulated in terms of velocity as the primary variable is developed for the simulation of the flow of bulk material and the structure response of the silo shell. The analysis shows that a change in the material elastic modulus has no effect on pressure in rigid – walled silos. The side wall friction, the stiffness of silo wall and the material constitutive relationships have significant effects on the distribution and magnitude of bulk material pressures on silo walls and also on the internal stresses in the silo shells as tried to analyze the study undertaken.

III. Conclusion

In this study the pressure behaviour of steel silos due to dynamic loading has analyzed which gives significance of improved storage structure by providing the safe and economical means of grain storage for long durations. Need of the hour is to strengthen traditional means of storage with modern inputs and to provide cheaper storage to farmers so as prevent enormous storage losses. The results reported here will be useful for designers working on the dynamic behaviour of structures made from stainless steel.

References

[1]. Ashok, Basave Gowda and Shakunthala, N. M. (2018); "Different types of Grain storage structure for Betterment of livelihood of Indian Farmers"; Intl. J. Pure App. Bio Sci; V -6(4); pp: 190-198.

[2]. Ajay K. Behera, Nilamber K. Singh and Maloy K. Singh (2012); "Compressive Behavior of AISI – 416 Stainless steel at Different rates of loading" ; Proc. World congress on Engg.; V – III; July 4-6.

[3]. Ajay Chaubisa (2018); "A study of RCC silos under Influence of Dynamic loading in accordance with IS – 1893: 2002"; Intl. J. Innov. Know. Concepts; V-6(2); ISSN: 2454-2415.

[4]. Dharmendra H . Pambhar and Shraddha R. Vaniya (2015); "Design and Analysis of Circular Silo for storing bulk materials" Intl. J. Advance Res. Engg. Sci. and Tech; V-2(5); pp: 2394-2444.

[5]. F. Ayuga, P.Aguado, E Gallego, A. Ramirez (2005); "New steps towards the knowledge of silos behaviour"; Intl. J. Agro Physics; V-19(1);pp: 7-17.

[6]. Indrajit chawdhury and Raj Tilak (2010); "Dynamic pressure on the circular silo under seismic force"; 14SEE; IITR; Dec. 17-19.

[7]. Kishore B. Vanghela and Hiten J. Shah (2017); "To study the Analysis, Design and Behaviour of corrugated steel silo"; Intl. J. Sci. Res. and Dev.; V-5 (05); pp: 198-203.

[8]. Nagnur Sobha, channel Geeta and chanamm a N (2006); "Indigenous grain storage structures and methods of storage" ; Indian J. of traditional Knowledge; V- 5 (1); pp : 114 – 117.

[9]. Lee , W.S. and Yeh, G.W. (1997); "The plastic deformation behaviour of AISI 4340 alloy steel subjected to high temperature and high strain rate loading conditions" ;J. Material Processing Technology; V-71; pp: 224 – 234.

[10]. Pradnya P. Dhamdhere and Y. R. Suryawanshi (2017); "A Study of comparison of steel Silos under influence of dynamic loading in accordance with is IS:- 1893 – 2002"; J, VJER; V-1 (2) pp : 144 – 149.

[11]. Sample R.L., Hicks PA, Lazare JV, Castermans, A (1988); "Towards integrated commodity and pest management in grain storage."; A Training manual for application in humid tropical storage system, FAO, Rome, Phillippines; pp: 1-526.

[12]. Sachid Anandam, K. and B. Jose Ravindra Raj (2016); "Behavior of silos and Bunkers"; Intl. J. Innvo. Res. Sci. , Engg. and Tech; V-5(3); ISSN: 2319 8753.

[13]. Tatko, Radoslaw and Kobielak, Sylwester (2008); "Horizontal Bulk material pressure in silo subjected to Impulsive load"; J. Shoch. and Vibration; V -15; pp: 543-550.

[14]. Thamga- chitja, J.M. S.L. hendriks, GF ortmann and M, Green. (2004) ;"Impact of maize storage on rural household food security in Northern K W Azulu-Natal" ; J. Family Ecology consumer Sci; V-32; pp: 8 – 15.

[15]. Tefera T., Kanampiu F, De Groote H, Hellin J., Mugo S, Kimenju S, Beyne Y, Boddupolli P.M , Shiferaw B, Benziger M, (2011) ; "The metal silo: An effective grain storage technology for reducing past harvest losses for reducing post harvest insect and pathogen losses in maize while improving small holders farmers food security in developing countries" ; J. Crop Prot., V- 30; pp : 240 -245.

[16]. Vnadara, C.J. ; P. Sabarish Kumar; M. Ahgendran (2015); "Study on structural analysis and design of RCC bin"; Intl. J. Engg. Res. Gen. Sci. ; V-3(3) ; pp : 1258-1267.

[17]. Xie, Yu (2015); "Structural behaviour of grain bin silo"; Electronic thesis and dissertations, 5312, Univ. Windsor, Ontario, Canada.

[18]. Yong Hongwu (1990); "Static and Dynamic analysis of the flow of bulk materials through silos"; Ph.D. Thesis; Univ. Wollongong; pp : 1-219.

[19]. Zacharg Gitonga, Hugo De Groote and Tadele Tefera (2015); "Metal silo grain storage technology and house hold food security in Kenya"; J. Dev. Agric. Economics; V – 7 (6); pp: 222- 230.

Er. Amit Kumar" Compressive Behaviour of steel silos under Dynamic Loading" International Journal of Engineering Science Invention (IJESI), Vol. 08, No.10, 2019, PP 09-13