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A Brief Review on Bunkers and Silos

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Abstract*—The demand for Storage Structures has increased due to increase of population. To provide storage for materials like grains, cereals, coal, cement etc, industries would prefer the structures called as Bins. The Bin can be termed as a Bunker whose diameter is large when compared to its height. Similarly, when the height of the container is larger than its diameter it is termed as a Silo. In recent times the Steel storage structures have replaced by the Reinforced concrete bins because of their simple maintenance and better architectural qualities. As per today's scenario, industries habitually go for single or multiple compartments of bunkers or silos to store the manufactured materials. The causes of failures of storage structures are due to shortcomings in the following criteria such as failure due to design, construction, usage and maintenance. This study describes a concise review of the bunkers and silos including their stability against failures & causes, and the factors required for economic and effective design.
Keywords*—Bin, Bunkers, Silos, Failures & causes, Economic & effective design.

I. INTRODUCTION

Bunkers are Shallow structures in which the plane of rupture of the stored material meets the top horizontal surface of the material before meeting the opposite sides of the structure. (Rupture is a failure mode in which a tough ductile material pulls apart rather than cracking). The side walls resist lateral pressure and the total load is supported by the floor of the bunker. Consequently in a silo the plane of the rupture of the stored material meets the opposite sides of the structure before meeting the top horizontal surface of the material. Due to high ratio of height to diameter, a considerable portion of the load is resisted by friction between the material and wall. Only a tiny proportion of the total weight of the material acts on the floor of the structure. Whereas in the bunkers, due to the shallow depth it is assumed that the friction between the wall and the fill is negligible. Apart from this, rectangular bins with the bottom floor consisting of four sloping slabs are termed as Hoppers. Silos are generally circular in cross section. For self cleansing and for emptying it is supported on a number of columns, by the way of a ring beam. Its bottom height is fixed in such a way that a truck can pass below that. It is covered with shallow spherical or conical dome or with a beam and slab type flat roof with suitable man hole. Further the silos may be classified as Flat bottom silo, Hopper silo and Truck load silo based on the requirement of storage and delivery of materials. The stored material exerts pressure on the side of a structure. This pressure varies during filling and discharging and also with the position of the discharging hole. It is difficult to analyse the pressure because of many factors. Hence approximate methods are followed which are suggested by Janssen and Airy.

II. OBJECTIVE

The main intention of this study is to know about the behaviour of bunkers and silos in various situations such as during earthquake, during filling & discharge of materials, during different failures etc., and the factors to be considered while design, erection and fabrication of the same.

III.LITERATURE REVIEW

Krishna T.Kharjule and Minakshi B.Jagtap studied the behaviour of the storage structures (bunkers and silos) during earthquake. They have analysed both RCC and steel silos which are used to store clinkers, raw coal and sulphur pellets and also the performance of the same due to earthquake loading. According to their project shear wall and steel panel can be used to improve the behaviour of the storage structures. They concluded that for the RCC silo shear wall can be implemented which may have thickness equal to the wall thickness of silo and for steel silo steel panel or steel plate can be provided instead of shear wall which plays the role of RCC shear wall. By the implementation of shear wall and steel panel, structure can obtain the increased stability.

Dharmendra H. Pambhar and Shraddha R. Vaniya made a comparative study between .net programming and manual design of circular silo. In their project influence of different parameters have discussed and analysed which lead to the conclusion that design of silo using .net was free from difficulty.

Karthiga shenbagam.N et al., designed more number of bunkers by changing the ratio of height to lateral dimensions in order to study the most economical configuration of bunkers to store a given volume of bituminous coal. To find the most economical size of bunker they have taken some constant length by breadth ratio and for each ratio, four numbers of bunkers with different breadth by

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depth ratio have been designed for different volumes. They have developed a program for this analysis using 'C' language which has been used to design the bunkers, columns and footing. Also they have implemented the basic recommendations of IS 4995-1974 and IS 456-2000 codes. Based on their design they have been found out the dimension of bunker which will lead to least amount concrete, steel and total cost. Finally they concluded that as the ratio of height by breadth increases, the total construction cost of the storage structure also increases.

Afsal Ansari et al., concentrated on the study of RCC silos which are mostly used for granular materials storage. In their study they stated that concrete storage units are somewhat economical in design and cost. Also it can offer protection to the stored materials needs little maintenance and free of hazards such as buckling or denting to some extent. For the analysis of most economical configuration of silos for volume of 125m^3 they have been designed twenty eight samples by changing the ratio of height to diameter and finally found out the most economical size. Their designs have been based on the recommendations of IS 4995-1974 (part 1-2) "criteria for design of reinforced concrete bins for the storage of granular and powdery materials" and IS 456-2000 codes. Finally they concluded that by increasing the height by diameter ratio, the total cost of construction will also increase. In detail they concluded that increasing diameter results in high cost & vice versa and increasing height results in reduced cost of construction.

Mueller.A et al., investigated the critical filling level of silos and bunkers with respect to seismic design. For the seismic design they have considered the lowest natural frequency, response spectra, acceleration function, masses and stiffness. They used response spectra method as per Euro code 8 for the design of coal bunkers in which vibration periods are larger which describes the shape of acceleration function that results in smaller acceleration and base shear. They made different assessment of the column's bases which are pinned or clamped, might produce model errors but those errors remain moderate due to diagonal bracing. In the response spectrum when the oscillation period is larger than control period, it is assumed that the seismic load will decrease, since the accelerations decrease. They concluded that the base shear cannot be decreased, if the frequencies of the structure are altered by increased mass, which is due to the reduction of acceleration with increasing period does not balance additional mass.

Adem Dogangun et al., studied, reviewed and discussed the main factors which cause damages to the silos. They have presented the unusual modes of failure due to different unconventional loading and some escalating failures such as loss of the container, contamination of material it contains, environmental damage, replacement cost, possible injury and loss of life that occurred in various regions of the world. They also provided a review of specific silo failures due to explosion and bursting, asymmetrical loads imposed during filling or discharging, large & non uniform pressure under soil, corrosion and deterioration of silos, internal structural collapse and failures from several earthquakes. They made a unique research about silo failures and factors along with failures. They invented the reasons and causes for failures and suggested some remedial measures to prevent from failure. Some of the solutions are, a) To prevent explosion and bursting, monitor the internal pressure and gasses produced by the stored bulk material. b) To prevent the silo from dent, buckling and collapse, the potential asymmetric flow patterns caused by rat holes, flow channels, asymmetric loading patterns created during filling or discharging are to be considered in the design. c) Apart from that, while designing non uniform base pressure resulting from lateral loads, earthquake loads, potential asymmetrical material loads should be considered. d) For empty and light silos, the wind load may be effective and for heavier and tall silos, the horizontal seismic loads may be more critical. e) Finally poor insufficient reinforcement in supports or columns, corrosion of metal silos and deterioration of concrete silos due to silage acids aggravate the damage and lead to failure.

Mohamed T.Abdel Fattah et al., made analysis of elevated concrete silos using finite - element solution. They have considered the filling process of saturated solids. In their analysis axis symmetric finite – element model is used to signify both the solids and structure. An elasto - plastic model is used for modelling of bulk solids and linear elastic model is used for modelling of structure. In their design to demonstrate both undrained and drained conditions, the filling process is idealized via multistage numerical technique. They found out that the effect of filling process is time – dependant and excess pore water pressure caused by filling process might control the magnitude of internal forces. According to their study, number of solutions can be obtained for combination of materials, geometry and loading conditions. They gave one key point regarding drained and undrained condition which is the maximum tension would be in contact with the undrained condition and the maximum compression would be in contact with the drained condition while designing the silo wall or hopper for hoop forces. They also considered the permeability of the filling material since the process is time dependant. The results of their investigation may be helpful for field testing program and evaluation of existing concrete silos.

Sachidanandam.K and Jose Ravindra Raj.B studied the causes for failure of bunkers and silos and illustrated them as, due to design, fabrication & erection error, improper usage and maintenance. They have studied about the powder flow and used that gathering in design of silos and bunkers which can discharge the material free from hang-up. Based on their study and learning from many projects, they listed some practical approach to the upcoming researchers. They are, a) requirement of flow pattern, b) measurement of powder properties, c) Based on the material to be handled and operational requirements, design models should be utilized. Also they evaluated the problems in silage juice level which means fermented green forage fodder stored in a silo, loading problems and measurement techniques for effective design.

Suvarna Dilip Deshmukh and Rathod S.T made a comparative study on the design and seismic behaviour of RCC silo. They have studied about the unusual failure modes and their causes. They have analyzed and designed as per IS 4995, Euro code (EN 1998-4:1999 and EN 1991-4:2006) and ACI code. For the design they have considered static and dynamic pressure exerted by stored materials & seismic loads. Based on their study they have been concluded that while designing silo wall, pressure due to seismic action must be considered. In their analysis they found out that varying reinforcement along depth of wall & more on the middle portion of wall could perform well.

Sivabala.P et al., analyzed the effect of shear wall panels on the dynamic response of a silo. They done a dynamic analysis of a typical silo and during that the effect of extra plates between the columns was evaluated. Their analysis showed significant change in the frequency and mode shape of the structure. Also they proved that the stability of structure increased with the presence of extra plates between supporting columns. Finally they concluded that by providing plates between columns, stability of structure can be increased in earthquake prone areas, stresses in structure can be decreased around 40%, and displacement of structure can be reduced around 25%.

Ramakrishna Vemula and Venkateswara Rao.K dealt with the cross sectional distortion phenomenon of circular cylindrical silo using Finite element model in ANSYS. They carried out a case study using pressure and wind load distribution based on the recommendations of IS codes. Also they carried out a three dimensional numerical simulation in detail on steel and concrete silo structure. For their analysis they have applied large internal loads internally & externally for static, modal, harmonic and buckling conditions. They made the following conclusions from their work. 1) The structure might fail at the centre portion of the legs. 2) Estimated cost of concrete reinforcement silo structure is more than the steel structure. 3) Concrete reinforcement structure might compete with the steel structure in many positive aspects.

Rajani S Togarsi analyzed the seismic response of reinforced concrete silo supported with shear walls and supported on only columns with no change in dimensions. The author modelled the structures using Finite element method package software SAP 2000 for soil type II located in the Zone II and considered the conditions such as empty silo, partially filled and fully filled with storage material. Load combinations were based on the IS 1893:2002 (part-I). The author found out the lateral displacement of reinforced concrete silo for both conditions which was mentioned earlier. Conclusion of the research was increased mass and stiffness lead to the increased lateral displacement and silo with full filled materials caused high lateral displacement when compared to the partially filled silo& empty silo. Also shear wall supported silo undergone less lateral displacement than silo supported on only columns.

Nateghi.F and M.Yakhchalian investigated the seismic behaviour steel silos with different height to diameter ratios with granular material – structure interaction. They have considered the complex dynamic behaviour of silos under seismic load. For the analysis they used Euro code, ABAQUS finite element package and applied hypo plasticity theory to describe stress rate as a function of stress, strain rate and void ratio. Shell elements were used to model silo wall and solid elements were used to model granular material. They have applied Coulomb friction law to model the interaction between wall & material. According to them the seismic behaviour of silos was influenced on the height to diameter ratio of silo.

Hamdy H.A. Abdel Rahim did assessment on the response of cylindrical elevated wheat storage silos to seismic loading. In addition to the other unusual failure modes, he considered the cantilever behaviour of high stacked up silo. In his paper he mentioned the difference between seismic behaviour of elevated silo and silo resting on ground. He used 3D finite solid elements to model a silo wall and bulk solid. For the dynamic analysis of silo, he used incremental iterative finite element technique with SAP2000 software package. For the analysis he made comparison between earthquake load with filling and discharging pressure for seven reinforced concrete silo with different height to diameter ratios. As a result he revealed that the elevated silos have more influence on earthquake which dependant of height to diameter ratio. Also his research concluded that the squat silo (large D and H) might have more resistance to earthquake & more economical.

Ashwini Bindari and K.N.Vishwanath analysed the effect of seismic and wind loads on steel silo structures. They compared the steel silos and concrete counterparts and listed the merits of steel silos such that it has high strength per unit weight and high ductility. Due to the ductile property the steel silo might give sufficient warning before failure by the way of increased deformations. They made analysis on high rise steel building frame with braced and unbraced supports with the help of SAP 2000 software package. For the dynamic analysis under the selected earthquake zone V, equivalent static method and response spectrum method were implemented. Based on their study, they made following conclusions, a) Base shear was more for seismic effect when compared to wind effect. b) Displacement of structure generally found to be reduced by providing braced frame for supporting silo structure. c) Braced system gave economical results compared to unbraced system in terms of frequency and displacement.

Indrajit Chowdhury and Raj Tilak suggested a procedure to incorporate the dynamic pressure due to earthquake in the analysis of circular silos. They carried out this analysis using conventional Jansen's method with some modifications and they did parametric study about dynamic pressure on wall of silo with different structural configuration. They proposed new mathematical model to apply within a design office frame work which did not need an elaborate FEM analysis and could well adapted in a spreadsheet or mathcad shell. They insisted that usual ignorance of vertical component of earthquake in structural design would encourage the lateral dynamic pressure and should not be ignored particularly for the huge capacity silo. Finally they concluded that ignorance of seismic effect would considerably under design the silo wall design procedure.

Dr.Amit Bijon Dutta studied the structural considerations due to load development in silo design. According to the author, loads exerted by bulk materials on silo structures can be divided into two, one due to initial fill and second due to the flow induced loads. He considered various flow types such as initial fill, mass flow-single outlet, funnel flow-single outlet and multiple outlet in his review. Also force resultant factors such as tension, vertical force, bending on circular wall, vertical bending of upper wall, vertical force on flat bottom and forces on ring beam were considered. Based on his review he concluded that if a silo is designed, built/fabricated & erected and properly operated, it will have a durable and safe life. It should be noted and understood that, doing the job properly in the initial place might reduce the possibility of failure and the cost of repair or re fabrication or reconstruction.

Dr.Kameshwari.B et al., studied the dynamic response of high rise structures under the influence of discrete staggered shear walls. Due to the restriction in the architectural design to adopt shear wall, they have introduced the new concept of discrete shear wall panels. They have analysed the various configurations of shear wall panel such as conventional shear wall, alternate arrangement of shear walls, diagonal arrangement of shear walls, zigzag arrangement of shear walls and influence of lift core walls. Out of these five configurations studied they found that zigzag arrangement system might control the response to earthquake loading and also diagonal shear wall configuration would be effective in earthquake prone areas. Apart from this shear walls placed along shorter plan gave better results than that in larger plan dimension.

IV. CONCLUSIONS

From the earlier research studies, it can be revealing that: Concrete storage structures are fairly economical than Steel structures in design and cost. Concrete storage units can compete with steel storage units in many positive aspects. Regarding seismic behaviour squat silo may possess good resistance and silo with suitable shear wall configurations may perform well during earthquakes. While designing silos and bunkers wind load and seismic effect should be considered for safe and durable design.

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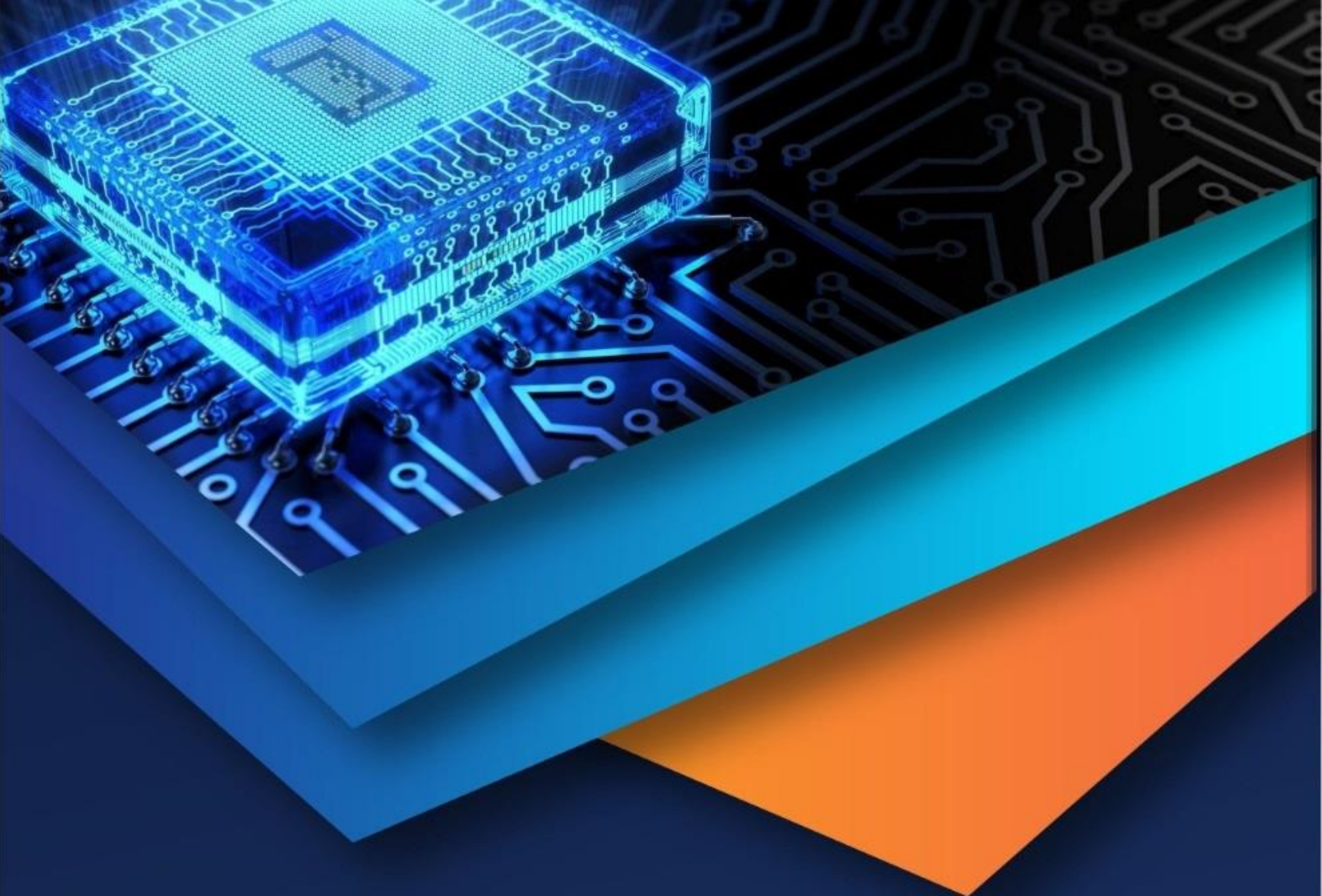

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