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A Review on Parametric Studyof Circular RCC Silo having Hopper Bottom

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Abstract—*Looking to the fast speed of development that is to be taken care of by professional engineers and globalization of professional services to be concentrated, it becomes important to appraise them in the area of design for industrial structures, which has a wide spectrum to be dealt with.Silo is one of the storage structure which is required for industrial plants to store various kinds of materials such as cement, coal, grains, etc. Hence it is necessary to judge regarding the design procedures for such structures, which includes the study of codal provisions leading to analysis and design along with detailing of the same. There are many silo developed in India for storage of cement which may be temporally or permanently. But now a day there are required space and economic design of large size silo.The present study is the step in the direction to give important technical information, illustrating the theoretical background and codal provisions along with detail design procedure with various h/d ratio of silo for same capacity of storage and use of staad-pro software for the analysis and design of various components of circular silo and give economical design of silo.*

Keywords-*h/d ratio, hopper bottom, circular silo, economical design, cement storage*

I. INTRODUCTION

Vessels of different shapes, size and material are needed for the storage of gaseous, liquid and solid products. The designer of storage structures has to deal with non-hazardous aqueous liquids such as water or volatile liquids such as gasoline. Storage of powdery material such as cement and sugar and granular material such as coal and wheat are other facets of the problem. The designer of storage structure must have links with petrochemical, food, agriculture, cement, mineral and pharmaceutical industries to supply the different structures suited to their needs [1].

Structure for the storage of solids is generally referred to by the name Bin. A bin is simply an upright container and the name includes shallow containers known as bunkers and tall structure known as silo [1]. Reinforced concrete bins usually rectangular but tall silos are cylindrical as shown in figure1. Normally 500 to 2000 tones of granular material is stored in a single bin and large quantities of the order of 10000 tones or more are to be stored, the material is divided into two or more bins forming a continuous nest or Battery [2]. In this multi-bin configuration, even the intermediate bin forming the intestinal space and the pocket bin formed at the end are used for the storage. Prestressed concrete silos are also extensively used for the storage of cement, and clinker, alumina, sugar etc. For the storage of powdery material in plastic industry, fiber-reinforced plastic silos are used [2].

Reinforced concrete is an ideal structural material for the building of permanent bulk-storage facilities for dry granular like fillings. Primarily concrete storage units are economical in design and reasonable in cost. Concrete can offer the protection to the stored materials, requires little maintenance, is aesthetically attractive, and is relatively free of certain structural hazards such as buckling or damaging [3].

The bins are always provided with hopper bottoms. The slope of hopper bottoms with horizontal is kept more than angle of friction between the grain stored and concrete so that when bottom door is opened the material starts rolling down on its own weight [4]. The bins are supported on a number of columns spaced at regular intervals. The distance between two adjacent columns and the height of the columns should be sufficient for a truck to pass, so that they can be directly loaded with the material stored when hopper bottom is opened [4].

Silos are special structures subjected to many different unconventional loading conditions, which result in unusual failure modes. Silos are cantilever structures with the material stacked up very high vertically. The walls of different type of silos are subject to earthquake loads from the stored mass, and these may substantially exceed the pressures from filling and discharge [4]. Coulomb's friction low was used for modelling of wall friction. The elevated silos response is highly influenced by the earthquake characteristics and is depending on the height to diameter ratio. Circular silos (both steel and reinforced concrete) are used for the store material in various industries like cement plants (clinkers), power plants (raw coal), oil and gas industry etc [4].

They were used widely in World War I, World War II, and the Cold War for weapons facilities, command and control centres, and storage facilities in the event of nuclear war also. Silo can also be used as protection from tornadoes [5]. Trench bunkers are small concrete structures, partly dug into the ground. Many artillery installations, especially for coastal artillery, have historically been protected by extensive bunker systems. Typical industrial bunkers include mining sites, food storage areas, and dumps for materials, data storage, and sometimes living housings [5].

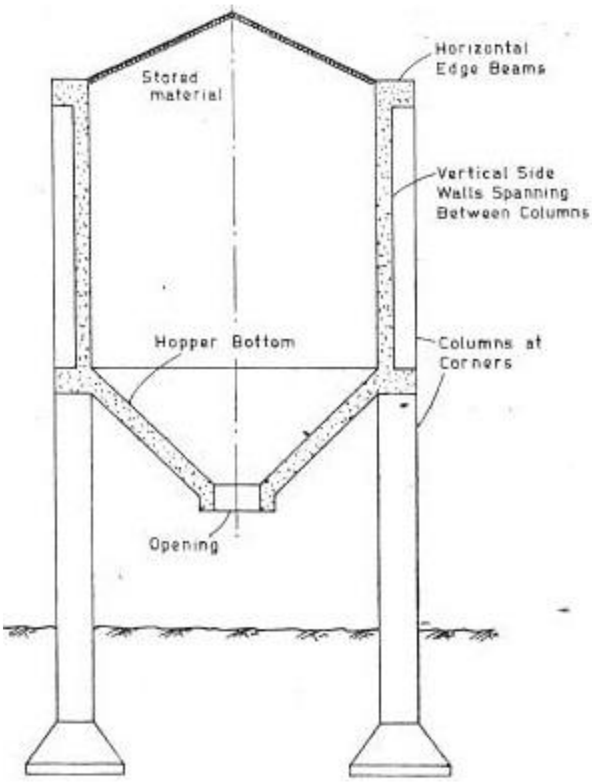

Figure 1. General arrangement of **Silo [9]**

To help ensure safety and better quality silo and bunker structures, India have already adopted codes and standards for silo and bunker design and construction. I.S 4995- 1974: Criteria for design of reinforced concrete bins for the storage of granular and powdery materials.
Part 1. General requirements and assessment of bin loads.
Part 2. Design criteria.

II. LITERATURE REVIEW

2.1 Silo Wall

J. C. Jofriet et. al., total load transmitted to the silo wall was 10-14% greater than the Canadian code for friction coefficient 0.3 using finite element analysis [10].
Sujay deshpande et. al., they represented that thickness of silo wall was increased as the silo capacity also increased. They also provided silo wall thickness for different material stored for 500kN capacity silo [9].

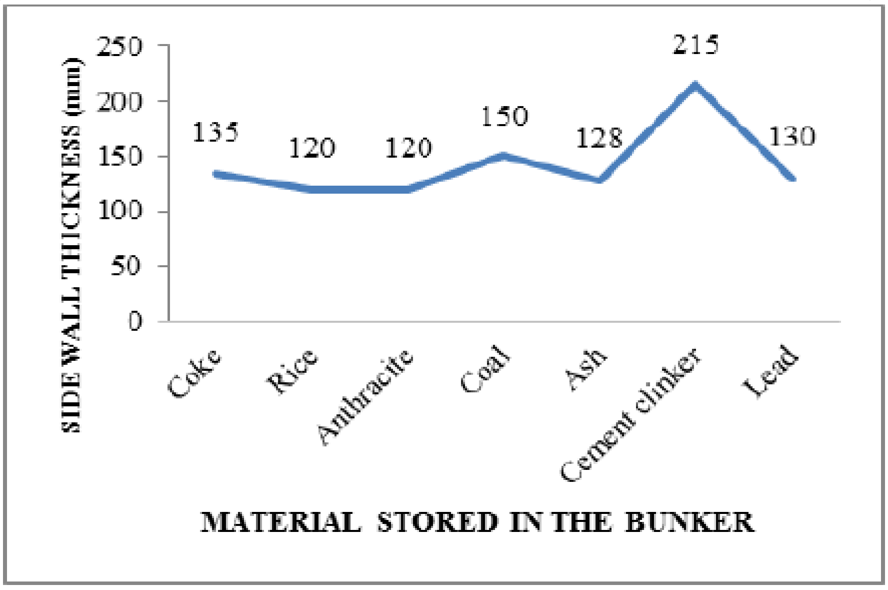

Figure 2. Variation of side wall thickness for different material stored in the **bunker [9]**

Anand Adi et. al., studied that the surface element as shear wall gave more economical result than bracing element for silo wall [8**]. Dharmendra pambhar et. al**., concluded that h/d ratio increased thickness of wall decreased [2].

2.2 H/B Ratio

S. A. Ramesh et. al., for 100 m³ to 200m³ range, most economical h/b ratio was 0.5 for storing bituminous coal. They also presented that h/b ratio increased the total cost of construction of the storage also increased [3].**Sujay Deshpande et. al.,** they gave result that silo capacity increases the plan dimension increases rather than the height of silo. h/b ratio decreases as the capacities of the bunker increases indicating the plan size increases rapidly when compared to height. They also provided graph shown below [9].

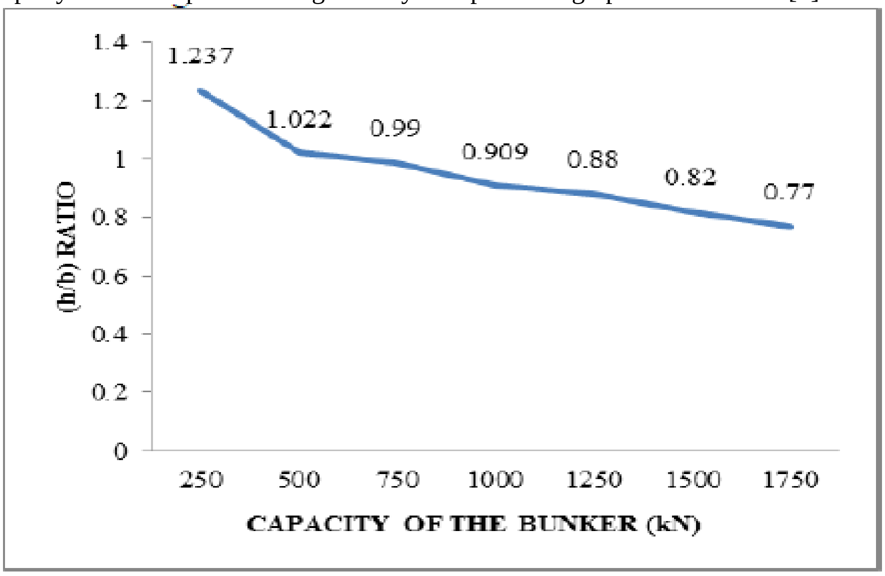

Figure 3.Variation of (h/b) ratio along the bunker capacity **[9]**

2.3 L/B Ratio

N. V. Manjunath et. al., they researched that 100m³ to 200m³ range silos have most economical ratio is 1 [3]. **Pavan gudi et. al.** in optimal plan of the silo for different capacities is square [8].

2.4 H/D Ratio

J. C. Jofriet et. al. studied h/d ratio of silo and the friction coefficient between wall and storing material have significant effect on horizontal wall pressure and on the proportion of vertical load carried by the silo wall [10].**Sachin S. Kulkarni et. al.,** studied for 100m³ volume, h/d ratio is 1.99. Also, h/d ratio increase the total cost increase [4].Chetan S. Deshpande et. al., observed that as h/d ratio varies from 1 to 3, diameter of silo reduces from 5.964 m to 4.602 m for horizontal pressure during filling condition [11].
Dharmendra pambhar et. al., concluded that h/d ratio increased thickness of wall decreased [2].

2.5 Displacement

Sagar Belagaonkar et. al., they presented that earthquake induced displacement which was time varied. Displacement of silo structure with 14 m column height decreases by 18.71% when compared to silo structure with 5 m column height for zone III [7]. Also, displacement of silo structure with 23 m column height increases by 24.82% when compared to silo structure with 14 m height for zone III [7].They concluded that displacement of silo structure with 14 m column height increases by 15.34% when compared to silo structure with 5 m column height for zone IV [7].Displacement of Silo structure with 23 m column height increases by 7.64% when compared to Silo structure with 14 m column height for zone IV [7].
Anand adi et. al., concluded that the displacement of silo with Plate element, Bracing element and Surface element are well within the permissible limits [8]. The displacement increases as zone increases. The displacement of the structure is generally found to be reduced from about 20% on providing surface element for all zones [8].

2.6 Base Shear

Swapnil Kadam et. al., presented base shear of the silo structure increases as the Zone of seismicity increases from zone III to zone V. Base shear of Silo structure with 14 m column height increases by 15.7% when compared to Silo structure with 5 m column height for zone III [7]. Also, base shear of Silo structure with 23 m column height increases by 0.7% when compared to Silo structure with 14 m column height for zone III [7].They presented that base shear of Silo structure with 14 m column height increases by 15.57% when compared to Silo structure with 5 m column height for zone IV [7]. Base shear of Silo structure with 23 m column height increases by 0.66% when compared to Silo structure with 14 m column height for zone IV [7].
Anand Adi et. al., studied base shear with silo with bracing element between supporting columns increased with increasing zone from II to V [8].

2.7 Lateral Pressure

Jasmin Gadhiya et. al., pressure variation directly proportional to the hydraulic mean radius [1]. Also, lateral pressure by ACI approach gives more conservative results [1].
J. C. Jofriet et. al., studied decrease in h/d ratio from 3.5 to 2.4 would provide an increase in horizontal design pressure of about 20%, which is depending on the silo height [10].
Krishna Kharjule et. al., concluded that lateral pressure for powdery material gave maximum pressure in Airy method [5].
Chetan S. Deshpande et. al., used Janssen's theory for calculating lateral pressure on the silo [11].

2.8 Hoop Tension

Dharmendra H. Pambhar et. al., studied that hoop tension in silo increased with height of silo from top [2]. They also provided chart of hoop tension for manual design and software design which is same [2].
Krishna Kharjule et. al., observed that difference in meridonal tension and hoop tension for hopper angle 60^o was 3.6% for cement storage [5].

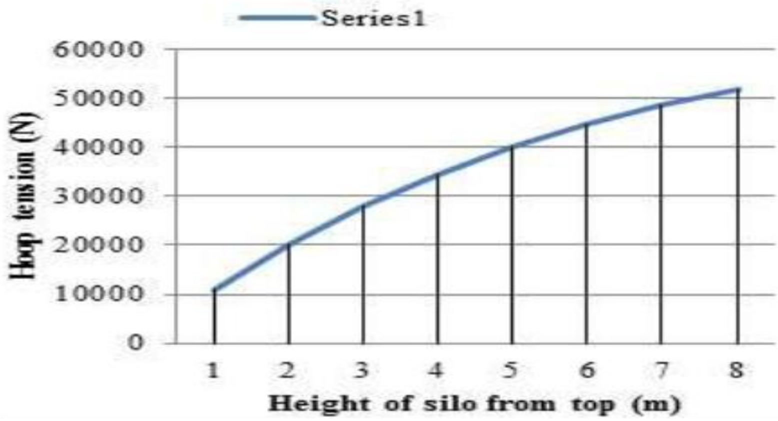

***Figure 4. Hoop tension for manual* design [5]**

2.9 Cost

Sachin S. Kulkarni et. al., found that the ratio of h/d increases the total cost of construction of the silo structure also increases [4]. It is also concluded that, increasing diameter accelerates the high cost and increasing the height of silo, the cost can be reduced [4].
Pavan Gudi et. al., concluded that when comparing conventional method of silo to optimized dimension design, average saving on concrete and steel quantity for 1000kN capacity of the silo are 7.20 % and 13.06% respectively [9].
N. V. Manjunath et. al., studied that h/b ratio increased the total cost of construction of silo storage structure also increased [3].

2.10 Other Parameter

Sagar belgaonkar et. al., concluded that time period of silo structure with 23 m height of column increases by 1.2% when compared with Silo structure 14 m height of column [7].

Anand adi et. al., the frequency of the silo is increased providing surface element which increase accounts for about 15% [8]. Thus providing surface element increases the stability of the structure, especially in earth quake prone areas or under dynamic loading [8].

Dharmendra H. Pambhar et. al., concluded that same result of stress and area of steel has been found during comparison of manual design and .net (VB) programming [2].

Krishna Kharjule et. al. concluded that minimum value of meridional tension takes place at an angle of 60º and the value of hoop tension decreases continuously [5].

III. CONCLUSION

From the above literature we conclude that

1) (h/b) ratio decreases as the capacities of the silo increases indicating the plan sizes increase rapidly when compared to height.
2) The pressure variation directly proportional to the hydraulic mean radius which ultimately dependent on numbers of compartments.
3) When increasing height and diameter ratio of silo decrease thickness of wall.
4) The displacement of Silo with Plate element, Bracing element and Surface element are well within the permissible limits.
5) Lateral pressure for granular material gives maximum pressure during flow condition in Janssenmethod. And Lateral pressure for powdery material gives maximum Pressure in Airy method.

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