PARAMETRIC STUDY OF 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 determined, 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 Circular RCC 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 Circular RCC Silo for same capacity of storage and using staad pro software for the analysis and design of various components of circular silo. After analysis of Circular RCC Silo, various parameters such as Natural Period, Displacement, Base Shear, Cost of structure and Lateral Pressure are compare which give 2.5 H/D ratio for economical design of Circular RCC Silo.

Key Words – Hopper Bottom, H/D Ratio, Economic Design, Natural Period, Base Shear

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. 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 figure1.1. Normally 500 to 2000 tonne of granular material is stored in a single bin and large quantities of the order of 10000 tonne 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. 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. 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 [5].

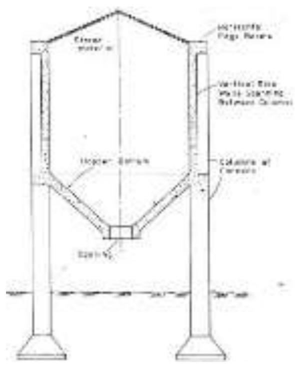


Figure 1General Arrangement of Silo[2]

II. CODES AND STANDARDS

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.

IS 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.

IS 456-2000: Plain and Reinforced Concrete - code of practice.

IS 875 (Part III): Wind Loads on Buildings and Structures - Proposed Drafts & commentary.

IS: 1893-2002: Criteria for Earthquake Resistant Design of Structure.

III. LITERATURE REVIEW

For 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].

For H/B ratio, A. S. Ramesh et. al., for 100 m³ to 200m³ range, most economical h/bratio 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 [9].

For H/D ratio, 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 5.964m to 4.602m for horizontal pressure during filling condition [11].

For Lateral Pressure, Jasmin Gadhiya et. al., pressure variation directly proportional to the hydraulic mean radius. 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].

For Cost, 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].

IV. OBJECTIVE OF THE STUDY

Following are the main objectives of the present study:

a) To understand behaviour of circular RCC silo.
b) To understand the modelling and design procedure of RCC silo using staad pro.
c) To analyse circular RCC silo having different h/d ratio.
d) To compare design parameters like Natural period, Displacement, Base Shear, Lateral Pressure having different h/d ratio.
e) To achieve optimum design of circular RCC silo.

V. STRUCTURAL MODEL

Here, work done analysis and design of different circular RCC silos having hopper bottom. These models are different with respect to h/d ratio. But, storing capacity of these model are same which are 125 m^3volume. Silo is design for storing Portland cement having density 16 KN/m^3.I work done on fourty models with different h/d ratio having different beam & column size of Circular RCC silo. The h/d ratio will be from 1.5 to 2.5. These models have 1.6, 1.7, 1.8, 1.9, 2.0, 2.1, 2.2, 2.3, 2.4, 2.5 h/d ratio. And these model have different beam & column size 230 x 300 mm, 230 x 380 mm, 230 x 450 mm, 230 x 525 mm etc.

Following are other data required for Silo models.

Density of cement = 16 KN/m^3,

Density of RCC (D_c) = 25 KN/m^3,

The ratio of horizontal to vertical pressure intensity (μ’) = 0.7,

Angle of repose (Ø) = 25^0,

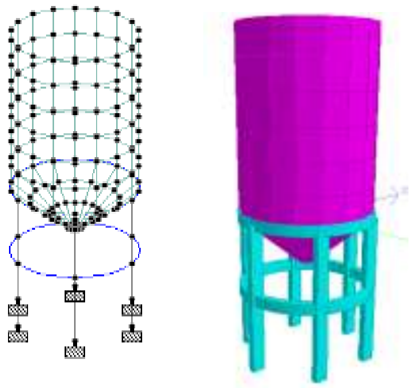
Typical of reinforcement = 500 HYSD bars,

Grade of concrete = M25,

Wall thickness = 150 mm provided.

Table 1 Data for analysis of RCC structure

H/D Ratio	H (m)	D (m)	h (m)	D (m)
1.6	7.2	4.5	1.9	0.5
1.7	7.5	4.4	2.0	0.5
1.8	7.75	4.3	2.3	0.5
1.9	8.1	4.25	1.9	0.5
2.0	8.4	4.2	1.8	0.5
2.1	8.75	4.15	1.45	0.5
2.2	9	4.1	1.4	0.5
2.3	9.35	4.05	1.1	0.5
2.4	9.5	4	1.0	0.5
2.5	9.9	3.95	0.9	0.5



(a) (b)

Figure 2 3D model (a) Grid line (b) Rendering view of 1.6 H/D ratio RCC Silo

VI. Analysis of Models

The structure is analyzed as per the loading combinations provided in IS: 456-2000. The following load combinations are used to determine various parameters of the structure.

1. 1.5 (DL + LL)
2. 1.2 (DL + LL +EQX)
3. 1.2 (DL + LL + EQZ)
4. 1.2 (DL + LL - EQX)
5. 1.2 (DL + LL - EQ Z)
6. 1.2 (DL + LL + WLX)
7. 1.2 (DL + LL + WLZ)
8. 1.2 (DL + LL - WLX)
9. 1.2 (DL + LL - WLZ)

VIII. RESULTS AND DISCUSSION

1 Base Shear

Following data are collected from different H/D ratio model from 1.6 to 2.5 for Base Shear.

Table 2 Base Shear of Circular RCC Silo with different H/D ratio and different section size

Sr. No.	H/D Ratio	Base Shear (V_b) (kN)			
		230 X 300 mm	230X 380 mm	230 X 450 mm	230 X 525 mm
1	1.6	32.28	33.95	35.41	36.98
2	1.7	32.58	34.3	35.7	37.24
3	1.8	32.89	34.52	35.96	37.5
4	1.9	32.895	34.525	35.963	37.582
5	2.0	33.25	34.87	36.29	37.81
6	2.1	32.52	34.08	35.46	36.93
7	2.2	32.19	33.73	35.07	36.51
8	2.3	31.89	33.39	34.7	36.1
9	2.4	31.5	32.95	34.235	36.6
10	2.5	31.42	32.86	34.12	35.47

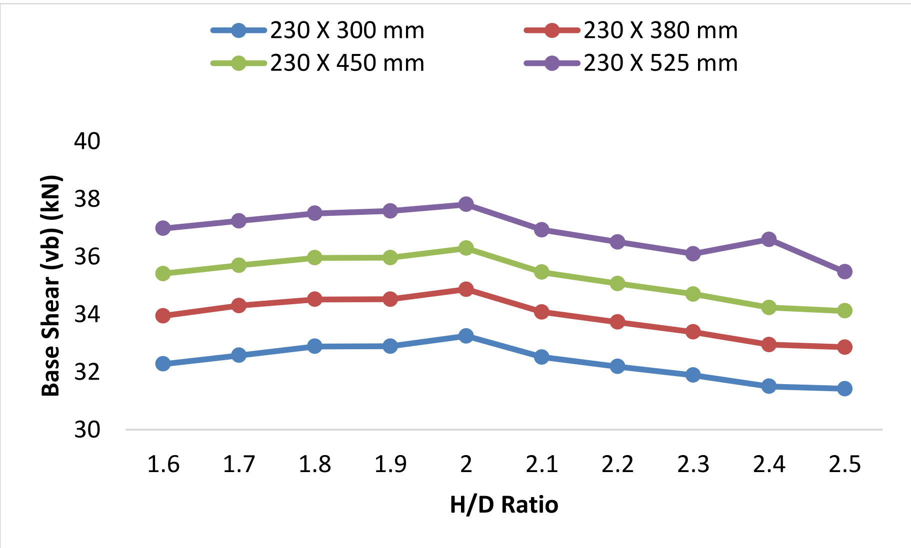


Figure 3 *Base Shear (V_b) Vs H/D Ratio for different size of Beam and Column*

Base Shear increases with increase in H/D ratio from 1.6 to 2.0. Then, Base Shear decreases with increase in H/D ratio from 2.0 to 2.5. As Beam and Column size increases Base Shear also increase. Maximum Base Shear occurred in 2.0 H/D ratio for 230 X 525 mm section size. Section size increases for 2.0 H/D ratio then Base Shear value increase 13.71%. H/D ratio increase from 1.6 to 2.0 for 230 X 300 mm section sizes then Base Shear value increase 3.0%.

2 Time Period

Following data are collected from different H/D ratio model from 1.6 to 2.5 for time period.

Table 3 Time Period of Circular RCC Silo with different H/D ratio

Sr. No.	H/D Ratio	Time Period (sec.)
1	1.6	0.52
2	1.7	0.528
3	1.8	0.53
4	1.9	0.545
5	2.0	0.55
6	2.1	0.56
7	2.2	0.57
8	2.3	0.58
9	2.4	0.59
10	2.5	0.60

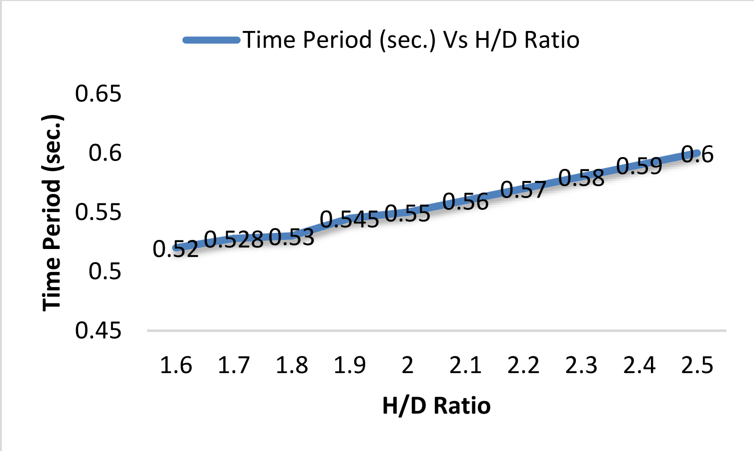


Figure 4 Time Period Vs H/D ratio for Circular RCC Silo

Time Period increases with increase in H/D ratio from 1.6 to 2.5. Maximum Time Period value is 0.6 sec. for 2.5 H/D ratio for 230. Minimum Time Period value is 0.52 sec. for 1.6 H/D ratio. H/D ratio increase from 1.6 to 2.5 then Time Period value increase 15.38 %.

3 Displacement

Following data are collected from different H/D ratio model from 1.6 to 2.5 for displacement.

Table 4 Base Shear of Circular RCCSilo with different H/D ratio and different section size

Sr. No.	H/D Ratio	Displacement (mm)			
		230 X 300 mm	230 X 380 mm	230 X 450 mm	230 X 525 mm
1	1.6	6.179	3.761	2.733	2.099
2	1.7	6.293	3.847	2.805	2.162
3	1.8	6.427	3.949	2.889	2.233
4	1.9	6.443	3.974	2.921	2.268
5	2	6.59	4.084	3.012	2.347
6	2.1	6.548	4.084	3.027	2.37
7	2.2	6.559	4.111	3.059	2.403
8	2.3	6.612	4.17	3.118	2.461
9	2.4	6.624	4.2	3.153	2.497
10	2.5	6.708	4.276	3.223	2.563

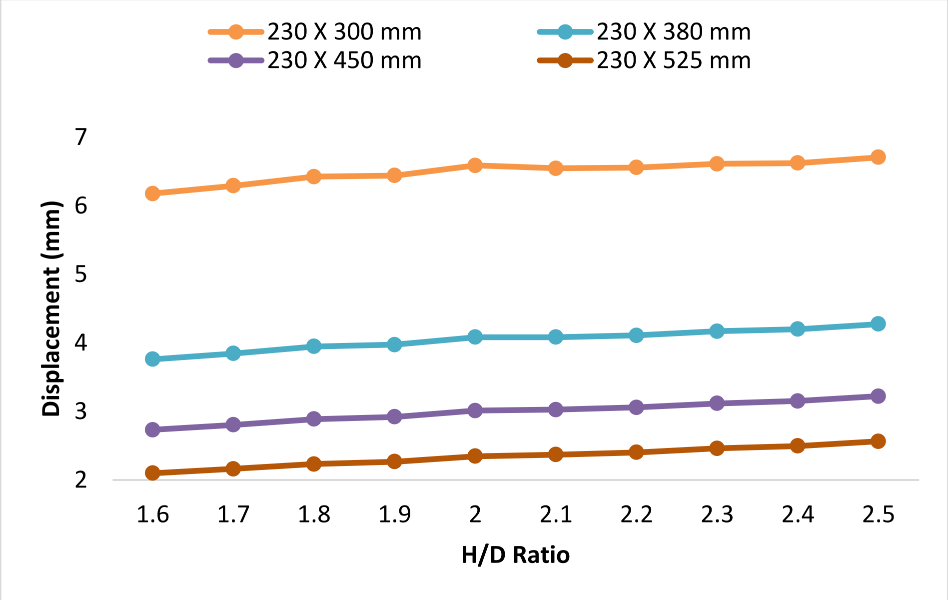


Figure 5 Displacement Vs H/D Ratio for different size of Beam and Column

Displacement increases with increase in H/D ratio from 1.6 to 2.5. As Beam and Column size increases Displacement also decrease. Maximum Displacement occurred at 2.5 H/D ratio for 230 X 300 section size. Maximum Displacement value is 6.708 mm for 2.5 H/D ratio for 230 X 300 mm section size. Minimum Displacement value is 2.099 mm for 1.6 H/D ratio for 230 X 525mm section size.

4 Lateral Pressure

Following data are collected from different H/D ratio model from 1.6 to 2.5 for Lateral Pressure.

Table 5 Lateral Pressure of Circular RCC Silo with different H/D ratio and different section size

Sr. No.	H/D Ratio	Lateral Pressure (N/mm^2)			
		230 X 300 mm	230 X 380 mm	230 X 450 mm	230 X 525 mm
1	1.6	0.535	0.534	0.533	0.532
2	1.7	0.516	0.515	0.514	0.513
3	1.8	0.495	0.494	0.492	0.491
4	1.9	0.475	0.475	0.475	0.475
5	2.0	0.477	0.477	0.477	0.477
6	2.1	0.476	0.476	0.476	0.476
7	2.2	0.477	0.477	0.477	0.477
8	2.3	0.496	0.494	0.491	0.489
9	2.4	0.498	0.495	0.492	0.489
10	2.5	0.469	0.469	0.469	0.469

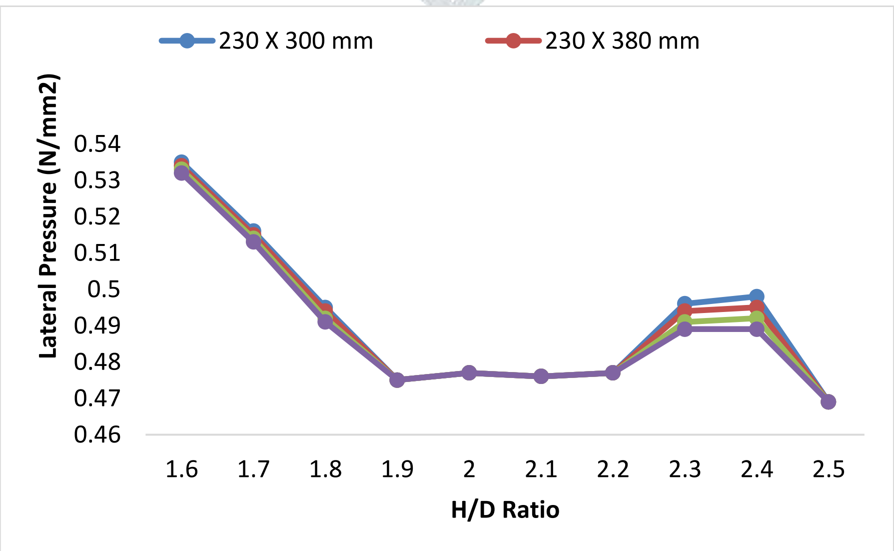


Figure 6 Lateral Pressure Vs H/D Ratio for different size of Beam and Column

Lateral Pressure decreases with increase in H/D ratio from 1.6 to 1.9. Then increase with H/D ratio from 1.9 to 2.4 after 2.4 to 2.5 decreases. As Beam and Column size increases Lateral Pressure also decrease. Maximum Lateral Pressure occurred at 1.6 H/D ratio for 230 X 300 mm section size. H/D ratio increase from 1.6 to 2.5 for 230 X 300 mm, 230 X 380 mm, 230 X 450 mm and 230 X 525 mm section sizes then Lateral Pressure value decrease 14.07 %, 13.85 %, 13.63 % and 13.43 %. Which are decreases continuously.

5 Cost of Structure

Following data are collected from different H/D ratio model from 1.6 to 2.5 for Cost of structure.

Table 6 Cost of Circular RCC Silo with different H/D ratio and different section size

Sr. No.	H/D Ratio	Cost of structure (Rs.)			
		230 X 300 mm	230 X 380 mm	230 X 450 mm	230 X 525 mm
1	1.6	41857	48519	57955	67782
2	1.7	41329	47991	57226	67058
3	1.8	40627	47285	56507	66321
4	1.9	41173	47813	56393	66656
5	2.0	41081	47703	56278	66042
6	2.1	40962	46798	55664	66385
7	2.2	40865	46996	55550	66266
8	2.3	40264	46891	55436	65652
9	2.4	40300	46290	54826	65534
10	2.5	40212	46202	54729	64955

Cost of structure decreases with increase in H/D ratio from 1.6 to 2.5. As Beam and Column size increases Cost of structure also decrease. Maximum Cost occurred at 1.6 H/D ratio for 230 X 525 mm section size.

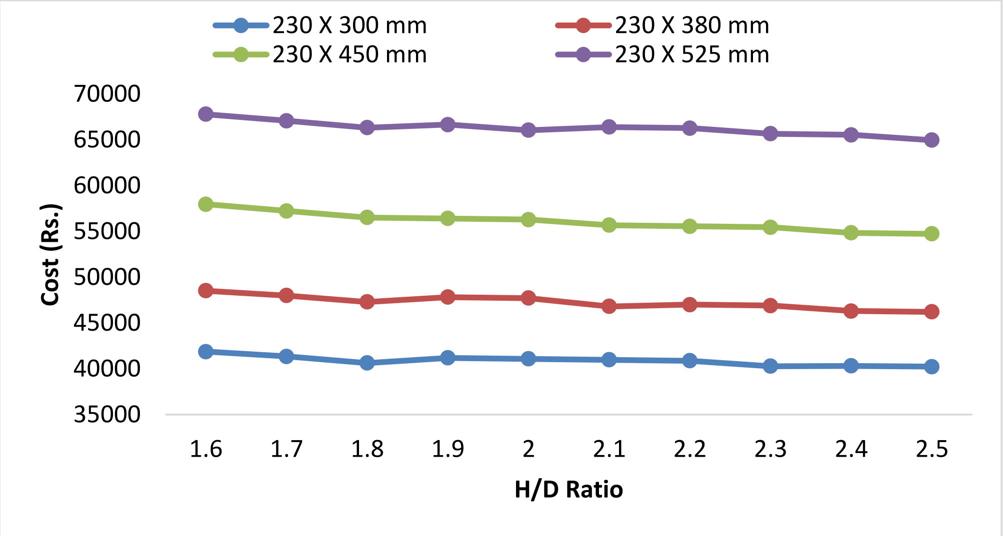


Figure 7 Cost of structure Vs H/D Ratio for different size of Beam and Column

IX. Conclusion

Base shear increases from 1.6 to 2.0 H/D ratio. After, Base shear decreases continuously with 2.0 to 2.5 H/D ratio. Beam and Column size increases Base Shear also increases for same H/D ratio. Minimum Base Shear is at 2.5 H/D ratio.

Time period of silo increases with H/D ratio of silo increases from 1.6 to 2.5. Time Period increases flexibility of structure also increases.

If H/D ratio of silo increases from 1.6 to 2.5, displacement of silo increases. Beam and Column size increases Displacement also decrease for same H/D ratio.

As H/D ratio of silo increases from 1.6 to 1.9, lateral pressure of silo wall decreases. Then increase with H/D ratio from 1.9 to 2.4 after 2.4 to 2.5 decreases. Beam and Column size increases Lateral Pressure also decrease.

If H/D ratio of silo increases from 1.6 to 2.5, Cost of silo decreases. As Beam and Column size increases Cost of structure also decrease. Minimum cost of structure is at 2.5 H/D ratio. Economical design of Circular RCC Silo H/D ratio is 2.5.

X. References

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