

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 3, March 2016

Behaviour of Silos and Bunkers

K.Sachidanandam¹, B.Jose Ravindra Raj²

P.G. Student, Department of Civil Engineering, Prist University, Thanjavur, Tamilnadu, India¹

Assistant Professor, Department of Civil Engineering, Prist University, Thanjavur, Tamilnadu, India²

ABSTRACT: It is now four and a half decades and resulted from all and introduced the first integrated method for characterizing powders for flow, and using this information to design a silos and bunkers that would discharge without hang-up. Sadly, many users and designers of silos and bunkers still do not benefit from this, so a lot of process vessels in industry still suffer from rat-holing, arching and bridging. Objections of cost, time and questionable accuracy were levelled at the original hopper design method, in spite of the breakthrough it represented. However, over the last 40 years these problems have been overcome with the introduction of faster, easier to use and more sensitive powder flow ability measurement techniques, and a lot of experience of what measurements matter with which materials and in what operational scenarios. Silo and bunker failure can occur due to many reasons, following these: 1) Due to design, 2) Fabrication and erection error, 3) Improper usage, 4) Improper maintenance. Now this design project will pull together various lessons learned from many years of silos and bunkers design projects, and show a practical approach to deciding a) Flow pattern is required (mass flow or core flow), b) Measurements need to be made of the powder properties, c) Design models should be used, based on the material being handled and the operational requirements of any given case.

KEYWORDS: bunkers, silos, storage structure

I. INTRODUCTION

A silo is a structure for storing bulk materials. In a silo the vertical are considerably taller than the lateral dimension resulting in a tall structure. Silos are used in agriculture to store grain or fermented feed known as silage. Silos are more commonly used for bulk storage of grain, coal, cement, carbon black, woodchips, food products and sawdust. A bunker is a defensive military fortification designed to protect people or valued materials from falling bombs or other attacks. Bunkers are mostly underground, compared to blockhouses which are mostly above ground. They were used extensively 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. Bunkers can also be used as protection from tornadoes. 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 quarters. When a house is purpose-built with a bunker, the normal location is a reinforced below-ground bathroom with fiber-reinforced plastic shells. Bunkers deflect the blast wave from nearby explosions to prevent ear and internal injuries to people sheltering in the bunker. Nuclear bunkers must also cope with the under pressure that lasts for several seconds after the shock wave passes, and block radiation. A bunker's door must be at least as strong as the walls. In bunkers inhabited for prolonged periods, large amounts of ventilation or air conditioning must be provided.



Figure-1: silo image



Figure-2: bunker image

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 3, March 2016

The main part of the silo and bunker are body, hopper is the actual storage area. Hopper is a funnel structure which facilitate unloading the unloading the materials from structure. The roof plate can be float in structure it is a transportation device. When there is top plate is conical the area must be in snow fall. Roofs generally contain mechanism for material inlet and sensor which measure material flow ratio in the structure. It also has stiffening beam welded to give structural stability. The geometry to a design structure we can take the optimizer to a select the standard parts.

II. DESIGN STUDIES

The design of silos and bins to store bulk solids involves bulk materials, geometric and structural consideration. Bulk materials consideration is important because frictional and cohesive properties of bulk solids vary from one solids to another, and these properties affect materials behaviours. In addition, a given bulk solids, flow properties can vary dramatically with changes in numerous parameters, particle size, temperature, total pressure. The most structure are very thin shells, with a radius which may typically 300 and 3000 times the thickness of wall ($300 < R/t < 3000$). Because they are thin with respect to dimension of the silos, they can be analysed as shells in order to withstand stresses from various load which the structure will experiences during its working life. It can be stiffened by plate and stiffeners. The silos and bunkers are designed according to the Euro codes (Eurocode 3, part 4-1, BS EN 1993-4-1). They have specified many loading condition like wind, earthquake, pressure, pressure, snow loads.

The Euro code also guides in many others aspect of design, construction and installation. It is also worth mentioning that the only other code available is the Japanese code (JIS 1987) which can helps in the design of a silos and bunkers structure. The problem – unreliable or irregular flow unlike liquids, powders support shear stress when at rest. Many subjected to pressure, they can retain increased strength. This is easily illustrated by picking up a handful of the powders and bulk solids also have a property known as “cohesion” which means that after they have been material and squeezing it, if it is not “free flowing” it remains in a ball when you open your hand. Such powders can form an “arch” or “rat-hole” inside a vessel, preventing discharge and requiring the action of hammering, vibration, aeration or other methods to promote flow. Examples of the effect of this problem are shown below. As a result, many hoppers on plants of all sizes and in all industries suffer from damage from hammering, popularly known as “hammer rash”. The flow interruptions give rise to production difficulties, and the hammering itself requires operators to divert from their other tasks; it commonly leads to safety issues with noise, hand injuries and back strain.

Load and materials of properties makes testing at actual conditions more important for proper silo and bins design than may at first appear. Considering the geometric design of a silo potential problem include arching across an outlet, rat holing through materials, and the flow pattern during the discharge. The three major aspects of silos design like involve bulk materials, geometric and structural. The design concept in silo for force resultant are like Tension, Vertical force in upper section, Bending in flat wall, Horizontal bending of a circular wall, Vertical bending of a upper wall, Vertical forces on a flat bottom, forces at ring beam. Other consideration are feeder design, Thermal loading. Causes of silos are design, constructions, silos usages maintenance. Silos operational loads can be classified are Initial flow Fills, Out flow loads. Out flow can be also separated by mean of Single out let and Multiple out let.

The present design guidelines were developed for bunker silos of up to 3 m height. With increasing wall height they are no longer applicable, but they are still used in the absence of other relevant design guide lines. These guidelines specify a load from the silage itself, but also a pressure from silage juice corresponding to a water column level of 1.5m below the maximum silage filling level. This silage juice level is based on measurements is to be carried out during filling of a silo with a wall height of 2 m. The effect of this extra load is less important with lower wall height, but at 4 m or more the over-dimensioning can be considerable since practical experience has shown that the extra pressure from silage juice appears to be overestimated. The outflow of silage juice does not appear to be of the order assumed since un wilted silage is no longer harvested in Sweden. According to JBR (1995) the equations are Horizontal pressure, q_{hk} on the silo wall (variable load with $j = 1.0$). $q_{hk} = 7.5 \cdot z \cdot \rho \cdot \gamma_{s,j}$ for $0 < z < z_0$ and $q_{hk} = 7.5 \cdot z_0 \cdot \rho \cdot \gamma_{s,j}$ for $z > z_0$ where z is the distance from compacted surface top edge (TE) to the level where the pressure is to be calculated, and z_0 is the distance from compacted surface TE to the maximum silage juice level. The normal silage juice level is regarded as being 1.5 m below (TE) for silos drainage system.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 3, March 2016

III. MATERIALS AND METHODS AND MEASURING SYSTEM

The measuring system consisted of two ladder racks, each with four pressure sensors. These were placed vertically along the internal face of the silo wall from the bottom to the top. The load sensors were less than 1 mm thick and were mounted on the rack at a spacing of 1.0 m, with the first sensor at 0.05 m from the silo bottom. The sensors were individually connected to an amplifier and a computer-based measuring program from which the data were imported to Microsoft Excel. The system recording rate was 0.1 Hz and the pressure range was 0e34 kPa.

IV. DESIGN PROCEDURE AND RESULTS

The factors are given for Silo and bunker sizing management is Drainage, Ground water, Feeding, site preparation, Bunker width, Height, length. To calculate the size of silo first determines the amount of dry matter. The dry matter will be feed each day from the structure. Originally the amount of dry matter fed will depend on the particular ration for each group of cattle. The amount of silo needed per day and volume of silage needed per day can be estimated knowing the silage density use the following formula. Dry matter density based on wet bulk density and moisture content. The tabulated format is also given for design purpose. Total dry matter per day = Drymatter X Number of Head.

Volume = Total dry matter per day/ Dry matter density

Table-1: Dry matter density based on wet bulk density and moisture content					
Wet Bulk Density	Moisture content %				
	55	60	65	70	75
Lp/ ft³	Lp/ ft³				
20	9.0	8.0	7.0	6.0	5.0
25	11.3	10.0	8.8	7.5	6.3
30	13.5	12.0	10.5	9.0	7.5
35	15.8	14.0	12.3	10.5	8.8
40	18.0	16.0	14.0	12.0	10.0
45	20.3	18.0	15.8	13.5	11.3
50	22.5	20.0	17.5	15.0	12.5

Considering limiting bunker length to about 120 feet, because very long silos require excessive driving to remove feed when the bunker silo is less than half full. Each silo could be sized to store each separate cutting. A multiple silo arrangement allows more flexibility to store other forages and different forage qualities.

Approximate silo and bunker capacities: Silos managements begin at harvest. For best results chop corn and sorghum silage 0.25 inches and hay silage at 3/8 inches theoretical length of cut. The moisture content should be between 55 and 70 percentages. High moisture contents give better packing and preservation. Several methods of distributing the forage in the silo are possible. A self-unloading wagon can be drawn through the silos its load along the way. The most common method is to dump the forage at the face of the pile and push it up with front end loader.

Capacity of silos: With reference to the normal practice width, height, length and volume based the quantity is tabulated for reference. In silo the condition and assumption are made for also given for design and storage purpose. (a) Vertical side walls, (b) Entire volume cannot be filled and front surface is at a 45 degree slope, (c) Silo dry matter densities are 12.5 to 16.00 for above materials.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 3, March 2016

Table-2: capacity of silos

Width	Height	Length	Volume Ft ³	Silage capacity (Ton)	
				Alfalfa	Corn
20	8	40	5760	37	46
	12	80	17760	115	142
	16	120	35840	233	287
30	8	40	8640	56	69
	12	80	26640	173	213
	16	120	53760	349	430
40	8	40	11520	75	92
	12	80	35520	231	284
	16	120	71680	466	573
50	8	40	14400	94	115
	12	80	44400	289	355
	16	120	89600	582	717

Table-3: Vertical pressure on silo wall

H/D	Ph or Pv (N)	Pw (N)	Stored material (N)	%Weight carried by the wall
1.0	170818	123419	294237	41.95
1.2	163544	146189	309733	47.20
1.4	158227	169771	327998	51.76
1.6	154682	194802	349484	55.74
1.8	151944	220762	372706	59.23
2.0	149698	247344	397042	62.30
2.2	152552	280017	432569	64.73
2.4	147102	304086	451188	67.40
2.6	146188	333560	479748	69.53
2.8	145440	363756	509196	71.44
3.0	144947	394714	539661	73.14

Table-4: Weight of stored material, self-weight taking by the silo wall for different H/D ratio

H/D	Pw (N)	Self-weight of the silo (N)	Compressive Stress (N/mm ²)
1.0	123419	24989	0.528
1.2	146189	27489	0.645
1.4	169771	30071	0.766
1.6	194802	32803	0.893
1.8	220762	35619	1.024
2.0	247344	38484	1.158
2.2	280017	41527	1.298
2.4	304086	44539	1.438
2.6	333560	47656	1.582
2.8	363756	50834	1.729
3.0	394714	54073	1.878

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 3, March 2016

V. DISCUSSION

There is growing interest among farmers in increasing their local production of animal feed since this can reduce transport and therefore the climate carbon footprint. A large amount of the roughage used by more livestock is silage based on grass and maize, which is stored in bunker and silos. A typical bunker and silo consists of a concrete slab and in-situ or precast concrete or wood wall panels. In the past bunker wall height is typically 2 and 3 m, but in recent years bunker silos with wall heights of 4 m or higher have become more common. Investment in bunker silos has doubled in during the last 10 years. The structural design of silo walls is based on the horizontal loads exerted by the silage during silo filling and storage. The hydrostatic load from the silage juice also has to be considered. The magnitude of this latter load is entirely dependent on the level to which the silage juice rises in the silo. In the design guidelines, the silo wall pressure exerted by the silage juice is taken to be the corresponding pressure arising from having a similar amount of water in the silo. Unlike liquids, powders support shear stress when at rest.

Many powders and bulk solids also have a property known as “cohesion” which means that after they have been subjected to pressure, they can retain increased strength. This is easily illustrated by picking up a handful of the material and squeezing it, if it is not “free flowing” it remains in a ball when you open your hand. Such powders can form an “arch” or “rat-hole” inside a vessel, preventing discharge and requiring the action of hammering, vibration, aeration or other methods to promote flow. Moist powdered talc consolidated in a badly designed feed hopper. The operator cleared this by Roding with a broom handle, and when this jammed in the screw it was ejected past him. As a result, many hoppers on plants of all sizes and in all industries suffer from damage from hammering, popularly known as “hammer rash”. The flow interruptions give rise to production difficulties, and the hammering itself requires operators to divert from their other tasks; it commonly leads to safety issues with noise, hand injuries and back strain.

There are various advantages and disadvantages of each flow pattern, again well described in standard texts. The rational method for hopper design is based on a model of stress distribution in the hopper, informed by measurements of the flow properties of the material being handled, that predicts the flow pattern that will occur and whether or not flow will be reliable. The key point to understand is that if you wish to use the method, you need to get a sample of the powder(s) that will go through the plant, and undertake some measurements of the flow properties. It recognizes that every different powder is unique in its flow properties, which is a fundamental trait of bulk solids. Finally of the study was to provide data to designing bunker and silo walls suitable, silage, at an economical. Specific objectives were to determine silage physical properties of importance for the horizontal wall pressure and evaluate the maximum silage juice level in silos with a wall height of 3 m or more.

VI. CONCLUSION

Based on detailed literature review in the area, following conclusions are drawn. (1) This study on silo and bunker wall design evaluated maximum silage juice levels, while the existing guidelines presumably overestimate the forces arising from silage juice for silos with wall height greater than 3 m. (2) The silage and Bunkers juice levels were measured by reading the level on measuring sticks in slotted 16-mm pipes placed vertically along the internal silo walls (Screw conveyor), or in one of the legs of a vertical ladder rack. (3) Measurements in wilted grass and maize were carried out in 24 silos and Bunkers during two seasons, while pressure profiles were measured during 10 cuts of wilted grass and maize harvests in one season, with approximately 400 pressure profiles per cut. (4) The pressure profile was measured by transducers mounted on the vertical ladder rack, which sent recordings to a data acquisition system displaying static load (pressures imposed by silage and Bunker material when the compaction machine was not present) and total load. (5) The difference between static load and total load was taken as the dynamic load. The static silo and Bunker wall (4 m) pressure was 16 kPa during filling and compaction and 22 kPa at the silo bottom 1e4 months after filling. (6) The hydrostatic pressures occurring when the silage became saturated with silage juice did not act as free water and the silage juice only had an effect after filling and did not interact with compaction. The dynamic load was approximately 17 kPa when the vehicle passed 0.1 m from the silo wall. (7) The horizontal load acting on the silo and bunker and bunker wall was greatest 0.5e1 m under the silage surface with compaction machine tyre width 0.5 m and machine weight 11.2e14.5 t.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 3, March 2016

REFERENCES

- [1] SIS. (2012). Ekonomibyggnader och Tillämpningar till Boverket och Jordbruksverkets regler avseende utformning av ekonomibyggnader för jordbruk, skogsbruk och trädgårdens närings- och samhällelig verksamhet [Farm building design based on codes from The Swedish National Board of Housing, Building and Planning and The Swedish Board of Agriculture]. SIS-TS 37:2012. Stockholm: Swedish Standards Institute Publishers AB.
- [2] Boverket. (2011). Boverkets föreskrifter och allmänna råd om tillämpning av europeiska konstruktionsstandarder (Eurokoder) [Boverket mandatory provisions and general recommendations on the application of European design standards (Eurocodes)]. Boverkets Föreskriftningssamling.
- [3] Eurocode. (2010). Eurocode 0 - Basis of structural design. EN1990:2002/A1:2005/AC:2010. Brussels: European Committee for Standardization.
- [4] BFS 2011:10, EKS 8. The Swedish National Board of Housing, Building and Planning. BSI. (1993). BS 5502 e 22: Buildings and structures for agriculture. Code of practice for design, construction and loading. London, UK: British Standard Institute.
- [5] Schemel, H., Furrer, C., & Hoffmann, T. (2010). Compression of chopped grass maize and grass in a bunker silo with vibrating rollers. In AgEng Clermont-Ferrand, France, September 6-8, 2010. ref 015.
- [6] ASABE. (2008). Design loads for bunker (horizontal) silos. ASAE EP538.2 OCT2008.
- [7] Gruyaert, E., De Belie, N., Matthys, S., Van Nuffel, A., & Sonck, B. (2007). Pressures and deformations of bunker silo walls. Biosystems Engineering, 97, 61-74.
- [8] Minitab. (2007). Minitab release 15 for Windows. State College, PA, USA: Minitab Inc.
- [9] R.J. Berry & M.S.A. Bradley (2006), Comparisons Between Observed Powder Behaviour In Industrial Feeders And Measured Powder Failure Properties Obtained Using A Short Cut Silo Design Procedure, 5th International Conference for Conveying and Handling of Particulate Solids (CHoPS-05 2006), Hilton Hotel, Sorrento, Italy, Aug 27-31.
- [10] Berry (2003), The Measurement of Cohesive Arches in Silos Using the Technique of Laser Ranging
- [11] Savoie, P., Amyot, A., & Thriault, R. (2002). Effect of moisture content, chopping, and processing on silage effluent. Transactions of the ASAE, 45(4), 907-914
- [12] ACI 549R - 97, State-of-the-Art Report on Ferrocement.
- [13] SJV. (1995). Jordbruksverkets Byggråd (JBR) (Swedish board of agriculture, building advice (JBR)). Jönköping.
- [14] O'Donnell, C. (1993). A study of the effects of silage effluent on concrete. Master of English Science Thesis. National University of Ireland.
- [15] Martens, P. (1993). Die Neufassung der DIN 11622 e Gefütterter Silos und Güterbehälter. In Proceedings of the Symposium Concrete for a Sustainable Agriculture. BIBM, Cembureau, ERMCO, CIGR. Bologna, Italy 21-23 April 1993.
- [16] Negi, S. C., & Jofriet, J. C. (November 1986). Computer-aided prediction of silo-wall pressures. ASAE. Applied Engineering in Agriculture, 2(2). St. Joseph, Michigan.
- [17] Kangro, A. (1986). Load measurements in bunker silos for silage. Report 48. Lund: Swedish University of Agricultural Sciences, department of Agricultural Buildings.
- [18] G.G. Enstad (1985) The ultimate critical outlet width for flow in mass flow hoppers: Theoretical and experimental studies, International Journal of Bulk Solids Storage In Silos, Vol. 1, No. 4, pp. 9-18
- [19] LBS. (1983). LALT-publikation 2 e Byggnadskonstruktioner [LALT publication 2 e Building constructions]. Jönköping: Swedish Board of Agriculture.
- [20] Nilsson, L. (1982). Last i ensilagesilos e genomgången av litteratur och normer [The loads in horizontal silos e a literature review of silo design codes]. Report 23. Lund: Swedish University of Agricultural Sciences, Department of Agricultural Buildings.
- [21] Messer, H. J. M., & Hawkins, J. C. (1977). The loads exerted by grass silage on bunker silo walls. Journal of Agricultural Engineering Research, 22(4), 327-339.
- [22] Bastiman, B. (1976). Factors affecting silage effluent production. Experimental Husbandry, 31, 40-46
- [23] Ferrocement Model Code - building code recommendations for Ferrocement.
- [24] I.S. 4995 (I) - 1974, "Criteria for Design of Reinforced Concrete Bins for the Storage of Granular & Powdery Materials, General Requirements and Assessment of Bin Loads"
- [25] I.S. 4995 (II) - 1974, "Criteria for Design of Reinforced Concrete Bins for the Storage of Granular & Powdery Materials, Design Criteria".