IOP Conference Series: Materials Science and Engineering

PAPER • OPEN ACCESS

The Cause Analysis of Collapse of a Granary

IOP Conf. Series: Materials Science and Engineering 473 (2019) 012053 doi:10.1088/1757-899X/473/1/012053

The Cause Analysis of Collapse of a Granary

Guoliang Zhu[1]

[1]GuiZhou Construction Science Research & Design Institute Co., Ltd, GuiZhou, China

zhuguoliang2371@sina.com

Abstract. The direct cause of the collapse of granary is irregular design, old breakage, lack of routine maintenance, and improper operation in the process of staff operation. The indirect reason for the collapse of granary is the customary operation of staff. If the grain height exceeds the grain line, it goes beyond the capacity allowed by the warehouse design, overloading the grain, and its side pressure exceeds the strength that the wall can bear, resulting in cracks and even collapse in the wall of the bungalow, which eventually leads to the occurrence of a buried accident. A granary was built in the 80s of last century, and it collapsed in the process of stacking grain. This paper analyzes the causes of collapse from the aspect of stress, according to the exploration situation, the actual calculation model is determined and the force calculation is carried out. The calculation parameters should be collected in force analysis, including: section size, strength, load and structural layout.

1. Introduction

The direct cause of the collapse of granary is irregular design, old breakage, lack of routine maintenance, and improper operation in the process of staff operation. Many accidents in the warehouse are caused by improper grain removal methods and the workers are buried by grain. Most of the hidden warehouses are hidden in the construction. Most of the warehousing enterprises where the grain is buried in the warehouse are mostly due to the use of the grain plate instead of the fixed type of grain retaining door, the grain plate needs to be manually disassembled, and the design of the grain retaining plate is unreasonable and there is no fixed safety rope (belt) on the top of the warehouse. The safety device is obviously insufficient. It promotes the occurrence of the accident; if the grain height exceeds the grain line, it exceeds the capacity allowed by the warehouse design, overloading the grain, and its side pressure exceeds the strength that the wall can bear, resulting in cracks and even collapse in the wall of the bungalow, which eventually leads to the occurrence of a buried accident, and the hidden danger of the silo, grain. In the process of feeding out the storehouse, once the cone hopper is not fixed well, the collapse of the steel plate or the falling of the cone can lead to the collapse and burial of the grain pile, and the hidden danger of the shallow round barn. In the process of grain production, an inverted conical funnel will be formed on the surface of the grain pile, and the "active funnel" on the surface of the grain pile can drag into any object in the grain pile and cause a major safety hazard to the production operators.

The indirect reason for the collapse of granary is the customary operation of staff. In recent years, accidents have found that most of the casualties are foreign workers, and most of them are outsourced workers, foreign construction workers and foreign grain sales personnel. Because of the relatively tired work of the grain depot, the outsourced personnel engaged in work are generally older and less educated, and the safety production training organized by the safety production supervision and management department is difficult to accept for them. The accidents are difficult to avoid when the foreign workers who are almost safely producing "zero training" do their homework. At the same time, many warehousing enterprises often do not operate according to rules and regulations, such as unguardianship on the job site, dismantling the food and other operations without safety rope (belt) and so on, which will cause the occurrence of accidents of grain pile buries.

The granary building was built in the 80s of last century. Its structural form is single brick wood structure, and its walls are fired brick walls. There are no structural measures such as gird. The triangular wooden frame, the purling of the gables, is directly shelved on the mountain wall by hard mountain purling. The thickness of the wall below the grain line is 370mm, and the thickness of the wall above the grain line is 240mm. The collapse of the barn is located at the end of the building, mainly for gables and roof spanning. The collapse of the gable is 12.63m and there are no girds in the middle. There are only three wooden columns with diameters of 180 to 200mm.

2. Analysis of force mechanism

The wall is the important bearing and maintenance component of the barn of the flat house, bearing the load of wind load and grain side pressure in the grain height range. The traditional cottage granary buildings are mostly built with brick concrete structure. Due to the special advantages of the grain storage function of the granary building and the unique advantages of the clay brick in moisture proof, moisture absorption and heat preservation. The granary is mostly fired clay brick, and its construction depends largely on the height of the pile. When the height of stacked grain is high, the cross section of the wall is thicker, and the vertical load of the upper structure is transferred to the foundation. The lateral pressure of grain is transferred to the silo wall by masonry, coupling beams, structural columns and foundation. In the vertical direction, the friction force is generated when the structure is self weight and the grain is transported, so the wall is a compression bending member. Because the grain friction is small and beneficial to the force of the silo wall, it can be calculated according to the bending member.

The middle of the caving wall of the collapsed granary is not set in the middle of the wall, and only three logs with a diameter of 180 to 200mm are set in the middle, so the central wall can be analyzed by the cantilever member embedded in the lower part and does not consider the pulling effect of the purling on the wall. The two ends of the gable are subjected to force analysis according to the lower part and one side articulated member. The most unfavorable part of the gable is the middle part, and the unit width is adopted to analyze the force.

The strength of the wall material is measured by the actual strength standard. The strength of masonry mortar is extracted by the penetration method and the strength of the masonry mortar is detected by the penetration method, and the strength of the block is by the rebound method [1]. Before the collapse, barns were stacked with sorghum, and the standard combination was applied to the wall.

3. Calculation of the actual bearing capacity of the wall

The actual strength of masonry mortar is 0.4Mpa and the actual strength grade of brick is MU7.5.

The calculation of bearing capacity of non-reinforced masonry member in bending is based on the following formula [2]:

$$M \leq fW \tag{1}$$

The shear capacity of non-reinforced masonry member in bending is calculated according to the following formula [2]

$$V \leq f_v bz \tag{2}$$

$$f = k_4 \sqrt{f_2} \tag{3}$$

$$z = \frac{I}{S} \tag{4}$$

$$f_v = k_5 \sqrt{f_2} \tag{5}$$

Flexural capacity of 370mm wall:

$$M = fW = 2.08kN.m \tag{6}$$

Shear capacity of 370mm wall:

$$V \leq f_v bz = 22.52kN \tag{7}$$

In the last-written formulas, M is the bending moment. M is the shearing force. b is the cross section width. h is the cross section height. W is the cross section resistance moment, for rectangular cross section, $W=bh^2/6$.

f is the flexural tensile strength of masonry is taken as the tensile strength of the longitudinal joint.

f_v is the shear strength of masonry.

z is the internal force arm, for rectangular cross section, z=2h/3.

I is the section inertia moment.

S is the Section area moment.

4. Loading calculation of sorghum on wall

As the granary is a masonry barn, the roof is a wooden house cover and a non reinforced concrete granary, the simplified calculation method is used for the mining of the barn, which does not consider the continuity of the storehouse along the height direction, the upper part of the silo wall, the wall section of a silo that does not bear the horizontal pressure stress in the lower part of the barn wall, and the constraints of the simplified roof and the floor [3]. The horizontal pressure standard value and vertical friction standard value of grain acting on the unit area of the warehouse wall at S depth is calculated according to the following formula [4]:

$$P_h = k\gamma s \tag{8}$$

$$P_t = k\gamma s \tan\delta \tag{9}$$

$$k = \frac{\cos^2\varphi}{\cos\delta\left[1+\sqrt{\frac{\sin(\varphi+\delta)\sin\varphi}{\cos\delta}}\right]^2} \tag{10}$$

$$k = \frac{\cos^2\varphi}{(1+\sin\varphi)^2} \tag{11}$$

In the last-written formulas, P_h is the standard value of horizontal pressure acting on the unit area of the warehouse wall.

P_t is the standard value of vertical friction acting on the unit area of the warehouse wall.

k is the side pressure coefficient of grain. When calculating horizontal pressure, use equation 10 and rest equation 11.

s is the distance from the top of the grain to the calculated section, unit is meters.

γ is the grain gravity density, unit is kN/m^3.

φ is the internal friction angle of grain.

δ is the external friction angle of the grain to the wall brush surface.

The stowage in the granary is sorghum, physical parameters [5] is:

$\varphi = 34^0$

$\delta = 27^0$

$\gamma = 7.74kN/m^3$

The bending moment of sorghum on the calculation depth of the cross section of the silo wall is:

$$M' = \frac{1}{6}P_h s^2 - 0.7\int_0^s p_t \frac{0.37}{2}dx \tag{12}$$

The shearing force of sorghum on the calculation depth of the cross section of the silo wall is:

$$V' = \frac{1}{2}P_h s \tag{13}$$

5. Allowable heap height calculation

According to flexural capacity:

$$M = 2.08kN.m \geq M' = \frac{1}{6}P_h s^2 - 0.7\int_0^s p_t \frac{0.37}{2}dx = \frac{1}{6}k\gamma s^3 - 0.7\int_0^s k\gamma s \tan\delta \frac{0.37}{2}dx$$
$$= \frac{1}{6}k\gamma s^3 - 0.7\int_0^s k\gamma s \tan\delta \frac{0.37}{2}dx \tag{14}$$

Figure out s ≤ 1.85m

According to shear capacity:

$$V = 22.52kN \geq V' = \frac{1}{2}P_h s = \frac{1}{2}k\gamma s^2 \tag{15}$$

Figure out s ≤ 4.06m

Taking the smaller values of the two, the actual allowable heap of Sorghum s=1.85m, see table 1 for details.

Table 1. Allow high calculation results of heap height.

Computational state	Allowable heap height (m)	Final value (m)
According to flexural capacity	1.85	1.85
According to shear capacity	4.06	

6. Cause analysis

If the grain height exceeds the grain line, it will exceed the capacity allowed by the warehouse design, and its side pressure exceeds the strength that the wall can bear, resulting in cracks and even collapse in the wall of the bungalow, which eventually leads to the occurrence of a buried accident.

According to the calculation of warehouse receipts, 200741 kg of sorghum was stacked before the barn collapsed, and the average grain height was 2.82m.

Before the collapse of the barn, the height of the sorghum pile is 2.82m, which exceeds the permitted height of 1.85m, resulting in the collapse of the gable. In addition, no structural measures such as gird and structural column can be set up in granary, which can not provide beneficial effects for gables and delay its destruction and collapse.

Summary

1. After calculation, the height of the sorghum before the collapse of the granary was 2.82 m, which exceeded the allowable height of 1.85 m, resulting in the out-of-plane collapse of the gables, which was the direct cause of the collapse of the granary.

2. The structure measures such as ring beams and structural pillars are not set up in the granary, which can not provide a beneficial effect for the gables and can not delay their destruction and collapse.

3. This analysis shows that the calculation parameters should be collected first, including the section size of the component, the strength of the material, the load action and the arrangement of the structure, and then the calculation model is determined according to the actual structural arrangement. The calculation model can be determined according to the code or structural mechanics. The calculation results should be analyzed to see if they are consistent with the actual situation, and if they are not, the correctness of the parameters should be checked.

References

[1] He X H, Di X T and Gao X W 2004 *Technical standard for inspection of building structure*.**2004**:28-33.
[2] Gao L Y, Xu J and Wan Z F 2011 *Code for design of masonry structure.* **2011**:35-38.
[3] Cai J Y, Jiang C R, Hou F Z and Qiu H T 1999 *Internal force analysis of lateral pressure of reinforced concrete silo*, Proceedings of the Eighth National Conference on Structural Engineering (first volume):132-136.
[4] Wang Z Q and Yang M Y 2014 *Code for design of grain storehouses.* **2014**:18-21.
[5] Jin X Y, Wang J and Wang G Y 2012 *Load code for the design of building structures.* **2012**:79-82.