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DEVELOPMENT OF A SANDCRETE BLOCK RHOMBUS

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ABSTRACT

The availability and cost of construction materials of traditional storage structures makes it adoption advantageous to the subsistence farmers despite their series of defects. The mud rhombus which is commonly used for grain storage in the northern parts of Nigeria has various defects occuring mainly in the roof, wall and foundation of the structure. These defects include cracks, leakages, and structural failure of parts among others. The main objective of this work is to develop a sandcrete block rhombus to solve the problems of cracks, insect pest infestation, structural failure of the foundation and roof as well as the unloading of stored grains. A 1.46 tones capacity experimental sandcrete block rhombus with a total volume of 2.46 m^3 was designed to store shelled maize. The main structure was constructed using sandcrete blocks, cement, gravel and roofed using wood and roof asbestos. A trapezoidal metal sheet inclined at 30^o across the structure was incorporated to enhance the easy discharge of the loaded grains. The loading and unloading outlets are well secured to avoid pilfering. The cost of construction of the sandcrete block rhombus was estimated to be ₦60,000. The use of more structurally durable materials as well as the ease of loading and unloading coupled with the locking devices gives the sandcrete block rhombus more advantage over the traditional rhombus. However further work need to be carried out to evaluate the performance of the sandcrete block rhombus using grain models of safe moisture content.

Keywords *Development, construction, Mud rhombus, sandcrete silo*

INTRODUCTION

The constant growth of the world's population requires substantial, adequate and constant sources for the production of food. Food storage has an important role to play in achieving this objective since agricultural production is seasonal while the demand for agricultural commodities is more evenly spread throughout the year. Inadequate storage method and facilities has been a major problem in developing countries which often leads to huge losses of agricultural produce (Gewinner *et al.,* 1996, Birewar, 1990).The major grain crops cultivated in Nigeria are maize, rice, millet, guinea corn, cowpea and Soya beans, with a large proportion of these food grains retained on the farm for home use. Huge losses of grains are incurred annually in Nigeria due to poor harvest and lack of good or non-availability of good storage facilities (Igbeka and Olumeko, 1991). In other to have farm produce all the year round in the best possible conditions, adequate storage is highly imperative since agricultural production is seasonal (Adejumo and Raji, 2007, Alonge, 2005). Proper storage is important to solve certain problem that arises from storage such as respiration and microbiological activities that takes place in stored grains, as well as the problem of insect damage and gain or loss of moisture by grain (Gewinner *et al.,* 1996). Generally, there are two method of grain storage, (i) Traditional method e.g. rhombus, platforms, cribs, etc (ii) Modified/ modern methods e.g. silos, reinforced underground pits, concrete silos, etc. The traditional method used in storing grains varies with the type of grains to be stored and available construction material. They are relatively inexpensive to construct since locally available natural materials are used. The design and capacity of these facilities is determined by the type and quantity of grains to be stored. The main advantage of the traditional storage structure is their low construction cost which makes them cheap and affordable by the farmers. Availability or accessibility of traditional storage method is also an advantage that makes the farmers to adopt them despite their series of defect (Igbeka and Olumeko, 1991, Adejumo and Raji, 2007, Birewar, 1990, Federal Department of Agriculture, 1992). The traditional storage method is associated with different types of defect which occurs mainly in the roof, wall and foundation of the structures. These defects include cracks, leakage, insect pest infestation and structural failure of parts among others. Most of these structures are not moisture proof, rodent proof and are not airtight. The problems of loading, unloading and cleaning are also common to the traditional grain storage structures (Adejumo and Raji, 2007, Alonge, 2005). The mud rhombus which is commonly used for grain storage in the northern parts of Nigeria usually has cracks and leaking roofs, making regular repair work or rebuilding necessary. These cracks on the walls provide ideal hiding places for insects. They are neither airtight nor rodent proof and are therefore associated with the problem of pest infestation which is enhanced with the problem of temperature fluctuation. Structural failure occurs in the foundation, wall and roof of the mud rhombus. Other problems associated with the use of mud rhombus for grain storage includes inadequate foundation, low elevation, difficulty of loading and unloading as well as cleaning of the structure (Gewinner *et al.,* 1996, Adejumo and Raji, 2007, Birewar, 1990, Alonge, 2005). The main objective of this work is to develop a sandcrete block rhombus to solve the problems of cracks, insect pest infestation, structural failure of the foundation and unloading of stored shelled grains.

MATERIAL AND METHOD

Design and theoretical consideration

The following factors are considered before the design of the silo:

1. *A structure that will keep the grain cool and dry*
2. *A structure that must be airtight to allow fumigation*
3. *A structure that will protect grains from insects and giant rodent*
4. *A structure that will ease loading and unloading*
5. *A structure that must be structurally stable with minimum and low maintenance cost*
6. *A structure that will secure stored products from pilfering.*

Pressure Analysis in Shallow Silo

In the analysis of pressure due to grains for shallow silos, it is assumed that the wall surfaces are smooth and that there is no friction between the wall surface and the supported grains. The wall is therefore only subject to lateral grain pressure while all the vertical loads due to grain are supported by the floor. Pressure analysis in shallow silo is done using the Rankine's equation, which is given by

$$L = WY\frac{1-Sin\theta}{1+Sin\theta} = WY\tan 45\frac{\theta}{2} \qquad 1$$

Where

L = Lateral pressure per unit of wall area

W = bulk density of the stored material

Y = Distance from the top surface of grain to the point within the grain of which the pressure is considered θ = angle of repose of the stored material. The lateral pressure increases linearly from zero at the top surface to a maximum value at the bottom of the stored grain. The total lateral pressure per unit of wall perimeter L_T can be calculated from the equation:

$$L_T = \frac{Wh^2}{2} \times \frac{1 - Sin\theta}{1 + Sin\theta} = \frac{Wh^2}{2} \tan 45 \frac{\theta}{2} \qquad 2$$

Where h is depth of stored grain.

The theoretical average floor pressure is calculated from equation below:

$$F = Wh \qquad 3$$

Assuming a bulk density of 600 kg/m³ and an angle of repose of 22.1º for maize (Mahadeven, *et al.*, 1999), the grain model has a volumetric weight of 5886 Kg/m³. The metal incorporated part of the structure was inclined at 30º to allow the flow of grains out of the structure by gravity and the square part has a dimension of 1.23 x 1.23 x 1.23 m. Therefore, the structure has a volume of 2.46 m³ and a capacity of 1.48 tonnes. The force acting on the roof with a depression of 38º is given by the formula:

Formula for Loading= 1.4GK + 1.6QK + WK 4

Where;

1.4GK+1.6QK = Point Load
GK = Dead Load
QK = Live Load
WK = Wind Load

Dead Load (GK) = Weight of the structure itself i.e. Weight of timber × Cross section of the timber

Live Load (QK) = Loads of transient or mobile structure

Wind Load (WK) = Impact of load wind on the structure obtained from local wind speed and converted to wind forces as follows:

$V_s = V \times S_1 \times S_2 \times S_3$ (m/s) and WK= $0.613 V_s^2$ (N/m²) 5

Vs = Design wind speed (m/s)

S_1 = Multiplying factor relating to topology which can generally be taken as 1.0, in a partially sheltered area and 0.99 in completely sheltered area.

S_2 = Multiplying factor relating to height above and wind breaking factor, obtained from ranges from 0.55-1.27.

S_3 = Multiplying factor related to the life of the structure which can be taken as 1.0 which corresponds to an excessive speed occurring once in 50years. (Oyenuga, 2005)

V = Basic wind speed, which is assumed to be 30m/s for Ogbomoso being the location of this experiment.

This gives a dead, live and wind loads of 0.06, 0.7 and 0.552 KN/m², respectively. Therefore the sum of the resultant forces of the roof acting on the structure is calculated as 2.03 KN/m² and the displacement of the structure under the applied system of loading 2.7×10^9 KN/m². Assuming the difference from the top surface of the grain to the point where pressure is considered is half of the height of the silo where grain is storable. Given the height of 1.23 m, the pressure height Y is 0.615 m. The lateral pressure per unit of wall area L is 5.2 KN/m^2 while the total lateral pressure per unit of wall perimeter L_T is 6.3 KN/m^2. The theoretical average floor pressure Fv is calculated to be 7.24 KN/m^2.

Design Features and Construction

The detail drawings of the side view, front and side sections of the designed sandcrete block silo are as shown in Figure 1, 2 and 3 respectively.

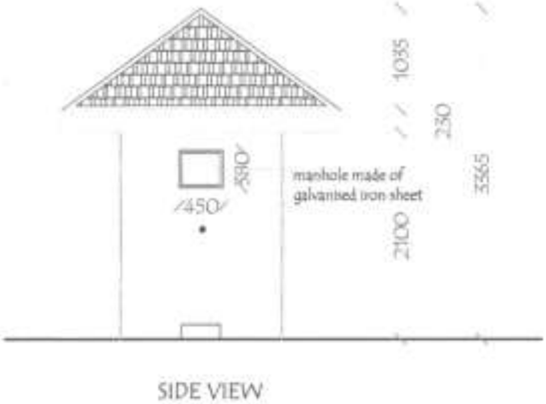

Figure 1: *The side view of the sandcrete block rhombus*

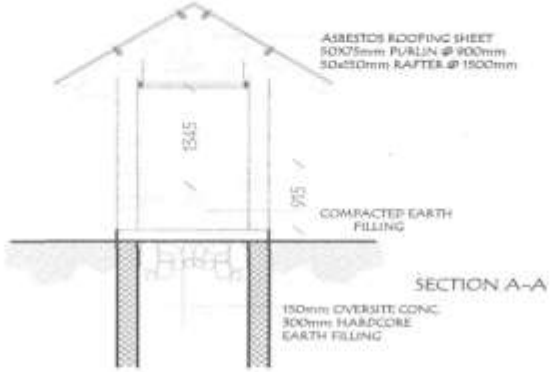

Figure 2: *The front section of the sandcrete block rhombus*

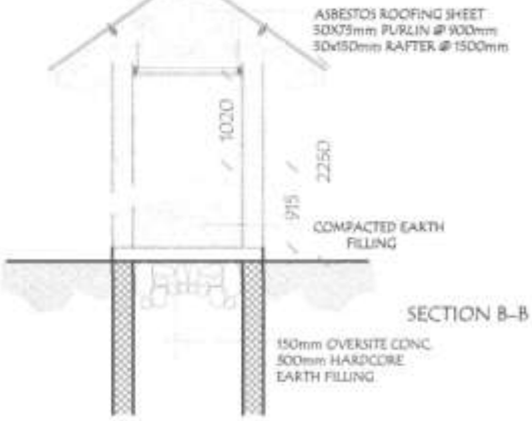

Figure 3: *The side section of the sandcrete block rhombus*

The component parts of the sandcrete silo were constructed and described as follows:

Foundation Section

A 1524 mm x 1524 mm trench was dug to a depth of 152.4 mm. The trench was laid with concrete mix (mixture of four head pan of sand, three head pan of gravel and twenty five kg of cement) to a height of 102 mm. Sandcrete blocks (152.4 mm) was laid with a 25.4 mm binding cement mortar thickness on the concrete foundation. The sandcrete blocks were laid to a height of 915 mm on three of the sides and 457.5 mm on the fourth side. The foundation was filled with well compacted sand to support the trapezoidal-like metal sheet that will be placed on the block wall at an angle of 30º (Plate 1).

Metal section

A 2 mm galvanized iron sheet was casted to form a trapezoidal like component, the plane between the two inclined side was made to project out to a length and breadth of 203.2 mm each. The 203.2 mm x 203.2 mm section was joined with another 203.2 mm and 203.2 mm x 127.0 mm metal plate to form a discharge outlet (Plate 2) for the structure and at the same time providing security for the stored produce.

Plate 1: Basement for metal plate **Plate 2: The metal section**

c. Wall Section

The wall was constructed with sandcrete blocks to a height of 1219 mm, from which eight PVC pipes of 20 mm× 177 mm was made to project from the inside of the structure to the outside at regular intervals on the four sides of the wall to serve as probe channels. The wall was plastered inside and outside with cement mortar. The loading inlet made of iron sheet of 305 mm× 457 mm was fixed on the right side of the wall.

d. Roof Section

The structure was roofed using 2000 x 3000 mm and 1000 x 1500 mm planks. The structure was roofed using roof asbestos to reduce the effect heat resulting from the sun radiation and which will as well reduce temperature fluctuations within the structure. The wall was made to be over hanged by eaves of 1500 mm to keep the structure in shade and protect the wall from rain.

RESULT AND DISCUSSIONS

A brief description of the designed and constructed sandcrete block rhombus

The designed and constructed sandcrete block rhombus is as shown in Plate 3.

Plate 3: ***Sandcrete block rhombus***

The sandcrete block rhombus is a four corners structure with an internal dimension of 1219 mm × 1219 mm and a total external height of 2744 mm. The inner part of the structure was incorporated with a 2 mm iron sheet which was casted in a trapezoidal form and was made to slant at an angle of 30° to ease the discharge of stored grains by gravity. The metal section was made to project out of the wall by 203.2 mm × 203.2 mm × 127.0 mm which serves as discharge outlet for the stored grains. A galvanized iron sheet was installed at the right side of the wall to serve as the loading inlet. The inner and the outer parts of the wall were plastered and the structure roofed with asbestos roofing sheet. Eight probe channels were inserted using 20 mm PVC pipes placed at regular intervals on the four sides of the structure. These channels were covered with PVC cover to prevent insect pest infestation. This is to allow for testing and monitoring purposes of the stored grains. The cost of construction was estimated to be ₦60,000. The advantages of the sandcrete block rhombus over the traditional rhombus include the following:

Structural Stability and Durability: The use of more durable materials such as cement, sand, sandcrete blocks etc in place of irregular stones, mud/clay, sticks, straws etc and the use of a concrete foundation has enhance the stability of the structure with minimal repair and maintenance cost.

Ease of Loading and Unloading: Loading is done through a loading inlet instead of loading through the roof as practiced for storage in the traditional rhombus. The incorporation of an inclined trapezoidal metal sheet in the unloading unit enhanced the discharge of the loaded grains through gravity. The inlet and outlet were provided with security lock to avoid pilfering.

Reduce Risk of Insect Pest Infestations and other Agents of Deterioration: The use of planks and roof asbestos instead of tree stems, straw, palm leaves used in the traditional rhombus will reduce insect infestation and water leakages into the structure. The problem of structural failure of the roof is also taken care of.

CONCLUSION

A sandcrete block rhombus was designed and constructed using more durable and readily available materials which make the structure more structurally stable than the traditional rhombus. The ease of loading and unloading coupled with the locking devices gives it more advantage than the traditional rhombus. However further work should be carried out to evaluate the performance of the sandcrete block rhombus using grain models of safe moisture content.

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