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WOOD PRODUCTS FOR GRAIN SILO CONSTRUCTION IN NIGERIA

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ABSTRACT: Metal silos used for the storage of grains under warm humid climate experience the problem of moisture condensation on the roofs and walls, and its redistribution within the grain bulk results in the deterioration of the stored grains. This is occasioned by the high thermal conductivity of the material of construction which offers very little resistance to the flow of solar heat into the silo enclosure. Experimentation with various grades of rubber as material for silo construction proved unsuccessful while little success was recorded with the use of various forms of concrete construction as the incidence of moisture condensation was still noticed. Wood products are tested as materials for silo construction aimed at reducing the temperature fluctuations and moisture condensation within the silo. Results show that the material has the potential of significantly reducing the temperature fluctuations within the silo and eliminating moisture condensation on the silo walls when compared to metal type. The use of local materials of construction will reduce the cost of the silo, while the simple construction and maintenance technologies, and the possibility of small unit capacity renders it of advantage to the Nigerian small-scale farmers. Mass production to reduce cost to what can be accomodated by small scale farmers is recommended.

1.0 INTRODUCTION

A silo is a container used for the storage of free-flowing solid materials such as agricultural produce and cement powder. The use of silo for the storage of agricultural materials in Nigeria is mainly for grains. The high unit capacities of silos of as much as 250 tonnes, and in some cases more, make them ideal as structures for large scale storage programmes. There are a variety of materials from which a silo could be constructed; however, the choice of materials is influenced by both economic considerations and climate of the environment where it is to be used.

Silos for the storage of agricultural produce were first introduced in Nigeria in 1957 by the United States Agricultural Department and for use in implementing the grain storage programme of Western Nigeria. The silos were manufactured from steel and aluminium. A few years after their introduction, the metal silos were found to experience the problem of moisture condensation on the walls and roofs and its redistribution whithin the bulk grain. This was attributed to the high thermal conductivity of the materials of construction which is as high as 204.17W/m°C for aluminium *[1]*, which offers very little resistance to the flow of solar radiation into the silo structure. The consequences were caking of grains, the development of hot spots, grain dampness and mould growth, grain germination and rapid development of insects in the event of infestation. Recognizing the relevance of the silo to the Nigerian agriculture, efforts were made to surmount these problems through the use of alternative materials of construction.

Single-walled mass concrete silos or those constructed from blocks have been tested and found to reduce the severity of moisture condensation and its associated problems while double-walled silos constructed from concrete

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The attraction for considering wood products as materials for grain silo construction is their low thermal conductivity. The average thermal conductivity across the grain for tropical hardwoods is about 0.18027 W/m°C*[1]*. With this low thermal conductivity of wood, it is envisaged that wooden silos will be able to reduce the temperature fluctuations within the enclosure which is relevant for grain storage.

2.0 MATERIALS AND METHODS: A 7m^3 capacity wooden silo was designed using the stressed skin panel approach*[9]*. The shape was of regular hexagonal section, each side measuring 1.2m with a height of 1.8m. The silo walls and floor were of double layers incorporating a 50mm air gap in between. The solid frame was of *Mansonia altissima* while the sheathing was of African mahogany face and core veneers bonded with phenol-formalydehyde adhesive. The inner and outer sheaths were respectively 6mm and 12mm thick. Within the vicinity of the wooden silo was a previously erected 1mm-thick cold-rolled steel silo of cylindrical shape, 2.3m in diameter, 1.7m in height and of almost the same capacity as the wooden one.

Two of the major requirements of a grain silo are the structural adequacy to be self-supporting and to support loads due to stored materials, and the provision of a favourable environment for the material stored. Once the designed silo was tested and found to be structurally adequate*[9]*, it was necessary that the condition within the silo enclosure be investigated.

The three sources of heat that could contribute to the fluctuations of temperature within a grain silo are the external heat from solar radiation which penetrates through the wall into the silo enclosure, the internal heat from metabolic activities of the grain, and respiration of organisms within the silo. When the stored material is thoroughly dried, clean and uninfested, the internal heat sources are negligible and the temperature fluctuation within the enclosure is a function of the ambient condition and the thermal conductivity of the silo material*[10, 11]*. Experiments on the relative efficiencies of silo materials in regulating the temperatures within a silo may therefore be carried out in unloaded silos, hence the use of empty silos for this study was considered justified. The designed silos and a metal one within the vicinity were therefore used for the study.

The two parameters of interest in this study were temperature fluctuations within the silo and moisture condensation on the inner walls of the silo. For data collection, maximum and minimum thermometers were installed inside the two silos and outside throughout the period of experimentation. Readings were taken thrice daily; morning, noon and evening.

3.0 RESULTS AND DISCUSSION: The results are presented in Table 1 and displayed graphically in Fig. 1. The data show that the minimum daily temperatures which generally occur in the mornings both within and outside the silos were generally higher within the wooden silo than the ambient as against the steel silo where the internal morning and minimum temperatures overlapped with, and on some days were lower than, the ambient temperatures. The consequence of this is a possibility of moisture condensation within the inner surface of the

Table 1

Temperatures and Temperature Fluctuations Within and Outside Silos

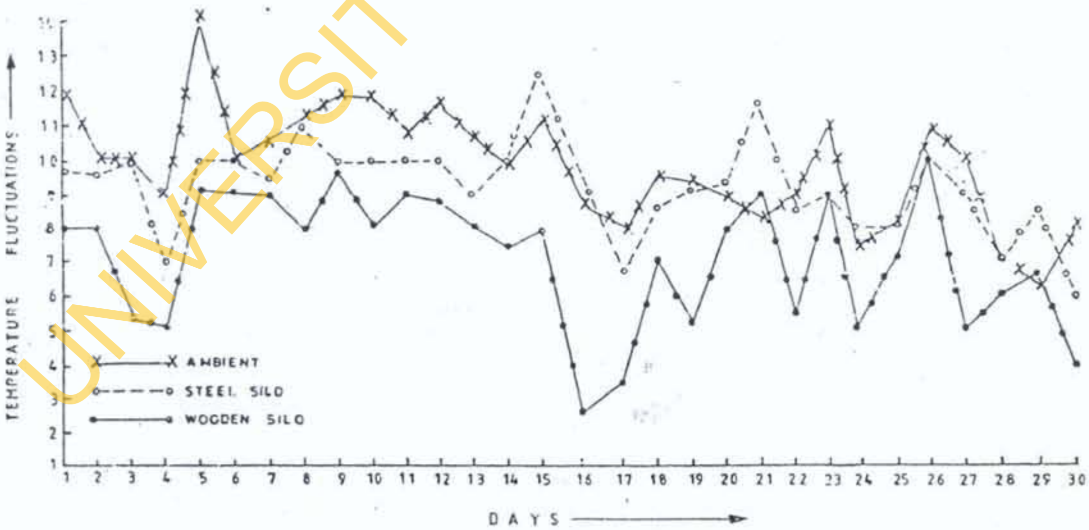
Day	Ambient Temperatures (°C)			Temperatures in Steel Silo (°C)			Temperatures in Wooden Silo (°C)		
	A+	B++	C+++	A+	B++	C+++	A+	B++	C++
1	24.0	36.0	12.0	24.8	34.5	9.7	26.0	34.0	8.0
2	27.0	37.0	10.0	25.4	35.0	9.6	27.0	35.0	8.0
3	25.0	35.0	10.0	26.0	36.0	10.0	27.0	32.4	5.4
4	25.0	34.0	9.0	25.0	32.0	7.0	26.6	31.8	5.2
5	21.80	36.0	14.2	22.0	32.0	10.0	22.0	31.0	9.0
6	24.0	34.0	10.0	24.0	34.0	10.0	25.0	34.1	9.1
7	26.4	37.0	10.6	29.0	38.5	9.5	28.2	37.2	9.0
8	25.8	37.1	11.3	24.0	35.0	11.0	26.1	33.0	7.9
9	26.1	38.0	11.9	28.1	38.0	9.9	27.4	37.1	9.7
10	26.2	38.0	11.8	26.0	36.0	10.0	27.0	35.0	8.0
11	25.8	36.5	10.7	26.0	36.0	10.0	26.0	35.4	9.4
12	26.4	38.0	11.6	26.0	36.0	10.0	26.8	36.6	9.8
13	26.2	36.8	11.6	26.0	35.0	9.0	27.0	35.0	8.0
14	25.2	35.0	9.8	25.0	35.0	10.0	26.0	33.4	7.4
15	25.8	37.0	11.2	24.0	36.6	12.5	27.1	35.0	7.9
16	23.30	32.0	8.7	20.2	30.0	9.8	24.4	27.0	2.6
17	24.0	32.0	8.0	20.3	27.0	6.7	27.1	30.5	3.4
18	22.0	31.5	9.5	20.4	29.0	8.6	23.0	30.0	7.0
19	24.2	33.5	9.3	20.3	29.5	9.2	24.0	29.2	5.2
20	26.0	35.0	9.0	20.6	30.0	9.4	26.1	34.0	7.9
21	25.3	33.5	8.2	20.4	30.0	9.6	26.0	35.0	9.0
22	26.0	35.0	9.0	26.0	34.5	8.5	26.5	32.0	5.5
23	25.0	36.0	11.0	26.0	35.0	9.0	26.3	35.2	8.9
24	25.6	33.0	7.4	24.0	32.0	8.0	26.0	31.0	5.0
25	22.0	30.0	8.0	22.0	30.0	8.0	23.0	30.1	7.1
26	24.0	34.8	10.8	24.0	34.0	10.0	24.5	34.5	10.0
27	26.0	36.0	10.0	24.0	33.0	9.0	27.0	32.0	5.0
28	26.0	33.0	7.0	26.0	33.0	7.0	26.0	32.0	6.0
29	24.0	30.2	6.2	25.5	34.0	8.5	26.0	32.6	6.6
30	25.5	33.5	8.0	26.0	32.0	6.0	27.0	31.0	4.0
Average			10.0			9.0			7.0

A+ = Minimum temperature

B++ = Maximum temperature

C+++ = Temperature fluctuation

FIG. 1: DAILY TEMPERATURE FLUCTUATIONS WITHIN AND OUTSIDE SILOS IN IBADAN



steel silo and its absence within the wooden one. These expectations were confirmed experimentally. The walls of the wooden silo were found warm when felt with the palm and dry when rubbed with absorbent tissue paper as against the steel silo, the walls of which were cold and wet visibly wetting the absorbent tissue paper.
Although maximum daily temperatures were recorded for the ambient and steel silo at noon while it occured in the wooden silo in the evening, the values were generally lowest for the wooden silo and highest for the ambient. Those for the steel silo were intermediate and on some days overlapped with the ambient. The result of this is a lower temperature fluctuation within the wooden silo than the steel one and the ambient. From the experiment carried out, the daily temperature fluctuations recorded were 7°C, 9°C and 10°C respectively for the wooden and steel silos, and the ambient. These results can be supported from the point of view of the thermal conductivity of the material of silo construction. Wood has a thermal conductivity of 0.18027 w/m°C as against 12 to 62 w/m°C for steel *[1]*. Wood products therefore have the potential to reduce the rate of solar heat penetration into the silo enclosure and also in the reverse direction. This accounts for why the minimum and maximum temperatures within the wooden silo are respectively higher and lower than for those recorded for the steel silo.

<u>4.0 BENEFITS OF WOODEN SILOS</u>: The following are some of the benefits to be derived from the use of wooden silos.

- Unlike steel and aluminium that are imported, the material will be readily available from the numerous forest reserves, sawmills and plywood factories scattered all over the country. The structure can therefore be cheaply obtained as there is a sure source of raw material.
- The design procedure presentd by Lucas and Mijinyawa *[9]* makes wooden silos quite simple to construct and operate. The components are easy to fabricate while repairs and modifications can be accomplished with readily available local technology.
- It can be produced in various small unit capacities to meet the need of individual rural farmers.
- It reduces temperature fluctuations and eliminates moisture condensation within the silo, thus providing a suitable environment for the storage of grains.

<u>5.0 CONCLUSION</u>: Wood products exhibit great potentials as materials for the construction of grain silos that could reduce the temperature fluctuations and eliminate the condensation of moisture on the inner walls which are the problems experienced with the use of metal silos. There are the additional advantages of reduced cost of silo structure since the materials of construction will be locally sourced, and the fabrication of small-unit capacity silos to meet the need of individual small-scale farmers with small surpluses.

<u>6.0 RECOMMENDATIONS</u>:

- Only naturally durable or appropriately treated timber species should be used for the construction of wooden silos. This is to curtail the incidence of biodeterioration of the silo structure and possibly its content while in service.

- To reduce the cost of production and accelerate the adoption rate among the targeted small-scale farmers usually with low income, a co-ordinated production system whereby the components are factory-produced, only to be assembled on site, is recommended.

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