COEFFICIENT OF FRICTION OF MAIZE AND SORGHUM GRAINS ON LATERIZED CONCRETE WALL

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ABSTRACT

The effect of moisture content on the coefficient of friction of maize and sorghum grains on laterized** concrete wall material has been investigated. The results obtained were compared with those obtained for galvanized sheet metal and plywood materials. Regression analysis was carried out on the data obtained. For the three wall materials considered, the correlation coefficients of the straight line relationship for the different samples tested were all greater than 0.990. High values of apparent cohesion were obtained for the three wall materials with laterized concrete wall having the highest value of 2.20KN/m^2 and galvanized sheet metal 0.01KN/m^2. The results further showed that an increase in grain moisture content resulted in an increase in the coefficient of friction obtained . Since coefficient of friction is a grain moisture content dependent, and increase in lateral pressures of grains on silo wall is also a grain moisture content dependent, it could be derived that an increase in coefficient of friction will bring about an increase in the lateral wall pressure resulting from the stored grain.

Therefore maximum value of coefficient of friction should be used in silo design.

**Laterized concrete is concrete in which some, or all the fine aggregate is from lateritic soils.

INTRODUCTION

The design ot silos of large diameter and height, or of special purposes, require a reliable calculation of horizontal and vertical material pressures. Super imposed on these pressures are pressures from objects that move within the grain, such as stirring devices. The two most widely used methods for predicting wall pressures are Rankine's and Coulomb'd (1)

To predict wall pressures in structures for the storage of grains, it is necessary to know the physical properties of stored materials in relation to their effects on material flow and bin-wall pressures. According to Tsang-Mui- Chung et al. (2), the proper design of grain handling equipment requires knowledge of its frictional characteristics.

The angle of internal friction has been considered as one of the physical properties directly affecting storage bin-wall pressures (3). Designers have generally assumed that the angle of repose and the internal- friction angle are equal and have used angle of repose values for determining bin-wall pressures. However, the methods used by various investigators to determine coefficient of friction of agricultural materials have usually been designed to suit the particular conditions of the material. The methods include the tilting of an inclined plane for static friction or moving of a given surfaced against the material for kinetic friction . Experimentally, shear box equipment has been used to determine the coefficient of frictions and angle of friction of agricultural materials (4,5). For this report, the use of shear box equipment was employed. This is because this equipment is suitable for particle sizes of up to 40mm (1).
The purpose of this paper is to report the results of research on the coefficient of friction of grains (maize and sorghum) on laterized concrete wall. This is with the view to obtaining relevant frictional data needed for the design of laterized concrete silos. The results obtained were compared with those of galvanized sheet metal and plywood.

MATERIALS AND EXPERIMENTAL PROCEDURE

SOIL SAMPLE COLLECTION

The lateritic soils used for this investigation were collected from a borrow pit situated along Ife-Ibadan Road. The coarse aggregates of an almost Uniform size of 12mm were obtained from crushed granite of igneous origin (Figure 1). The cement used was locally produced at the Shagamu factory of the West African Portland Cement Company. The properties of this cement conform to British Standard (B812) part 2 of 1970 for Ordinary Portland cement.

MAIZE AND SORGHUM GRAINS COLLECTION

The maize grain used for this investigation was white hybrid and was obtained from Animo Farm Limited situated at Ede, eighty-five kilometers from Obafemi Awolowo University, Ile-Ife. The sorghum grain used was collected from International Brewery Farm situated along Ilesa-Akure Road.

EXPERIMENTAL DESIGN

Parameters usually considered to play a major role in the internal friction and coefficient of friction include grain size, grain shape and grain moisture content (3). For this work, grain shape and size were assumed constant and uniform since only one species of each grain type was used. The only factor considered was moisture content which was at about 8%, 10%, 14% and 16% levels. According to some researchers (2,5,6), the presence of moisture on the wall surfaces of grain silo may cause an increase in friction due to increasing adhesion. Work is in progress on how different species of grains and the presence of moisture on wall surfaces affect the frictional properties of different silo walls.

EXPERIMENTAL PROCEDURE

Three wall surfaces were used for this experiment, vis: laterized concrete, galvanized sheet metal and plywood. Laterized concrete slabs of 100mm x 100mm were moulded to fit into the base of the shear box equipment. The galvanized sheet metal (gauge 18) and the plywood (13mm thick) were cut to plates of size 100mm x 100mm to fit into the base of the same shear box equipment. The wall materials were placed inside the base of the brass box until the surface assumed the same level with the edge of the base such that the surface of each wall material represented the shearing plane.

The moisture content of the grains was varied by adding calculated amount of water to the grains inside a bottle used as a grain wetter. This was done by pouring a known weight of grains into the wetter, a calculated amount of water (see equation 1 below) was poured into the grains and the wetter was corked. The wetter was rotated by hand to distribute water uniformly on the grains. The grain was mixed several time daily for the seven days it was kept in the wetter, and was used as promptly as possible without prolonged storage. From the known weight of grain (w_s) the amount of water added (w) to raise the moisture content from M_1 to M_2 is given by

$$\bar{w} = \frac{w_s\ (M_2 - M_1)}{(1 - M_2)} \qquad \ldots\ldots\ldots\ldots \quad (1)$$

For the filling of the brass box, the "sprinkle-fill" method was used (7). The method allows the grain kernels to arrange themselves with long axis in horizontal position which is a preferred orientation. The experiment was performed under ambient temperature, hence it was assumed that the effects of temperature and relative humidity were reduced to the minimum.

ANALYSIS AND DISCUSSION OF RESULTS

A regression analysis was carried out on .he sets of the data of normal stress (γ) and shear stress (γ) at each moisture content for each grains on each shear surface. Figures 2 and 3 show typical examples of the curves obtained and the relationship between shear stress and normal stress for maize and sorghum grains on laterized concrete wall. These curves were obtained using the following regression equations:

(a) Y= 1.47+ 0.31X ---------- for Figure 2
(b) Y= 0.225 + 0.55X ---------- for Figure 3

Similar equations were obtained relating shear stress and normal stress for plywood and galvanized sheet metal walls. All the equations obtained were used to determine the coefficient of frictions shown in Tables 1 and 2.

The correlation coefficients of the straight line relationship for the different samples tested were all greater than 0.990 (Tables 1 and 2). Figures 2 and 3 show the relationship between shear stress and normal stress for maize and sorghum grains on laterized concrete wall at different moisture content levels. The relationship follows the same trend for maize and sorghum grains on galvanized sheet metal and plywood (Tables 1 and 2) with increase in normal stress resulting in increase in shear stress.

The coefficient of friction of maize and sorghum grains on all the three surfaces considered increase with increase in grain moisture content (Figures 4 and 5). For example, of the three wall materials tested, galvanized sheet metal gave the lowest coefficient of friction of 0.16 for about 8% maize grains moisture content, followed

Table 1: Coefficient of friction of maize grains on different wall materials

Wall material	Grain moisture (%)	Apparent (cohesion (KN/m²)	Coefficient (C) of fric-tion (μ)	Correlation coefficient (r)
Laterized concrete	7.89	1.16	0.349	0.998
	10.14	2.01	0.396	0.996
	11.93	1.98	0.486	0.991
	14.27	2.20	0.564	0.993
	15.63	2.03	0.575	0.992
Plywood	8.01	1.10	0.326	0.993
	10.15	1.50	0.374	0.987
	11.97	2.00	0.448	0.990
	14.25	2.08	0.510	0.991
	15.92	2.02	0.579	0.996
Galvanized sheet metal	7.93	0.04	0.159	0.996
	10.11	0.50	0.265	0.997
	11.95	0.81	0.288	0.997
	14.27	1.02	0.302	0.991
	15.71	0.93	0.329	0.993

Table 2: Coefficient of friction of sorghum grains on different wall material

Wall material	Grain moisture (%)	Apparent (cohesion (KN/m²)	Coefficient (C) of fric-tion (μ)	Correlation coefficient (r)
Laterized concrete	7.92	0.24	0.520	0.991
	9.99	0.80	0.490	0.990
	11.98	1.00	0.533	0.989
	14.06	1.20	0.550	0.990
	15.88	1.38	0.663	0.987
Plywood	7.96	0.26	0.380	0.992
	10.11	0.40	0.340	0.988
	11.87	0.34	0.360	0.990
	14.13	0.24	0.440	0.989
	16.12	0.08	0.540	0.990
Galvanized sheet metal	8.10	0.22	0.340	0.990
	10.14	0.18	0.280	0.990
	11.93	0.20	0.320	0.995
	14.15	0.19	0.340	0.989
	16.02	0.23	0.380	0.991

by plywood and laterized concrete having 0.33 and 0.35 respectively for the same grain moisture content (Table 1). In the case of sorghum grains on different wall surfaces, though the coefficient of friction increased with increase in moisture content, there was a fall in the coefficient of friction obtained at about 10% moisture content.

For example, from figure 5 for laterized concrete wall, at about 8% of the grains moisture content the coefficient of friction was 0.52. This value was 0.03 lower at about 10% but rose by 0.01, 0.03 and 0.14 at about 12%, 14% and 16% moisture content respectively (Table 2). The same trend was observed for other wall materials tested. This was very much unlike the case with maize grains on different wall surfaces. One may attribute this disparity to the sorghum grains being smaller in size and roundish in shape than maize grains.

Another inference from Table 1 is that for the three material surfaces, there exist apparent cohesion in the range of 0.01kN/m^2 to 2.20kN/m^2, the highest value of 2.20kN/m^2 being for laterized concrete surface while 0.01kn/m^2 is for galvanized sheet metal. The values of apparent cohesion obtained for galvanized sheet metal compare favourably with the existing values. However, for the laterized concrete, the values were higher. It is unusual to obtain such high apparent cohesion. According to Mohsenin (6), some researchers consider cohesion as due to experimental error and not a property of the material. Experimental error may not be the only reason for such high values of apparent cohesion obtained.

This study has shown that the nature of the surfaces of laterized concrete which was not as smooth as that of galvanized sheet metal could have been responsible for higher values of apparent cohesion obtained. It also could have been caused by the actual stickiness between the grains due to grain moisture content. Besides, addition of water to increase the absorbed water by grains increased grain surface water which consequently increase the adhesion between the grain and the material surfaces and hence the values of apparent cohesion obtained. Since these has not been any information on apparent cohesion for laterized concrete wall surface, this study will serve as a base for further studies on the frictional properties of laterized concrete.

USE OF THE DATA COLLECTED

The stability of silos in services depends on many factors. The most important of them all is the pressure exerted on such silo walls by the stored material. The pressure in turn is dependent on such parameters as diameter of silo, depth of stored material and the moisture content of stored material. The moisture content of stored material has a direct effect on the coefficient of friction of stored material on the silo wall surface. Coefficient of friction is one of the parameters involved in Janssen Equation (see equation 2 below) which is widely accepted for the prediction of pressure distribution inside the silos.

$$P_L = \frac{WR}{\mu}(1 - e^{-k\mu h/R}) \quad \text{.....(2)}$$

where P_L = lateral bin wall pressure (kN/m^2)
W = unit weight of stored material (kN/m^3)
R = hydraulic radius of silo (m)
μ = coefficient of friction of stored grain on silo wall surface
k = pressure ratio (i.e. ration of lateral to vertical pressure) = P_L/P_v
h= depth of stored material at any point (m)

In this study, the coefficient of friction of grains determined will be used for the design of laterized concrete silo.

CONCLUSION

It has been shown from the analysis and discussion of results that an increase in moisture content of grains resulted in an increase in the coefficient of friction obtained. An increase in

moisture content of stored grains inside the silo may, in addition to aiding grains deterioration, make grain kernels to expand thereby causing a considerable increase in lateral pressures exerted on the silo wall. Since coefficient of friction is a grain moisture content depended, it follows that increase in coefficient of friction will result in increase in lateral pressures of grains on the silo wall and therefore maximum value of coefficient of friction should be used in silo design. In all cases of silo design, the danger of high moisture and the resulting high coefficient of friction should be considered. Therefore, the design pressures should be increased significantly or a higher factor of safety be used in order to reduce the effect of the coefficient of friction on the pressure exerted on silo wall.

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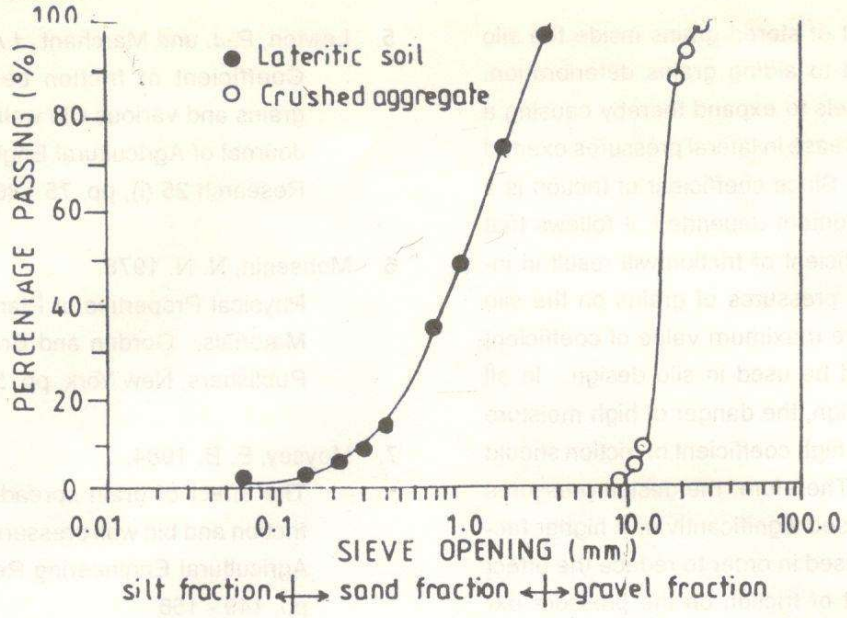


Figure 1 Sieve analysis of lateritic soil sample and crushed aggregate used in the test

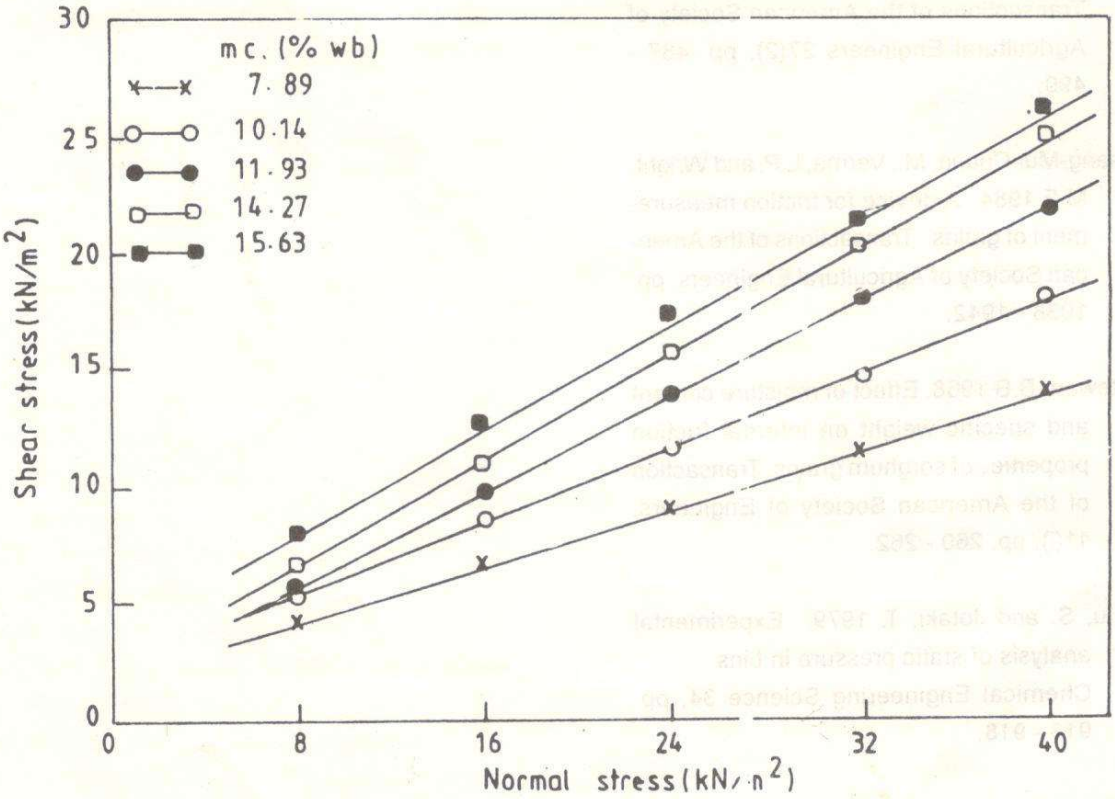


Figure 2 Shear stress vs normal stress for maize grains on laterize concrete wall at different moisture contents.

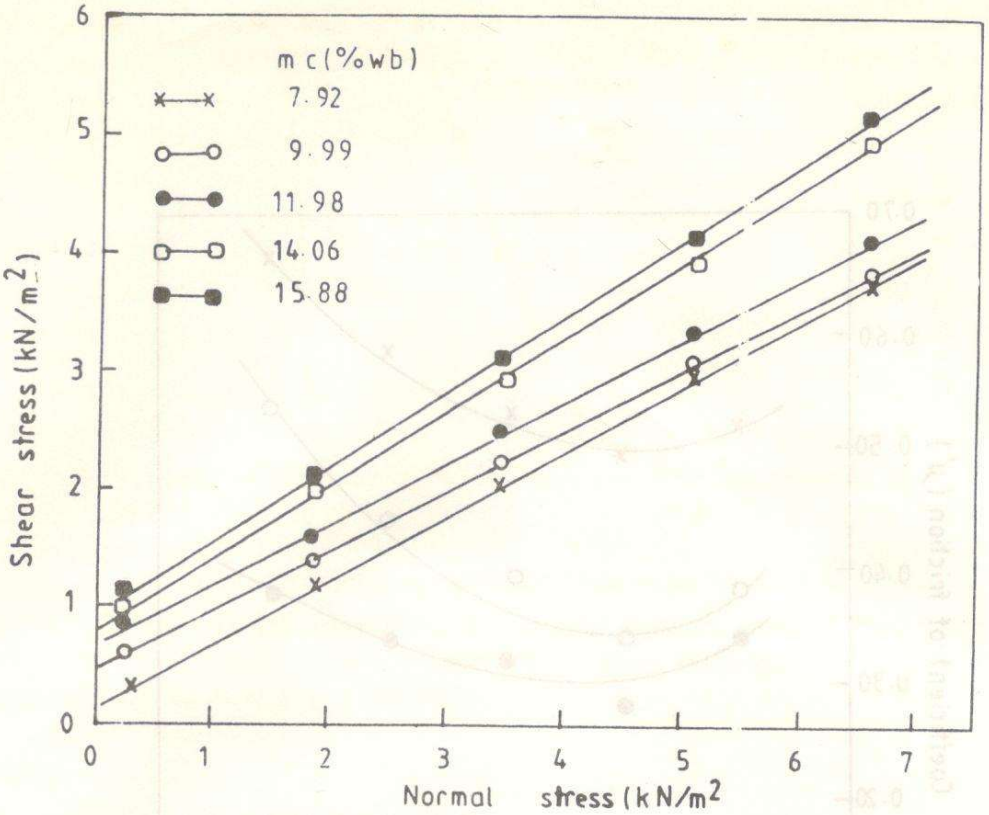


Figure 3 Shear stress vs normal stress for sorghum grains on laterized concrete wall at different moisture content

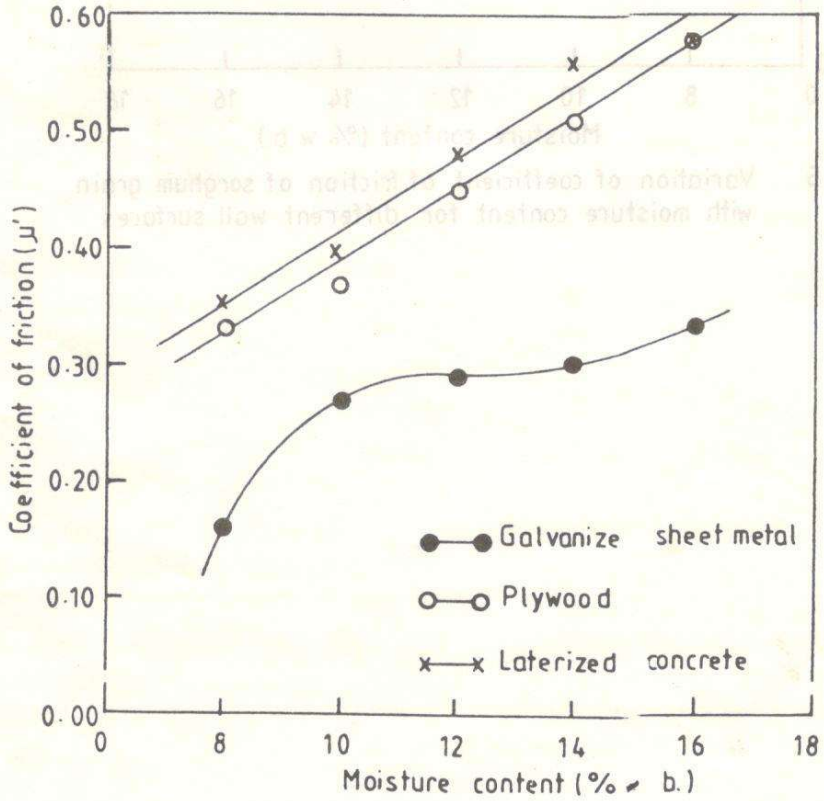


Figure 4 Variation of coefficient of friction of maize grain with moisture content for different wall surfaces

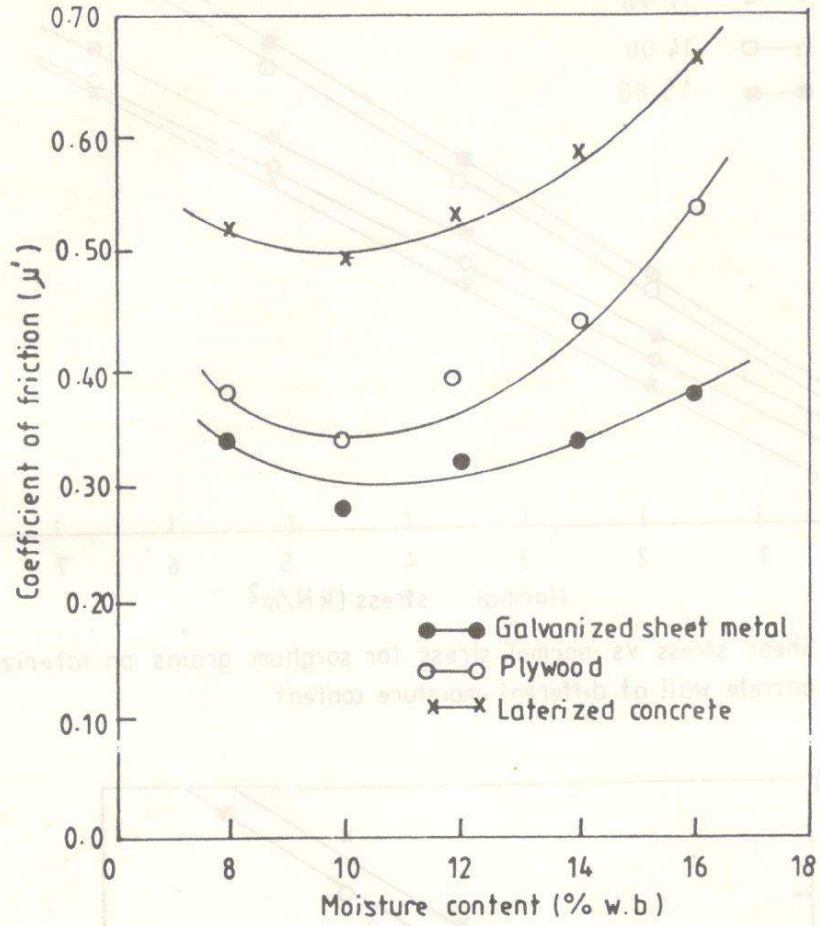


Figure 5 Variation of coefficient of friction of sorghum grain with moisture content for different wall surfaces