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Comparison of Physical and Flow Properties of Crystal Sugar and Confectionery Sugar

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Abstract:- The Brazilian agricultural production exceeds the storage capacity, so the construction of a silo becomes essential. The physical and flow characteristics of the analyzed product are essential in the silo design. Therefore, the present work aims to determine the physical and flow properties of different types of sugar for the design of vertical silos. The experiment was carried out at the Laboratory of Rural Constructions and Ambience - LACRA of the Federal University of Campina Grande, in the city of Campina Grande-PB, analyzing crystal sugar and confectioner's sugar, measuring the physical characteristics (moisture content, granulometry and density) and flow (angle and effective angle of internal friction, average cohesion and angle of friction between the product and the silo wall). It was concluded that the products are classified as fine grains, with flow difficulties.

Keywords:- *storage; flow; hopper.*

I. INTRODUCTION

Cultivated since the colonial period, sugarcane has become one of the main crops in the Brazilian economy. Brazil is not only the largest producer of sugarcane, but also the first in the world in sugar production [17]. It is in this aspect of relevance of this agro-industrial sector that the need for knowledge and dissemination of information relevant to the storage processes is justified, avoiding any type of risk to the quality of the product.

Brazilian storage capacity is limited, vertical silos emerge as an alternative to solve this problem [15], [2], [4].

Vertical silos are structures commonly used by industries, agricultural and mineral sectors to store and conserve bulk, granular or powdery solid products ([14], [8], [3], [10]. Vertical silos are widely used and enable mechanized loading and unloading features, such as elevators and conveyor belts, cleaning machines and dryers, aeration and thermometry systems [6].

The flowability of powdery products, which is defined as the ability of a powder or solid to flow under a given set of conditions, is a complex characteristic of a material, and is highly dependent on the state of the product and the application it is used for. is being used. In specific terms, knowledge of the flow properties of powders is important, as the flow resistance strongly and non-linearly depends on the instantaneous consolidation degree [20].

Flow characterization methods are often used to choose the most suitable building material for a given process and as predictive tools to analyze the performance of the product flow process. Therefore, these methods play a very important role in the process of developing silos for the storage of these products. There are several methods to characterize the flow properties of products, such as using shear [19].

One of the main problems in silo design is the exact prediction of load distribution in the silo body, with special attention to the pressures exerted on the walls due to the thrust of the stored product [13], [16], [5]. These pressure distributions depend on the behavior of the product, the interaction between the stored product and the silo wall, and also the flow properties during the loading and unloading process [9],[8],[1].

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II. MATERIALS AND METHODS

The experiment was conducted at the Laboratory of Rural Constructions and Ambience (LaCRA) of the Federal University of Campina Grande, located in the city of Campina Grande-PB.

To determine the granulometry of the products, a set of ABNT/ASTM standard sieves was used, which were assembled in descending order, depending on the mesh, and shaken in an electric vibrator for a period of 5 minutes. After this process, the sieves were removed and weighed on a 0.01g precision electronic balance. Based on the difference in mass on each sieve, the granulometric fractions of the products were determined.

The moisture content was measured following ICUMSA (International Commission for Uniform Methods of Sugar Analysis) guidelines, in triplicate, using 30 g of the product for each repetition. The samples were deposited in aluminum containers, then weighed on a scale with a precision of 0.001 g to obtain the total mass of the product, and taken to an oven with forced air circulation at a temperature of 105 ± 3°C for a period of time. time interval of 3 hours. Then, the containers were cooled in a desiccator and weighed again, obtaining the dry mass.

The flow properties investigated in this work were: specific weight, as a function of consolidation (γ), angle of internal friction (ϕi), effective angle of internal friction (δ), cohesion (C), angle of friction with the wall (ϕw). To determine the flow properties, the methodology recommended by [7] was adopted and, for data acquisition, the direct shear cell by translation (TSG 70-140), internationally known as " Jenike Shear Cell” (Figure 1).

Figure 1:- Direct shear cell and TSG 70-140 apparatus.

With the results in hand and with the aid of a computer graphics software, the curves of normal stress versus shear stress (σ, τ) were drawn for the loads used, which made it possible to draw the Mohr stress circles (Figure 2).

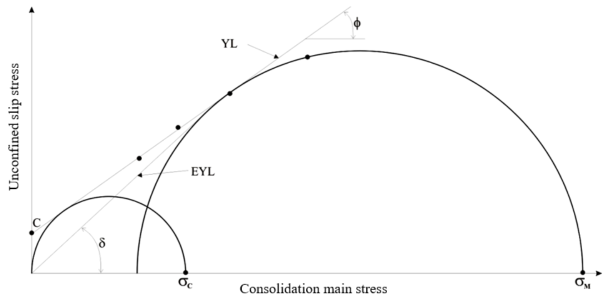

Figure 2:- Places of geometry and angles of internal friction.

The angle of friction with the wall (ϕw) was determined by the same equipment described above, having a change in the base of the lower ring of the Jenike cell by the sample of the wall material, and also the load adopted. The wall materials used in this experiment were rough steel, stainless steel, aluminum and acrylic as they are frequently used in the construction of silos.

The normal load levels adopted in this work are shown in Table 1.

Normal Loads	
Pre-shear (N)	Shear (N)
50	35; 20; 10
35	20; 10; 7
25	10; 7; 4,4

Table 1:- Levels of normal loads used in the direct shear test.

III. RESULTS AND DISCUSSION

Figure 3 shows the granulometric curves of the two analyzed products, making it possible to see that crystal sugar has almost all of its particles with a dimension immediately greater than 0.296 mm, while icing sugar has a greater distribution of particles in the other sieves, being the sugars classified as fine grain.

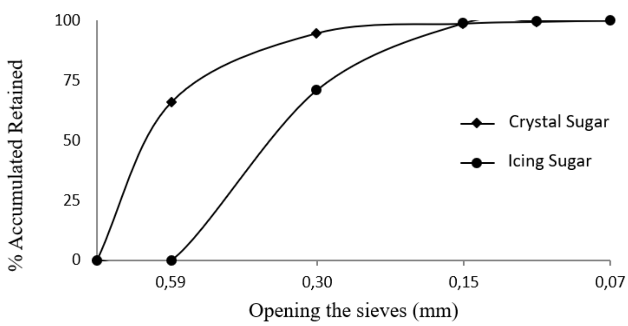

Figure 3:- Product granulometric curves.

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The moisture contents verified during the tests for crystal sugar were 0.304% (b.u) in the samples collected at the beginning of the experiment and 0.244% (b.u) of the samples collected at the end of the experiment, for icing sugar, the content moisture content of 0.323% (b.u.) at the beginning and 0.256% (b.u.) at the end of the tests, in accordance with expectations due to its manufacturing process. During the test period, the products remained in an environment with a controlled temperature of 20°C and reduced air humidity.

The flow properties of the products are shown in Table 2, in which it is important to highlight a greater variation between the lower and upper limits, obtained for the internal friction angle (Ø) of the icing sugar, around 11%, while for the crystal sugar this variation did not exceed 6%. According to LOPES NETO & NASCIMENTO [12] who state that the higher the limits for Ø, the greater the shear facility and, consequently, the flow. It is noted that crystal sugar has higher limits for Ø, so it will have an easier flow when compared to icing sugar.

Corroborating the statement, it is found that the cohesion of particles (C) in which the highest result was obtained for icing sugar, indicating that it is a product of high cohesion, which may develop problems in its unloading, under different storage conditions.

Product	γ		φ		δ		φw		C (Pa)	
	Inf	Sup	Inf	Sup	Inf	Sup	Inf	Sup	Inf	Sup
Crystal Sugar	970,7	999,2	31,2	36,5	34,0	38,0	14,9	21,2	107,8	177,2
Icing Sugar	862,3	875,2	25,0	36,0	32,0	39,0	20,8	27,3	141,0	886,0

Table 2:- Flow properties of sugars

γ - consolidated specific weight (N m-3); Ø - internal friction angle (°); δ - effective internal friction angle (°); Øw - internal friction angle with smooth steel wall (°); C - average particle cohesion (Pa); Inf, Sup - lower and upper limits, respectively.

Figures 4(a) and 4(b) represent the consolidation stresses (σM) and unconfined slip stresses (fC) for the load series of 50, 35 and 25 N for the analyzed products. It is observed that the highest values of σM were obtained for icing sugar (Figure 5b) between 9121 and 16646 Pa, demonstrating that this product develops a higher state of active stress; on the other hand, for the same product, the highest values of fC were also observed, which indicates the need to reach high stress values for mass shearing to occur.

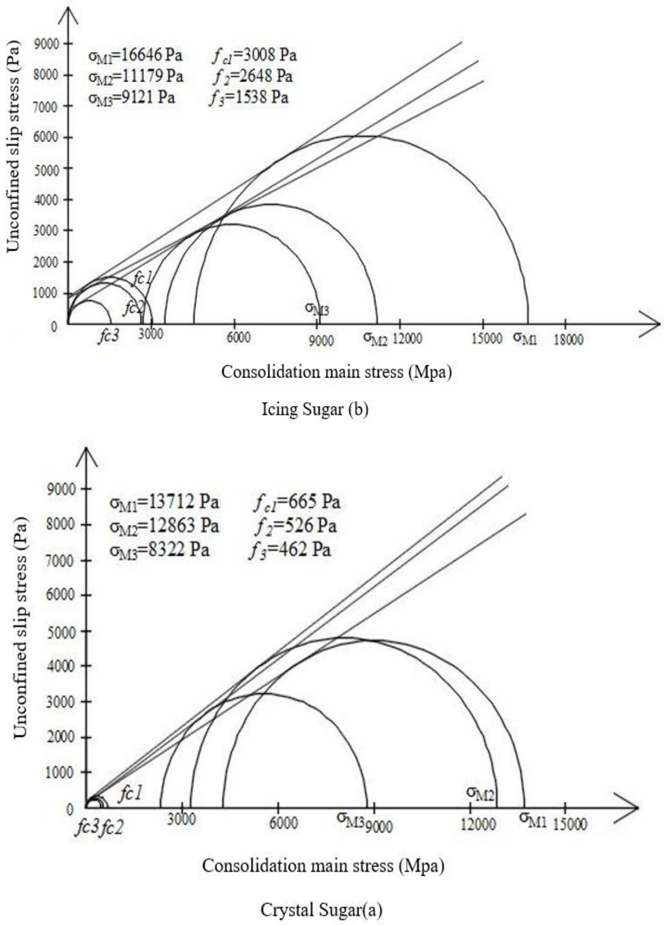

Figure 4:- Mohr stress circles for: crystal sugar (a); and icing sugar (b).

IV. CONCLUSIONS

After analyzing the results, the types of sugar analyzed were classified into fine grains, with flow difficulties.

All physical and flow properties for the analyzed materials were established and encourage an addition to the database for future research.

We suggest, for future work, the continuity of the production of experimental data on physical and flow properties of different types of materials, to promote future research, since studies with computer simulation become increasingly common.

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