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VERTICAL SILO PRESSURE ANALYSIS WITH UNUSUAL BUILDING MATERIALS

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ABSTRACT

With the incapacity in the Brazilian storage network, leveraged by the constant increase in national agricultural production, the construction of a silo becomes essential, where some of the problems in its dimensioning are the distribution of pressures of the product stored in the construction material. Thus, the present work aims to determine the pressure exerted by bean cultivars, according to EUROCODE 1. The experiment was conducted at the Laboratory of Rural Constructions and Ambience - LACRA of the Federal University of Campina Grande, in the municipality of Campina Grande- PB, analyzing the different types of beans: carioquinha (Phaseolus vulgaris L.), black (Phaseolus vulgaris L.) and macassar (Vigna unguiculata). We analyzed the physical and flow characteristics of the products, and used two unusual materials for silo sizing, acrylic and wood, determining the pressures exerted by these cultivars in the storage silo, based on Eurocode 1. It was concluded that the products are classified as coarse grains, with free flow, the pressures exerted by the product are consistent with the norms established in the Eurocode 1 standard, considering all the suggested safety factors.

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INTRODUCTION

Brazilian agricultural production grows so fast that its storage capacity cannot keep up, thus problems in the storage of agricultural products are observed, which provides economic losses for producers, thus, the construction of vertical silos appears as an alternative to solve this problem (Bandeira *et al*., 2020). Grain production grows sharply annually due to increased crop productivity, grain production in Brazil according to the National Supply Company, it is estimated for the 2020/21 crop a total of 268.7 million tons, an increase of 11 million tons compared to the 2019/20 harvest (CONAB, 2021). Beans (Phaseolus vulgaris L.) are an important source of protein, fiber, iron, carbohydrates, minerals and vitamins for millions of people in both developing and developed countries (Lin *et al*., 2008). It is estimated that there are 55 species of the genus Phaseolus (Carneiro, 2005). This genus comprises all species known as beans, being Phaseolus vulgaris L. the best known and the one that has numerous varieties such as carioca, purple, mulatinho, black, among others (Pires *et al*., 2005).

Vertical silos are structures commonly used by industries, agricultural and mineral sectors to store and conserve in bulk, granular or powdery solid products (Bandeira et.al., 2021; Dornelas et. al., 2021). Vertical silos (bulk carriers) are widely used in Brazil and provide mechanized loading and unloading facilities, such as elevators and conveyor belts, cleaning machines and dryers, aeration and thermometry systems (Baroni *et al*., 2017).

In studies Ding (2014) and Fank *et al*. (2018), state that the pressures that occur during the discharge are not perfectly understood, noting that the pressure at the beginning of the discharge is very close to the pressure at the end of the discharge. The distribution of loads along the body of the silo is a significant problem for its dimensioning. 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 (Martinez *et al*., 2002; Costa, 2013; Tascón, 2017; Ayres *et al*., 2020).

MATERIALS AND METHODS

All shear tests were performed, as well as the empirical determination of pressures along the silo body, in the Rural Constructions and Ambience Laboratory (LaCRA) of the Agricultural Engineering Department of the Federal University of Campina Grande (UFCG), Campus de Campina Grande – PB, Brazil. In this research we used three bean cultivars, carioquinha (Phaseolus vulgaris L.), black (Phaseolus vulgaris L.) and macassar bean (Vigna unguiculata), with moisture content of 2.91%, 3.53% and 3.03% (bs), respectively, all being classified as coarse grain (Figure 1). Flow properties were determined: consolidated specific weight (γ), internal friction angle (ϕ), effective internal friction angle (δ) and friction angle of the product with the wall (ϕ w). Adopting the methodology recommended by the OPERATING INTRODUCTION FOR THE TRANSLATIONAL SHEAR TESTER (TSG – 70/140) using the “Jenike Shear Cell” device Figure 2.

Figure 1. Types of beans analyzed, (a) Carioquinha beans, (b) Black beans and (c) Macassar beans

Two tests were performed: product shear and product shear with the wall material (wood, acrylic and aluminum), in order to determine the internal friction angle, effective internal friction angle, the friction angle with the wall and the cohesion of the product. We used the methodology established by the EUROCODE 1 (2006) standard to calculate the pressures in the silo body, with the following equations:

$$p_{hc} = \frac{\gamma \, x \, A}{\mu \, x \, U} \qquad p_{hd} = p_{hc} \, x \, ch$$

$$p_v = \frac{p_{hc}}{k} \qquad p_{wc} = p_{hc} \, x \, \mu$$

$$p_{wd} = p_{wc} \text{ x cw} \qquad U = \frac{A}{p}$$

$$k = 1{,}1 \, x \, (1 - sen \, \emptyset_e) \qquad \mu = tg \, \emptyset_w$$

Were,

ɣ - Consolidated Specific Weight (N/m³)
A - Silo Cross Section Area (m²)
µ - Friction Coefficient
p - Silo Perimeter (m)
U - Hydraulic Radius (m)
Φe - Effective Internal Friction Angle (°)
k - Ph and Pv ratio
Phc - Horizontal Loading Pressure (Pa)
ch - Overpressure Coefficient
Phd - Horizontal Discharge Pressure (Pa)
Pv - Vertical Pressure (Pa)
Pwc - Loading Friction Pressure (Pa)
cw - Overpressure Coefficient
Pwd - Discharge Friction Pressure (Pa)

RESULTS AND DISCUSSION

On Table 1, the results of the flow properties of the bean cultivars, necessary to determine the pressure exerted by the material in the storage silo, are presented. The results of the consolidated specific weight (γ) carioquinha, black and macassar beans presented mean values of 7991.3412 N/m³, 8086,1640 N/m³ and 8058.8567 N/m³, respectively. The average consolidated specific weight of carioquinha beans is within the AS 3774 (1996) and EUROCODE 1 (2006) standard, where the upper limit is 8000 N/m³, however, black beans and macassar are slightly above the established limit by the standards.

Two different types of material were analyzed for making the storage silo, thus measuring the friction angle of the product with the selected confection material, shown in Table 2.

Table 1. Flow properties of the analyzed products

Cultivars	γ (N/m³)		Φe (°)		Φi (°)		C (Pa)
	inf	sup	inf	sup	inf	sup	
Carioquinha	7923,34	8072,12	28	30	29	31	250,667
Black bean	8055,04	8106,09	26	27	27	28	50
Macassar	8008,54	8147,5	24	25	24	25	64

Table 2. Angle of internal friction with the wall of the analyzed materials

Angle of Internal Friction with the wall Φ_W(°)				
Material		Carioquinha	Black bean	Macassar
Acrylic	Bottom	1,2	1,4	1,2
	Higher	6,8	7,4	8,2
Wood	Bottom	8,4	9,3	11,5
	Higher	12,3	14,3	15,9

Based on the information obtained, shown in Tables 1 and 2, applying them to the sets of equations standardized by EUROCODE 1,we were able to theoretically measure the pressures along the silo body, which are shown in Figures 2, 3 and 4, to the carioquinha,black and macassar beans, respectively. We observed overestimated values for the normalized theoretical pressures, due to the imposed and cumulative safety coefficients throughout the calculation, which often do not agree with those found experimentally. We also observed that in all situations the friction pressures for wood silos are higher than those calculated for acrylic, which is justified by the higher roughness of wood when compared to acrylic. We observed the change in horizontal and vertical pressures for both situations, showing the influence of the geometry of the different types of beans, and their individual physical properties.

Figure 2. Jenike equipment used to determine flow properties

Couto *et al*. (2013), Gallego (2015), Wójcik *et al*. (2017), Fank *et al*. (2018) and Meira *et al*. (2020) in their work observed this superiority in theoretical pressures when compared to experimental pressures, due to the safety coefficient used in the determination of pressures, which in turn extrapolates the pressures measured experimentally. We also observed that as suggested by the international standard BS EN 1991/4 (2006), the horizontal unloading pressures in all products were higher than the horizontal loading pressures, since this is obtained by multiplying an overpressure coefficient stipulated by the standard for the unloading on the horizontal pressure loading. The same observed by Couto *et al*. (2013), who found variations regarding the elevation of values obtained through the BS EN 1991/4 standard during unloading.

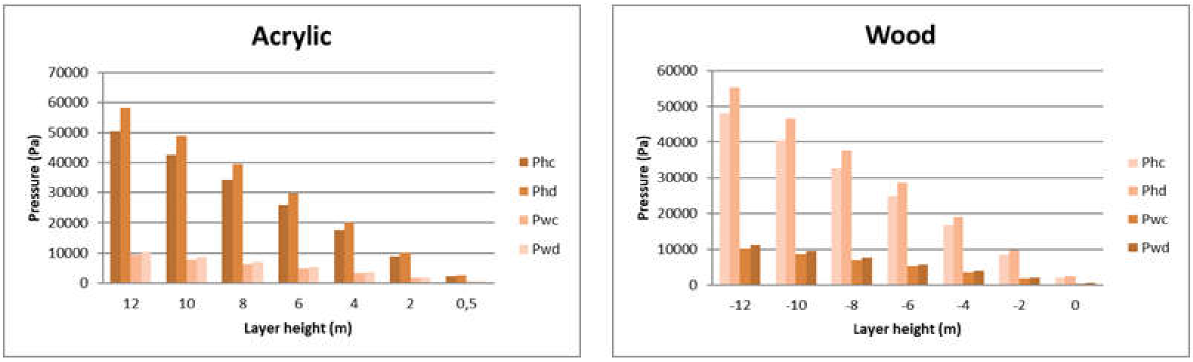

Figure 3. Graphic representation of the behavior of carioquinha bean pressures on the silo walls for the different types of steel Analyzed

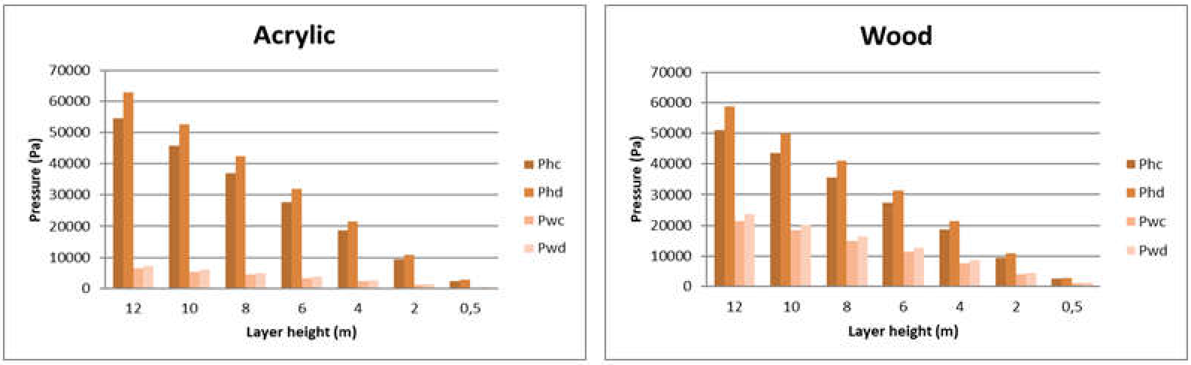

Figure 4. Graphic representation of the behavior of black bean pressures on the silo walls for the different types of steel analyzed

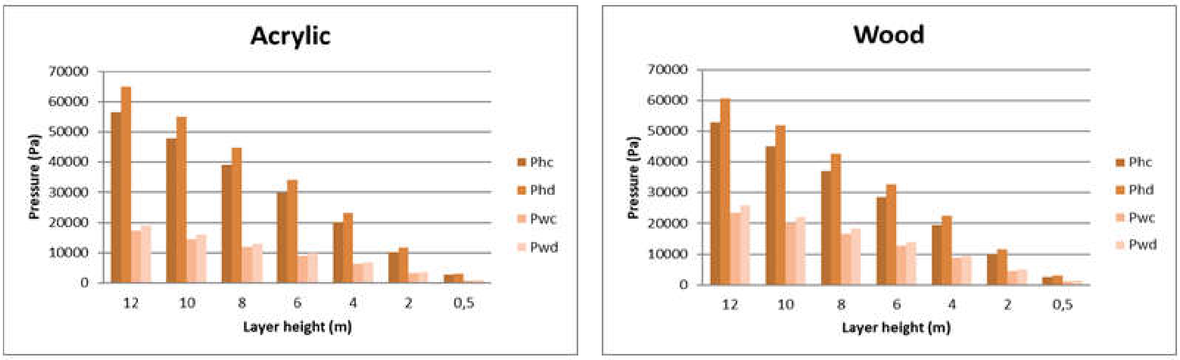

Figure 5. Graphic representation of the behavior of macassar bean pressures on the silo walls for the different types of steel analyzed

CONCLUSION

It was observed that the overpressure coefficient stipulated by the standard, for pressure calculations during the unloading of stored products, and that, considering some specific physical and flow properties of each product, we theoretically verify that the variables are superior to the standard values. As the roughness of the material increases, the friction pressures of the stored product tend to vary, due to the change in the resistance that the material imposes on the product flow.

REFERENCES

AS 3774. 1996. *Australian Standard. Loads on bulk containers***.** Sydney.

Ayres, G. D. J.,do Nascimento, J. W. B. & Mascarenhas, N. M. H. 2020. Rompimento de arcos coesivos em silos verticais com emprego de pneumaticos: Uma revisão bibliográfica. Revista de CiênciasAgrárias, 2020,43(4): 390-395.

Bandeira, D. J. A., Lima, M. J. N. da C., Oliveira, A. N. de., Branco, R. R. C., Nascimento, K. L. do., Costa, R. F., & Nascimento, J. J. da S. 2021. Physical and flow properties of common bean cultivars for the design of vertical silos. *Research, Society and Development*, *10*(12), e208101220347. https://doi.org/10. 33448/rsd-v10i12.20347

Bandeira, D. J. A., Nascimento, J. J. da S., & Nascimento, J. W. B. do. 2020. Flow analysis of poultry feed in slender vertical silos with inverted cone insert. *Research, Society and*

Baroni, G. D., Benedeti, P. H. &Seidel, D. J. 2017. Cenários prospectivos da produção e armazenagem de grãos no Brasil. *Revista Thema*, 14(4), 55-64.

BS EN 1991:4. 2006. *Eurocode 1. Actions on structures*. Silos andtanks, p.112.

Carneiro, H. S. 2005. Comida e sociedade: significados sociais na história da alimentação. *História: Questões & Debates*. 42(1), 71-80.

Conab-Companhia Nacional de Abastecimento (2021) *Acompanhamento safra brasileira de grãos*, v.8–Safra 2020/21, n. 4 -Quarto levantamento, Brasília, p. 1-85, janeiro 2021. ISSN

2318-7913. https://www.conab.gov.br/info-agro/safras/graos/boletim-da-safra-de-graos.

Costa, C. A. DA. 2013. *Propriedades físicas, mecânicas e de fluxo de produtos agroindustriais*. (Dissertação de Mestrado). Universidade Federal de Campina Grande, Campina Grande, PB.

Couto, A., Ruiz, A., Herráez, L., Moran, J., Aguado, P. J. 2013. Measuring pressures in a slender cylindrical silo for storing maize. Filling, static state and discharge with different material flow rates and comparison with Eurocode 1 part 4. *Computers and Electronics in Agriculture*. v. 96, p. 40–56.

Development, *9*(11), e63091110369. https://doi.org/10.33448/rsd-v9i11.10369

Ding, S., Ji,Y., Senbin, Y., Rotter, J.M., Li, Q. 2014. Measurements of pressure and frictional tractions along walls of a large-scale conical shallow hopper and comparison with Eurocode1991-4:2006. *Thin-WalledStructures*, p. 231–238.

Dornelas, K. C., Silva, V. R., Pessoa, Y. C. C., Nascimento, J. W. B. 2021. Propriedades físicas e de fluxo de produtos granulares para projeto de silo. *Research, Society and Development*, v. 10, n.10, e234101018754.

Fank, M. Z., Nascimento, J. W. B., Cardoso, D. L., Meira, A. S., Willrich, F. L. 2018. Vertical pressures and compressive friction force in a large silo. *Scientific Paper, Agricultural Building and Environment* • Eng. agríc. (Online) 38 (4).

Gallego, E., Ruiz, A., Aguado, P. J. 2015. Simulation of silo filling and discharge using ANSYS and comparison with experimental data. *Computers and Electronics in Agriculture*, v.118, p. 281–289.

Lin, L., Harnly, J., Pastor-Corrales, M. S., Luthria, D. L. 2008. The polyphenolic profiles of common bean (*Phaseolus vulgaris* L.). *Food Chemistry*. 107(1), 399–410.

Martinez, M. A., Alfaro, I., Doblare, M. 2002. Simulation of axisymmetric discharging in metallic silos. Analysis of the induced pressure distribution and comparison with diferent standards. *EngineeringStructures*, 24(12), 1561-1574.

Meira, A. S., Nascimento, J. W. B., Silva, V. R., Nascimento, R. T., Soares, H. R. 2020. *Análise comparativa de pressões horizontais durante o carregamento em silos verticais metálicos*. Pesquisa e Ensino em Ciências Exatas e da Natureza, 4:e1539.

Pires, C. V., Oliveira, M. G. A., Cruz, G. A. D. R., Mendes, F. Q., De Rezende, S. T., Moreira, M. A. 2005. Composição físico-química de diferentes cultivares de feijão (*Phaseolusvulgaris* L.). *Alimentos e Nutrição*, 16(2), 157-162.

Tascón, A. 2017. Design of silos for dust explosions: Determination of vent area sizes and explosion pressures. *Engineering Structures*, 134, 1-10.

Wojcik, M., Sondej, M., Rejowski, K., Tejchman, J. 2017. Full-scale experiments on wheat flow in steel silo composed of corrugated walls and columns. *Powder Technology*.

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