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About Some Mechanical Properties Regarding Sandwich Samples Reinforced with Poplar Strips and the Core from Crushed Corn Cobs with Hybrid Dammar-Based Matrix

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Abstract: *In this research some composite materials built in sandwich type style are studied. The lower and upper layers, that reinforce the samples, are made from poplar strips. The core is made from crushed corn cob and the adhesion of all parts (layers and core) is made by using hybrid resins based on a combination from dammar resin and the synthetic acrylic one (with its hardener). The static and dynamic mechanical behaviour by testing the samples to tensile and bending were studied. Two types of hybrid resins were used: one abbreviated as type B with the percentage of 60% dammar and 40% acrylic resin with hardener and one abbreviated as type C with the percentage of 65% dammar and 35% acrylic resin with hardener. A general conclusion from this study it was: the mechanical properties decrase with the dammar percentage increase. This fact can be explained by the decreased mechanical properties of the natural dammar resin compared to the synthetic acylic one.*

Keywords*: sandwich strips, crushed corn cobs, hybrid resin, poplar strips*

1. Introduction

The renewable energy that comes from animals and plants is called biomass. It is known that the biomass sources come from: wood and wood processing wastes that come, for example, from packaging; waste materials from agriculture like corn, sugarcane, woody plants and so on; biogenic materials like wool, paper or cotton; organic matters derived from animals also known as animal manure [1]. This energy is considered a quite good alternative to fossil fuels. One of the important parts that result from corn production is its cob which is considered a natural biomass resource.

There is estimated a 164 Tg of corn cobs obtained every year from the corn agricultural production [2]. Another estimation regarding the corn cob production was made in [3] where it was concluded that for 10 kg of corn grain production there is obtained a 1.8 kg residue of corn cob. The microstructure and fibrous composition for corn cobs were investigated in [2] and it was concluded that it contains cellulose, hemicellulose and lignin. Three parts were also found in [4] and their effect on the corn cob's elastic modulus, crushing strength and toughness modulus was investigated. The chemical parts, density, water absorption, fire resistance or thermal insulation capacity for different components that are part of corn cob microstructure were evaluated in [5, 6]. At a macrostructure level, the corn cob was characterized in [7] and it was found out that the three main parts that characterize it are the pith, woody ring and the glume.

It was also found out that the corn cob contains the same fiber components as wood, so it can be used as a material for buildings [8-11]. The research from [12] contains the development of particle boards from crushed corn cobs and sawdust. The binder used was made from urea formaldehyde. There were made density, water absorption, thickness swelling and three points bending tests. The best properties were obtained for composites with 50% corn cobs. The authors from [13] have studied the thermal insulation of combined earth materials and corn cob aggregates and they found out that the thermal

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conductivity of bricks that contain 6 wt% corb cobs is lowered with 38% compared to bricks that are made only from earth materials. Compared to expanded clay, in [5] it was found out that the corn cob concrete has a lower density, compressive strength and thermal conductivity; but the autors stated that the material can be used for pavement regularization layers.

Many studies affirm that natural aggregates such as corn cob must be treated further to reduce their size, shape and the incompatibility with the cement matrix [14, 15]. One of the treatments methods is the alkali one which removes the hemicelluloses, pectins and other minor parts [16]. The possibility of corn cob to replace river sand was investigated in [17] by applying to them a treatment of cement paste. The treatment decreased the corn cobs water absorption. The insertion of the treated corn cobs in mortars leaded to ductility improvement and thermal insulation properties but decreased the workability and strength. The investigation from [18] highlights the increase in flexural and tensile strength with the addition of corn cob in wood plastic composites made from sawdust or pulping sludge. The bonding of all components was made with polyvinyl chloride resin.

Other researches use the corn cob in ash state because it has pozzolanic properties. For example, the corb cob in ash state has less water absortion, increased resistance to sulfanate attack [19] and a decrease in concrete compressive strength when used in the concrete composition [20, 21]. In [22] there is made a study regarding the influence of corn cob and sunflower stalk ashes over the flexural and compressive strengths and chemical attack of hydrochloric acid of the concrete that contains these ashes. There is made a concrete with insertions of corn cob and sunflower stalk ashes between 2.5 and 5%. The best values for compressive and flexural strengths were obtained for the concrete with 2.5% insertions of corn cob ashes.

The present research is about manufacturing some sandwich bars reinforced with poplar strips and the core made from crushed corn cob. There are used two types of matrices: the first one is a hybrid resin with a combination between dammar 60 and 40% acrylic resin ClaroCit (with its hardener) and the second one is also a hybrid resin with a combination between dammar 65 and 35% acrylic resin ClaroCit (with its hardener). This study is a continuation of the research made in [23] because the hybrid resin is now used in combination with crushed corn cob as a core for some sandwich bars. In [23] it was concluded that the hybrid resin only combined with crushed corn cob has quite low mechanical properties and limited usages in the engineering field.

2. Materials and methods

For this research, some composite sandwich bars are manufactured and their mechanical properties are studied. The core is made from two types of hybrid resins: first type is obtained with a combination between dammar 60 and 40% acrylic resin ClaroCit (with its hardener) and will have the abbreviation **B** in the next paragraphs and the second type is obtained with a combination between dammar 60 and 40% acrylic resin ClaroCit (with its hardener) and will have the abbreviation **C** in the next paragraphs. The proportion for the synthetic resin between the acrylic one and its hardener is the one recommended by the producer: 6 parts of hardener for 10 parts of resin, by weight. The hybrid resins were obtained by using the same procedure presented in [23]. The upper and lower layers of the sandwich samples are made from poplar strips and will have de abbreviation **W** in the next paragraphs.

2.1. Tensile test of the sandwich bars

The tensile test is made by using the universal testing machine Instron 1000 HDX with the 1000 kN cell force and the main characteristics presented in [24]. There are created 15 samples for tensile test according to the standard [25] with the imposed dimensions of 250 mm length and 25 mm width. For this test, all the samples that are used in the next paragraphs will have the abbreviation **T**.

In conclusion, for a sample that is tensile tested the abbreviation will be in this way: T (tensile) B (resin type B) W (the poplar type of wood) followed by a number that is from 1 to 15 which indicates the number of the sample from the 15 tested specimens. Two examples with specimens for each type of hybrid resin (types B and C) are presented in Figure 1 and 2.

Figure 1. An example with the sandwich sample type TBW7

Figure 2. An example with the sandwich sample type TCW12

2.2. Bending test of sandwich bars

The second test is the three points bending and 15 samples were created according to the standard [26] with the imposed dimensions of 150 mm length and 12.7 mm width. For this test, all the samples that are used in the next paragraphs will have the abbreviation **B** and the samples marking will be like in the example given in the paragraph 2.1. The bending test is made by using the universal testing machine LGB with the 100 kN cell force and the main characteristics presented in [27].

2.3. Free vibrations of sandwich bars

The third test is to determine the dynamic characteristics from the sample free vibrations. For this test, all the samples that are used in the next paragraphs will have the abbreviation **V** and the samples marking will be like in the example given in the paragraph 2.1. The tested samples have the dimensions of 250 mm length and 25 mm width. In order to record the free vibrations there will be used the same experimental montage with the apparatus parts that are mentioned in [28] used also for the dynamic study of composite bars. Several free lengths of 100, 120, 140, 160, 180 mm are used for the vibrations recording.

3. Results and discussions

3.1. Tensile test results

The stress-strain loop for a representative specimen from the TBW series is presented in Figure 3. The stress- strain loop for a representative specimen from TCW series is presented in Figure 4. All the results from the tensile test are written in Table 1.

Table 1. Tensile test values for TBW and TCW series

Sample type	**Modulus of elasticity (MPa)**			**Breaking strength at tensile (MPa)**			**Specimen expansion at break for tensile test (%)**		
	Arithmetic mean	Mean linear deviation	Survey dispersion	Arithmetic mean	Mean linear deviation	Survey dispersion	Arithmetic mean	Mean linear deviation	Survey dispersion
TBW	4726	6.32	7.76	62.9	0.139	0.178	7.48	0.021	0.028
TCW	4171	23.556	30.672	52.9	1.013	1.289	8.375	0.072	0.123

In Table 1 there is also determined the arithmetic mean $\overline{x}$, mean linear deviation $\overline{y}$ and the survey disperssion $\overline{\Phi_x}$ by using the relations (1-3) where j is the number of the current sample, n is the number of total samples (n=15) and x is the experimental value.

$$\overline{x} = \frac{\sum_{j=1}^{n} x_j}{n} \quad (1)$$

$$\overline{y} = \frac{\sum_{j=1}^{n} |\overline{x} - x_j|}{n} \quad (2)$$

$$\overline{\Phi_x} = \sqrt{\frac{\sum_{j=1}^{n} (\overline{x} - x_j)^2}{n}} \quad (3)$$

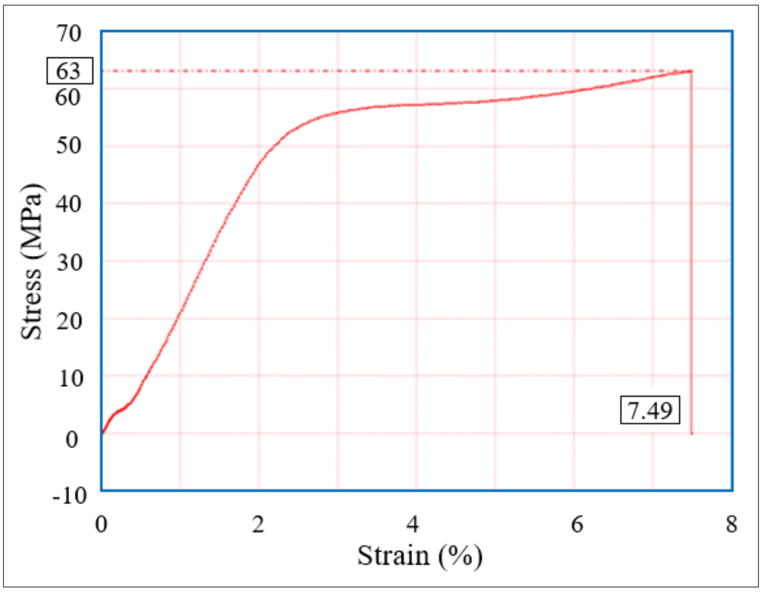

Figure 3. The stress-strain loop for a representative specimen from the TBW series (TBW7)

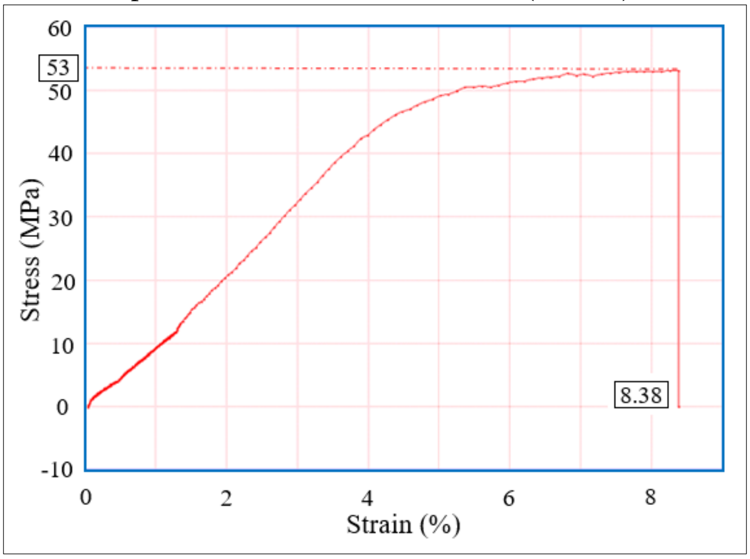

Figure 4. The stress-strain loop for a representative specimen from the TCW series (TCW12)

From the Table 1 results, there cand be seen that the samples with the type B matrix have increased tensile properties compared to the ones made from type C.

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3.2. Bending test results

The force-traverse stroke loop for a representative specimen from the BBW series is presented in Figure 5. The force-traverse stroke loop for a representative specimen from BCW series is presented in Figure 6. All the results from bending test are written in Table 2. In Table 1 there is also determined the arithmetic mean $\overline{x}$, mean linear deviation $\overline{y}$ and the survey dispersion $\overline{\Phi_x}$ by using the same relations (1-3).

Table 2. Bending test values for BBW and BCW series

Sample type	**Breaking strength at bending (MPa)**			**The maximum force value where the breakage took place for bending (MPa)**			**The maximum displacement at the samples breakage (mm)**		
	Arithmetic mean	Mean linear deviation	Survey dispersion	Arithmetic mean	Mean linear deviation	Survey dispersion	Arithmetic mean	Mean linear deviation	Survey dispersion
BBW	42	0.161	1.364	11.2	0.112	0.148	6.65	0.036	0.047
BCW	35.6	0.387	0.483	10.4	0.239	0.338	7.18	0.147	0.17

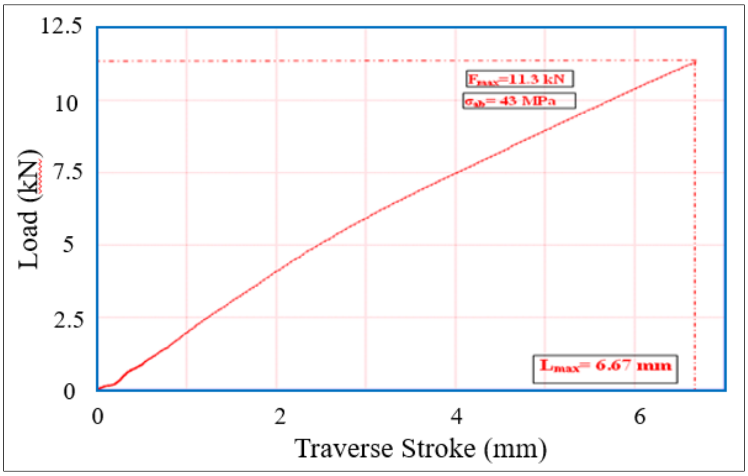

Figure 5. The force-traverse stroke loop for a representative specimen from the BBW series (BBW4)

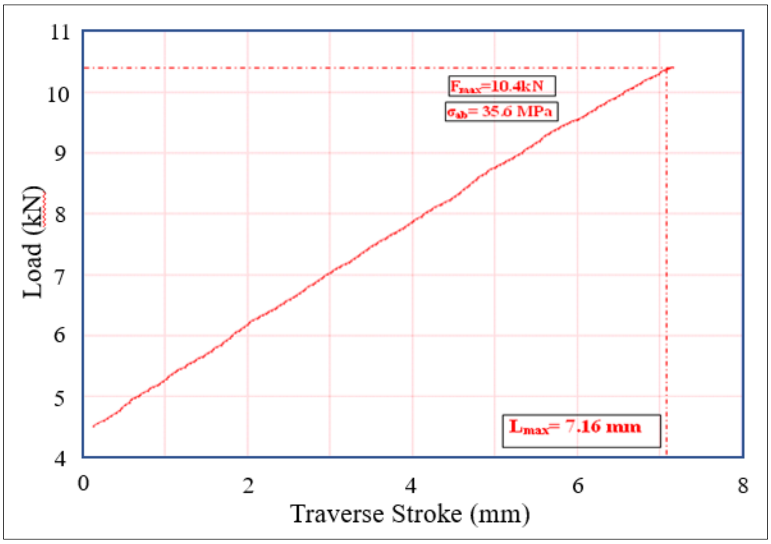

Figure 5. The force-traverse stroke loop for a representative specimen from the BCW series (BCW9)

From the Table 2 results, there cand be seen that the samples with the type B matrix have increased bending properties compared to the ones made from type C.

3.3. Free vibrations results

The vibration recording with the damping factor calculus are presented in Figure 6 for the sample VBW with the 140 mm free length. The vibration recording with the damping factor calculus are presented in Figure 7 for the sample VCW with the 140 mm free length. All the frequency and damping factor results for all the chosen free lengths are written in Table 3.

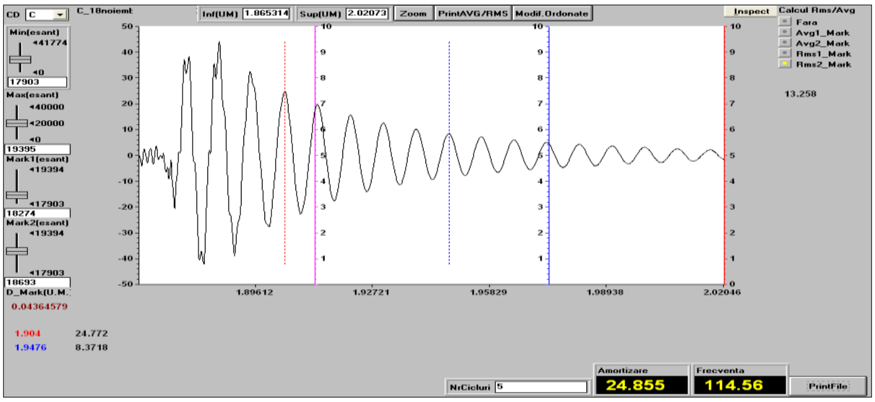

Figure 6. The free vibrations recording with the damping factor calculus for the sample VBW with the 140 mm free length

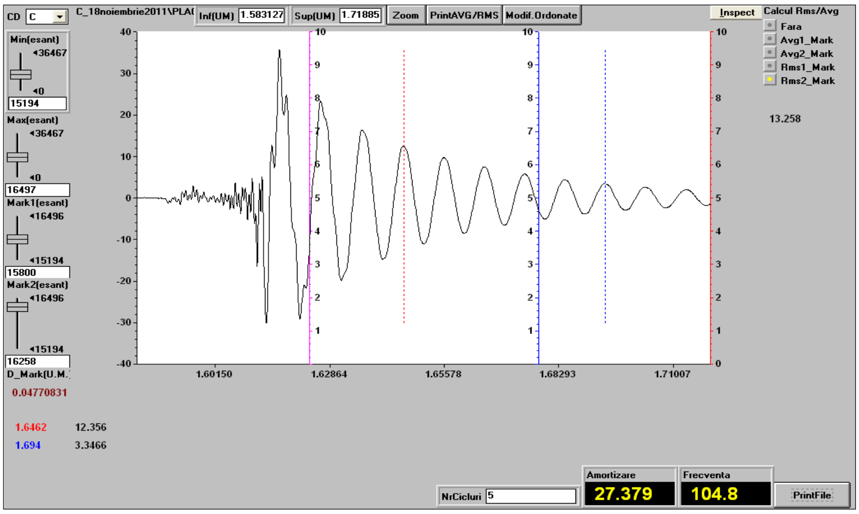

Figure 7. The free vibrations recording with the damping factor calculus for the sample VCW with the 140 mm free length

Table 3. Bending test values for BBW and BCW series

Sample type	Free length (mm)					
	Vibration parameter	100	120	140	160	180
VBW	Frequency	214.5	152.6	115.5	89.7	69.3
VBW	Damping factor	42.7	30.8	24.8	19	15.3
VCW	Frequency	198.8	132.2	104.5	80	57.4
VCW	Damping factor	50.5	38.1	27.3	19.9	17.5

From the Table 3 it can be concluded that the frequency decreases and the damping factor increase with the dammar percentage increase.

4. Conclusions

In this study, sandwich bars are made from poplar strips as reinforcements and the core made by crushed corn cob mixed with two types of hybrid resins used as matrices. The first matrix is a hybrid resin with a combination between dammar 60 and 40% acrylic resin ClaroCit (with its hardener) and the second matrix is also a hybrid resin with a combination between dammar 65 and 35% acrylic resin ClaroCit (with its hardener). This research is a continuation from a previous study where there were obtained quite low mechanical properties for the hybrid resin with the crushed corn cob and it was stated that this combination can be used as a core for manufacturing sandwich materials. So in this research, there is used this kind of core for manufacturing sandwich materials.

From the tensile test results there can be concluded that the mechanical properties decrease with the increase of the dammar resin percentage (lower properties are obtained for the specimens with the matrix from type C resin). This can be explained by the fact that the natural dammar resin has lower properties compared to the acrylic resin and an increase in dammar rate would bring a decrease to the mechanical parameters like breaking strength, Young modulus. An increase of dammar percentage brings elasticity to the samples, so the specimens with type C matrix have a higher expansion at break compared to the samples with type B matrix. The sample conclusions are obtained also for the bending test: lower mechanical properties if type C resin is used compared to type B, but increased displacement at breakage because the dammar resin improves the specimens elasticity.

From the Table 3 where there are written the free vibration results the next idea can be extracted: the samples with type B resin have improved frequency compared to the ones that have type C as a matrix. There is already known, from previous studies [29], that between dynamic rigidity and frequency is a direct proportional relation. So, if the frequency increase, the dynamic rigidity is also increased. The rigidity is the property of materials to oppose to the elastic deformations which means that the increase of synthetic resin decreases the specimens elasticity. Also from the Table 3 there can be observed that the damping factor is higher with the rise of dammar percentage because, as stated above, this increase brings an extension to elasticity.

From the experimental values, there can be concluded that the studied sandwich material can be used for: top or cross rail for chairs; top part of a table; rail, stile or backing for closed closets; top shelves for open closets and so on.

References

1.*** Biomass explained. Available online: https://www.eia.gov/energyexplained/biomass/ (accessed on 16th of February 2023)
2. TAKADA, M., NIU, R., MINAMI, E., SAKA, S., Characterization of three tissue fractions in corn (Zea Mays) cob, *Biomass Bioenergy*, 115, 2018, 130-135.
3.TSAI, W.T., CHANG, C.Y., WANG, S.Y., CHANG, C.F., CHIEN, S.F., SUN, H.F., Cleaner production of carbon adsorbents by utilizing agricultural waste corn cob, *Resour. Conserv. Recycl.*, 32, 2001, 43-53.
4.ANAZODO, U.G.N., NORRIS, E.R., Effects of genetic and cultural practices on the mechanical

properties of corn cobs. *J. Agric. Eng. Res.*, 26, 1981, 97-107.
5.PINTO, J., PAIVA, A., VARUM, H., COSTA, A., CRUZ, D., PEREIRA, S., FERNANDEZ, L., TAVAREZ, P., AGARWAL, J., Corn's cob as a potential ecological thermal insulation material. *Energy Build.*, 43, 2011, 1985-1990.
6.PINTO, J., CRUZ, D., PAIVA, A., PEREIRA, S., TAVAREZ, P., FERNANDEZ, L., VARUM, H., Characterization of corn cob as a possible raw building material, *Constr. Build. Mater.*, 34, 2012, 466-474.
7.ZOU, Y., JUN, F., CHEN, Z., REN, L., The effect of microstructure on mechanical properties of corn cob, *Micron*, 146, 2021, 103070.
8.KIM, S., KIM, S., CHANG, S.J., CHUNG, O., JEONG, S.G., Thermal characteristics of mortar containing hexadecane/xGnP SSPCM and energy storage behaviors of envelopes integrated with enhanced heat storage composites for energy efficient buildings, *Energy Build.*, 70, 2014, 472–479.
9. KHIARI, R., MHENNI, M.F., BELGACEM, M.N., MAURET, E., Chemical composition and pulping of date palm rachis and Posidonia oceanica - a comparison with other wood and non-wood fibre sources, *Bioresour. Technol.*, 101, 2010, 775–780.
10. BINICI, H., AKSOGAN, O., DEMIRHAN, C., Mechanical, thermal and acoustical characterizations of an insulation composite made of bio-based materials, *Sustain. Cities Soc.*, 20, 2016, 17–26.
11.RAMOS, A., BRIGA-S´ A, A., PEREIRA, S., CORREIA, M., PINTO, J., BENTES, I., TEIXEIRA, C.A., Thermal performance and life cycle assessment of corn cob particleboards, *J. Build. Eng.*, 44, 2021, 102998.
12.AKINYEMI, A.B., AFOLAYAN, J.O., OLUWATOBI, E.O., Some properties of composite corn cob and sawdust particle boards, *Constr. Build. Mater.*, 127, 2016, 436-441.
13.LABOREL-PRÉNERON, A., MAGNIONT, C., AUBERT, J.E., Characterization of barley straw, hemp shiv and corn cob as resources for bioaggregate based building materials, *Waste Biomass Valor*, 9, 2018, 1095-1112.
14.WANG, C., WANG, H., OESER, M., MOHD HASAN, M.R., Investigation on the morphological and mineralogical properties of coarse aggregates under VSI crushing operation, *Int. J. Pavement Eng.*, 22, 2021, 1611-1624.
15.VO, L.T.T., NAVARD, P., Treatments of plant biomass for cementitious building materials – a review, *Constr. Build. Mater.*, 121, 2016, 161-176.
16. MWAIKAMBO, L.Y., ANSELL, M.P., Chemical modification of hemp, sisal, jute, and kapok fibers by alkalization, *J. Appl. Polym. Sci.*, 84, 2002, 2222-2234.
17. SHAO, K., DU, Y., ZHOU, F., Feasibility of using treated corn cob aggregates in cement mortars, *Constr. Build. Mater.*, 271, 2021, 1-13.
18. PRATHEEP, V.G., PRIYANKA, E.B., THANGAVEL, S., JASON GOUSANAL, J., BIJOY ANTONY, P.T., KAVIN, E.D., Investigation and analysis of corn cob, coir pith with wood plastic composites, Materials Today: Proceedings, 45, 2021, 549-555.
19.BINICI, H., YUCEGOK, F., AKSOGAN, O., KAPLAN, H., Effect of corncob, wheat straw, and plane leaf ashes as mineral admixtures on concrete durability, J. Mater. Civ. Eng., 20, 2008, 478–483.
20.KAMAU, J., AHMED, A., HIRST, P., KANGWA, J., Permeability of corncob ash, anthill soils and rice husk replaced concrete, *Int. J. Sci. Environ. Technol.*, 6, 2017, 1299–1308.
21.MEMON, S.A., KHAN, M.K., Ash blended cement composites: Eco-friendly and sustainable option for utilization of corncob ash, *J. Clean. Prod.*, 175, 2018, 442–455.
22.ȘERBĂNOU, A.A., GRĂDINARU, C.M., MUNTEAN, R., CIMPOEȘU, N., ȘERBĂNOIU, B.V., Corn Cob Ash versus Sunflower Stalk Ash, Two Sustainable Raw Materials in an Analysis of Their Effects on the Concrete Properties, *Materials*, 15, 2022, 1-17.
23. RĂDOI, A.I., CIUCĂ, I., STĂNESCU, M.M., BOLCU, D., NICOLICESCU, C., MIRIȚOIU, C.M., BOGDAN, M., Studies Regarding Some Mechanical Properties for a Hybrid Resin Used to Build Composites Reinforced with Corn Cob Powder, *Mater. Plast.*, **59**(2), 2022, 24-31.

24.*** Industrial Series HDX Models. Available online: https://www.instron.com/en/products/testing-systems/universal-testing-systems/high-force-universal-testing-systems/static-hydraulic/hdx (accessed on 18th of March 2023)
25. *** ASTM D3039, Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials. Available online: https://www.astm.org/d3039_d3039m-08.html (accessed on 20th of March 2023)
26.*** ASTM D790-17, Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials. Available online: https://www.astm.org/d0790-17.html (accessed on 20th of March 2023)
27.*** LBG Testing Equipment. Available online: https://www.lbgsrl.com/en (accessed on 18th of March 2023)
28. CIUCĂ, I., STĂNESCU, M.M., BOLCU, D., MIRIȚOIU, C.M., RĂDOI, A.I., Study of mechanical properties for composite materials with hybrid matrix based on dammar and natural reinforcers, *Environ. Eng. Manag. J.*, 21, 2015, 21, pp. 299-307
29. MIRIȚOIU, C.M., BURADA, C.O., STĂNESCU, M.M., BOLCU, A., Dynamic and static behaviour of composite sandwich platbands with Kevlar honeycomb core, *Romanian Journal of Materials*, 48, 2018, 101-107.

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