TECHNICAL UNIVERSITY OF CLUJ-NAPOCA

ACTA TECHNICA NAPOCENSIS

Series: Applied Mathematics, Mechanics, and Engineering
Vol. 65, Issue Special II, September, 2022

A STUDY ABOUT SOME COMPOSITES WITH THE MATRIX FROM POLYESTER RESIN AND NATURAL REINFORCEMENTS

Alexandru Ioan RĂDOI, Cosmin Mihai MIRIȚOIU, Dumitru BOLCU, Marius Marinel STĂNESCU, Mihaela BOGDAN, Adriana PĂDEANU

Abstract: *For this study we manufacture some composites made from a synthetic resin which is obtained by the reaction of some dibasic acids and polyhydric alcohols. This resin is called Crystal super transparent and is a polyester type. This resin is combined with some reinforcers: chicken feathers, corn ear leaves and needles from three firs. The composites will be obtained by the lay-on-hands technique. The casting is made at* 20^0 *C. After casting, we obtain some plates with the dimensions identical to an A4 sheet of paper. From the obtained materials we slash some samples for experimental tests (tensile and vibrations). From the tensile experiment we obtain some mechanical properties: the longitudinal modulus of elasticity, the breaking stress at tensile test and breaking elongation. The dynamic behavior of the studied materials will be obtained by free vibration tests. In the end, we make comparisons between the results and we extract the final deductions.*

Key words: *polyester resin, chicken feathers, tree firs, corn ear leaves, tensile test, vibrations.*

1. INTRODUCTION

If the chicken feathers are used as reinforcers in composites building then it is obtained good solution for the getting rid of feather waste and provides extra money for the meat industry [1]. If the chickens are sacrificed for meat, then the feathers usually become junk and their elimination is difficult, being made by burning in fields which pollutes the environment [2].

The possibility of using the chicken feathers as aggregates for concrete building was investigated in [3,4]. Good durability and resistance to chicken feather degradation have been attributed to an extended cross-link and a strong covalent bond in its structure.

Composite materials with a ratio 3/7 between lignosulfonate powder and natural fibers are studied in [5]. There were used as natural fibers the next reinforcers: flax, hemp, straw and jute. There were made some bending tests and its was determined the modulus of elasticity with the value around 7700 MPa and the breaking stress at bending of 24.1 MPa. There are presented other investigations in [6], [7], [8] and [9]. In [9] some mechanical parameters from corn cobs composites combined with glass filaments and a resin made by copolymerization of an epoxide with another compound were determined. There were used some abbreviations for the studied specimens, such as: CGE1 (27.5% corn, 2.5% fiberglass), CGE 2 (25% corn, 5% fiberglass), CGE 3 (22.5% corn, 7.5% fiberglass) and CGE 4 (20 % corn, 10% fiberglass). There are obtained values for the tensile stress at break between 14,5 and 18 MPa and for the longitudinal elasticity modulus between 690 MPa and 900 MPa.

In this research we propose the study of some composites with the matrix from Crystal super transparent resin. Chicken feathers, corn ear leaves and needles from tree firs are used as reinforcers for the proposed composites. The samples will be built by lay-on-hands technique at 20^0C.

2. SAMPLES MANUFACTURING AND EXPERIMENTAL TESTS

We have manufactured some mixtures from the next materials: Crystal super transparent polyester resin with the reinforcers made from chicken feathers, corn ear leaves and needles from tree firs. In order to build a layer for the reinforcer, we have followed the next procedure: on a sheet of cellulose fibers, we put a slim coat of resin and then, side by side, we have lay down the reinforcers. In the figures 1,2 and 3 there is shown a layer with the reinforcers placed side by side on the sheet of cellulose fibers were it was initially applied a slim coat of resin.

Fig. 1. Crystal super transparent resin and chicken feathers/sheet of cellulose fibers layer

Fig. 2. Crystal super transparent resin and needles from tree firs/sheet of cellulose fibers layer

Fig. 3. Crystal super transparent resin and corn ear leaves/sheet of cellulose fibers layer

We have manufactured 10 layers with the procedure described above and, finally, we have casted them together by putting a small coat of Crystal super transparent resin. The final materials had 10 layers after casting with the Crystal super transparent. For all the materials studied in this paper we used an amount of 65% reinforcer and 35% matrix (resin + hardener). We also tried higher amounts for the reinforcers but, in terms of mechanical attributes, we obtained negative results (the values decreased considerably and thus, the materials obtained did not make sense practice usage). In fig. 4 there is an example with the final material obtained from Crystal super transparent resin and needles from tree firs.

Fig. 4. The final material made with Crystal super transparent resin and needles from tree firs/sheet of cellulose fibers layer

2.1 Static experimental results

From the final material obtained after casting, we have slashed some specimens with the next size: 200x25x8 mm. The tensile test is made with the experimental setup from ASTM D3039. 5 samples of each type were slashed and tested. In fig. 5 there are presented the samples obtained, by slashing, from the final material with chicken feather/sheet of cellulose fibers layer. In fig. 6 there is presented the hook's law curve for a representative sample made of chicken feather/ sheet of cellulose fibers and Crystal super transparent resin.

All results obtained from the static tensile experiment are given in table 1, where E is the longitudinal modulus of elasticity, R_m is the tensile strength at the specimen break and A is the breaking elongation.

Fig. 5. The samples from chicken feathers/sheet of cellulose fibers and Crystal super transparent resin for tensile test

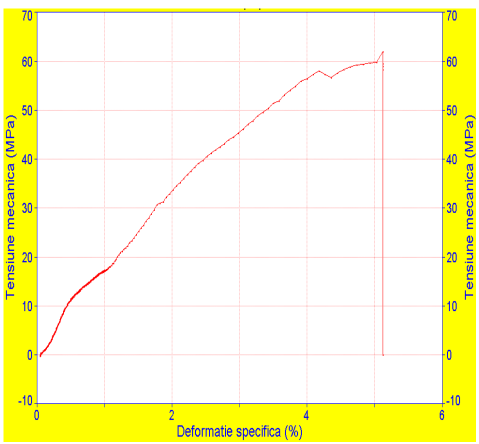

Fig. 6. The hook's law curve for a specimen made of chicken feathers/sheet of cellulose fibers and Crystal super transparent resin

Table 1

Statically experimental results

Samples	E (MPa)	R_m (MPa)	A (%)
Pines/paper+polyester	1266±197	27±7	6.89±2.2
Corn/paper+polyester	2200±175	24±4	5±2
Feather/paper+polyester	3427±130	62±11	5.1±1.7

2.2 Dynamic experimental results

It is studied the materials dynamic behavior by using the next testing setup: the specimens were immovable at one end and left free at the other one where an accelerometer Bruel&Kjaer was placed at about 1 cm from the edge. We have used several free lengths for the samples. . It is used a similar experimental montage in [10].

Like is [10], we have chosen various free lengths for the samples: 100, 120, 140, 160 and 180 mm. A force was initially applied, the force was removed and the specimen was left to freely vibrate. From those vibrations we have calculated the next dynamic variables: rigidity, the longitudinal elastic modulus, the own frequency that corresponds to the first eigenmode, the damping characteristic divided to unit mass, the damping characteristic divided to unit length and the ratio of the average power loss to the peak load loss, during a specified period of time.

According to [10], the damping characteristic divided to unit mass can be determined by following the next procedure:

- the results where the displacement is null are determined;
- the cancellation movement period is determined;
- the own frequency ν, the own pulsation ω and the damping characteristic divided to unit mass μ are determined with (1), (2) and (3).

$$\nu = \frac{1}{T} \tag{1}$$

$$\omega = \frac{2 \cdot \pi}{T} \tag{2}$$

$$\mu = \frac{1}{k \cdot T} \cdot \ln\left(\frac{\psi_i}{\psi_{i+k}}\right) \tag{3}$$

$$EI = 39.478418 \cdot \rho \cdot g \cdot w \cdot \left(\frac{\nu \cdot l^2}{\xi^2}\right)^2 \tag{4}$$

$$E_{dyn} \approx 38.32 \cdot \rho \cdot \left(\frac{l^2 \cdot \nu}{g}\right)^2 \tag{5}$$

$$\eta \approx 0.3183099 \cdot \mu \cdot \nu^{-1} \tag{6}$$

$$C = 2 \cdot \mu \cdot \rho \cdot g \cdot w \tag{7}$$

The equations (1) … (7) present the mechanical characteristics obtained through free vibrations for the investigated specimens by using the Euler-Bernoulli theory. In the relationships (4), (5), (6) and (7), we have denoted the next parameters: ρ the material density, g and w the specimens dimensions that characterize the transversal area (base and height), ξ is a constant that comes from the specimens supporting conditions and has the value of 1.875 for a bar that is immovable at one end and free at the other [10], l is the bar free length. All the experimental results and the dynamic parameters are presented in Table 2.

Table 2

Dynamical experimental results

Sample	**Free length (mm)**	**Damping factor (Ns/m/kg)**	**Eigenfrequency (1/s)**
Feather + polyester	100	36.9636	123
	120	27.598	85.3842
	140	19.9492	62.99416
	160	15.1803	47.96236
	180	9.8451	37.80832
corn+ polyester	100	27.5	68.94
	120	21.7	59.388
	140	19.5	48.193
	160	16.055	37.857
	180	12.106	35.503
pines+ polyester	100	51.175	155.48
	120	39.141	107.87
	140	30.123	91.69
	160	25.65	75.081
	180	19.998	64.171
Density (kg/m^3)	**Specific mass (kg/m)**	**Young modulus (MPa)**	**Dynamic stiffness (Nm^2)**
475	0.095	456	0.459
475	0.095	456	0.459
475	0.095	460	0.463
475	0.095	463	0.466
475	0.095	452	0.455
500	0.1	297	0.315
500	0.1	220	0.234
500	0.1	269	0.285
500	0.1	283	0.3
500	0.1	399	0.423
550	0.11	729	0.849
550	0.11	728	0.848
550	0.11	974	1.135
550	0.11	1115	1.289
550	0.11	1304	1.519

Loss factor	**Damping factor per unit length (Ns/m/m)**
0.096	7.023
0.103	5.244
0.101	3.79
0.1	2.884
0.083	1.871
0.127	5.5
0.116	4.34
0.129	3.9
0.135	3.211
0.109	2.42
0.105	11.258
0.115	8.611
0.105	6.627
0.109	5.643
0.099	4.4

The free vibrations recording for a sample reinforced with chicken feathers and free length of 180 mm is presented in figure 7 with the calculus of damping factor per unit mass.

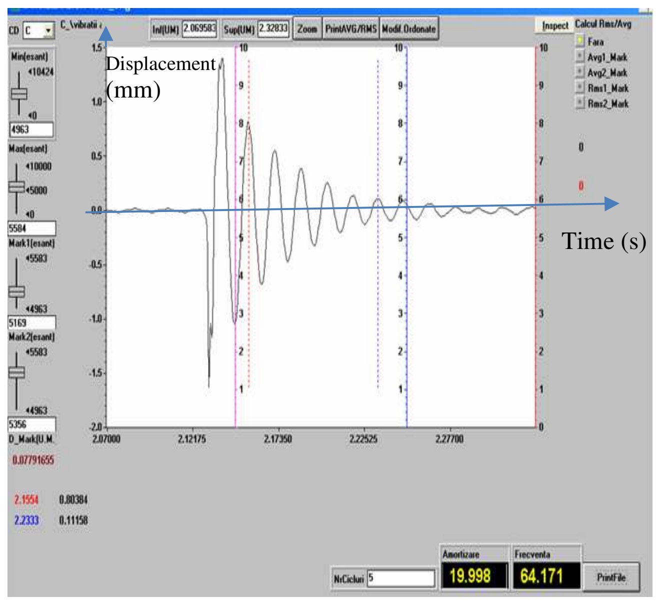

Fig. 7. The damping factor and eigenfrequency calculus of a sample from chicken feathers/ sheet of cellulose fibers and Crystal super transparent resin, free length of 180 mm

3. DISCUSSIONS AND CONCLUSIONS

From the fig. 6 we can see that the hook's graphic has three different stages of behavior: first stage is characterized by the fact that the loading is supported by the reinforcers and the Crystal super transparent resin the, also the Hook law is validated and there is a proportionality between the stresses and strains; the second stage is characteized by a non-linearity in the hook's graphic because the matrix breaks which means that the breaking strength value is obtained in some and the adhesion between the reinforcers and the Crystal super transparent resin is lost; the las stage of the hook's graphic is characterized by a linear tendency which suggest that the strength is took over by the reinforcers and the final breakage appears in the fibers is reached the tensile strength. The highest static mechanical characteristics are obtained for the samples reinforced with chicken feathers/sheet of cellulose fibers.

From the table 2 the next conclusions can be extracted:

- the damping characteristic divided to unit mass and the damping characteristic divided to unit length decrease with the free length quadrate of the tested specimens
- there are differences in the stiffness values for the samples reinforced with pines and corn ear leaves which shows that there are deffects in the samples structures (there are points where the reinforcement layers are not poropoerly connected, which resulted in different stiffness values; the same conclusion can be also extracted from the different values of dynamic Young modulus)
- the best adheshion is obtained for the samples made from chicken feathers, fact that is shown by the appropiate values obtained at the dynamic tests for Young modulus and stiffness
- the own frequency decreases with the free length quadrate of the investigated specimens
- the highest dynamic stiffness value is obtained for the samples refinroced with pines from tree firs/paper.

The damping characteristic divided to unit mass and the damping characteristic divided to unit length analysis show that these parameters must be experimentally determined through free vibrations for each type of specimen because it is very hard to obtain a quantitative correspondence with the factors that affect the damping characteristic directly or indirectly.

Specimens' geometrical values, the specific mass (the multiplication between the transversal area and the material density) or the material quantity from the specimen, elastic and damping characteristics of compound materials can affect the damping characteristic.

This type of composites can be used for: making furniture parts (like doors or shelves for wardrobes), in-house decorations, table tops or cars dashboards.

4. REFERENCES

[1] Choudary, R.B., Voleti, R.S., Boorlagadda, P.A., Bhargava, N.R.M.R., *Characterization of avian feather fibers,* Int. J. Mat. Sci, 4, pp. 433-444, 2009.

[2] Hong, C.K., Wool, R.P., *Development of a bio-based composite material from soybean oil and keratin fibers*, Appl Polym Sci, 95, pp. 1524–1538, 2005.

[3] Gil, P.M., Ruth, G.C., *Chicken feathers as substitute for fine aggregates in concrete*, Mindanao J Sci Tech, 13, pp. 109-131, 2015.

[4] Menandro, N.A., *Waste Chicken Feather as Reinforcement in Cement-Bonded Composites*, Philippine J Sci., 139, pp. 161-166, 2010.

[5] Privas, E., Navard, P., *Preparation, processing and properties of lignosulfonate-flax composite boards*, Carbohydr. Polym, 93, pp. 300–306, 2013.

[6] Panthapulakkal, S., Sain, M., *Agro-residue reinforced high-density polyethylene composites: fiber characterization and analysis of composite properties*, Composites: Part A, 38, pp.1445–1454, 2007.

[7] Luo, H., Xiong, G., Ma, C., Chang, P., Yao, F., Zhu, Y., Zhang, C., Wan, Y., *Mechanical and thermo-mechanical behaviors of sizing-treated corn fiber/polylactide composites*, Polymer Testing, 39, pp. 45–52, 2014.

[8] Panthapulakkal, S., Sain, M., *Agro-residue reinforced high-density polyethylene composites: fiber characterization and analysis of composite properties*, Composites: Part A, 38, pp.1445–1454, 2007.

[9] Garadimani, K.R., Raju, G.U., Kodancha, K.G., *Study on mechanical properties of corn cob particle and E-glass fiber reinforced hybrid polymer composites*, Am. J. Mater. Sci. 5, 3C, pp.86–91, 2015.

[10] Miriţoiu, C.M., Stănescu, M.M., Bolcu, D., *Researches regarding a new hybrid vegetal resin*, Materiale Plastice, 57, pp. 37-45, 2020.

Un studiu despre câteva compozite cu matrice din rășină poliesterică și ranforsanți naturali

Pentru acest studiu noi fabricăm compozite dintr-o rășină sintetică care este obținută din reacția unor acizi dibazici și alcooli polihidroxilici. Această rășină este denumită Cristal super transparentă și este de tip poliesterică. Această rășină se combină cu câțiva ranforsanți: pene de găină, foi de porumb și ace de brad. Compozitele se obțin prin tehnica turnării manuale. Turnarea se realizează la 20^0 C. După turnare obținem niște plăci cu dimensiunile identice cu ale unei hârtii A4. Din materialele obținute debităm câteva epruvete pentru teste experimentale (tracțiune şi vibrații). Din experimental de tracțiune obținem câteva caracteristici mecanice: modulul de elasticitate longitudinal, tensiunea de rupere la testul de tracțiune și alungirea la rupere. Comportamentul dynamic al materialelor studiate se va obține prin test de vibrații libere. În final, facem comparații între rezultate și exprimăm concluziile finale.

RĂDOI Alexandru Ioan, Eng., Phd. student, University of Craiova, Faculty of Mechanics, Dept. of Applied Mechanics and Civil Construction, alexandru.radoi85@gmail.com, Calea București Street, No. 107, Craiova, Dolj, 200512.

MIRIȚOIU Cosmin Mihai, Phd., Junior lecturer, **Corresponding author** University of Craiova, Faculty of Mechanics, Dept. of Applied Mechanics and Civil Construction, miritoiucosmin@yahoo.com, Calea București Street, No. 107, Craiova, Dolj, 200512.

STĂNESCU Marius Marinel, Phd., Professor, University of Craiova, Faculty of Mechanics, Dept. of Applied Mechanics and Civil Construction, mamas1967@gmail.com, Calea București Street, No. 107, Craiova, Dolj, 200512.

BOLCU Dumitru, Phd., Professor, University of Craiova, Faculty of Mechanics, Dept. of Applied Mechanics and Civil Construction, dbolcu@yahoo.com, Calea București Street, No. 107, Craiova, Dolj, 200512.

BOGDAN Mihaela, Eng., Senior lecturer, University of Craiova, Faculty of Mechanics, Bogdan.mihaela123@yahoo.com, Calea București Street, No. 107, Craiova, Dol, 200512.

PĂDEANU Adriana, Eng., Auxiliary Personnel, University of Craiova, Faculty of Mechanics, padeanuadriana2000@yahoo.com, Calea București Street, No. 107, Craiova, Dol, 200512.