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MECHANICAL BEHAVIOR OF FLEXIBLE RECYCLED PVC BIO-LOADED BY 10% CHICKEN FEATHERS

A. Lakhdar *   A. Moumen   Z. Laabid   Kh. Mansouri

Laboratory of SSDIA, Hassan II University of Casablanca, Higher Normal School of Technical Education, Mohammedia, Morocco
lakhdarabdelghani11@gmail.com, moumenaziz1@gmail.com, laabid.zineb@gmail.com, khmansouri@hotmail.com
**. Corresponding Author*

Abstract- The study of the recyclability of a material requires improving its degraded performance after aging, flexible PVC among the most widely used plastics in the world. After its degradation by an artificial aging model, a bio-load in the form of chicken feathers is added to it, trying to restore it to these initial characteristics. In this study, we experimentally and numerically present the effect of adding 10% chicken feathers on the flexible PVC material already aged according to an aging model already presented. The experiments show that the addition of 10% chicken feathers is able to modify the mechanical characteristics of the PVC material. Numerical models of analysis of multidisciplinary systems and phenomena have shown and continue to show their effectiveness, in particular when it comes to predicting the results of experiments for complex studies. The numerical tool used in this study is the finite element model, which, thanks to its precision, makes it possible to correctly predict the behavior of flexible PVC bio-loaded with 10% chicken feathers and to numerically validate the results of experiments. The results show that the mechanical characteristics of bio-loaded PVC were modified by reducing the stiffness and increasing the elongation at break.

Keywords: Flexible PVC, Chicken Feathers, Finite Element Model, Recycling.

1. INTRODUCTION

PVC is one of the most used materials, already ranked second, which generates a significant amount of waste every year. Many reuses of chicken feather waste are used industrially, but they are still insufficient compared to the annual tonnage of waste in the world [6].

Among its uses, there is for example the use of feather waste for the manufacture of shoes as shown in Figure 1, or mixed with waste cardboard to make a composite material in Figure 2 or other uses which are still modest [1, 17].

The recycling of this material is one of the most important necessities, this process has a negative influence on the behavior of this material by degradation of the mechanical characteristics [2-5]. One of the solutions to this problem is the addition of bio-loads during recycling. The bio-load used is the chicken feathers in powder form obtained by a process of collecting, washing, drying and finally grinding [6-7].

Figure 1. Example of a feather composite shoe prototype [1]

Figure 2. Waste chicken feathers and cardboard used as acoustic panel material [7]

The experimental study is carried out by a tensile test to determine the characteristics of the material with and without addition of 10% of the bio-load.

Numerical modeling makes it possible to process physical phenomena by a computer tool thanks to mathematical modeling, which is the art or science of representing a physical reality in abstract models accessible to analysis and calculation. Represented a physical phenomenon by mathematical equations with a development limited to very large orders to try to minimize the differences by approaching reality [8-9].

Numerical simulation is the process which makes it possible to calculate the solutions of these models on a computer and thus to simulate physical reality. the use of simulation is more and more common at the industrial level in order to guarantee the speed and reliability of the design, and to open the field of innovation.

The digital study is progressing rapidly, at the same rate of growth as the power of computers, which allows to give more relevant results.

Numerical simulation is located at three stages of the mechanical systems design process: upstream, to choose a solution, to intermediate to optimize the chosen architecture, and at the end to validate the process.

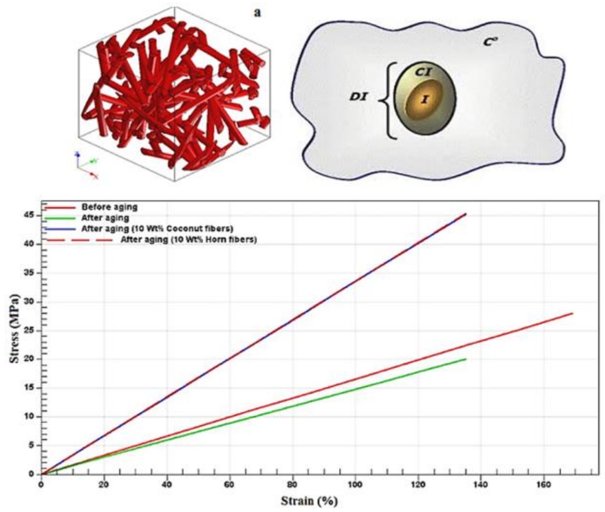

Figure 3. Example of numerical modeling of bio-loaded PVC material [2]

In this article we take the last step of the simulation to numerically validate the effect of adding 10% of chicken feathers on the flexible PVC material already artificially aged, an experimental study has already been made on the addition of three percentages 5, 10, and 15%.

The study in this article serves to validate the solution chosen (the addition of 10% of feathers) which greatly improved the mechanical performance of aged flexible PVC.

2. EXPERIMENTAL STUDY

2.1. Process

Adding chicken feathers (Figure 4) to a material begins by collecting its feathers first. We know that chicken feathers are thrown all over the place in large garbage cans, in slaughterhouses and on other surfaces. They are simply thrown away or cremated [17].

Chicken feathers are first collected washed several times and dried according to a well-defined procedure [9], then crushed in an industrial variable speed crusher to finally obtain a feather powder as shown in Figure 5.

Figure 4. Chicken feathers

The flexible PVC already exposed to artificial aging which has changed its characteristics by reducing the elongation at break and increasing the rigidity, is also crushed in the same mill to obtain a powder.

The two materials are then taken with 90% of the soft PVC powder and 10% of chicken feather powder, everything is well ground to mix well, the next step is to extrude the bio-filled PVC with the percentage of feathers to obtain specimens shown in Figure 6.

Figure 5. Chicken feather powder obtained by the variable speed crusher

Figure 6. Test specimen

The test pieces are then taken for a tensile test in the machine shown in Figure 7, to obtain stress results as a function of the deformation and to interpret them according to the other results obtained by the same procedure on the aged PVC without addition of bio -load and draw the influence of 10% chicken feathers on the mechanical characteristics of flexible PVC and on the recyclability of this material ranked second in the world in terms of use.

Figure 7. Tensile test machine

2.2. Results of the Experimental Study

Tensile tests carried out on bio-loaded PVC with 10% chicken feathers and recycled for the first time show an improvement in the mechanical behavior of the material compared to the unloaded one, there is an improvement in rigidity and elongation at failure, Figure 8 and Table 1 summarize its results

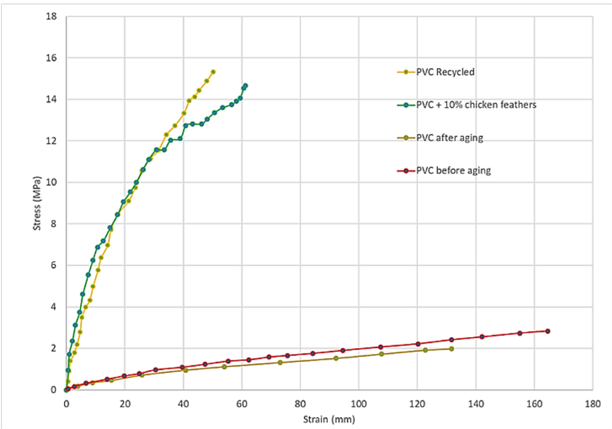

Figure 8. Experimental tensile test results

Table 1. Experimental results

	Stress at break (MPa)	Strain at break (mm)
Flexible PVC before aging	02.83	164.53
Flexible PVC after aging	01.97	131.67
Flexible PVC recycled without bio-loads	15.32	50.23
Flexible PVC bio-loaded with 10% of chicken feathers	14.65	61.25

It can be seen in the results that aging has modified the flexibility of flexible PVC by reducing the elongation at break, the change induced by recycling clearly appears on the modification of rigidity, the material becomes more rigid.

The addition of the bio-load in the form of 10% chicken feathers improved these two characteristics over the results of the recycle without load, it decreased the stiffness and increased the elongation at break.

3. NUMERICAL STUDY BY FINITE ELEMENT METHOD

3.1. Description of the Method

The finite element method is used to numerically solve partial differential equations [8-15]. They can for example see analytically the behavior of some physical systems (mechanical, thermodynamic, acoustic, etc.).

This method is based on a good mesh and the assembly of the subdomains of the material to be treated.

The finite element method (FEM) has shown its efficiency in many cases of calculation of structures. The main stages in the construction of a finite element model are the following:

- Discretization of the continuous medium into subdomains;
- Construction of the nodal approximation by subdomain;
- Calculation of the elementary matrix corresponding to the integral form of the problem;
- Assembly of elementary matrix;
- Taking into account of the boundary conditions;
- Solving the system of equations.

3.2. Geometry

The distribution is chosen at random by the modeling software. Figure 9 shows the 3D distribution of the bio-charge in the PVC matrix while Figures 10, 11 and 12 shows the planar distribution in the three planes.

Figure 13 and Table 2 show the location of the closest distance between the particles of the bio-load in the matrix, with a maximum value of 0.35 mm

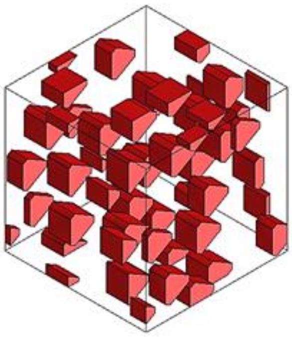

Figure 9. 3D distribution of chicken feathers in the flexible PVC matrix

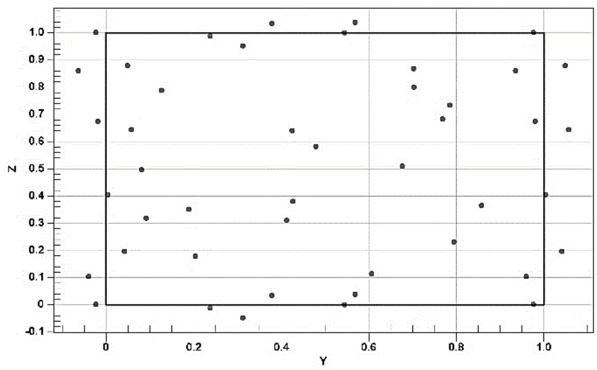

Figure 10. Distribution of the bio-load in the flexible PVC matrix in the plane (Y, Z)

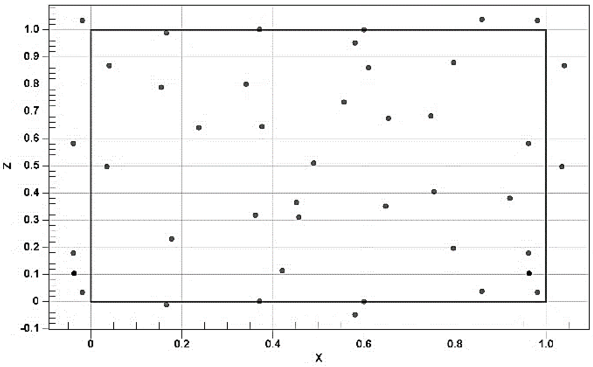

Figure 11. Distribution of the bio-load in the flexible PVC matrix in the plane (Z, X)

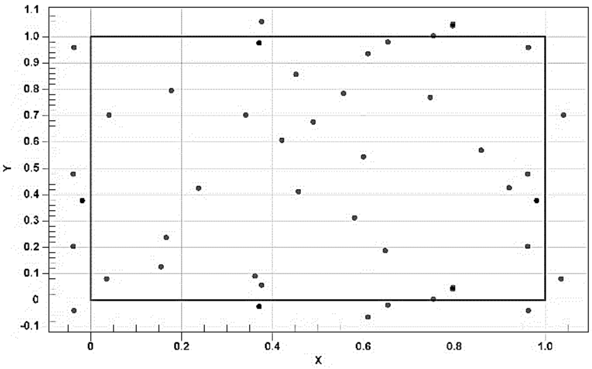

Figure 12. Distribution of the bio-load in the flexible PVC matrix in the plane (X, Y)

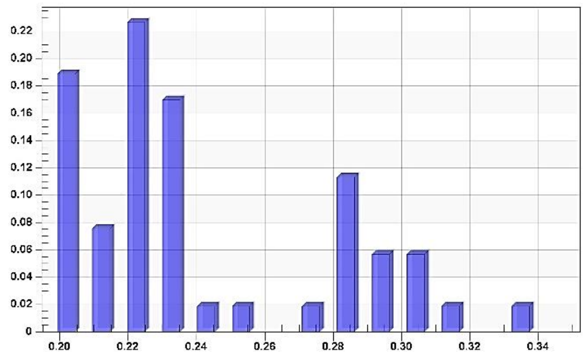

Figure 13. Location of the nearest neighbour distance

Table 2. Position of the chicken feathers fiber in the matrix of the flexible PVC

position	X	Y	Z
Mean	0.477	0.495	0.504
Standard deviation	0.327	0.34	0.352
Minimum	-0.0521	-0.0486	-0.0601
Maximum	1.07	1.05	1.05

3.3. Mesh and Boundary Conditions

Obtaining good results depends on a good mesh. a finer mesh implies a long computation time but very good results, the total number of elements is from 69160 to 108913 nodes, the mesh is represented in Figure 14, and the various mesh parameters are shown in Table 3.

The mesh is used by triangular default in this modelization, with a number of elements determined according to the dimensions of the test specimen used.

The boundary conditions in Figure 15, obtained by fixing one of the end faces and loading the other by a force of about 5.6N distributed over the section of the test specimen.

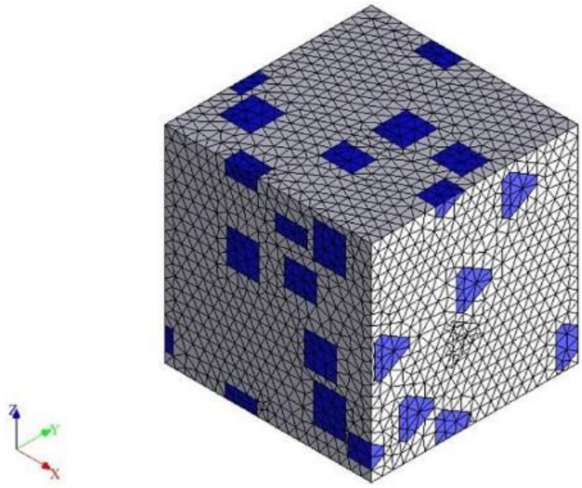

Figure 14. Mesh and boundary conditions

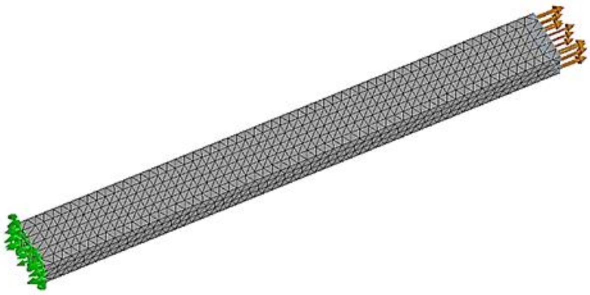

Figure 15. Mesh and boundary conditions

Table 3. Parameters of mesh

	Flexible PVC bio-loaded with 10% of chicken feathers
Elements	69160
Nodes	108913
Size (mm)	0.029181
Min size (mm)	0.0058362

3.4. Bio-Loads and PVC Matrix

The bio-load used in this article is of animal origin which is in most cases incinerated, it is light at a lower cost [16-18].

Since it is difficult to obtain the average mechanical characteristics of this type of bio-load, one carried out assumptions for a numerical modelization, among these assumptions one took that the material is elastic (Figure 16).

The curve of the recycled flexible PVC is obtained by an experimental study [9]. Table 4 summarizes the data of the flexible PVC matrix and the chicken feathers bio-load.

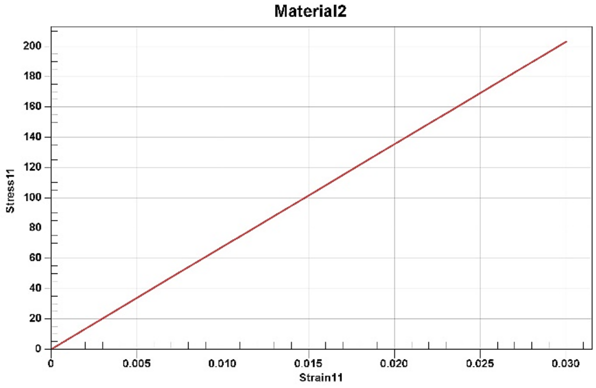

Figure 16. Chicken feathers tensile test curve

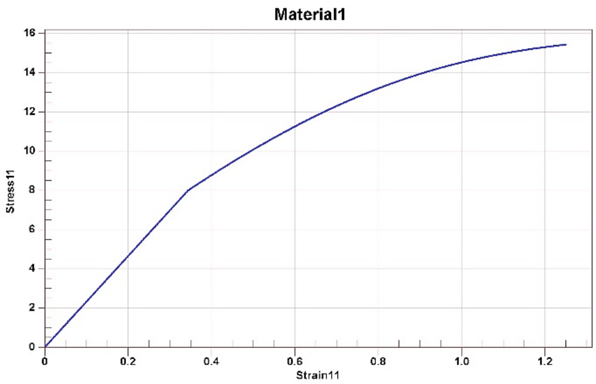

Figure 17. Recycled flexible PVC tensile test curve

Table 4. Numerical properties of Horns fibers in MPa

	Young modulus (MPa)	Stress at break (MPa)
Flexible recycled PVC	23.26	15.32
Chicken feathers	6700	203

4. RESULTS AND DISCUSSION

The modeling software gives us in Table 5 properties of this new composite material, composed of a matrix in the form of flexible PVC and 10% of chicken feathers.

Table 5. mechanical characteristics

	PVC without bio-load	PVC bio-loaded by 10% of chicken feathers
Axial Young's modulus	23.260	28.422
In-plane Young's modulus	23.260	28.422
In-plane Poisson's ratio	0.30000	0.29237
Transverse Poisson's ratio	0.30000	0.29237
In-plane shear modulus	8.9462	10.996
Transverse shear modulus	8.9462	10.996

The most important property is Young's modulus which inform us about the rigidity of this new material to be compared with the rigidity of PVC without bio-load, to test the effect of the addition of 10% of chicken feathers on the already aged flexible PVC matrix.

Figure 18 shows the curves of the tensile test carried out digitally of PVC with and without bio-loading, it can be seen that bio-loaded material has gained in flexibility by increasing elongation at break and a slight increase in rigidity. Therefore, the bio-load to improve mechanical performances of this material especially flexibility.

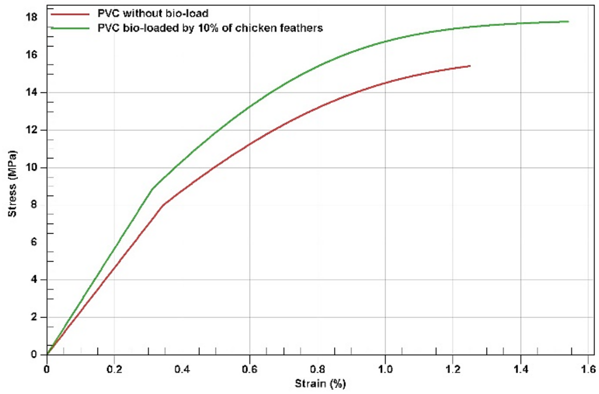

Figure 18. Tensile test curves for PVC with and without chicken feathers

5. CONCLUSION

The study of the literature shows that millions of tons of chicken feathers waste are simply lost in the wild or incinerated, the uses of this bio-load being still modest.

In this article we have tried to add value to this material by injecting it into a recycling process for a widely used plastic material to try both to improve the performance of this type of plastic that is flexible PVC, and also to increase the bio-load.

Due to its availability and depending on the increasing consumption of chickens, chicken feathers are an important material to be valued.

In this article we have added 10% chicken feathers to the flexible PVC matrix in an attempt to improve these characteristics degraded by aging.

The use of 10% chicken feathers on this type of material modified the mechanical characteristics by increasing the flexibility by improving the elongation at break, also with a slight increase in rigidity.

This study carried out on chicken feathers will be compared to another study already published, carried out on flexible PVC loaded with other types of bio-load (cow horns and coconut) to find the most adequate bio-load that allows improve the mechanical performance of this material.

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BIOGRAPHIES

Abdelghani Lakhdar was born in Kelaa of Sraghnas, Morocco in 1981. He is a Ph.D. student at ENSET Institute, University Hassan II Casablanca, Morocco since 2017. His research is focused on contribution to experimental and numerical characterization of bio-based PVC subjected to aging and recycling.

Aziz Moumen was born in Inezgane, Morocco in 1987. He is a Ph.D. student at ENSET Institute, University Hassan II Casablanca, Morocco since 2018. He has the expertise in modeling the mechanical properties of the biomaterials classified as eco composites and obtained by natural bio loading. His focus is based on contributing to solve the demands of production companies in terms of continuous improvement of industrial materials.

Zineb Laabid was born in Mohammedia, Morocco in 1990. She is a Ph.D. student at ENSET Institute, University Hassan II Casablanca, Morocco since 2020. Here research is focused on contribution to the numerical characterization of bio-based polymers by intelligent models.

Khalifa Mansouri was born in Azilal, Morocco in 1968. He is now a teacher of computer science and researcher at ENSET Institute, University Hassan II Casablanca. His research is focused on Real Time Systems, Information Systems, e-Learning Systems, Industrial Systems (Modeling, Optimization, and Numerical Computing). Diploma ENSET Mohammedia in 1991, CEA in 1992 and Ph. D (Calculation and optimization of structures) in 1994 to Mohammed V University in Rabat, HDRin 2010and Ph.D(Computer Science) in 2016to Hassan II University in Casablanca.