SUSTAINABILITY OF ORGANIC MATRIX COMPOSITES WITH MARINE SEDIMENTS. EXPOSURE TO LOW TEMPERATURES

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ABSTRACT

The management of dredged sediments is a general concern due to the quantities produced and their potential harmfulness. Indeed, for example, in France, more than 70% of the volume of dredged sediments are stored without real protection that could give rise to a transfer of pollutants. This is the case of metallic pollutants which, due to changes of physico-chemical conditions for storage, can be solubilized and migrate to the underlying soils. Many studies were therefore conducted to assess the toxicity of these sediments and develop new materials.

The authors have chosen to use marine sediments as mineral filler in a biopolymer matrix based on animal protein. A feasibility study has shown the potential of these materials on the basis of the mechanical performances. However, in order to identify the areas of use of a new material, it is important to study the effect of environmental factors on its mechanical characteristics.

This contribution concerns the exposure of developed materials at negative temperatures. It was found that when exposed to -40 ° C for 24 h, tensile and bending properties are little altered. After cyclic exposures - 20 ° C / + 20 ° C it was observed that in the case of tensile strength, the gap between the materials exposed and unexposed to the variations in temperature decreases as the percentage of sediment increases. The behavior of the Young Modulus is also improved by the presence of sediment. In the case of bending, cycles of temperature decrease significantly the resistance but the effect of the percentage of sediment is little marked. There is little difference in flexural modulus with exposure to the temperature cycles regardless of the percentage of sediment.

It is thus seen that the addition of marine sediments in the biopolymer matrix has a weak influence on the behaviour of the material when exposed to negative temperatures.

Keywords: Marine Sediments, Biopolymer, Negative Temperatures, Mechanical Characteristics

INTRODUCTION

The dredged sediment management is considered as a global problem. Around the world, they are polluted and toxic. Industrial and urban wastes amplify the sediments' contamination. Previous study focuses on the concentrations of heavy metals in Tunisian gulf sediments which are contaminated slightly by Fe ranging from 0.5 to 1.6%, Co (20- 34 ppm) and Ni (39-67 ppm) and they are rich in Pb (56-142 ppm) and Zn (45-150 ppm) [1].

In France, more than 70 % of the volume of the dredged sediments are stored without protection that could give rise to transfer of pollutants. Several studies were conducted to assess the toxicity of these sediments and develop new different materials [2], [3].

In this study, the marine sediments are used as mineral filler in a biopolymer matrix based on animal protein. Previous works show the effect of marine sediments on the mechanical properties of the composite HEMS (Hemoglobin/Marine Sediments) [1], [5], [6]. The addition of marine sediments increases the stiffness, hardness and compressive strength. However, the flexural and tensile strength decrease. But acceptable values are maintained. The composites HESM are intended to be used in environmental conditions, their long term durability and aging behaviors would be prime concern.

The use of fillers in an organic matrix in order to improve the durability of composites has been the subject of a number of scientific works [7]-[11].

The main goal of the present paper is to study the effect of environmental factors (exposure to low temperature - 40°C and cyclic exposure - 20°C/+20°C) on the mechanical properties of the HEMS composites.

MATERIALS AND METHODS

Raw Materials

In this work, the marine sediments (MS) are extracted from Dunkirk Harbour with a bulk density of 2780 kg/m^3 and their particle sizes ranges from 0.08 to 2000 µm.

In this study, a protein of atomized beef blood has been used. This protein is obtained from the French company ''Vapran''(vepro 95 BHF). Its bulk density is 1370 kg/m^3.

The HESM composites were produced by adding various amounts (5 and 15 %) of MS in the organic matrix based on animal protein.

Testing And Characterization

The tensile tests were carried out using a universal testing machine Shimadzu AGX (capacity 10 kN) which is equipped with an extensometer type SSG50-10 Shimadzu. Trapezium software was used for the control of the machine and data acquisition. The tensile tests were performed at a constant cross-head speed of 2mm/min.

Flexural tests were determined by the same machine. The flexural experiments were carried out at a constant cross-head speed of 3 mm/min.

The exposure of HESM composite samples to -40°C for 24 hours, was carried out in a climatic chamber type Binder KBWF720. The samples are then removed, left in the open air for 24 hours and tested in flexural and tensile properties.

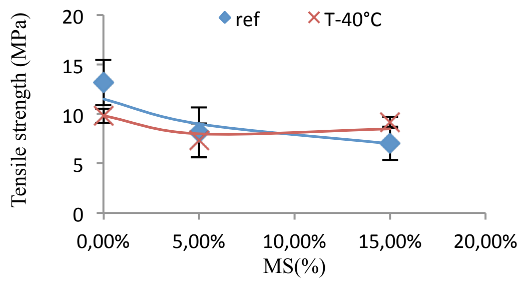
The freeze thaw tests was conducted in a climatic chamber BINDER MK720. The samples were submited to 30 temperature cycles between - 20°C and + 20°C. Each cycle lasts 24 hours. Temperatures range with a speed of rise and fall of 6 °C / h ± 1 °C / h. The samples were then brought to room temperature and their bending and tensile properties were tested.

EXPERIMENTAL RESULTS

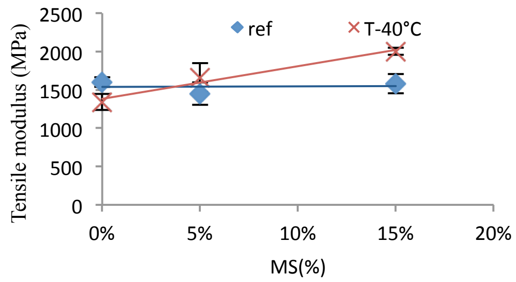
Exposure To Negative Temperatures -40°C

Figures 1 and 2 show the evolution of the tensile and flexure properties of the composite thermally unexposed and exposed at -40°C for 24 hours according to different percentages of marine sediments. It can be noticed that when the composites are exposed to -40°C, tensile and bending properties are little affected. Indeed in the case of the tensile strength, the curves are almost confounded (Fig. 1a).

In the case of the bending strength, until the percentage of addition of 5% MS the Fig. 2a curves show that a slightly decreasing tendency. And the curve of the exposure composite is the same as that of reference composite. From this percentage, the flexure strength greatly decreases compared to the reference sample. Similarly, for the flexure modulus (Fig. 2b), the curves show almost the same gap as that showed in the case of flexure strength.

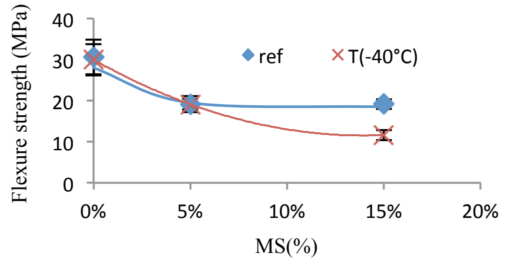


a. Tensile strength

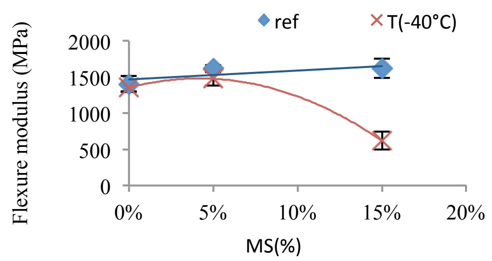


b. Tensile modulus

Fig.1 Tensile properties of the HEMS composites before and after exposure to the temperature (-40 ° C) for 24 h



a. Flexure strength



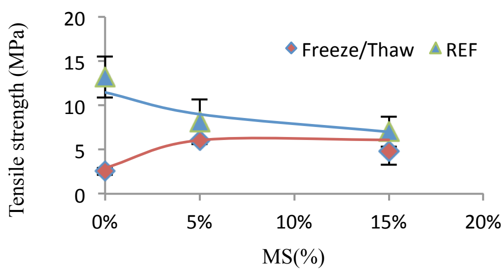
b. Flexure modulus

Fig.2 Flexure properties of the HEMS composites before and after exposure to the temperature (-40 ° C) for 24 h

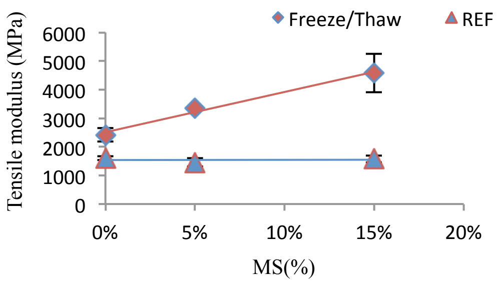
From Fig. 1b, Young's moduli of the samples which have been exposed to low temperature (-40 ° C) are higher than those of non exposed one. Except for the case of pure polymer, the modulus are almost merged. Indeed, when 15% MS is adding into the composite, Young's modulus increases about 27%. According to [10] this is due to the contraction under the effect of the negative temperature, leading to a structure such as stone in which the disentanglements are almost absent.

Exposure To Freeze/Thaw Cycle Test

The influence of thermal cycles freeze/thaw between -20 and +20 °C on the tensile and flexural properties of HEMS composites was illustrated by Fig. 3 and Fig. 4. The exposure to these thermal cycles causes a drop in the tensile strength but the gap between the tensile strength of exposed and unexposed composites decreases as the percentage of marine sediments increases. For example, for HESM0%, the tensile strength greatly decreases to be about 75%, while in the case of HESM15%, the tensile strength just decreases to approximately 31%. This can be explained by the fact that the thermal cycles cause the growth of microcracks, the coalescence of the latter causes their mutual locking in the presence of mineral fillers [12].



a. Tensile strength

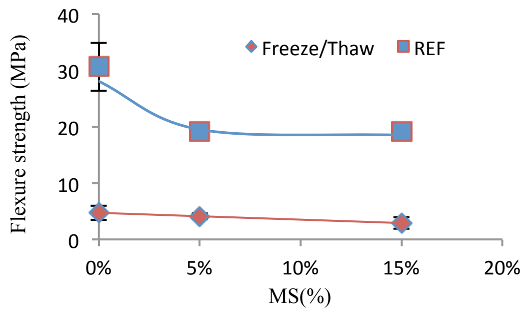


b. Tensile modulus

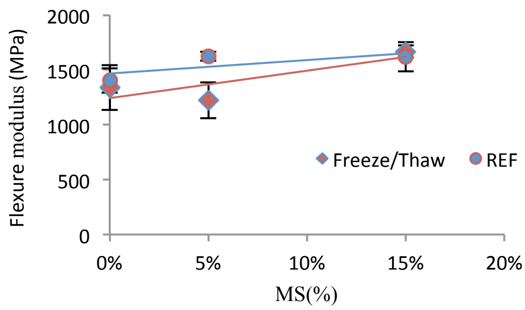
Fig.3 Tensile properties of the HEMS composites before and after exposure to Freeze / thaw cycle test

Therefore, these treatments have the effect of increasing the Young's moduli of the exposed samples compared to those of the unexposed samples. When the percentage of marine sediments increases, the modulus increases.

A low number of cycles as in the case of this study (30 cycles) may therefore improve the mechanical properties such as Young's modulus, based on the hypothesis that the microcracking enhances the redistribution of stresses in the composite [12], [13]. The flexural strength decreases significantly in contrast to flexural moduli. Indeed, when loading in bending, the load distribution is not the same for all layers. The external layers support a higher load, so that they have more influence on the global performance. For specimens tested in the freeze-thaw cycles, the external layers are more exposed to thermal cycles. It thus appears that the outer layers have more influence on the bending strength than the modulus [9].



a. Flexure strength



b. Flexure modulus

Fig. 4 Flexure properties of the HEMS composites before and after exposure to Freeze / thaw cycle test

CONCLUSIONS

In this study, the durability of composites HEMS was investigated under low temperature -40°C and cycling temperatures from -20°C to +20°C.

The obtained results showed that when the HEMS composites were exposed to low temperature -40°C for 24h, tensile and bending properties are little affected.

In addition, the incorporation of marine sediments has a weak influence on the material behaviour. However, in the case of freeze/thaw cycling, for the tensile strength, the gap between the composites exposed and unexposed to the variations in temperature decreases as the percentage of marine sediments increases. The behavior of the tensile modulus is also improved by the presence of marine sediments. Concerning the flexure strength, the latter decrease significantly after the exposure to cycling temperatures but the effect of the percentage of sediment is little marked. In the case of flexure modulus, there is little difference with exposure to temperatures cycling regardless of the percentage of sediments.

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REFERENCES:

[1] Ayed A, Ben Mammou A, Abdeljaoued S, Essoni N and Fernex F, "Caractérisation Géochimique des sedimentsde surface du Golfe de Tunis ", Bull. Inst. Natn. Scien. Tech. Mer de Salammbô, Vol. 30, 2003, pp 135-142.

[2] NgocThanh T, "Valorisation de sédiments marins et fluviaux en technique routière ", PhD Thesis, Artois University, 2009.

[3] Brakni S, "Première Approche vers une valorisation de granulats artificiels à base de sédiments de dragage portuaire : application en génie côtier ", Thesis, Artois University, 2008.

[4] Zarrad I, Jeridi M, Montrelay N, Dheilly RM, Houessou J, Bouaziz J, Queneudec M, Saï K, "Valorization of Marine Sediments in a Proteinic Biopolymer: Modeling of the Mechanical Behavior", J Polym Environ, Vol. 23, 2015, pp. 227-234.

[5] Zarrad I, Montrelay N, Houessou J, Dheilly RM, Bouaziz J, Quéneudec M, "The effect of marine sediments on the mechanical properties and thermal stability of proteinic biopolymer", J.Polymer composites 25 AUG 2015, DOI: 10.1002/pc.23730

[6] Zarrad I, Montrelay N, Houessou J, Bouaziz J, Dheilly RM, Quéneudec M, " Valorization of marine sediments in organic matrix composites: feasibility study", in Proc. 4th Int. Symposium on sediment management, 2014, Ref no 58.

[7] Mohan TP, Kanny K, "Water barrier properties of nanoclay filled sisal fibre reinforced epoxy composites", Compos A Appl Sci Manuf ,vol. 42(4), 2011, pp. 385–93.

[8] Choudalakis G, Gotsis A, " Permeability of polymer/clay nanocomposites: a review", Eur Polymer J, vol.45(4), 2009, pp. 967–84.

[9] Eesaee M, Shojaei A, "Effect of nanoclays on the mechanical properties and durability of novolac phenolic resin/woven glass fiber composite at various environments ", J. of Composites: Part A, vol. 63, 2014, pp. 149-158.

[10] Ray B C, Rathore D, "Durability and integrity studies of environmentally conditioned interfaces in fibrous polymeric composites: critical concepts and comments", J. of Advances in Colloids and Interface Science, vol. 209, 2014, pp. 68-83.

[11] Vlasveld DPN, Daud W, Bersee HEN, Picken SJ, "Continuous fibre composites with a nanocomposite matrix: Improvement of flexural and compressive strength at elevated temperatures", Composites Part A. Applied Science and Manufacturing, vol. 38, 2007, pp. 730–738.

[12] Cormier L, "Effets du froid, de l'humidité et des cycles de gel et dégel sur les propriétés mécaniques des composites verre/époxy utilises pour la fabrication de pales d'éoliennes", Mémoire pour l'obtention de maitrise en génie mécanique. Université de Québec, Ecole de technologie supérieure. Montréal, 2009.

[13] Dutta PK, "Thermo-mechanical behavior of polymer composites. In Advanced multilayered and fibre-reinforced composites", in Proc of the NATO Advanced Research Workshop, 1997, p. 539-55.