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Effect of pre-pressure on compressive behavior of a natural biocomposite

[1]Kaffash, A., [2]Janpoor, J., [3]Safaeian, P., [4 *]Yousefsani, S.A., and [5]Tahani, M.
[1] M.Sc. Student, Department of Mechanical Engineering, Ferdowsi University of Mashhad, Mashhad, Iran
[2]Assistant Professor, Industrial Fungi Biotechnology Department, Research Institute for Industrial Biotechnology, Academic Centre for Education, Culture and Research (ACECR)-Khorasan Razavi Branch, Mashhad, Iran
[3] B.Sc. Student, Department of Mechanical Engineering, Ferdowsi University of Mashhad, Mashhad, Iran
[4] Assistant Professor, Department of Mechanical Engineering, Ferdowsi University of Mashhad, Mashhad, Iran
[5] Professor, Department of Mechanical Engineering, Ferdowsi University of Mashhad, Mashhad, Iran

*(corresponding author: yousefsani@um.ac.ir)

***Abstract*- The unbridled growth of bio-hazardous waste generation is a global environmental challenge that has attracted researchers' attention to the development of new generations of engineered biocompatible and biodegradable materials. Fully natural biocomposites made of wood fibers extracted from agricultural residues and bound together by sustainable growth of fungal network matrix are widely under investigation over the last few years as potential alternatives to synthetic foams. In this study, three cylindrical samples of a mycelium-based biocomposite with identical composition and dimensions but different pre-pressures were fabricated, and their mass-specific compressive properties were studied at different compression levels. This biocomposite material consists of a natural substrate of shredded leaf sheaths of date palm, as the reinforcement fibers, within a network of *Pleurotus*, a fungal mycelium species, as the binding matrix. Results showed that compressive strength varies with pre-loading and ranges from 0.34 to 4.55 MPa, which is comparable with synthetic packaging foams.**

Keywords: Biocomposite; wood fibers; fungal matrix; compressive properties

I. INTRODUCTION

Polymer foams with low density, high specific strength, and good thermal and acoustic insulation properties are interesting synthetic materials for many applications like packaging industries [1]; however, since 1970s the waste generation in packaging industries has become an environmental challenge [2], considering the fact that most synthetic materials are not biodegradable. Mycelium biocomposites (MBCs) have been recently introduced as potential eco-friendly alternatives for polystyrene [3]. Unlike polymer foams, which are fabricated by irreversible synthesis of oil-based materials, these biodegradable composites are fabricated by growth of fungal species within a natural wooden substrate. In this study, for an MBC, made of chopped leaf sheaths of date palm waste as the reinforcement fibers and a growing fungal mycelium species, forming the binding matrix, the physical and compressive properties are studied empirically. Various MBC samples with identical composition but different pre-pressures are fabricated and tested under quasi-static displacement-controlled axial compression, and the effect of pre-pressure on their compressive properties are investigated.

II. MATERIALS AND METHODS

Natural Components

Vegetative form of culinary-medicinal king oyster mushroom (*Pleurotus eryngii*) is capable of spatiotemporal growth in a symbiotic relationship within the natural wooden substrates, and hence, forming a dense matrix that binds the fibers together. It gets the nutrients necessary for growing by decomposition of lignocellulosic compounds from the agricultural crop waste [4]. The wooden fibers obtained by chopping the agricultural wastes from leaf-sheath date palm

are used as the substrate. These natural fibers not only provide sufficient nutrients for mycelium network growth, but also reinforce the fungal matrix under tension and bending [5].

Sample Preparation

Similar cylindrical samples of MBC with the 1:1 diameter-to-height ratio and diameter of 55±0.5 mm were fabricated using the protocol shown in Fig. 1. Briefly, 30% wt (weight percentage) of dry ingredients, including the fibers and wheat bran (to provide additional nutrition) with the relative weight ratio of 1:4, were mixed with 37% wt water in an autoclavable 3-liter polypropylene bags, followed by inoculating 33% wt of mycelium spawn. The mixture was left for incubation under controlled temperature and moisture. After 7 days of growth in a chamber, the mixture was molded into the hollowed PVC tubes and subjected to axial compressive pre-loads of 6, 10, 13, and 15 kg (the sample under 10 kg pre-load was infected and rejected). After 21 days of growth, the samples were heated and completely dried to stop further incubation and prevent the infection (Fig. 1).

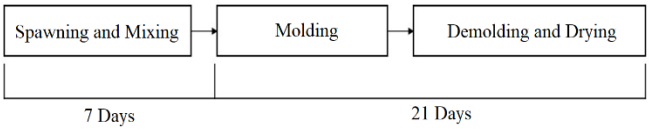

Fig. 1: Preparation protocol

Compression Test

According to the ASTM C165 materials testing standard, the samples were tested under quasi-static displacement-controlled axial compression via Zwick Z250 testing machine with a 5 N preload and crosshead speed of 10 mm/min. The test was terminated at almost 75 percent strain, and the force-displacement data was recorded and the corresponding stress-strain data were calculated.

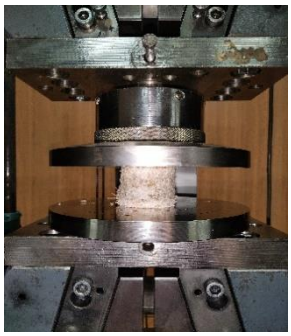

Fig. 2: Compression testing

III. RESULTS AND DISCUSSION

As expected, similar to polymer foams, these MBC samples exhibit no identifiable yield point under compression, so their compressive strength was measured and compared at the 70% strain level. As reported in Table I, the denser the specimen (the one subjected to higher pre-pressure) the higher the specific compressive strength and Young's modulus. Although it can be concluded that increase of pre-pressure can improve the compressive properties, it should be noted that the excessive pre-loading can prevent the mycelium from growing considering the fact that there is no enough oxygen in the overloaded sample, and hence, the MBC fabrication might be entirely disrupted. There seems to be a tradeoff between the fungal growth capability and pre-loading, which needs to be further investigated in future works. Moreover, the compressive strength of the MBC samples with different pre-pressures ranging from 0.34 MPa (at 30% strain – not reported here) to 4.55 MPa (at 70% strain) is comparable to Polystyrene foams, with 0.03–0.69 MPa [6]. It can be seen that MBCs are lightweight, low-cost, eco-friendly fiber-reinforced biocomposites with compressive properties comparable to their synthetic counterparts.

TABLE I: SUMMARY OF COMPRESSIVE PROPERTIES FOR SPECIMENS WITH DIFFERENT PRE-PRESSURES.

Pre-Pressure (kg)	Density (g/cm^3)	Compressive Strength at 70% Strain (kPa)	Specific Compressive Strength at 70% Strain (kPa/g)	Compressive Young Modulus (kPa)
6	0.208	3300	129.2	562.2
13	0.210	4269	158.3	751.7
15	0.213	4549	166.4	789.3

IV. CONCLUSION

In this study, different samples of MBCs with identical composition but different pre-pressures were fabricated and tested under quasi-static displacement-controlled compression in order to study the effect of pre-pressure on their compressive properties. It was shown that the compressive pre-loading can increase the compressive strength and modulus. However, applying excessive pre-pressure may compromise the fungal growth and disrupt MBC fabrication process. It is also concluded that the MBC is comparable to Polystyrene in terms of compressive properties.

REFERENCES

[1]. F. Jin, M. Zhao, M. Park, and S. Park, "Recent Trends of Foaming in Polymer Processing : A Review," pp. 1–24, 2019, doi: 10.3390/polym11060953.

[2]. E. Pongrácz, *The environmental impacts of packaging*, no. November. 2007.

[3]. G. A. Holt, G. McIntyre, D. Flagg, E. Bayer, J. D. Wanjura, and M. G. Pelletier, "Fungal mycelium and cotton plant materials in the manufacture of biodegradable molded packaging material: Evaluation study of select blends of cotton byproducts," *J. Biobased Mater. Bioenergy*, vol. 6, no. 4, pp. 431–439, 2012, doi: 10.1166/jbmb.2012.1241.

[4]. L. Yang, D. Park, and Z. Qin, "Material Function of Mycelium-Based Bio-Composite: A Review," *Front. Mater.*, vol. 8, no. September, pp. 1–17, 2021, doi: 10.3389/fmats.2021.737377.

[5]. W. Ghori, N. Saba, M. Jawaid, and M. Asim, "A review on date palm (phoenix dactylifera) fibers and its polymer composites," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 368, no. 1, 2018, doi: 10.1088/1757-899X/368/1/012009.

[6]. M. Jones, A. Mautner, S. Luenco, A. Bismarck, and S. John, "Engineered mycelium composite construction materials from fungal biorefineries: A critical review," *Mater. Des.*, vol. 187, 2020, doi: 10.1016/j.matdes.2019.108397.