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# Investigation of some mechanical properties of composite materials made of LDPE and bamboo at two different rates

## Bambu ve LDPE'den üretilmiş kompozit malzemelerin bazı mekanik özelliklerinin incelenmesi

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### Abstract

In this study, some mechanical properties of wood-plastic composite material produced from bamboo (Bambusoideae) were investigated. Wood-plastic composite materials were produced by mixing Low Density Polyethylene (LDPE) material and bamboo fibers at the rates of 5% and 10%. The produced wood-composite samples were subjected to tensile strength and bending strength tests and the results were examined. The results showed that the tensile strength decreased by 6% as the bamboo ratio increased from 5% to 10%. In addition, increasing the bamboo ratio from 5% to 10% increased the average bending strength of each test group by 44.75%.

***Keywords***: Bamboo, Fiber, LDPE, Wood-plastic composite.

### Öz

Bu çalışmada, bambu liflerinden üretilen ahşap-plastik kompozit malzemenin bazı mekanik özellikleri araştırılmıştır. LDPE malzeme ile bambu liflerinin %5 ve %10 oranlarında karıştırılmasıyla ahşap plastik kompozit malzemeler üretilmiştir. Üretilen ahşap-kompozit örnekler çekme mukavemeti ve eğilme mukavemeti testlerine tabi tutulmuş ve sonuçları incelenmiştir. Sonuçlar, bambu oranı %5'ten %10'a yükseldikçe çekme mukavemeti % 6 oranında azaldığı göstermiştir. Ayrıca, bambu oranının %5'ten %10'a yükseltilmesi, her bir test grubunun ortalama eğilme mukavemetini % 44,75 oranında artırmıştır.

***Anahtar Kelimeler***: Bambu, Lif, LDPE, Ahşap-plastik kompozit.

## 1. Introduction

Wood composites are divided into two main classes: thermoset glues and wood composites produced with materials such as thermoplastic and cement. Wood material and thermoset glues are used in the production of thermoset based wood composites. Joining under heat is achieved with the press. Thermoplastic based wood composites contain wood material and plastics such as polyethylene (PE), polypropylene (PP) and polyvinyl chloride (PVC). Materials called Wood Plastic Composites (WPC) are produced with a mixture of wood flour and thermoplastic-based polymers (Tufan et al., 2015).

WPCs took roles in many industry areas due to their superior properties such as resistance to moisture, good dimensional stability, use of waste materials in production, color and size adjustment, and resistance to fungi and insects. It has become one of the fastest growing areas, especially in the forest products sector (Tufan et al., 2015).

WPC refers to materials formed by combining two or more materials with different adhesives. Wood composites, on the other hand, refer to materials obtained by combining wood material with another wood material or other material using adhesives. Composites refer not only to panel products but also to molded products formed by a combination of wood and other materials. These products range widely from fiberboard to laminated materials (Güller, 2001).

The concept of WPC describes a wide range of materials, from PE to PVC as a polymer and from wood flour to natural fibers as filler. In the last twenty years, the popularity of WPCs has increased, and they are used in many areas of use in our daily life, such as flooring, automotive panels, fences, garden furniture, camellia, hiking trail, exterior cladding, frames, etc. started to take place. Mostly, waste wood dust generated in the forest products industry is used as a filling material in the production of WPCs (Ozmen et al., 2014).

WPCs refer to composites containing wood in any form and thermosets or thermoplastics. Of these, thermoset plastics, when hardened, do not soften by reheating. Examples are epoxy and phenolic resins, which are well known in the forest products industry. Thermoplastics can soften again when heated. Examples of these are PE and PVC. Thermoplastics are used in many different commercial products such as milk cartons, grocery bags and siding (Clemons, 2002).

Due to their superior properties compared to plastic and wood, WPCs have started to find wide usage areas all over the world. The important advantages are having low cost compared to plastic, being easily degradable in nature and having less polluting effects on the environment, having better dimensional stability compared to wood material, produced in the desired size and shape, in different colors, being resistant to fungi and insects, and being produced from recycled materials (Suinanç, 2007).

Tufan et al. (2015) investigated the effects of different polymers, high density polyethylene (HDPE) and polypropylene (PP) on some physical, mechanical and thermal properties in WPCs samples. They provide these materials from disposable cups and recycled polymers. Results showed that using these materials did not negatively affect physical, mechanical and thermal properties in WPCs samples.

Kouhi et al. (2021) studied combining bamboo fiber with LDPE by adding some agents as composite materials and analyzed some of their mechanical properties. Results indicated that flexural properties of composites were improved by adding a coupling agent to the combination of bamboo fiber and LPDE.

Bamboo grows in tropical climates, reaches maturity in a short period of 3-4 years and is used in many fields such as paper, furniture, construction, food, and chemical industry (Okur, 2006).

LDPE is the most common polymer material for some industry fields. Therefore, an urgent solution is needed to reintegrate it into high volume production. The reinforcement of recycled LDPE with natural fibers such as bamboo provides a solution for the re-use of the recycled LDPE (Kouhi et al., 2021)

LDPE is branched polyethylene and easily obtained. It is inexpensive because it does not require special conditions. It is very difficult for very large polymer molecules to come together physically in a certain order, to take place in a certain lattice to crystallize (Kılıçkalkan, 2012).

LDPE is a milky white, opaque, waxy-like material, slightly harder than PVC, hazy as a film, and can be transparent if very thin. LDPE is a chemical and corrosion resistant plastic. No solvent dissolves at ordinary temperature, but swells in hot solvents such as benzene and carbon tetrachloride (Kılıçkalkan, 2012).

The aim of this study is to see the effects of different amounts of bamboo fibers on the bending and tensile strength of WPC produced from LDPE and bamboo. Therefore, 5% and 10% bamboo fibers were mixed with LPDE in an extruder. The prepared specimens in an injection machine were tested and the results were evaluated.

## 2. Material and Method

### 2.1. Materyal

In this study, the tensile and bending strength properties of composite materials produced with bamboo (Bambusoideae) and LDPE materials were investigated. Therefore, the materials used in this study are as follows.

#### 2.1.1. Bamboo

In this study, bamboo material with an average length of 200 cm and an average diameter of 12 cm, which was obtained from the crop field of the Faculty of Forestry at Karadeniz Technical University, was used in 5 % and 10 % of the composite mixture. Figure 1 shows the bamboo plant used in this study.

Figure 1. The bamboo plant used in this study
Şekil 1. Bu çalışma kapsamında kullanılan bambu bitkisi

#### 2.1.2. Low-Density Polyethylene (LDPE)

In this study, LDPE material was used to mix with bamboo fibers. LDPE is a flexible type of polyethylene with a density of 0.85-0.90 g/cm$^3$. Since the molecular structure is in a branched form, the crystallization rate is relatively low. Its melting point is around 110°C (Uzun, 2017).

### 2.2. Method

In the production of bamboo-LDPE composite material produced for this study, the bamboo plants were prepared for chipping and they were chipped with the help of a coarse chipping machine. Figure 2 shows the coarse chipping machine.

Figure 2. Coarse chipper
Şekil 2. Kaba yongalama makinesi

With the help of the coarse chipping machine, bamboo straws are formed into smaller sized chips. The chips are shown in Figure 3.

Figure 3. Coarse bamboo chip
Şekil 3. Kaba bambu yongası

The bamboos, which were reduced to chip size, were then separated into their fibers with the help of a disc refiner. The knives used in the refinery are shown in Figure 4 and the refinery machine in Figure 5.

During the fibering process in the refinery, flaking was facilitated by adding water along with bamboo chips from the chip inlet. The reason for adding water is that water penetrates into the spaces of bamboo chips. In this way, it prevents the chips from fibering more easily between the refiner discs and the fibers from being damaged during the fibering process. After the fibering process, the bamboo fibers obtained were purified from excess water and dried by lying. This drying process at room temperature took approximately two weeks.

Figure 4. Refiner blade
Şekil 4. Rafinör bıçağı

Figure 5. Refiner machine
Şekil 5. Rafinör makinesi

The purpose of this drying process is to dry the fibers for two weeks at room temperature in order to eliminate defects such as cracking and torsion by causing a shock effect on the fibers in the case of drying in the drying oven due to the high humidity of the fibers. After this process, the fibers are prepared to be put into the drying oven. The humidity of the bamboo fibers was reduced to 5% by drying the prepared bamboo fibers in the drying oven at 100 degrees for 45 minutes.

After this drying process, the dried bamboo fibers were classified into 1 mesh, 1.5 mesh and 3 mesh sizes with the help of a vibrating sieve. Figure 6 shows the smallest bamboo fibers coming out of the vibrating screen.

Figure 6. Bamboo fibers in 1 mesh size coming out of the vibrating sieve
Şekil 6. Sarsak elekten çıkan 1 mesh boyutundaki bambu lifleri

The bamboo fibers remaining on the 3 mesh sieve were ground with the help of the mill until they were turned into powder again. After these processes, 5% and 10% bamboo fiber and LDPE were proportioned in the extrusion machine and combined with the help of high temperature. Figure 7 shows the extruder.

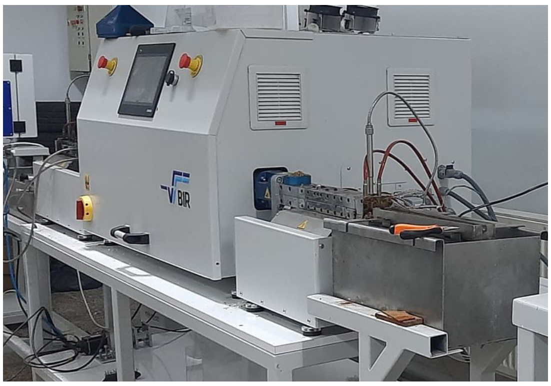

Figure 7. Extruder
Şekil 7. Ektrüzyon makinesi

The product taken from the outlet was dipped into the cold water pool and directed to the crusher. Figure 8 shows the granulation of the product coming out of the cold water pool with the help of a crusher.


Figure 8. Crusher machine
Şekil 8. Kırıcı makinesi

Here, the product, which is produced in a long and single piece with the help of a crusher, is turned into granules and made ready for use in the injection machine. The granules coming out of the crusher are shown in Figure 9.

Figure 9. Bamboo-LDPE mix granules
Şekil 9. Bambu-LDPE karışımı granülleri

The final products were obtained by remelting the granulated product with the help of heat in the injection machine, whose working principle is similar to the extrusion machine, and pressing it into the mold. The injection machine is shown in Figure 10.

Figure 10. Injection machine
Şekil 10. Enjeksiyon makinesi

### 2.2.1.Bending Test

A total of eight test samples were prepared for the 5% and 10% bamboo fiber reinforced LDPE composite material for the bending test, and a test specimen with the size of 80×10×5 mm is shown in Figure 11. Composite test specimens obtained from bamboo-LPDE mixture were subjected to bending test in MTS Universal Testing Machine under 25 mm/min loading speed based on ASTM D-790-17 standard. Figure 12 shows the loading of the bending test.

Figure 11: LDPE bamboo composite test sample with different percentage values prepared for bending test.
Şekil 11: Eğilme testi için hazırlanmış LDPE bambu kompozit test örneği

### 2.2.2. Tensile Test

A total of eight specimens were prepared for the 5% and 10% bamboo fiber reinforced LDPE composite material prepared for the tensile test, and a typical specimen with the size of 115×25×5 mm is shown in Figure 13.

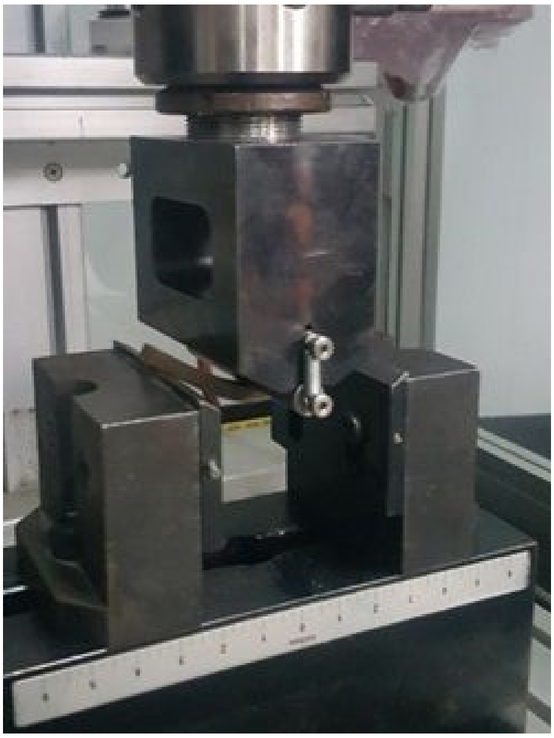

Figure 12. Bending test of bamboo-LPDE composite material under a certain load.
Şekil 12. Bambu-LPDE kompozit malzemesinin belirli bir yük altında eğilme testine tabi tutulması

Figure 13: LDPE bamboo composite test sample with different percentages prepared for tensile testing
Figure 13: Çekme testi için hazırlanmış LDPE bambu kompozit test örneği

Composite test specimens obtained from bamboo-LPDE mixture were subjected to tensile test in MTS Universal Testing Machine under 25 mm/min loading speed based on ASTM D-638-14 Standard. During loading, an extensometer was mounted on the sample and the amount of elongation was measured. Figure 14 shows the loading of the tensile test.

## 3. Results and Discussions

### 3.1. Bending Test

The curves in Figure 15 show typical load-displacement curves of 5% and 10% bamboo added LDPE composite materials as a result of the bending test.

Figure 14. Tensile testing of bamboo-LPDE composite material with the aid of an extensometer under a certain load
Şekil 14. Bambu-LPDE kompozit malzemesinin belirli bir yük altında ekstansometre yardımıyla çekme testine tabi tutulması

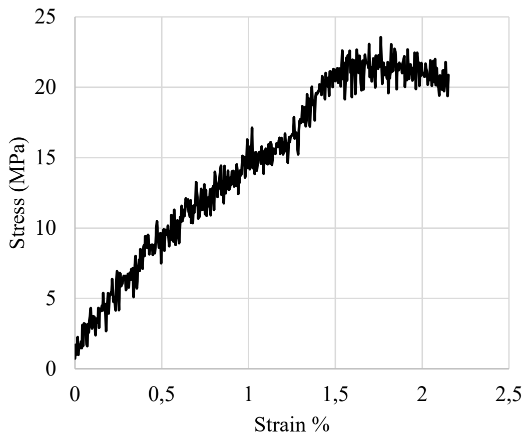


Figure 15a) Typical load-displacement curve for 5% bamboo reinforced LDPE composite materials.
Şekil 15a) %5, bambu katkılı LDPE kompozit malzemelere ait tipik yük-yer değiştirme eğrisi.

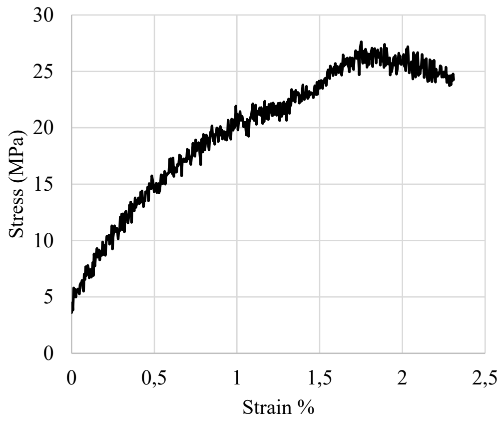


Figure 15 b) Typical load-displacement curve for 10% bamboo reinforced LDPE composite materials.
Şekil b) %10, bambu katkılı LDPE kompozit malzemelere ait tipik yük-yer değiştirme eğrisi.

The samples prepared for the bending test were subjected to the bending test with 4 repetitions for each percentage value under the ASTM D-790-17 standard, and the results with the average of the values belonging to each percentile group are given in Table 1.

Table 1. Average values of 5% and 10% bamboo added LDPE composite materials.
Tablo 1. %5 ve %10 bambu katkılı LDPE kompozit malzemelerine ait ortalama değerler.

| | Bamboo Rate (%) | Bending Strenght Maximum Load (N) |
|---|---|---|
| Test Specimen | 5 | 22,39 |
| | 10 | 32,41 |

As can be seen from the bending test results, it was observed that the average bending strength values of the composite materials increased as the bamboo ratio increased from 5% to 10% in LDPE composite materials. Likewise, Ozmen et al. (2014) observed that the bending strength values of composite materials produced by combining Polypyrene material and MDF wastes increase to a certain extent when the MDF waste ratio is increased from 10% to 40%. At this point, this study is consistent with the literature.

### 3.2. Tensile Test

The curves in Figure 16 show typical load-displacement curves for LDPE composite materials with 5% and 10% bamboo additives as a result of tensile testing.

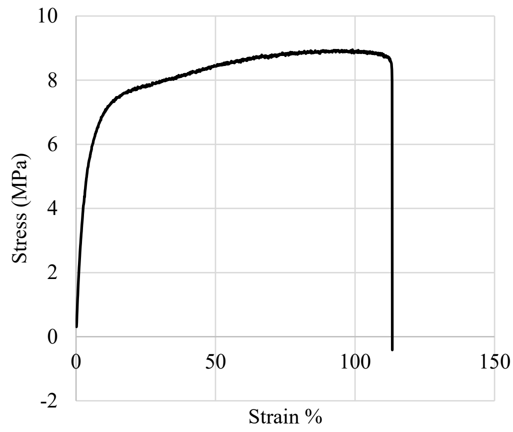


Figure 16a) Typical stress-strain (load-displacement) curve of 5% bamboo reinforced LDPE composite materials obtained as a result of the tensile test.
Şekil 16a) Çekme testi sonucu elde edilmiş % 5, bambu katkılı LDPE kompozit malzemelere ait tipik yük-yer değiştirme eğrisi.

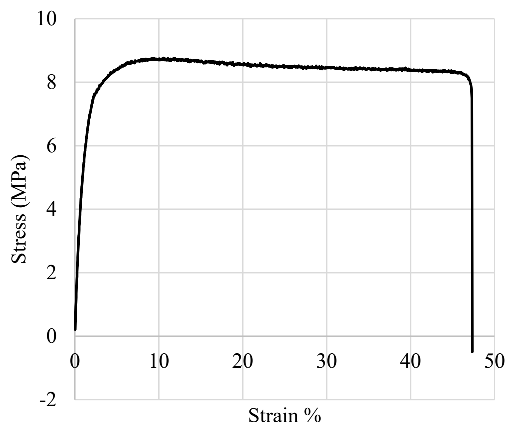


Figure 16b)Typical stress-strain (load-displacement) curve of 10% bamboo reinforced LDPE composite materials obtained as a result of the tensile test.
Şekil 16b) Çekme testi sonucu elde edilmiş %10, bambu katkılı LDPE kompozit malzemelere ait tipik yük-yer değiştirme eğrisi.

The samples prepared for the tensile test were subjected to bending test with 4 repetitions for each percentage value under ASTM D-638-14 standard, and the results with the average of the values belonging to each percentile group are given in Table 2.

Table 2. Average values of 5% and 10% bamboo added LDPE composite materials
Tablo 2. %5, %10 bambu katkılı LDPE kompozit malzemelerine ait ortalama değerler

| | Bamboo Rate (%) | Tensile Strenght Maximum Load (N) |
|---|---|---|
| Test Specimen | 5 | 9,05 |
| | 10 | 8,48 |

As can be seen from the tensile test results, it was observed that the tensile strength values of the composite materials decreased when the bamboo ratio in composite materials was increased from 5% to 10%. Likewise, Delgado et al. (2012) observed that the tensile strength of the composite materials they produced from LDPE and bamboo flour decreased as the amount of bamboo increased. Likewise, Ozmen et al. (2014) found that the tensile strength values of the test specimens obtained by adding fiberboard wastes to the production of WPCs decreased as the fiberboard waste participation rate increased. This may be due to the deterioration of the compatibility of the bamboo and LDPE matrix in the composite material, and therefore, the increase in porosity leads to a decrease in tensile strength. Robledo Ortiz et al. (2020) investigated that the tensile strength of short natural fiber-filled composites was decreased because of the compatibility between fiber and matrix which leads to higher porosity content.

## 4. Conclusions

In this study, the bending and tensile strength values of composite materials obtained by adding 5% and 10% bamboo fibers to LPDE material were investigated. The results showed that the addition of 5% to 10% bamboo fiber to the composite material increased the bending strength values on average. On the other hand, increasing the bamboo fiber ratios from 5% to 10% decreased the tensile strength. An impact test can also be done as a suggestion to increase the scope of this study.


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