

# Parameters Affecting Sound Absorption in Fiber Composites: A Case Study for *Luffa Cylindrica*\*

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## Özet

Gürültü kirliliğinin insan sağlığına olan olumsuz etkileri tüm dünyanın dikkate aldığı bir problem haline gelmiştir. Çeşitli psikolojik ve fizyolojik rahatsızlıklara sebep olan istenmeyen gürültünün kontrol altına alınmasına yönelik pek çok çalışma yapılmaktadır. Bu bağlamda işitme bozukluğu, dinlenme ve uyku bozukluğu, psikofizyolojik ve zihinsel sağlık problemleri gibi insan sağlığını ciddi anlamda tehdit eden gürültü kirliliğini kontrol altına alabilmek için akustik malzemelerin üretilmesine olan ihtiyaç da artmıştır. Ülkemizde 'Binaların Gürültüye Karşı Korunması Hakkında Yönetmelik' 30082 sayılı Resmi Gazete'de 2017 yılında yayınlanmıştır. Bu yönetmeliğin amacı, her türlü yapı için insanların maruz kalacağı gürültü düzeyinin kişilerin beden ve ruh sağlığına etki etmeyecek şekilde uygun koşulların oluşturulmasıdır. Seddeq (2009), gürültüyü kontrol altına almak ve akustik açıdan istenen bir ortam yaratmak için farklı malzemeler ve çeşitli teknikler kullanıldığını ve bu tekniklerden bir tanesinin de sesin yutulması olduğunu söylemiştir. Ses dalgasının geldiği yüzeydeki malzemenin fiziksel özelliklerine göre enerjinin değişen miktarında farklılıklar olur. Bu nedenle yüzeylerde kullanılan bitirme malzemeleri özelliklerine göre sesin kontrol edilmesinde ve istenmeyen sesin yutulmasında kullanılır. Sesin yutulması için kullanılan malzemeler genellikle lifler, köpükler, delikli paneller, zarlar, rezonatörler ve farklı kompozit malzemeler olarak sıralanabilir. Nor ve diğ. (2004) özellikle inşaat sektöründe tercih edilen ses yutucu malzemelerin cam veya mineral yünü malzemeler olduğunu belirtmişlerdir. Ayrıca Nor ve diğ. (2004) bu malzemelerin ticari pazardaki hakimiyetleri sebebiyle alternatif malzemelerin üretiminin nispeten zayıf kaldığını da eklemiştir. Ancak son yıllarda duvar veya panel içerisinde kullanılan cam ve mineral yünü malzemelerin özellikle uygulama sırasında akciğer problemleri, göz problemleri gibi işçi sağlığına olan olumsuz etkileri sebebiyle farklı malzemelere yönelim başlamıştır. Biswal (2016), araştırmacıların özellikle lifli kompozit malzemelerde daha iyi mekanik özellikler göstermesi, daha kolay elde edilebilmesi ve daha ucuz olmaları sebebiyle sentetik lifler yerine organik liflere yöneldiğini söylemiştir. Organik liflerin akustik malzeme olarak kullanım avantajı; maliyetinin daha düşük olması, kolaylıkla elde edilebilir olması, yenilenebilir ve aşınmaya dayanıklı olması, uygulama kolaylığı ve uygulama ve kullanım sırasında insan sağlığını tehdit etmiyor oluşudur.

Gürültünün insan sağlığına olan tehditinin yarattığı sorun ve bu soruna çözüm ararken kullanılan ses yutucu malzemelerin de farklı bir açıdan sağlığını tehdit etmesi problemleri tespit edilmesi üzerine bu çalışmanın çıkış noktası 'İnsan sağlığını tehdit etmeyen, kolay ulaşılabilir malzemeler kullanarak bir ses yutucu bitirme malzemesi üretmek mümkün müdür?' olmuştur. Çalışmanın amacı, doğal lifler kullanarak üretilecek çevre dostu kompozit bitirme malzemesi ile sesin yutulmasını sağlamak ve yutuculuk performansı gerektiren mekanlarda bu malzemenin kullanılmasını sağlamaktır. Bunun için öncelikli olarak doğal lifler ile oluşturulan kompozit malzemelerle yapılan çalışmalar incelenmiştir. Bu çalışmalarda sesin yutulmasını etkileyen parametreler tespit edilmiştir. Literatür taraması çalışma içinde kullanılacak bitki lifinin belirlenmesinde ve süreçteki yöntemlere karar verilmesinde yardımcı olmuştur. Çalışma kapsamında doğal bir malzeme olan su kabağı (*Luffa Cylindrica*) lifleri, bağlayıcı bir termoset malzeme olan epoksi ile bir araya getirilerek kompozit bir malzeme üretilmiştir. Daha sonra, belirlenen parametrelere göre elde edilen kompozit malzeme örnekleri incelenmiş ve ses yutma performansına yönelik sonuçlar değerlendirilmiştir. Empedans tüpü kullanılarak malzemelerin ses yutma performansının ölçüldüğü çalışmada; malzeme kalınlığı ve liflerin kompozit içerisinde kullanım formunun ses yutma üzerindeki etkileri ayrı ayrı incelenmiştir. Ayrıca, özellikle yüksek frekanslarda iyileştirme ya da çınlama kontrolü

gereken mekanlarda Ses Azaltım Katsayısı (NRC) önemli olduğu için elde edilen numunelerin NRC değerleri de belirlenmiştir. Elde edilen sonuçlar ve karşılaştırmalar grafikler ve tablolar halinde sunulmuştur.

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**Anahtar Kelimeler:** Luffa Cylindrica, Doğal Lifli Kompozitler, Ses Yutucu Malzemeler

## Abstract

The negative effects of noise pollution on human health have become a problem that the world takes into consideration. Many studies have been conducted to control the noise that causes various psychological and physiological disorders. In this context, producing acoustic materials has increased to control noise pollution that seriously threatens human health such as hearing impairment, rest and sleep disturbance, psychophysiological and mental health problems. In Turkey, the regulation named 'Binaların Gürültüye Karşı Korunması Hakkında Yönetmelik' was published in 2017. The purpose of this regulation is to create suitable conditions for all kinds of structures in such a way that the noise level to which people will be exposed does not affect their physical and mental health. Seddeq (2009) stated that different materials and various techniques are used to control noise and create an acoustically desirable environment, and one of these techniques is sound absorption. Depending on the physical properties of the material on the surface from which the sound wave comes, there are different amounts of changes in the sound energy. For this reason, the finishing materials used on the surfaces control the sound. The materials used to absorb the sound can generally be listed as fibers, foams, perforated panels, membranes, resonators, and different composite materials. Nor et al. (2004) and Zulkifli et al. (2008) stated that the preferred sound absorber materials in the construction sector are glass or mineral wool materials. Also, Nor et al. (2004) added that the production of alternative materials remains relatively weak due to glass and mineral wool material's dominance in the commercial market. However, during the application glass and mineral wool materials used in walls or panels, cause lung and eye problem. The result of the health risks, different materials especially the natural ones, are preferred. Biswal (2016) stated that researchers tend to use organic fibers instead of synthetic fibers in fiber composites, because they have better mechanical properties, are easier to obtain and cheaper. Advantages of using organic fibers as acoustic material; lower costs, easily available, renewable and wear-resistant, ease of application and not threaten human health during application and use.

After determining the negative effects of noise on human health and health problems caused by some sound absorbing materials, especially during application, the starting point of this study was 'Is it possible to produce a sound absorber finishing material using easily accessible materials that do not threaten human health?'. The aim of the study is to provide sound absorption by using environmental friendly composite finishing material to be produced by using natural fibers and to provide the use of this material in places requiring absorption performance. For this purpose, literature searches have been done on the studies with composite materials formed with natural fibers. In these studies, the parameters affecting sound absorption were determined. The literature review was helpful in determining the plant fiber and matrix to be used in the study and in deciding the methods in the process. Within the scope of the study, a natural material named 'Luffa Cylindrica' fibers were combined with epoxy which is a binder thermoset material, to produce a composite material. Then, composite material samples obtained according to determined parameters were examined and results related to sound absorption performance were evaluated. In the study, the sound absorption performance of the materials was measured using an impedance tube and the thickness of the material and the usage of the fiber forms on the sound absorption were investigated separately. In addition, NRC values of the samples obtained were determined since the Sound Reduction Coefficient (NRC) is important, especially in places requiring improvement or resonance control at high frequencies. The results and comparisons are presented in graphs and tables.

*\* This study is based on the Thesis study named 'Prediction Model of Sound Absorption Coefficient with Artificial Neural Networks in Composite Materials Produced with Luffa Cylindrica Fibers' which is currently studied by Oya Keskin as PhD thesis in Istanbul Technical University.*

**Keywords:** Luffa Cylindrica, Fiber Composites, Sound Absorption

## 1. INTRODUCTION

Noise is one of the most important problems related to environmental pollution and needs to be controlled. For this reason, every country has their own regulations on noise and sound control in buildings. In Turkey, A Regulation on Protection of Buildings Against Noise was published in the Official Newspaper (Resmi Gazete) No. 30082 in 2017 [1]. The purpose of this regulation is to create suitable conditions for all kind of structures to protect people from the negative effects of noise pollution. There are different methods to control the noise inside and outside. Seddeq (2009) stated that different materials and various techniques are used to control noise and to create an acoustically desirable environment. One of these techniques is sound absorption [2]. The sound is absorbed by the finishing materials. Depending on the physical properties of the material on the surface from which the sound waves reach, there will be differences in the varying amount of energy. For this reason, the finishing materials used on the surfaces are used to control the sound according to the properties and to absorb the unwanted sound. The materials used to absorb the sound can generally be listed as fibers, foams, perforated panels, membranes, resonators, and different composite materials. Nor et al. (2004) stated that the mostly preferred sound absorber materials in the construction sector are glass or mineral wool materials. Also, they added that the production of alternative materials remains relatively weak due to glass and mineral wool material's dominance in the commercial market [3]. However, during the application of glass and mineral wool materials used in walls or panels, they cause lung and eye problem. The result of the health risks, different materials especially the natural ones are preferred.

Biswal (2016) stated that researchers tend to use organic fibers instead of synthetic fibers in fiber composites, because they have better mechanical properties, are easier to obtain and cheaper [4]. Multicomponent materials were introduced by Ersoy (2001) in the process of material development [5]. Mankind has tried to reduce the durability of composite materials by adding animal and vegetable fibers since the first period. The most common definition of composite material is "Composites are multifunctional material systems that provide properties that cannot be obtained from any discrete material. In terms of composition and characteristics, they are structures that physically join two or more compatible materials which are sometimes in form". Advantages of using organic fibers in a composite material are lightness, design flexibility, high power, better damage resistance, higher chemical resistance, higher impact resistance, higher fracture toughness, better corrosion resistance, low coefficient of thermal expansion, higher fatigue resistance and reducing potential component costs. So that, natural polymeric materials such as cellulosic fibers, vegetable oils, bark, cotton, wool, silk are considered as viable alternatives to conventional synthetic polymeric materials for a variety of industrial applications.

On the other hand, sustainability has become an important issue in recent years and the predictable depletion of oil resources has necessitated the usage of biopolymer materials. Biopolymers obtained from different natural sources have the potential to assist in the transition towards sustainable and green development. Sustainable composites are a certain class of

composites where at least one of the components (binder or reinforcement) is obtained from natural sources. Depending on the type of reinforcement and the polymer binder, the green composites can be divided into three main types. First one is fully renewable composites which the binder and reinforcement are from renewable sources. Second group includes partially renewable composites which the binder is obtained from renewable sources and reinforced with a synthetic material. And the third group which includes the sample composites of this study is partially renewable composites which a synthetic binder is reinforced with natural fiber.

One kind of natural fibers is plant fibers which are hydrophilic due to the large number of hydroxyl groups in their structure. As a result of hydrophilic structure, the fibers are not resistant to water and moisture. Hemicelluloses are often responsible for moisture absorption and water ingress from natural fibers can be explained by capillary action. Waxed materials on the surface help the water molecules to hold onto the fiber. So that, alkalization is a method to clean the cellulosic layer from the fiber's surface [4].

The binder is a continuous phase and binds the fibers together in the composite. The force is transmitted from the binder to the fiber, which means the binder transfers the load. Fibers can be trapped by support of binder. Binder prevents fibers from twisting and also the binder protects the fiber and prevents its abrasion. There are 3 main parameters to consider before select a binder material [6]:

- 1- Usage Performance
  - Compliance with environmental conditions
  - Thermal resistance
  - Chemical resistance
  - Electrical performance
  - Optical properties
  - Toxic limits
- 2- Transaction Properties
  - Curing time
  - Curing conditions
  - Loss of volume
- 3- Economic Efficiency
  - Raw material supply
  - Cost
  - Choice

## **2. STUDY**

### **2.1 Materials**

In this study, *Luffa Cylindrica* fibers are used as a reinforced part of the composite material. *Luffa Cylindrica* is a member of the family Cucurbitaceae. Structure of the fruit is fibrous vein. It has a woody structure consisting of fibers in different directions. It consists of 60% cellulose, 30% hemicellulose, 10% wood extract [7]. As in the Figure 1, there are 3-5 holes in the ovary.

In this study, epoxy resin has been used in the composites as the binder. Epoxy has high physical and chemical properties and also provides ease of application.



**Figure 1.** Luffa Cylindrica ovary

## 2.2 Parameters

Many studies have been conducted on the sound absorption performance of composite materials produced with using natural fibers. Different parameters which affect the absorption of sound according to the properties of the fibers were investigated. In this study, 2 parameters are determined according to Luffa Cylindrica fiber's physical properties. These parameters are fiber form and material thickness. In order to observe the effect of the fiber form used in the composite on the sound absorption, it was decided to use the fibers in mat and fragmental form. Composite materials of 1cm and 3cm thickness were produced to check effect of material thickness which is another parameter.

## 2.3 Sound Absorption Tests and Results

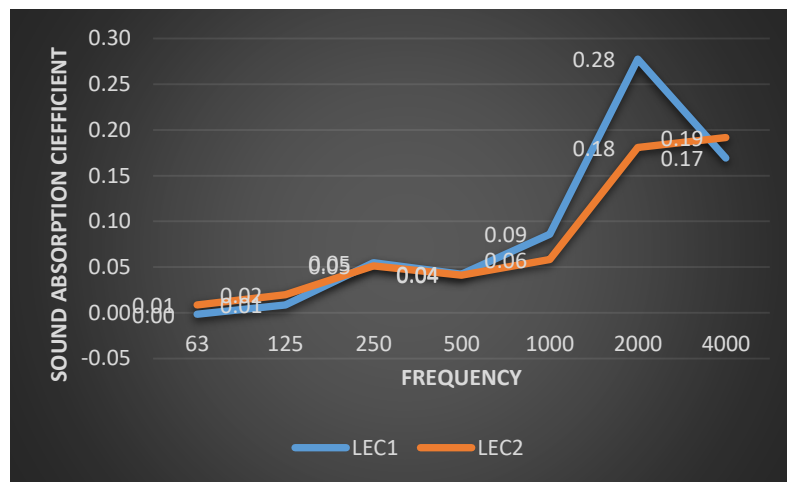
At the beginning of the study, silicone molds are prepared to produce composites. Then, fibers are cleaned with fresh water and alkalization process has been done. Third, according to parameters which are determined in chapter 2.2, composite samples are produced. And at the final, sound absorption coefficient of the samples has been calculated by using impedance tube. Fiber ratio was determined as 2% for all composite samples and applied. Table 1 shows the physical properties of 4 composite samples.

After the sound absorption tests were completed, the results obtained and the effects of the determined parameters on the sound absorption were analysed. Figure 2 and Figure 3 show the effect of fiber form on sound absorption. In Figure 2, 1cm thickness samples which are LEC1 and LEC2 are compared. According to the graph, it can be said that fiber form is not very important in low and medium frequencies for 1cm thickness samples. However, at 1000Hz and 2000Hz, the use of fibers as mat gives the best sound absorption performance. Nonetheless, 3 cm thick samples LEC 3 and LEC 4 in Figure 3 show that fragmental fiber form gives the better results at all frequencies. Unlike 1cm samples, composites produced with mat fibers showed lower absorptivity than fragmental form. One reason for this is as the material thickens, the fabric moves away from the surface. This is because randomly distributed fragmental fibers are more

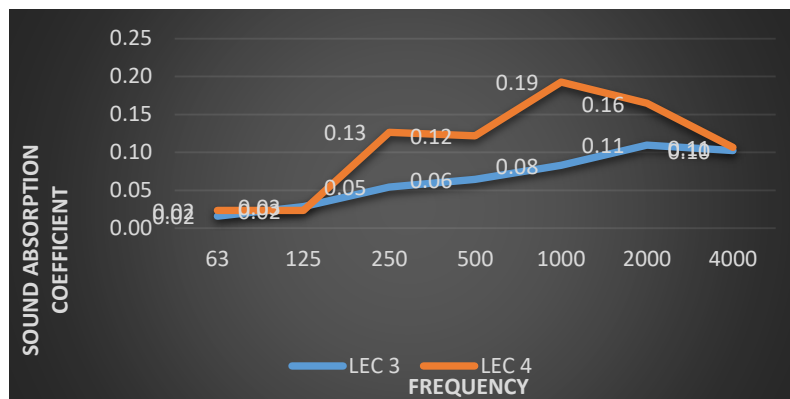
uniformly distributed in the material during curing, and fibers close to the surface might improve the sound absorption performance.

**Table 1.** Physical Properties of Luffa Cylindrica Fiber Composite Samples

Material Code	Thickness	Ratio by Weight		Fiber Form
		Fiber	Epoxy	
LEC 1	1 cm	2%	%98	Mat
LEC 2	1 cm	2%	%98	Fragmental
LEC 3	3 cm	2%	%98	Mat
LEC 4	3 cm	2%	%98	Fragmental



**Figure 2.** Comparison of LEC 1 and LEC 2 to see the effect of fiber form on sound absorption



**Figure 3.** Comparison of LEC 3 and LEC 4 to see the effect of fiber form on sound absorption

Other parameter which is material thickness is analyzed in Figure 4 and Figure 5. In the Figure 4, LEC 1 and LEC 3 samples are compared. It is known that thickness is a more effective parameter at low frequencies. When we look at the graph, we can see that the thickness of 1000Hz and above is not effective on sound absorption. The reason why the LEC 1 coded sample with a thickness of 1cm at higher frequencies is more absorptive than the LEC 3 can be said to be the proximity of the fibers on the surface because of the low material thickness. The best sound absorption performance for all thicknesses of mat fiber composites with 2% fiber ratio has been achieved at 2000Hz. According to Figure 5 which includes comparison of LEC 2 and LEC 4 samples, it can be said that the reason for the increased sound absorption coefficient in the LEC

2 sample is the increasing in fiber activation level by increasing the frequency of the acoustic waves occurring since the material thickness is not very high. Therefore, the sound absorption performance of the material at higher frequencies is better than the lower frequencies. Here, it is advisable to increase the material thickness to achieve better results at low frequencies. At this point, in the LEC 4 sample, only the thickness was increased and the sound absorption performance increased at low frequencies, provided that the physical properties of the composite were kept the same. However, fluctuations in high frequencies were also observed here. As a result of this, it can be said that low frequency acoustic waves are absorbed in the interior due to the thickening of the material.

At final, Noise Reduction Coefficient (NRC) values of composite material samples were calculated. The NRC is a single number of sound absorption performance of a material. Of course, it is not the right approach to look at the NRC number only when selecting a sound absorptive material. However, it is not a wrong approach to select materials using NRC coefficient, especially in places where improvement or resonance control is required at high frequencies. So, Figure 6 indicates that LEC 4 sample which is 3cm thickness and fiber form is fragmental, has the best NRC number on sound absorption.

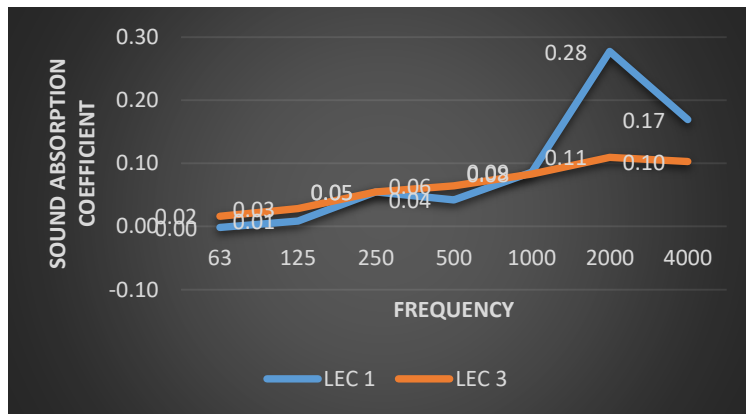


Figure 4. Comparison of LEC 1 and LEC 3 to see the effect of material thickness on sound absorption

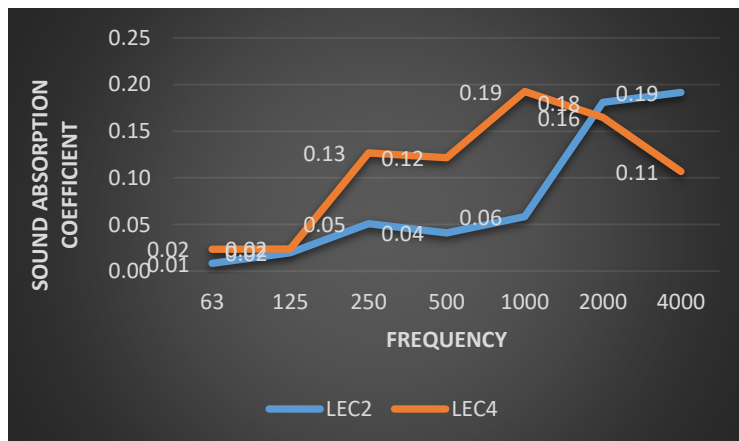
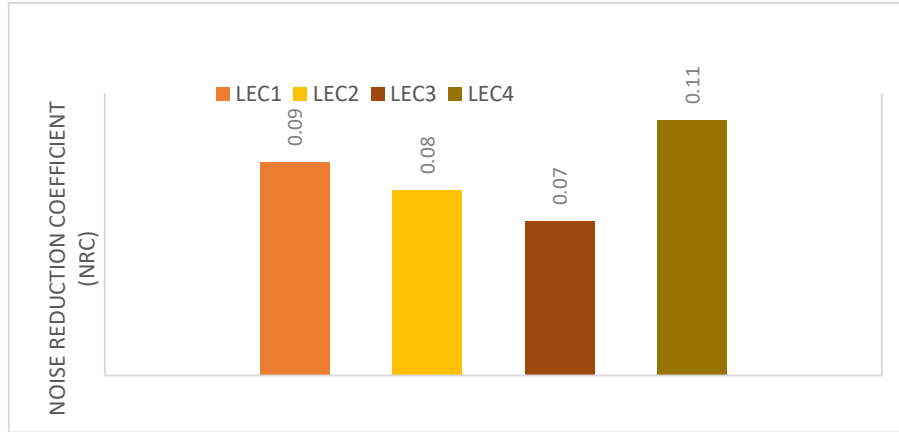


Figure 5. Comparison of LEC 2 and LEC 4 to see the effect of material thickness on sound absorption



**Figure 6.** Noise Reduction Coefficient (NRC) of Sample Fiber Composite Materials

### 3. CONCLUSION

All studies in the literature show that usage of natural fibers in composite materials is increasing day by day not only for human health but also for sustainability. Luffa Cylindrica fibers are suitable for usage in fiber composites. Luffa Cylindrica fibers can also be preferred because of their ease of processing, low cost and ease of growing conditions. On the other hand, epoxy as a binder has good physical and chemical properties except its high cost may be the disadvantage.

Literature searches show that there are many parameters that affect the sound absorption in natural fiber composites. In this study, two of them have been analysed. According to the test results, material thickness and fiber form have an effect on sound absorption. However, other factors such as fiber diameter and the distribution of fibers in the composite must also be taken into consideration. For example, as it is known, thin fibers are more absorptive because they create more vibration. Unfortunately, it is difficult to measure Luffa Cylindrica fiber's thickness due to its reticulated structure. So, this is the parameter we cannot check but it still has impact on the sound absorption. Therefore, it would not be right to make very accurate judgments about the parameters examined in this study. Future studies is going to be for more parameters with more sample numbers.

### 5. REFERENCES

- [1] Resmi Gazete: Binaların Gürültüye Karşı Korunması Hakkında Yönetmelik, 2017.
- [2] Seddeq, H. S.: Factors influencing acoustic performance of sound absorptive materials. Australian Journal of Basic and Applied Sciences, 3(4), 4610-4617, 2009.
- [3] Nor, M. J. M., Jamaludin, N., & Tamiri, F. M.: A preliminary study of sound absorption using multi-layer coconut coir fibers. Electronic Journal Technical Acoustics, 3, 1-8, 2004.
- [4] Biswal, M., Sahu, S. K., & Asha, A. V.: Vibration of composite cylindrical shallow shells subjected to hygrothermal loading-experimental and numerical results. Composites Part B: Engineering, 98, 108-119, 2016.
- [5] Ersoy, H. Y. : Kompozit malzeme. Literatür Yayınları, 2001.
- [6] Wang, R. M., Zheng, S. R., & Zheng, Y. G.: Polymer matrix composites and technology. Elsevier, 2011.
- [7] Ghali, L., Msahli, S., Zidi, M., & Sakli, F.: Effect of pre-treatment of Luffa fibres on the structural properties. Materials letters, 63(1), 61-63, 2009.