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Research Article

Environmentally-Friendly Recycled Leather-Reinforced Composite: Thermal and Acoustic Properties

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Abstract

Increase in energy consumption and environmental pollution are some of the main problems of today. One of the ways to overcome these problems is to increase the use of recycled materials. Heat and sound insulation in buildings can play an important role in saving energy and reducing environmental pollution with composite materials made from recycled leather. This study investigates the possibility of reusing leather scraps. Composite material was produced by cutting leather waste for thermal and sound insulation of buildings into small pieces and pressing them in a mechanical mold using polyvinyl acetate binder. The effect of the thickness of the developed new leather-added composite materials on their thermal and acoustic insulation properties was examined. When the thermal and acoustic properties of the composites were evaluated, it was determined that the PVA/skin thicknesses forming the mixture varied depending on the mean temperature and frequency (Hz). As a result of the measurements, it was seen that the sound at the 3000 Hz frequency, to which the human ear is most sensitive, was absorbed by 61%.

Keywords: Recycled, Environmentally, Leather, Thermal, Acoustic, Composite.

Çevre Dostu, Geri Dönüştürülebilir, Deri Takviyeli Kompozit: Isı ve Akustik Özellikleri

Öz

Enerji tüketimindeki artış ve çevre kirliliği, günümüzün temel sorunlarından bazılarıdır. Bu sorunların üstesinden gelmenin yolarından biri de geri dönüştürülmüş malzeme kullanımını artırmaktır. Binalarda ısı ve ses yalıtımı, geri dönüştürülmüş deriden yapılan kompozit malzemeler ile enerji tasarrufunda ve çevre kirliliğinin azaltılmasında önemli bir rol oynayabilir. Bu çalışma, deri artıklarının yeniden kullanılma olasılığını araştırmaktadır. Binaların termal ve ses yalıtımına yönelik deri atıklarını küçük parçalar haline getirip polivinil asetat bağlayıcı kullanarak mekanik bir kalıpta preslenmesiyle kompozit malzeme üretimi yapılmıştır. Geliştirilen yeni deri katkılı kompozit malzemelerin kalınlıklarının termal ve akustik izolasyon özelliklerine etkisi incelenmiştir. Kompozitlerin termal ve akustik özellikleri değerlendirildiğinde karışımı oluşturan PVA/deri kalınlıklarının, mean temparature ve frequency (Hz) bağlı olarak değiştiği belirlenmiştir. Ölçümler sonucunda insan kulağının en hassas olduğu 3000 Hz frekanstaki sesin %61 oranında absorblandığı görülmüştür.

Anahtar Kelimeler: Geri Dönüşümlü, Çevreci, Deri, Termal, Akustik, Kompozit.

1. Introduction

Naturally sourced products create an interesting market today with their sustainable environmentally friendly production technologies, reusability and waste recycling features. Among composites, polymers and polymer composites are materials of increasing importance all over the world. They have a wide range of applications in industry due to their high mechanical, physical and chemical properties. Although polymers have many different properties, they cannot fully fulfill the tasks expected from them alone [1,2]. Therefore, they must be supported with different substances.

Since leather has a porous structure, its use in applications for sound and heat insulation has been the subject of many studies. To provide thermal and sound insulation, some traditional materials with essentially low thermal conductivity, structures such as cellulose, felt and leather, are widely used. It is thought that the use of leather wastes, which have porous and light structures with high performance in terms of thermal and acoustic insulation, together with conventional materials or their use instead will provide the desired improvements. The production of materials that will provide the high performance features required by today's technology is important for many sectors. Compared to traditional materials, leather waste materials attract attention due to their structures with superior properties such as high specific surface area, high porosity, low density, low dielectric constant, excellent sound and heat insulation.

The thermal insulation property of a material is measured by thermal conductivity (λ). Thermal conductivity is the rate of heat transfer per unit length of a material in a direction perpendicular to its surface, per unit cross-sectional area of a material, as a result of the temperature gradient. Thermal conductivity is considered the most important parameter for evaluating thermal insulation material. A material with a thermal conductivity lower than 0.07 W/mK can be considered a thermal insulator [3].

Acoustics is a field in which sound production and propagation is studied in different environments. Sound occurs when a material or object vibrates. These vibrations spread from the transistor to the receiver in the form of waves in a solid, liquid or gas medium. Therefore, a sound wave is the transfer of energy emitted by a source material or object to the medium. A sound wave is characterized by its frequency, wavelength and amplitude. The interaction of sound waves with the surface of the receiver can change the wave properties depending on the surface properties of the receiving material or object. Sound wave can be absorbed, transmitted, reflected, refracted and emitted from the surface. The change in sound properties has been used in many scientific applications to date, including composites used in the field of acoustic insulation [3].

Sound absorption occurs when all the emitted sound waves are absorbed by the receiver. Sound absorption is an important phenomenon when it comes to sound insulation. Different materials are available for sound absorption. Sound absorbers can be porous or resonant type. Fibrous materials convert acoustic energy into heat energy when sound waves hit the absorber. Sound absorption measures the amount of energy absorbed by the material, and the sound absorption coefficient varies between 0 and 1.

Porous absorbers are materials in which sound propagation occurs in a network of interconnected pores in such a way that viscous and thermal effects cause the dissipation of acoustic energy. Carpets, acoustic tiles, open-cell acoustic foams, curtains, cushions, mineral wool such as cotton and glass wool are such materials. Acoustic and thermal effects are affected by other physical properties of the material, such as pore diameter, density and thickness. The thickness of composite structures is one of the important parameters affecting sound absorption. If the acoustic impedance on the surface of composite structures matches that of the environment, the sound will not be reflected back into the environment, the thicker the structure, the greater the sound impedance. In this case, in order to have effective sound absorption in the structure, the thickness of the structure must be at least one tenth of the wavelength of the incoming sound wave. Due to the long wavelength, thicker structures are required to absorb low-frequency sound. The acoustic impedance on the surface of thick composite structures will absorb more sound that is not reflected back into the environment, especially in the low frequency range. The contact between the materials forming the composite structure is the most important, it affects the continuous conduction path in the thickness direction and therefore determines the thickness thermal conductivity.

Lakrafli meat. get. In 2013, the effects of moisture and weight/volume ratio on the thermal conductivity of wastes and composites were experimentally investigated and it was stated that thermal conductivity increased with increasing humidity [4]. Senthil, 2015, Composites were prepared from leather waste by mixing it with natural and synthetic fibers in various proportions. These composites were converted into yarns and fabrics and examined for their physicochemical and mechanical properties. It was stated that it can be used in the textile and leather industry[5]. Teklay, 2017 prepared composite sheets by combining leather wastes and various plant fibers in various proportions. Resin binder and natural rubber latex were used as binding agents. The physicochemical properties of the prepared composite layers were examined. It has been stated that the performance of plant fiber composite sheets varies depending on the nature of the binder and the rate of use [6]. Senthil, 2018, acupuncture-effective leather composite insoles were produced from leather waste and characterized physico-chemically [7]. Li, 2020, Bi/Ce-natural leather composite with X-ray attenuation in the energy range of 20−120 keV, low mass density, good mechanical properties, high water vapor permeability, and excellent bending strength was successfully produced. produced composite sheets using leather fiber and bamboo fiber. The mechanical, thermal and acoustic properties of the composite plate were examined. It has been stated that the produced sheets have application potential [8]. Tauhiduzzaman, 2023, In this study, composite sheets were produced using leather fibers obtained from shaving powder and leather cutting residues and different plant fibers and were characterized physico-chemically. It showed that banana fiber composite was more thermally stable [9]. Kılıç, 2024, Composite materials for automotive bumpers consisting of recycled high-density polyethylene and leather polishing powder waste in different proportions were produced and investigated in terms of mechanical properties[10-15]. Optimum mechanical performance was achieved with composites containing 30% leather polishing powder by weight [16-22].

When current applications are examined in the literature, leather reinforced composite material studies are frequently encountered. In this study, the thermal and acoustic properties of the composite consisting of PVA/leather and additives were examined depending on the thickness.

2. Materials and Methods

2.1. Used materials

In the preparation of polinivil acetate emulsion composites; Vinyl acetate homopolymer was used as matrix material and waste leather pieces were used as filler. Distribution was achieved homogeneously using a mixer at room temperature. The composite material produced with recycled material from leather production waste was carried out with 2 samples of 15 mm and 30 mm in size according to TS EN ISO 10534-2 Standard. Figure 1 shows the PVA/Leather added composite produced.

Figure 1. Produced PVA/Leather added composite

3. Experimental Studies

3.1. Thermal Conductivity Measurement Results

The device consists of two plates, upper and lower. The temperature of the upper part of these plates is 40°C and the temperature of the lower part is 10°C. The sample is placed between these plates and measurements are taken. The hot plate contacts the composite with a pressure value of 200 Pa. Thermal conductivity was measured according to the international standard ASTM C518 (2017). It was observed that PVA penetrates into the skin and its form is preserved during pressing, and therefore the thickness and heat conduction coefficient of the porous composite structure improves. Figure 2 shows the connection between thermal conductivity coefficient and mean temperature and thickness.

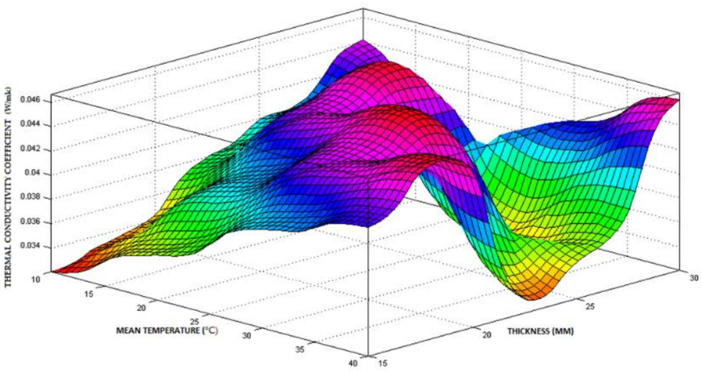

Figure 2. The relationship between thermal conductivity coefficient and mean temperature and thickness

When examined in terms of thickness, considering the lowest transmission coefficient and the highest coefficient values, it is seen that it varies between 0.0034 and 0.044 W/mk. Figure 3 shows the connection between thermal conductivity coefficient and mean temperature.

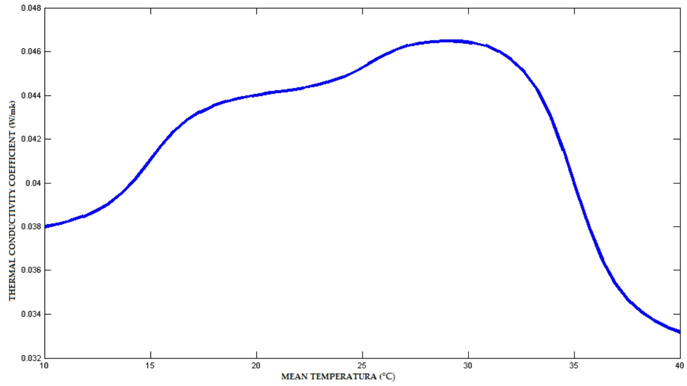

Figure 3. The connection between thermal conductivity coefficient and mean temperature

When the heat conduction coefficient values are examined, it has a low heat conduction coefficient value of 0.0321 W/mK at 10 °C and a high heat conduction coefficient value of 0.041 at 34 °C. Figure 4 shows the connection between thermal conductivity coefficient and thickness.

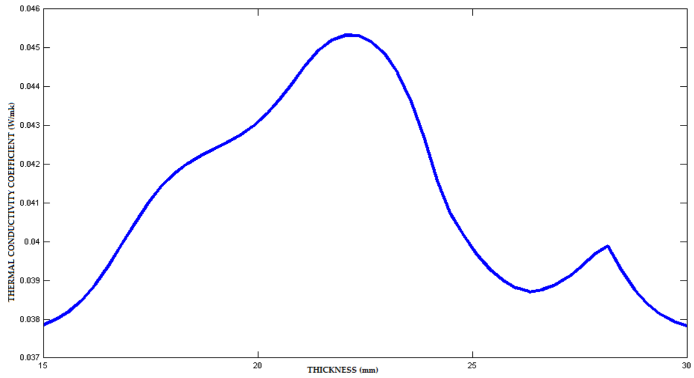

Figure 4. The relationship between thermal conductivity coefficient and thickness

Melting PVA penetrates into the skin and maintains its form during pressing, therefore the heat conduction coefficient of the porous composite structure has improved. A heat conduction coefficient of 0.0464W/mK was obtained at 30 °C temperature and 22.5 mm thickness. However, considering that the heat conduction coefficient value is 0.0339 W/mK, especially at 30 °C temperature and 26 mm thickness, it can be said that there is a negative effect on the composite material due to filling its pores during pressing. This essentially caused a negative effect on the heat conduction coefficient due to the poor thermal stability of PVA.

3.2. Acoustic Measurement Results

3.2.1.Absorption Coefficient Measurement Results

Samples were cut to specific sizes and placed in the device. After the device was turned on, the device's microphones were first calibrated. Microphones control sounds coming from the environment. To ensure accurate measurement, the location of the two microphones is changed. There are two tubes, large and small, and the replacement operations are carried out in these tubes respectively. Curves are obtained from these two tubes, and these curves are sound absorption coefficient curves. The sound absorption coefficient graph is given in Figure 5.

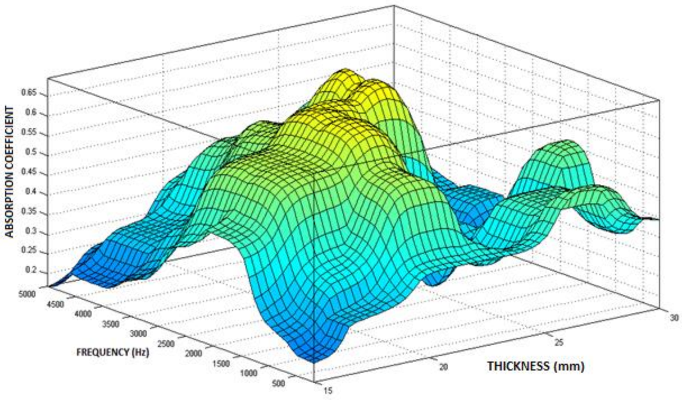

Figure 5. Relationship between absorption coefficient and frequency and thickness

The increase in the thickness of the material also increases the sound absorption coefficient. Low frequencies in the range of 100-500 Hz are the control region, in this part the absorption coefficient of 15 mm sized samples reached 0.0271. This situation is due to the rigid structure of the composite. Therefore, the absorption coefficient value was lower in other thicknesses. Figure 6 shows the connection between absorption coefficient and thickness.

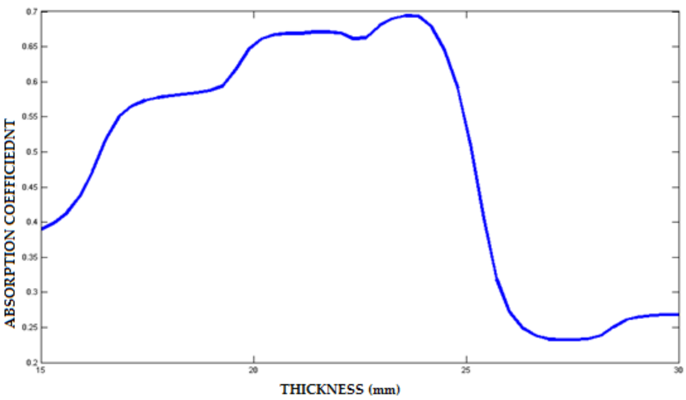

Figure 6. Relationship between absorption coefficient and thickness

In the 23.2 mm thick samples section between 2000-3000 Hz, the samples gave better results in terms of absorption coefficient values. From here it can be said that the leather-reinforced composite will show better sound insulation properties at high frequencies. Figure 7 shows the connection between absorption coefficient and frequency

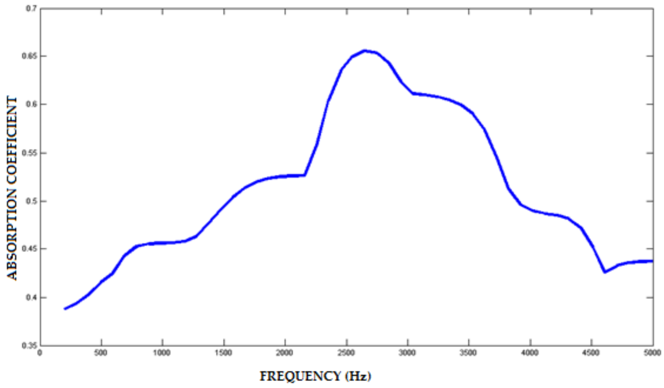

Figure 7. Relationship between absorption coefficient and frequency

It is the overlap frequency region in the 3500-4500 Hz range. Absorption coefficient generally decreases in this region. However, as the frequency value increases to 3000 Hz, the improvement in sound transmission loss values in leather-reinforced composites draws more attention. Low absorption coefficient reaches low and high frequency values, the use of composite samples will be more appropriate at medium frequencies.

3.2.2. Sound Transmission Loss Levels Measurement Results

Sound transmission loss is the logarithmic ratio of the energy coming into the material to the energy transferred to the opposite side. It is basically measured by two methods. These are the impedance tube method and the acoustic room method. In the study, measurements were made using the Impedance (Kundt) tube method. The sound transmission loss graph of the obtained data is given in Figure 8..

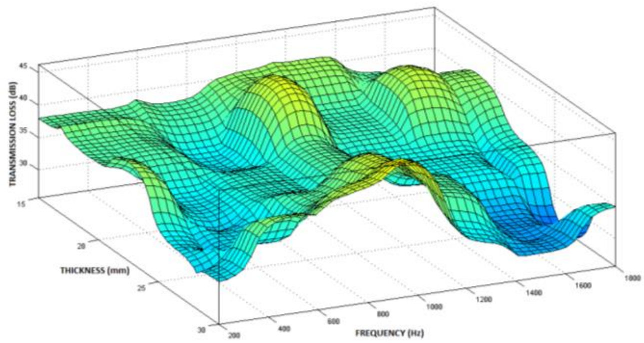

Figure 8. Connection between transmission loss levels and frequency and thickness

As the thickness of the material increases, sound transmission loss levels decrease. High frequencies in the range of 1400-1600 Hz are the control region, in this part, 30 mm size samples reached transmission loss levels of 29.7. This situation is due to the rigid structure of the composite. That's why the transmission loss levels value gave lower results in other thicknesses. Figure 9 shows the connection between transmission loss levels and thickness.

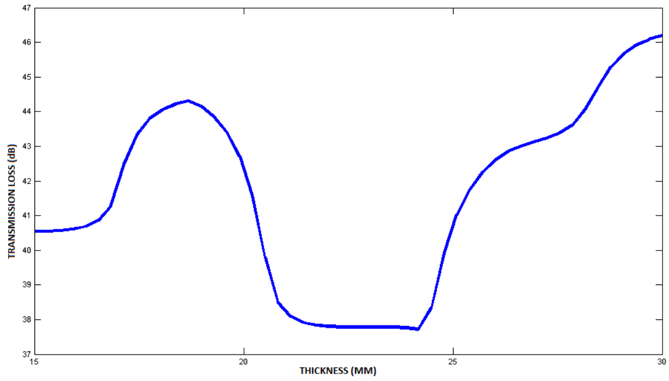

Figure 9. Connection between transmission loss levels and thickness

In the 21.3-23.2 mm thick samples section, the samples gave lower results in terms of transmission loss levels. From this, it can be said that the leather-added composite will show better insulation properties at higher thicknesses. Figure 10 shows the connection between transmission loss levels and frequency.

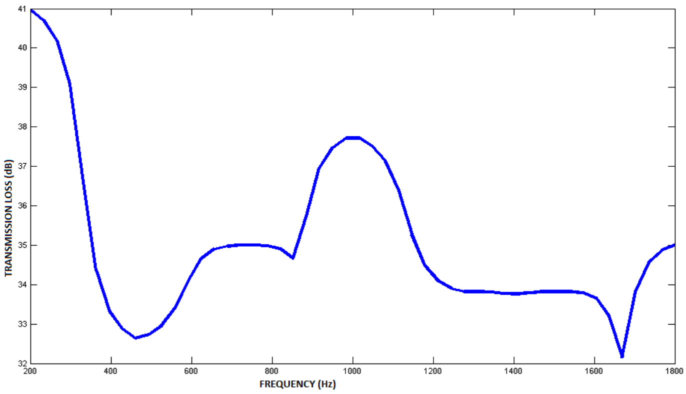

Figure 10. Connection between transmission loss levels and frequency

It is the overlap frequency region in the 1000-1200 Hz range. Transmission loss levels generally decrease in this region. However, in the frequency range of 450-650 Hz, there was an improvement in sound transmission loss values in PVA/leather added composites. It reaches low sound transmission loss values at low and high frequencies, and the use of composite samples at medium frequencies will be more appropriate.

4. Results and Discussion

According to the heat conduction coefficient measurement results;

Obtaining highly porous structures in thermal insulation contributes positively. When comparing PVA/leather added composite structures, samples with thicker structure showed good performance. PVA addition caused the thermal conduction coefficient to increase and therefore gave a good result in terms of performance. According to the thermal conductivity results; The 15 mm thick composite material gave the highest thermal conductivity value, and the 30 mm thick composite material gave the lowest value. The material, which has a low thermal conductivity coefficient, is ideal for thermal insulation applications.

According to the results of sound absorption coefficient measurements,

The main parameter effective in sound absorption coefficient is size. Especially when looking at the sound insulation values between 3000-4000 Hz, 25-27 mm thick composites showed good performance in terms of sound absorption. The sound absorption coefficient increases with the thickness of the samples. It is thought that increasing the material thickness causes an increase in the amount of micropores in the sample. The friction between the sound waves and the surface increases and the amount of sound energy converted into lost heat energy increases. The lowest result was for the 15 mm thick material and gave a sound absorption coefficient value of 0.37. The highest value was for the 24 mm thick material and gave a sound absorption coefficient value of 0.68. Leather reinforced composites have better acoustic absorption behavior at high frequencies than synthetic fiber reinforced composites.

According to the sound transmission loss measurement results;

It is seen that PVA/leather added composites give better results. The composite has a rigid structure. Rigid structures generally affect the sound transmission loss performance positively. While it is more appropriate to use 25-30 mm thick composites with PVA/leather additives in the low (0-400 Hz) and medium frequency (800-1200) ranges, it is not appropriate to use 20-25 mm thick composites in the high frequency (above 1300).

5. Conclusion

In this study, composite containing PVA/leather was produced. The resulting composite structure aims to minimize heat losses and reduce the reach of sounds at frequencies audible to the human ear. Thermal and acoustic tests were performed on the prepared samples, respectively, and the obtained data were interpreted. Sound absorption coefficient, sound transfer loss and heat conduction coefficient measurement results show that the produced composite meets the desired properties. When the thermal and acoustic properties of the composites were evaluated, it was determined that the PVA/skin thicknesses forming the mixture varied depending on the mean temperature and frequency (Hz).

To reduce the heat conduction coefficient value of layered structures; It is necessary to increase their thickness and at the same time obtain a more voluminous structure. Obtaining highly porous structures in thermal insulation contributes positively to the heat conduction coefficient value.

In order to increase the sound absorption coefficient values of layered structures and to positively affect the sound transfer loss values; Their thickness needs to be increased. As a result of the measurements, it was seen that the sound at the 3000 Hz frequency, to which the human ear is most sensitive, was absorbed by 61%. It is also thought that the thickness of the layered structure consisting of skin may have increased the sound absorption coefficients. The sound transfer loss value of the resulting layered structure was low. The reason for this is that the thickness of the layered structures, unlike the materials used in previous studies, is thought to increase the roughness of the channels in the composite containing PVA/leather, and as a result, the friction between the surface in contact with the sound waves and the sound waves will increase. The amount of sound energy increases with the increase in the amount of friction, and the increase in the amount of pores in the material used for insulation purposes in sound insulation applications has increased the insulation feature of the material.

As a result, leather waste was evaluated and a new composite material that was low-cost, sustainable and respectful of nature was produced. This new composite material can be used in heat and sound insulation in the construction and automotive sectors. This study contributed to the literature on thermal and acoustic properties.

References

[1] Mrowiec, B. (2018). Plastics in the circular economy (CE). Environmental Protection and Natural Resources, 29(4), 16-19.

[2] Choudhary, K., Sangwan, K. S., & Goyal, D. (2019). Environment and economic impacts assessment of PET waste recycling with conventional and renewable sources of energy. Procedia CIRP, 80, 422-427.

[3] Padhye, R., & Nayak, R. (Eds.). (2016). Acoustic textiles (p. 242). Berlin/Heidelberg, Germany: Springer.

[4] Lakrafli, H., Tahiri, S., Albizane, A., Bouhria, M., & El Otmani, M. E. (2013). Experimental study of thermal conductivity of leather and carpentry wastes. Construction and Building Materials, 48, 566-574.

[5] Senthil, R., Inbasekaran, S., Gobi, N., Das, B. N., & Sastry, T. P. (2015). Utilisation of finished leather wastes for the production of blended fabrics. Clean technologies and environmental policy, 17, 1535-1546.

[6] Teklay, A., Gebeyehu, G., Getachew, T., Yaynshet, T., & Sastry, T. P. (2017). Conversion of finished leather waste incorporated with plant fibers into value added consumer products–An effort to minimize solid waste in Ethiopia. Waste management, 68, 45-55.

[7] Senthil, R., Sastry, T. P., Saraswathy, G., Das, B. N., & Gobi, N. (2018). Leather insole with acupressure effect: new perspectives. Journal of Polymers and the Environment, 26, 175-182.

[8] Li, Q., Wang, Y., Xiao, X., Zhong, R., Liao, J., Guo, J., ... & Shi, B. (2020). Research on X-ray shielding performance of wearable Bi/Ce-natural leather composite materials. Journal of Hazardous Materials, 398, 122943.

[9] Tauhiduzzaman, M., Mottalib, M. A., Rahman, M. J., & Kalam, M. A. (2023). Preparation and characterization of composite sheets from solid leather waste with plant fibers: a waste utilization effort. Clean Technologies and Environmental Policy, 1-14.

[10] Kılıç, E., Fullana-i-Palmer, P., Fullana, M., Delgado-Aguilar, M., & Puig, R. (2024). Circularity of new composites from recycled high density polyethylene and leather waste for automotive bumpers. Testing performance and environmental impact. Science of The Total Environment, 919, 170413.

[11] Lakrafli, H., Tahiri, S., Albizane, A., El Houssaini, S., & Bouhria, M. (2017). Effect of thermal insulation using leather and carpentry wastes on thermal comfort and energy consumption in a residential building. Energy Efficiency, 10(5), 1189-1199.

[12] Çeven, E. K., & Günaydin, G. K. (2018). Investigation of moisture management and air permeability properties of fabrics with linen and linen-polyester blend yarns. Fibres & Textiles in Eastern Europe, (4 (130), 39-47.

[13] Pu, H., Shu, C., Dai, R., Chen, H., & Shan, Z. (2022). Mechanical, thermal and acoustical characteristics of composite board kneaded by leather fiber and semi-liquefied bamboo. Construction and Building Materials, 340, 127702.

[14] Massoudinejad, M., Amanidaz, N., Santos, R. M., & Bakhshoodeh, R. (2019). Use of municipal, agricultural, industrial, construction and demolition waste in thermal and sound building insulation materials: A review article. Journal of Environmental Health Science and Engineering, 17, 1227-1242.

[15] Ghermezgoli, Z. M., Moezzi, M., Yekrang, J., Rafat, S. A., Soltani, P., & Barez, F. (2021). Sound absorption and thermal insulation characteristics of fabrics made of pure and crossbred sheep waste wool. Journal of Building Engineering, 35, 102060.

[16] Thilagavathi, G., Muthukumar, N., Krishnanan, S. N., & Senthilram, T. (2019). Development and characterization of pineapple fibre nonwovens for thermal and sound insulation applications. Journal of Natural Fibers.

[17] Chen, Y. X., Wu, F., Yu, Q., & Brouwers, H. J. H. (2020). Bio-based ultra-lightweight concrete applying miscanthus fibers: Acoustic absorption and thermal insulation. Cement and Concrete Composites, 114, 103829.

[18] Karimi, F., Soltani, P., Zarrebini, M., & Hassanpour, A. (2022). Acoustic and thermal performance of polypropylene nonwoven fabrics for insulation in buildings. Journal of Building Engineering, 50, 104125.

[19] Mehrzad, S., Taban, E., Soltani, P., Samaei, S. E., & Khavanin, A. (2022). Sugarcane bagasse waste fibers as novel thermal insulation and sound-absorbing materials for application in sustainable buildings. Building and Environment, 211, 108753.

[20] Islam, S., & Bhat, G. (2019). Environmentally-friendly thermal and acoustic insulation materials from recycled textiles. Journal of environmental management, 251, 109536.

[21] Samanta, K. K., Mustafa, I., Debnath, S., Das, E., Basu, G., & Ghosh, S. K. (2022). Study of thermal insulation performance of layered jute nonwoven: a sustainable material. Journal of Natural Fibers, 19(11), 4249-4262.

[22] Ali, M., Alabdulkarem, A., Nuhait, A., Al-Salem, K., Iannace, G., & Almuzaiqer, R. (2022). Characteristics of agro waste fibers as new thermal insulation and sound absorbing materials: hybrid of date palm tree leaves and wheat straw fibers. Journal of Natural Fibers, 19(13), 6576-6594.