THE INVESTIGATION OF AIR, HEAT AND SOUND PERMEABILITY OF PERLITE COATED NONWOVEN FABRICS WITH DIFFERENT WEIGHTS

Seyda EYUPOGLU[1], Habip DAYIOGLU[1], Nigar MERDAN[1], Mehmet KILINC[2]

[1]Istanbul Commerce University, Architecture and Design Faculty, Department of Fashion and Textile Design, Istanbul-Turkey
[2]Giresun University, Sebinkarahisar School of Applied Science, Department of Fashion Design, Giresun-Turkey

scanbolat@ticaret.edu.tr

Abstract: In this study, polyester (PET) nonwoven fabrics with different weights were coated with perlite stone powder with particle sizes between 210-590 µm. Before coating procedure, water repellency treatment was applied to the samples and then the same amount of polyurethane base coating with perlite stone powder was applied on the nonwoven samples. After coating, the samples were cured at 100°C for 10 minutes. Finally, air, heat, and sound permeability of samples were investigated with regards to the weight of samples. According to the results, the increase in weight of samples caused to improve air permeability and acoustic insulation of samples. Furthermore, the decrease in weight of samples caused to decrease in the thermal conductivity coefficient of samples.

Keywords: Nonwoven, Air Permeability, Thermal Insulation, Acoustic Insulation

Introduction

In the world, energy consumption causes to increase pollution, environmental degradation, and global greenhouse emission. Building, transportation, and agricultural sectors are the most effective sectors to contribute to energy consumption. Furthermore, almost 40% of energy consumption results from the building sector (Pargana et al., 2014).

The growing environmental awareness throughout the world induces to use insulation materials resources in the all sectors (Nguyen et al., 2014). Moreover, high energy consumption, and climate changes obligate to use more sustainable and energy saver materials. Especially, thermal insulation materials play an important role in energy saving. In the buildings, to achieve better thermal insulation with commonly used insulation materials, thicker walls are suggested. However, the use of thicker walls can cause to increase cost and effect architectural restrictions. Consequently, in order to meet the demand of energy efficiency in buildings, it is necessary to develop thermal insulation materials with low thermal conductivity (Patnaik et al., 2015).

In thermal insulation applications, the widely used insulation material in the building industry is glass fiber derived from silica and synthetic fibers based on petroleum resources. Furthermore, demand for the use of sustainable, natural, and biodegradable materials has increased day after day (Patnaik et al., 2015). In the literature, Korjenic et al. investigated the thermal insulation properties of composites reinforced with jute, flax, and hemp. According to the results, the thermal conductivity coefficients of samples are 0.0458-0.0393 W/m K (Korjenic et al., 2011). In the other study, the thermal conductivity coefficients of cotton stalk fibers were investigated. The results show that the thermal conductivity coefficient is correlated with density. The thermal conductivity coefficients of samples are 0.0585 to 0.0815 W/m K, which is close to the expanded perlite (Zhou et al., 2010). Da Rosa et al. produced six insulating boards with the use of rice husk, sunflower stalks, and gypsum as binder. The thermal conductivity coefficients of samples are low values (Da Rosa et al., 2015). In order to gain thermal insulation to buildings, the textile materials are used as construction materials (Briga-Sá et al., 2013; Arumugam et al., 2015; Chen et al., 2015).

Since perlite stone has porous structure and cost-effective, it is used as acoustic and thermal insulation material. Furthermore, perlite stone is natural, biodegradable, ecological, and sustainable material. Because of having such properties, perlite stone is used in thermal insulation, agriculture, and filtration sectors (Kabra et al., 2013). The chemical composition of perlite stone is given in Table 1.

Table 1. Chemical Composition of Perlite (Raper and Raper, 2014).

Compositions	Quantity (%)
SiO_2	70-75%
Al_2O_3	12-15%
Na_2O	3-4%
K_2O	3-5%
Fe_2O_3	0.5-2%
MgO	0.2-0.7%
CaO	0.5-1.5%

In this study, in order to improve the thermal and acoustic insulation properties of PET nonwovens with different weights, the samples were coated with perlite stone powder. The results show that the weight of samples effects the thermal conductivity, air permeability, and sound absorption properties.

Materials and Methods

Materials

In this study, PET nonwovens with different weight such as 120, 140, 180, and 500 g/m^2 were used for the experiments. In order to improve the thermal and acoustic insulation properties of fabrics, perlite stone powder grinded by using ball mill and sifted to get a particle size between 210-590 μm was used. Perlite stone powder was coated with polyurethane based binder to PET nonwoven fabrics. In order to prepare coating paste, RUCO-COAT PU 1110 (Rudolf Duraner), RUCO-COAT FX 8011 (Rudolf Duraner), and RUCO-COAT TH 821 (Rudolf Duraner) were mixed. The coating chemicals were purchased from Rudolf Duraner Incorporated Company, headquartered in Bursa, Turkey. The properties of coating materials are given in Table 2.

Table 2. The Properties of Coating Materials.

Material Name	Properties of materials
RUCO-COAT PU 1110	Water based aliphatic polyether polyurethane dispersion in anionic form
RUCO-COAT FX 8011	Blocked isocyanate cross-linking agent in anionic structure
RUCO-COAT TH 821	Synthetic thickener acrylate in anionic structure

Water Repellency Finishing Treatment

PET nonwovens were applied with water-repellent finishing by using RUCODRY DFY fluorocarbon based and purchased from Rudolf Duraner Inc. in accordance with padding method in order to impede absorbing of nonwoven fabric of polyurethane based coating material. Then, the samples were dried by using stenter drier (ATAC Lab. Machines GK40E) at 100°C for 5 min.

Coating Procedure

PET nonwoven fabrics were coated with polyurethane and perlite stone powder by the use of ATAC Lab. Machines RKL40 coating machine. After coating process, samples were dried at 80 ºC for 10 minutes by the use of ATAC Lab. Machines GK40E dryer machine.

Measurement of Thermal Conductivity

Thermal conductivity coefficients of the samples were measured by using P.A.HILTON LTD.H940 instrument according to the TS 4512 Standard (TS 4512 Standard: Determination of heat transfer coefficient of textile materials, 1985). The samples were prepared in 25 mm diameter. Thermal conductivity coefficients of samples were calculated with the following equation (Kılıc and Yigit, 2008),

$$Q = -k.A.\frac{dT}{dx}$$

where Q is the heat flow (W), A is surface area (m²), x is the thickness of sample (m), T is the temperature difference (K), and k is the thermal conductivity coefficient (W/m K) of sample.

Measurement of Acoustic Insulation

Sound absorption coefficients of materials were measured in accordance with ISO 10534-2 standard (ISO 10534-2 Standard. Acoustics – determination of sound absorption coefficient and impedance in impedance tubes – Part 2: Transfer-function method, 1998) by using a measuring instrument of Brüel & Kjaer Impedance Tube, which is based on two microphone transfer function method.

Measurement of Air Permeability

Air permeability test was carried out under 200 Pa pressure and 20 cm^2 testing area according to DIN53887 test standard (Standard: DIN 53887 Testing of textiles; determination of air permeability of textile fabrics, 1966).

Results and Discussion

Measurement of Thermal Conductivity Coefficients

Thermal conductivity coefficients of samples were calculated with the Fourier equation. Figures 1 and 2 show the thermal conductivity coefficient of samples coated with perlite stone powder.

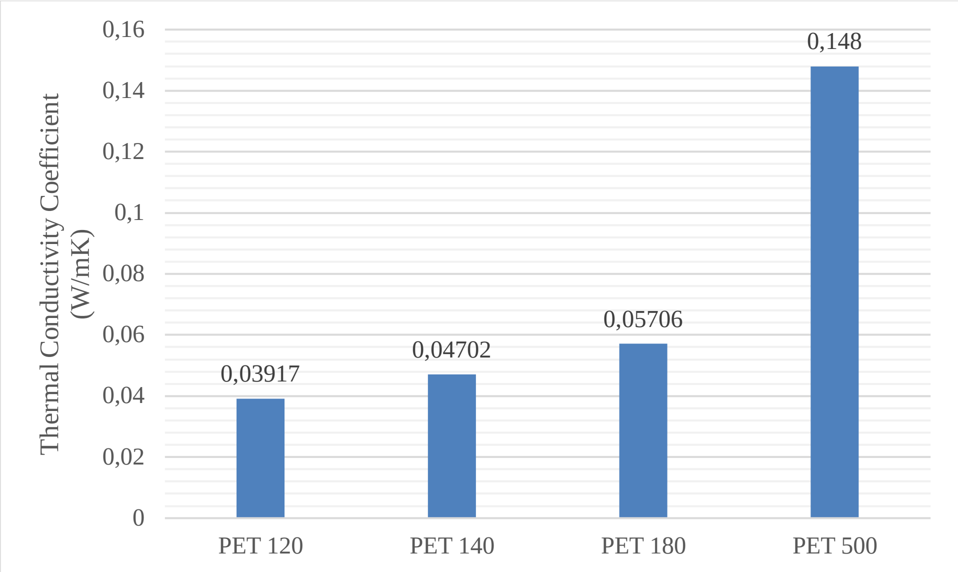

Figure 1. Thermal conductivity coefficients of PET nonwovens.

Thermal insulation and thermal conductivity coefficients are inversely proportional. The meaning is that the material with low thermal conductivity coefficient is ideal for thermal insulation applications. It is seen from Figure 1, PET120 nonwoven sample has better thermal insulation. Because of low thickness of PET120 nonwoven sample, it has better thermal insulation property. Besides, the thickness and the thermal insulation coefficients of the materials are directly proportional. In other words, a decrease in material thickness causes to decrease the thermal insulation coefficient.

Measurement of Sound Absorption Coefficients

Figure 2 shows the sound measurement results of the nonwovens.

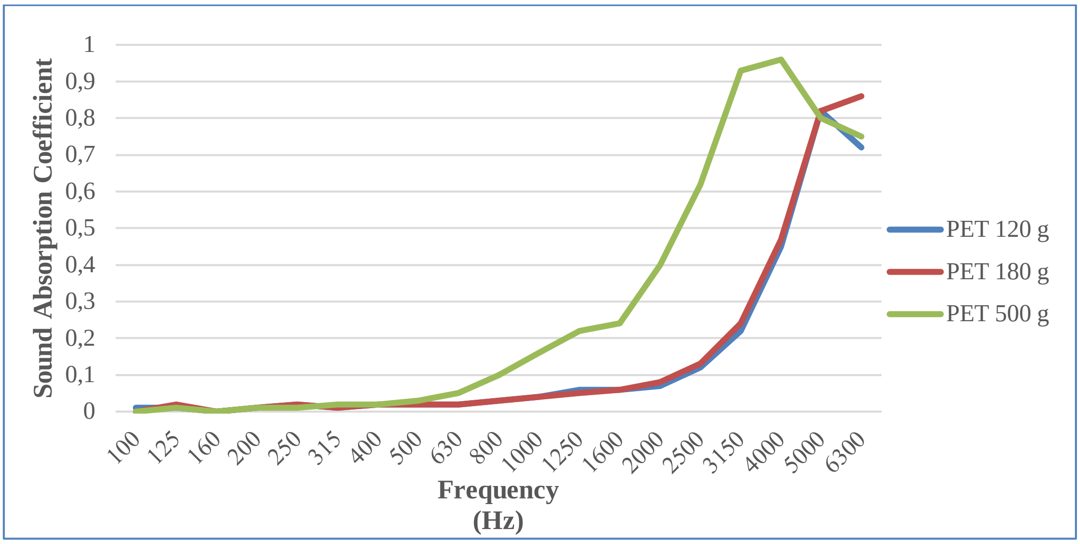

Figure 2. The Sound Absorption Coefficients of PET nonwovens.

According to the results, the sound absorption coefficient increases with the weight of samples. It is considered that increase of material thickness causes to increase in the amount of micro pore within the sample. It is observed that PET500 nonwoven fabric has the best sound absorption property. Furthermore, PET500 nonwoven is the thickest material. The increase in thickness of surface causes to increase the travelled distance of sound waves. As a result, the frictions between sound waves and surface increase and the amount of sound energy converted lost heat energy rises.

Measurement of Air Permeability

The air permeability results of the nonwovens are given in Figure 3.

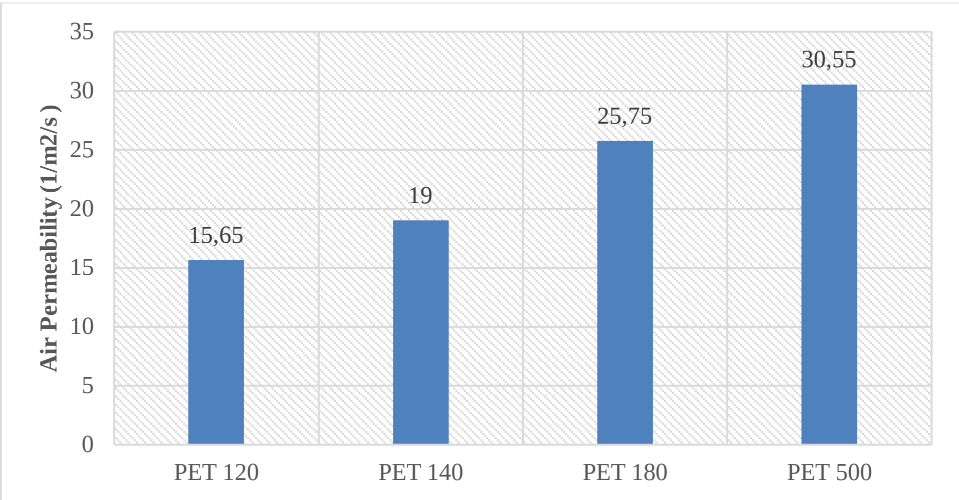

Figure 3. Air Permeability of PET nonwovens.

According to the air permeability results, the increase in weight of samples causes to improve the air permeability of samples. Moreover, it is deemed that the amount of air in PET 500 nonwoven is more than the other samples.

Conclusion

In this study, the use of PET nonwovens in building textiles was investigated to improve thermal and acoustic insulation. For this purpose, PET nonwovens with different weights were coated with perlite stone powder. After the coating process, the air permeability, thermal and acoustic insulation properties of samples were compared with regards to the weight of samples. According to the results, the increase in weight caused to improve the acoustic insulation and air permeability of samples. Furthermore, the decrease in weight of sample caused to increase in thermal insulation.

References

Arumugam, V., Mishra, R., Militky, J., & Novak, J. (2015). Thermo-acoustic behaviour of 3D knitted spacer fabrics, *Fibers and Polymers*, *16*(11), pp. 2467-2476.

Briga-Sá, A., Nascimento, D., Teixeira, N., Pinto, J., Caldeira, F., Varum, H., & Paiva A. (2013). Textile waste as an alternative thermal insulation building material solution, *Construction and Building Materials*, *38*, pp.155-160.

Chen, J. J., Yu, H. Q., Guo, Z., You, J. Z., & Song, W.F. (2015). On sound absorption and thermal properties of non-wovens, *Thermal Science*, *19*(4), pp. 1470-1472.

Da Rosa, L. C., Santor, C. G., Lovato, A., da Rosa, C. S., & Güths, S. (2015). Use of rice husk and sunflower stalk as a substitute for glass wool in thermal insulation of solar collector, *Journal of Cleaner Production*, *104*, pp. 90-97.

ISO 10534-2 Standard. Acoustics – determination of sound absorption coefficient and impedance in impedance tubes – Part 2: Transfer-function method, 1998.

Kabra, S., Katara, S., & Rani, A. (2013). Characterization and study of Turkish perlite, *International Journal of Innovative Science, Engineering and Technology*, *2*, pp. 4319-26.

Kılıc, M., & Yigit, A. Isı transferi. Bursa, Alfa Aktuel, 2008.

Korjenic, A., Petránek, V., Zach, J., & Hroudová, J. (2011). Development and performance evaluation of natural thermal-insulation materials composed of renewable resources, *Energy and Buildings*, *43*(9), pp. 2518-2523.

Nguyen, S. T., Feng, J., Ng, S. K., Wong, J. P., Tan, V. B., & Duong, H. M. (2014). Advanced thermal insulation and absorption properties of recycled cellulose aerogels, *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, *445*, pp. 128-134.

Pargana, N., Pinheiro, M. D., Silvestre, J. D., & de Brito, J. (2014). Comparative environmental life cycle assessment of thermal insulation materials of buildings. *Energy and Buildings*, *82*, pp. 466-481.

Patnaik, A., Mvubu, M., Muniyasamy, S., Botha, A., & Anandjiwala, R. D. (2015). Thermal and sound insulation materials from waste wool and recycled polyester fibers and their biodegradation studies, *Energy and Buildings*, *92*, pp. 161-169.

Raper, G., & Raper, L. (2014). Odour Controller, *Google Patent*.

Standard: DIN 53887 Testing of textiles; determination of air permeability of textile fabrics, 1966.

TS 4512 Standard: Determination of heat transfer coefficient of textile materials, 1985.

Zhou, X. Y., Zheng, F., Li, H. G., & Lu, C. L. (2010). An environment-friendly thermal insulation material from cotton stalk fibers, *Energy and Buildings*, *42*(7), pp. 1070-1074.

