SOUND INSULATION PROPERTIES OF STRUCTURE DESIGNED FROM APPAREL CUTTING WASTE

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ABSTRACT

In this paper an insulation structure from apparel cutting waste was designed and its sound insulation properties were investigated. Shredded polyester apparel cuttings were used as the raw material for an insulation structure. The obtained results show that the insulation structure made from apparel cutting waste has good sound absorption compared to standard sound and thermal insulators. The average sound absorption of the samples was between 54.7% and 74.7%, for a frequency range of 250-2000Hz. The research demonstrates a way to decrease environmental pollution by using polyester apparel cuttings waste for insulation purposes in roof construction and internal walls.

Key Words: *apparel cutting waste, building insulation materials, sound insulation*

1. INTRODUCTION

Traditionally, textiles in buildings are predominantly used for aesthetics; however they also demonstrate various functional performances. Decorative textile materials (carpets, curtains, upholstery, textile wall coverings etc.) can assist in acoustic conditioning of space. Moreover, as the most common sound absorbing materials are porous, textile materials can be used as sound insulating and sound absorbing materials in building. The most common structure for this purpose is non-woven textiles. Many scientists, such as Shoshani and Yakubov [1, 2, 6], Shoshani and Wilding [3], Shoshani and Rosenhouse [4], Lou et al.[5], have studied the acoustic behaviours of non-woven fabrics. Other researchers have also conducted similar work on woven [7, 8, 9] and knitted fabrics [10, 11]. Garai and Pompoli's [12] and Narang's [13] investigations were devoted to examining the sound absorption coefficient of polyester fibre materials with regard to mass density and sample thickness values.
However, only few have considered textile waste as an insulation material. Studies have been conducted on the thermal insulation properties of textiles [14, 15], as well as using it as sound absorption material [5]. In general, when recycling textile waste, fabrics with loose structure, such as knits, are preferred as taking the material back to fibrous form requires less effort and lower energy consumption compared to woven fabrics. Whether the material is virgin or recycled, the efficiency of sound absorption materials is related to the porous structure and thickness of the elements.
Today's most burning environmental problems arise from ever increasing volumes of worldwide production and consumption and the associated material flows. According to the 2011 FAO/ICAC survey issued by the United Nations, the world fibre consumption, and therefore the consumption of final product made of fibres, e.g. clothing, home textiles or industrial textiles, has grown nearly 30 times since the 1950s [16]. The growing consumption of textile products is an indicator of the growing amount of textile waste generated in the world today. Therefore, finding innovative ways of reusing textile waste can lead to environmental, sustainable and economic benefits. This research aims to develop a new insulation structure composed from apparel cutting waste from woven polyester fabric and investigate its sound insulation properties.

2. EXPERIMENTAL

2.1 Materials

Polyester fabric cuttings were used as raw material for designing a new insulation structure. The characteristics of fabrics used for preparation of samples A, C, and D are shown in Table 1. Differences among the three fabrics arise from mass, structural characteristics and fibre content. Sample B obtained from knitted polyester fabric 70/25/5 PES/cotton/ Lycra in partly fibrous form was used for comparison.

Table 1. Properties of used fabrics

Fabric	**A**	**C**	**D**
Thickness (mm) Cv (%)	0.16 2.17	1.2 1.80	1.6 1.38
Mass per unit area (g/m^2) Cv (%)	92 3.13	245 1.16	272 1.38
Warp density (cm^{-1})	74	37	44
Weft density (cm^{-1})	45	25	28
Warp count (tex)	7.4	36	36
Weft count (tex)	7.4	36	36
Fiber content (%)	100 PES	100 PES	70/25/5 PES/Co/Ly

To prepare the fabric cuttings for the insulation structure they were additionally shredded in different sizes using a cutting machine with rotational knives, (Table 2). Subsequently, the shreddings were used as filler in casings made of 100% polypropilen non-woven fabric. To be comparable to commercially available insulation materials the designed sample thickness was 100mm. The isolation structure was secured by stitching with stitches along its length and width distanced on 15 cm (Figure 1). A total of ten samples, of which nine samples with different degree of shredded fabric and one sample with partially fibrous structure were prepared.

Table 2. Sample characteristics and preparation

Sample	Type of material	Fabric form	ρ(kg/m^3)
A_1	cutting waste	partially cut, pieces with different size	215,6
A_2	cutting waste	cut into small pieces with different size	209,1
A_3	cutting waste	in original form without preparation	226,4
A_4	cutting waste	in original form without preparation	249,4
B	knitted fabric partially fibrous	mechanical recycling	127,0
C_1	cutting waste	cut, pieces' average dimensions 6x4cm	249,4
C_2	cutting waste	cut, pieces' average dimensions 8x4cm	265,4
D	cutting waste	cut, pieces' average dimensions 8x4cm	173,9
ABC	cutting waste -fabric A knitted fabric partially fibrous -fabric B cutting waste -fabric C	A- cut, pieces with different size B- knitted fabric partially fibrous C-cut, pieces' average dimensions 6x4cm	164,3
ABD	cutting waste -fabric A knitted fabric partially fibrous -fabric B cutting waste -fabric D	A- cut, pieces with different size B- knitted fabric partially fibrous D- cut, pieces' average dimensions 8x4cm	163,0

Figure 1. New insulation structure

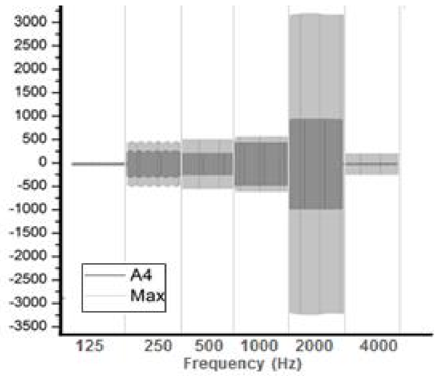

Figure 2. Change of sound amplitude with frequency for sample A4 and reference

2.2 Determining sound absorption properties

As the obtained sample dimensions were not suitable for standard sound absorption tests, a modified testing procedure based on impendence tube technique was used. The procedure used a sound generator (KYE Systems Corp Multimedia hi fi speaker system sp-diameter), microphone (A4 mi-10), GoldWave computer software for sound recording and filtering, and Origin software for analyzing the recorded sound. The sound signals were generated for 30s on frequencies of 125, 250, 500, 1000, 2000, and 4000Hz, i.e. 5s on each frequency. Three tests for each of the samples were conducted. The recorded sound was filtered using Gold Wave software on each of the 6 frequencies, with cutoff frequency of ±5%. The same procedure was conducted for a referent sample, using air as a sound transmission medium. The amplitudes of the sound signal on each frequency for each sample were recorded. An example of the referent sound amplitude dampening when inserting an insulation structure is given on Figure 2.

3. RESULTS

To calculate the sound absorption coefficient (α) the difference of amplitude of the sample sound absorption and the referent sound absorption was used:

$$\alpha = 100 - \frac{b}{c} \cdot 100 \ (\%) \quad (1)$$

where:
b – amplitude of the sound waves through the insulation structure
c – referent amplitude of the sound waves

The results for the sound absorption coefficients of the samples are given in Table 3, whereas the resulting sound absorption curves on Figure 3.

In order to obtain a single figure rating the noise reduction coefficient (NRC) defined as the arithmetic average of sound absorption coefficients at 250, 500, 1000, and 2000Hz was calculated for the samples, Table 3.
All samples show increasing sound absorption with the increase of frequency. For the lowest measured frequency of 125Hz the sound absorption is minor, ranging from 11.89% to 34.95%. At mid frequencies (500, 1000 Hz) an increase of sound absorption can be seen, achieving the maximum values at 1000Hz for most of the samples, ranging from 69.9% to 91.5%. The high frequencies show a trend of decreasing sound absorption.

Table 3. Sound absorption characteristics of samples

Sample	α (%)						NRC (%)
	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	
A_1	22.52	41.36	68.94	85.56	80.99	70.33	69.21
A_2	11.89	23.69	69.45	81.45	95.43	73.99	67.51
A_3	29.70	44.62	67.57	77.83	68.27	56.07	64.57
A_4	34.95	55.01	84.16	84.78	67.78	56.07	72.93
B	30.09	41.53	63.00	91.50	85.05	62.81	70.27
C_1	14.05	41.28	70.40	77.97	70.99	71.68	65.16
C_2	32.07	57.72	71.36	75.70	72.59	53.76	69.34
D	13.33	42.20	46.74	78.89	50.99	88.25	54.71
ABC	16.22	50.60	64.25	69.90	91.98	86.71	69.18
ABD	36.76	50.02	76.93	82.75	89.38	61.27	74.77

4. DISCUSSION

The obtained insulation structures exhibit sound absorption properties typical of fibrous materials. The sound absorption curves of all samples show the same trend with maximum absorption achieved at the interval of 1000Hz to 2000Hz. Improved absorption at higher frequencies is typical of porous structures, as they function through the mechanism of dissipative absorption which is particularly efficient at high frequencies.

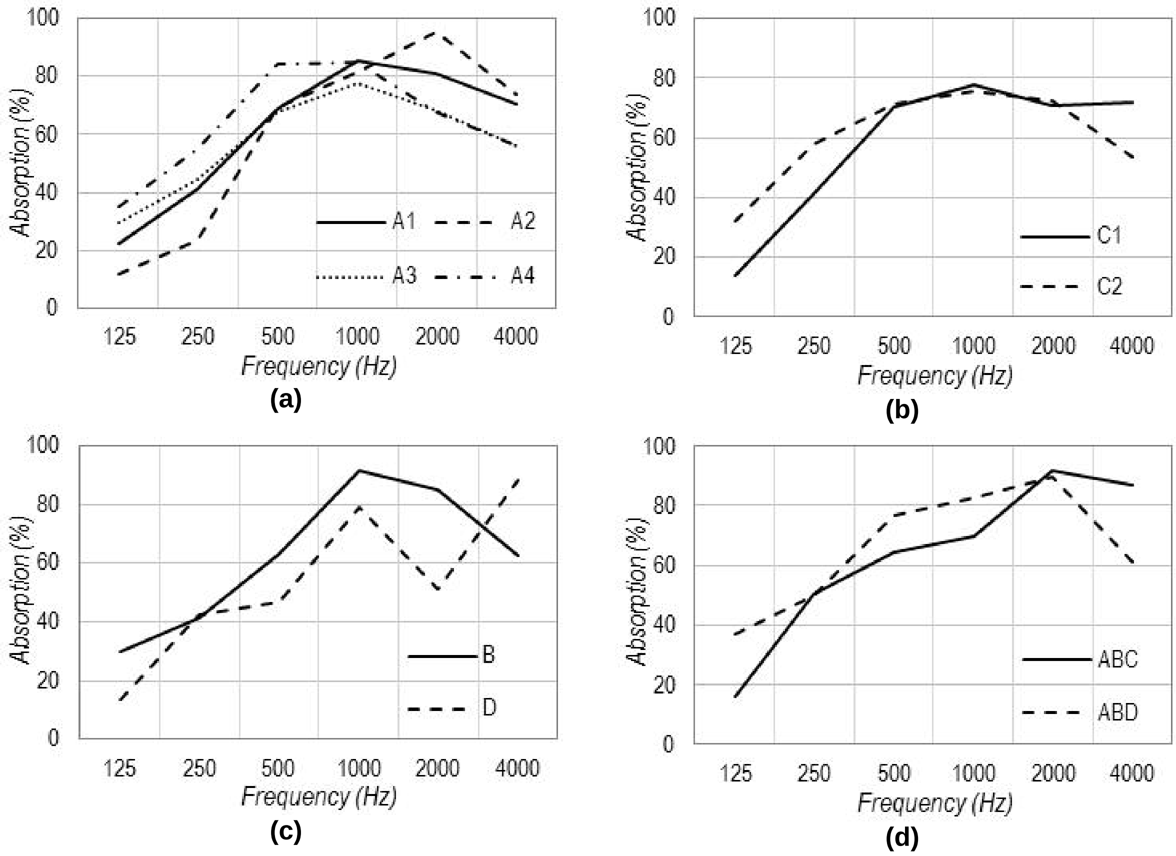

Figure 2. Absorption curves for samples A (a), C (b), B and D (c), ABC and ABD (d)

Sound insulators function by blocking the transmission of airborne sound, thus any gaps in the structure allow sound to "leak", in just the same ways that water can pass through seemingly insignificant holes. Therefore, the more homogenous the textile structures the better their sound insulation properties should be. As homogeneity is easily achieved in structures containing materials in partially fibrous form, such as sample B, in comparison to those made of fabric cuttings, structure B should theoretically have better sound absorption properties. However, the variation coefficient of NRC for the tested samples is 7,3% indicating that all obtained structures, regardless of the preparation method, have comparatively similar sound absorption properties. In other words, when taking into account the human perception of sounds the difference in sound insulation provided by the various samples is negligible. The achieved sound absorption with NRC ranging from 54,71% to 74,77% is comparable to commercially used insulators, such as glass wool (NRC=66,3% for thickness of 50mm and density of 50kg/m^3), stone wool (NRC=63,8% for thickness of 50mm and density of 80kg/m^3) or polystyrene (NRC=51,8% for thickness of 50mm and density of 28kg/m^3) [17].

5. CONCLUSIONS

The research work presented in this paper was concentrated on the analysis of sound insulation properties of a novel insulation structure composed from polyester apparel cutting waste. The obtained noise reduction coefficient of this structure is similar to the values of insulators commercially used in building for thermal and sound insulation. Applying textile waste as an insulation material may bring environmental, sustainable and economic advantages, as the material in question is readily available and the production process is simple and cheap, although its use is limited to internal walls and roofing constructions.

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