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Sustainable Panels with Recycled Textile Materials for Improving Classroom Acoustics

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ABSTRACT
The production processes of traditional acoustic materials make an unfavourable impact on the environment. Therefore, a new "green drive" introduces new eco-friendly alternatives for noise control. Aiming to improve the quality of an existing classroom with poor acoustics, a recycled textile material was implemented in the interior design of the classroom. The low production cost, based on the reuse of waste materials, and the porous structure make the recycled textile material a promising solution for building sustainable panels for eco acoustic treatments. In order to evaluate the acoustic potential of this eco-material, acoustic measurements were carried out in the classroom before and after the treatment. The acoustic efficiency of the textile was determined by comparing and analysing the measured and calculated acoustical quantities.

Keywords: Recycled textile, Reverberation time, Classroom acoustics
I-INCE Classification of Subject Number: 35

1. INTRODUCTION

Due to the growth of the global population and technological progress, the mankind is facing extensive pollution of the environment from all types of waste. Huge amounts of wastewater, pollutant gases and solid waste are prevalent everywhere, leading to degradation of the eco system to an alarming level. Textile waste is not one of the leading solid wastes, but the textile consumption trend nowadays (pay one for two) has progressive growth. In 2014, EU-28 produced 2.29 million tons of textile waste. Only 20% of the textile waste is recycling and almost 80% is going to landfill or incineration, which means that the textile consumption mostly follows the system take-make-waste. In 33% of global textile production is cotton, 60% synthetic fibres and 7% others, [2].

Sound communication, which is the fundamental mechanism for perception, transmission, exchange of information, imposes the need for acoustic optimization of the rooms. Depending on the purpose of the room, various criteria for acoustic quality are set, starting from elementary comfort to precisely defined acoustic needs in rooms with specific purpose as concert halls, theatres, recording studios, etc. Low quality of classroom acoustics leads to poor speech perception, poor listening comprehension, sound-induced disturbance and vocal fatigue in teachers, [4, 5].

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The main objective of this research is to find alternative sustainable materials that have production technology with low use of energy, water, chemicals and reduced CO2 emission and with satisfactory sound absorption properties that can be applicable for various acoustic treatments. Recycled textile has potential regarding their porous fibrous structure. Their use in acoustic treatment will give additional value to a significant part of the textile waste.

2. RECYCLED TEXTILE

One of the main room acoustic parameters is the reverberation time. The acoustic quality of indoors is correlated to the shape and dimensions of the room, as well as to the material features of the inner contour of the room. In order to reduce the reverberation time in an already built room, it is necessary to increase the sound absorption through an appropriate selection of surface treatments. The absorption coefficient is used to define the ability of material to absorb sound. There are many researches that explore the absorption properties of different types of recycled textiles [7, 8, 9].

The structure of the textile (mostly polyethylene) is consolidated without any binder, by interlacing the fibers, Figure 2. At first, textile waste is collected from various textile industries, then it is selected and sorted according to the composition and recycled to obtain staple fibers. For the purpose of this research, 4 mm thick recycled textile is used.

Figure 1 – Recycled textile.

3. ACOUSTIC TREATMENT OF CLASSROOM

With adaptation of the basement space of the Faculty of Civil Engineering in Skopje, an auxiliary classroom was built, Figure 2. The classroom has a rectangular shape with plane dimensions of 6.73 m x 13.76 m and height, h = 3.00 m up to the beam and h = 3.30 m up to the slab. The walls are built from plastered concrete, the ceiling is from uncovered ribbed concrete slab and the floor is made of laminate. On the walls, painted plywood panels are hanged. These panels are used during the student exhibitions. The windows are single with wooden frames. It is obvious that all of the interior surfaces of the considered classroom are hard and exclusively reflective. There is a lack of sound absorption surface and therefore, a long reverberation time (bad acoustics) in the classroom is expected.

To reduce the reverberation time in the classroom, recycled textile with thickness of 4 mm is used to cover all the plywood panels that are hanged on all four walls. Also every third span between the ceiling ribs is covered with recycled textile. In total, 80 m^2 of recycled textile is built-in in the classroom, Figure 3. This treatment was implemented to examine the absorption capacity of the recycled textile and their acoustic possibilities only, without considering the aesthetics of the classroom. Using different textile colours and panel design, more elegant solutions may arise.

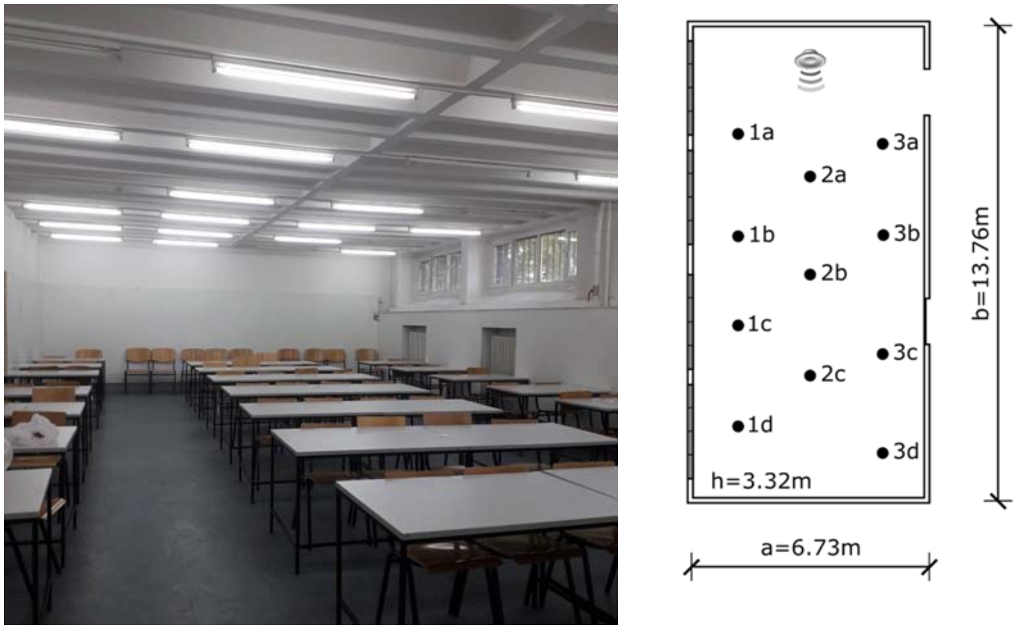

Figure 2 – Interior and geometry of the classroom.

In order to examine the acoustic quality of the classroom, several measurements were performed before and after the treatment of the classroom to determine the reverberation time. Pink noise was generated throughout speakers and measurements were made using Cirrus 171b sound level meter (class 1 microphone, microphone pre-amplifier, 1:3 octave band filters). The sound source was located on the usual teacher's position, centrally in relation to the width of the room and 11 pupil's (measurement) positions were used to pick-up the sound signals. The sound source position and the pattern of the measurement positions are given in Figure 2.

Figure 3 – Acoustical treatment of the classroom.

4. RESULTS AND DISCUSIION

For each measuring position, the reverberation time is obtained as the mean value of three measurements. The reverberation time values for all 11 positions measured before the treatment are given in the Figure 4 and measured after the treatment in Figure 5.

The reverberation time before the treatment, as expected, has significant values. For low frequencies, the reverberation time has values between 2.5 sec and 3.5 sec, for middle frequencies between 2.1 sec and 2.5 sec and for high frequencies between 1.6 sec and 2.1 sec. For low frequencies, the reverberation time after the treatment has values between 1.6 sec and 2.1 sec, for middle frequencies between 1 sec and 1.6 sec and for high frequencies between 0.8 sec and 1 sec.

From the results, it can be seen significant improvement after the treatment. For the higher frequencies, the reverberation time reduction is around 50% and for lower frequencies around 40%, Figure 7.

The thickness of the material is correlated to the absorption of the low frequency and as a rule of thumb, it should be at least a quarter of the wavelength of the incident waves. Therefore, to increase the efficiency of the recycled textile the thickness of the textile should be increase.

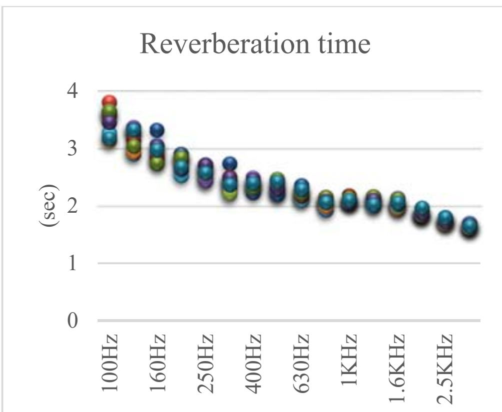

Figure 4 – Reverberation time before the treatment.

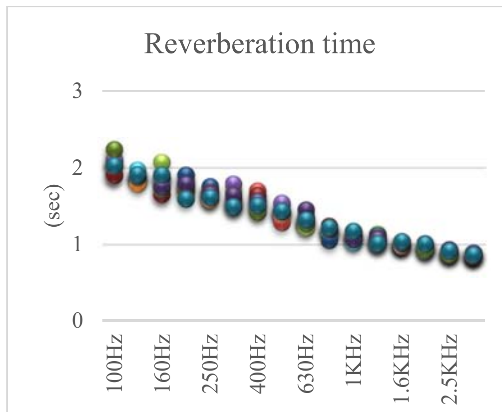

Figure 5 – Reverberation time after the treatment

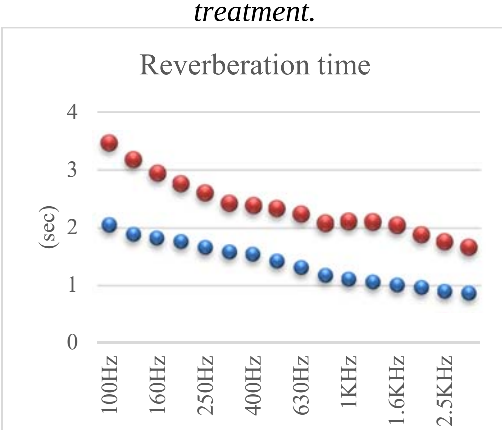

Figure 6 – Average reverberation time before and after the treatment.

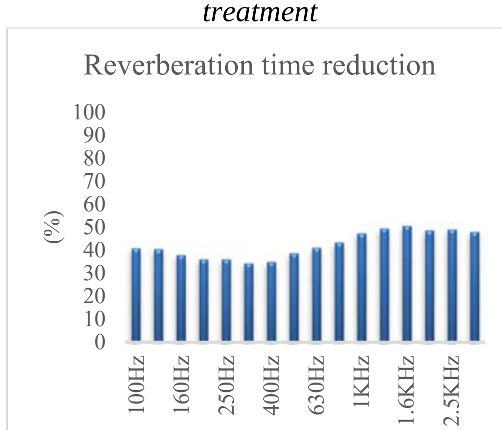

Figure 7 – Reverberation time reduction after the treatment.

Very often in the practice, the sound quality parameter C50 is used to determine the clarity of a sound in a speech room. This parameter represents the ratio between early sound energy, i.e. the sound energy arriving in the first 50 msec and the sound energy after that, expressed in decibels. The greater the value of this parameter, the greater the clarity of the sound in the room is, because in that case the direct sound and early reflection that are the carriers of the original sound are dominant in comparison to the late reflection that reduces the clarity of the sound. This parameter can be calculated in the function of the reverberation time based on the relations derived by Baron and Lee [6] in the octave spectrum. The calculated values for C50 before and after the treatment for each measurement position are presented in Figure 8.

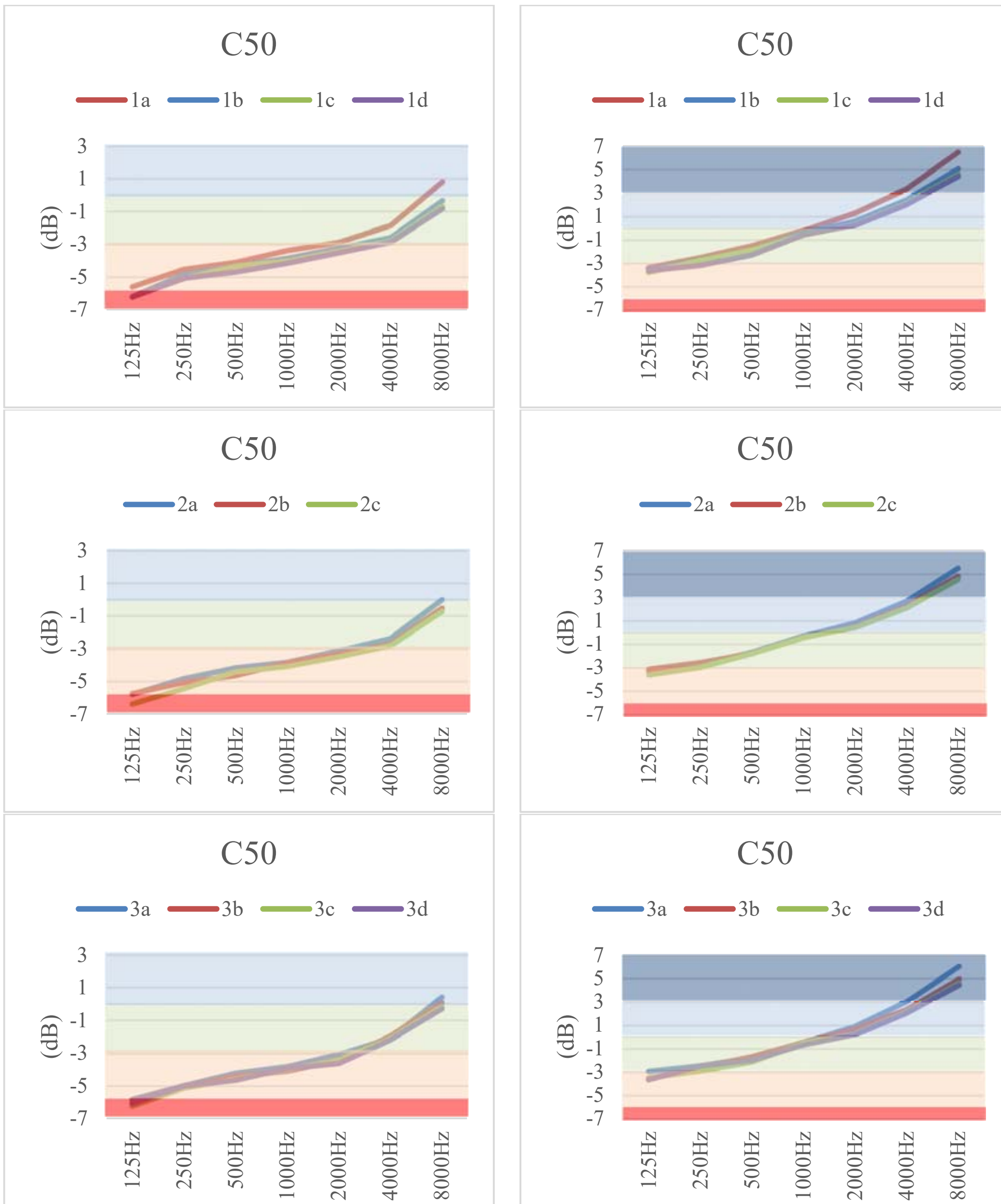

Figure 8 – Clarity, C50, before and after the treatment.

Clarity can be bad, poor, fair, good and excellent and these regions are presented on the graphs. Before the treatment, only small part of the high frequency region has a good clarity and the other part fair clarity, low and middle frequency region has poor clarity and part of the low frequency bad clarity. After the treatment, the clarity curves are shifted into fair, good and excellent region and only part of low frequency are in the poor quality region.

The Speech Transfer Index, STI is one of the basic parameters for assessing the comprehensibility of speech in one room and in a diffuse field can be calculated by the relation derived by Baron and Lee [6]. The calculated values for STI before and after the treatment for each measurement position are presented in Figure 9.

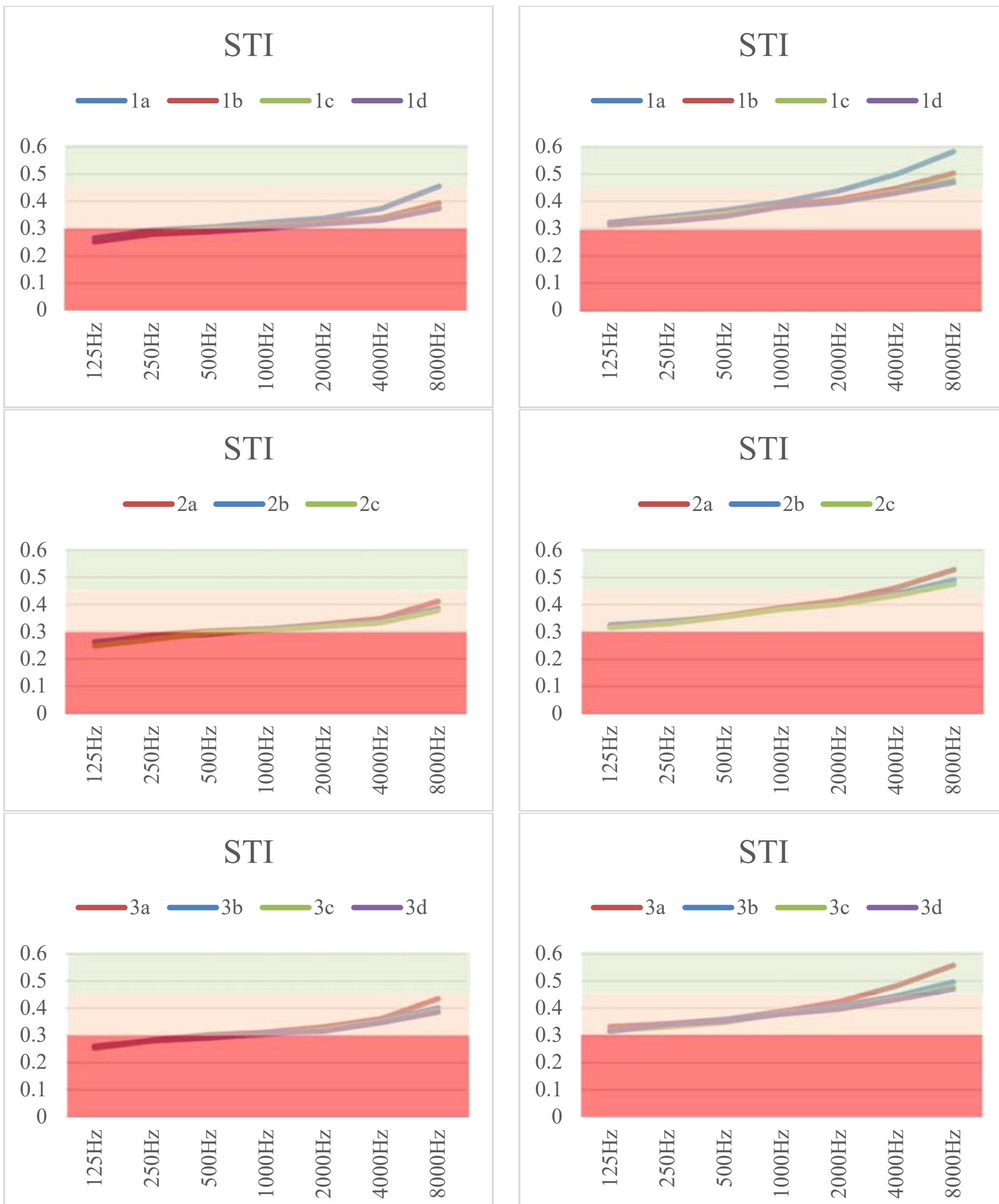

Figure 9 – Speech transmission index, STI, before and after the treatment.

Unintelligible, poor and fair regions of STI are presented in the graphs, good speech intelligibility is for STI >0.6 and excellent for STI>0.75. Before the treatment, the STI curve is in the unintelligible and poor region and after the treatment in the poor and fair area.

The results show that the recycled textile has improved the acoustic quality of the classroom throughout reducing the reverberation time for 40-50% and increasing the clarity and speech transmission index. However, it is not sufficiently, especially in the low and middle frequency regions. In order to improve the efficiency of the textile, higher thickness should be considered, Figure 10.

Figure 10 – Acoustical panels from recycled textiles.

5. CONCLUSIONS

The recycled textiles implemented in the classroom are formed from raw materials from the waste collected in more textile enterprises in Macedonia. The measured and calculated results have shown that these recycled textiles with their porous fibrous structures are promising solution for acoustic application. They are also sustainable and cheaper than many other materials. On the other hand, this alternative use of the waste is towards maximizing the economic and environmental benefits. By engineering the thickness, density, porosity, fibre surface area, a sustainable and affordable sound absorbing panels may be produced.

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