Modelling, Measurement and Control B
Vol. 87, No. 3, September, 2018, pp. 172-179
Journal homepage: http://iieta.org/Journals/MMC/MMC_B

Textile wastes in building sector: A review

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https://doi.org/10.18280/mmc_b.870309

Received: 17 February 2018
Accepted: 28 April 2018

Keywords:
acoustic properties, hygrothermal properties, mechanical properties, sustainable materials, textile waste

ABSTRACT

Textile waste can be classified as pre-consumer and post-consumer waste. Pre-consumer waste is by-product materials originated from the textile industries; post-consumer residues are defined as any type of article made from manufactured textiles discarded because of damages or ageing. The purpose of this paper is to report a state of the art of feasible applications in building industry of the textile waste. Textile fibers mainly could be used to realize insulation products. Moreover, the fabrics acted as reinforcement in the matrix of composites or as an alternative they are used in lightweight bricks. Textile threads can be also employed as a reinforcement fibers in cement based renders. The role of the residual textile fibers as sustainable and innovative raw materials is studied. The mechanical, hygrothermal, acoustic properties of innovative building composites are investigated.

1. INTRODUCTION

In the last decades the problems related to the disposal of waste have assumed a growing importance due to the increase of their production following the escalation of consumption. In a developed industrial society, waste management constitutes the main activity to ensure the environment protection. By reducing waste fluxes to landfills and by increasing waste reuse allow to avoid or mitigate the waste impact on the environment [1].

In the textile sector, the fashion cycle makes the style obsolete before the real end of life of the dresses, generating waste and over consumerist practices. A textile fabric can provoke pollution from the earliest stages of production (pre-consumer waste) to the end of its useful life (post-consumer waste) [2]. Pre-consumer waste or post-industrial waste includes all fiber, yarn and fabric waste produced during the garment manufacturing process, whereas post-consumer waste consists of all clothing discarded by the users because they are considered worn out or not fashionable. The recycling of pre-consumer and post-consumer waste can help significantly to reduce the environmental impact associated with the textile industry by limiting the need for landfill.

The environmental effects associated with the building industry could also be reduced. The world of construction industry has significantly grown in the last few decades and, as consequence, its harmful environmental effects are increased. Traditional buildings consume a huge amount of energy and raw materials both during their life, construction and demolition phases. Therefore, it is important to develop sustainable strategies for the energy saving. Passive building design can be considered one of the main important answer to the issue of the energy consumption. Lalmi et al. [3] investigate a bioclimatic greenhouse using the solar energy storage system to ensure internal thermal comfort. The excessive consumption of raw materials will provoke definitely the scarcity of the resources for the future generations. Therefore, it has become very important to consider the eco-friendly materials produced by secondary raw materials [4].

Several researches [5-9] have investigated the utilization of waste to produce building materials in order to improve the environment protection and the sustainable development.

The textile recycling can be classified into two categories: the recycling within the production process and the recycling out of the production process. The first category regards the reuse of textile wastes as raw material with a production process analogous to the textiles one, i.e. the home furnishing articles. The recycling out of the production process concerns the reuse of the textile wastes as new raw materials in a different production process, i.e. the develop of composite materials in the building industry [10].

Despite the potential for use of waste textile fibers, the recycling rate is not significant. Economic reasons and insufficient public awareness have led to unsustainable waste disposal methods. Most of textile waste materials as nylon, polyester or polypropylene are still disposed as municipal waste provoking environmental problems due to their slow degradation and due to their high non-renewable petroleum resources content [11].

The inclusion of these leftovers products in a new manufacturing process could be the development of a new model of circular economy. This is a new strategy to achieve a sustainable environment by reducing waste and by maximizing the added value of new products. The challenge is the development of an economy model based on the industrial production that will not only have a positive impact on the environment but also contributes to economic growth [12]. The textile waste offers many attractive opportunities in different sector, i.e. the automotive industry, the construction industry or the energy sector. Nunes et al. [13] and Avelar et al. [14] used textile fibers in response to an increasing demand of alternative forms of thermal energy.

This paper presents a state of the art of the use of textile waste to produce innovative and sustainable composite building materials. The hygrothermal, acoustic and mechanical properties of these materials were also investigated.

2. TEXTILE BUILDING MATERIALS

The earliest research approaching to the use of textile waste for building materials was published in 2003 [15], this means that it is a fairly new activity. The interest in textile building materials has increased since 2012 and, especially since 2014 a great number of experimental results have been published (Figure 1).

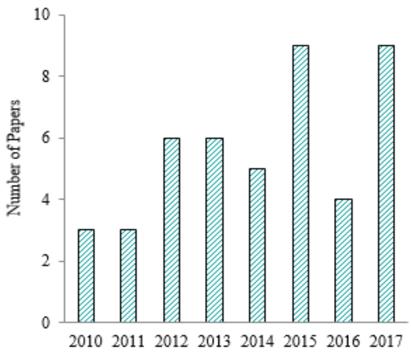

Figure 1. Numbers of papers published annually

Textile waste find mainly application as insulating materials, but also as lightening of bricks. Waste yarns could be valid alternative reinforcement for mortar and render.

The prevailing method used to produce textile composites materials is the mixing of textile fibers with epoxy or formaldehyde resins. The needle-punching technique and the thermoforming of textile waste with polyester fibers are the most efficient processes to produce insulating mats because both processes avoid the addition of toxic binders to the mix.

The needle-punching technique is the oldest method of producing nonwoven fabrics. This technique provides a mechanical binding in which some of the fibers are driven upward or downward by barbed needles. The needling action interlocks fibers and holds the structure together by friction forces.

Polyester (PET) is widely used in the beverage bottles and textile industry. Nowadays there is a great recycling of PET from bottles, but recycling of PET from fabrics is still a big challenge. PET fabrics are often mixed with other fibers, i.e. cotton, creating mixtures that are very difficult to dispose. These fibers are often incinerated to recover energy, but many are still often set down in landfills. PET is a synthetic fabric made from petrochemicals non-biodegradable materials, so its degradation is harmful to the environment. Different methods have been studied to dispose of the PET fabrics (i.e. PET extraction, or cellulose extraction from cotton/PET blend fabrics, or PET dissolution), but they are unfeasible because of their high cost. The use of polyester textile fibers in construction materials is a sustainable alternative of recycling non-renewable resources, creating a new low cost raw materials [16].

3. HYGROTHERMAL, ACOUSTIC AND MECHANICAL PROPERTIES

Hygrothermal, acoustic and mechanical requirements have to be satisfied when considering a building material. The main challenge of future buildings is the reduction of energy consumption in their cycle of life. In order to reduce the heating and cooling demands, different strategies are focused on improving the insulating properties of the building envelopes. Efficient insulation materials are also important to reduce the impact of noise [17]. The use of waste allows the manufacturing of bio insulation materials able to minimize the environmental impacts of buildings reducing the energy demand both during the construction phase and the use, and able to ensure suitable acoustic performance [18].

3.1 Hygrothermal properties

The thermal conductivity (λ) is considered the most important parameter when evaluating thermal insulation. According to Smith [19] the thermal conductivity value of the air is very low compared to a solid matrix. For this reason, porous materials find wide applications as thermal insulators. Textile fabrics consist in a solid matrix characterized by a huge fraction of interconnected voids [20]. The porous structure of fabrics waste can contribute to increase the porosity of building materials in which they are incorporated. Hadded et al. [21] analyzed the thermal behavior of two recycled textile samples, i.e. waste linter and waste tablecloth. It was found that the thermal performances of the materials were mainly influenced by their porosity. The tablecloth structure showed better thermal insulation capacity than linter structure due to the air trapped in the numerous pores.

Tortuosity (ratio of the open pores length and the material thickness) reduces the free passage of heat flux, improving the insulating performances of materials. El Wazna et al. [22-23] utilized 100 % wool (W) and 100 % acrylic (A) fibers to manufacture needle-punched non-woven mats. They controlled some parameters of the needle punching process, i.e. the speed and the thickness of needle, the needle punch depth, the number of barbs and the stitch angle, to improve the tortuosity and the porosity of the mats. All tested samples exhibited good thermal insulation properties, better than other conventional insulation materials (glass wool, mineral wool and extruded expanded polystyrene).

Gounni et al. [24] designed a test wood cell in order to analyze the thermal insulation potential of a non-woven material mainly composed of acrylic spinning waste (As). The outside temperature of the walls of the test cell outfitted with as were compared with the temperature of the control wall without As. Experimental test results showed that the walls outfitted with as exhibited a lower outside surface temperature with a reduction in the heat flux exchanged.

Patnaik et al. [25] carried out a research about different type of innovative needle-punched mats. Two mats were obtained from two type of 100 % waste wool fibers (CW and DW), two others mat from the combination of the two type of wool waste and recycled polyester (CWP and DWP), the last one was manufactured from 100 % recycled polyester (RPET). Test results suggested the possibility to develop suitable materials for roof ceiling insulation with thermal conductivity value comparable to 100 % wool fibers insulators. A protective barrier on the wool fibers was created by spraying silicon in order to avoid that an excessive absorption of moisture affected the thermal performances of the samples. Test results showed that all samples absorbed a quantity of moisture slightly higher than the maximum requirement of 2 % according to standards.

Sometimes, in order to ensure sufficient cohesion between textile fibers to create building materials, the thermal bonding manufacturing processes were used. Hassanin et al. [26] developed insulating panels mixing different combination of Tetra Pak® waste and wool yarn waste. Several mixes of Tetra Pak® and different percentages of wool waste (from 0 % to 20 %) were hot pressed in two stages to reach a thickness of 5 mm. Results showed that the addition of textile fibers caused the increase of the porosity and, as consequence, the decrease of the thermal conductivity. Sedlmajer et al. [27] used the thermal bonding method by bi-component PE fibers. Five different insulating mats were produced with various textile fibers. The textile waste combination tested were cotton pure/recycled PES/bico fibers (40/40/20), recycled PES/bico fibers (80/20), cotton raw/recycled PES/bico fibers (40/45/15 or 45/40/15). All tested materials exhibited good thermal properties but the mats with higher cotton content showed, at the same volume weight, greater performances than the materials with higher proportion of polyester fibers. The effects of the density value and the temperature on the thermal behavior of building materials were studied by Drochytka et al. [28]. They prepared testing samples with polyester fibers and synthetic bi-component fibers by thermal bonding method. Samples with density of 65 kg/m³, 80 kg/m³ and 90 kg/m³ were prepared. The coefficient of thermal conductivity was measured at four different temperatures (from 10 °C to 40 °C). The thermal conductivity decreased with the decrease of temperature and the increase of density.

Figure 2 shows the thermal conductivity of some analyzed insulating mats. For the references [22-23] are shown the mean values of λ and the density values of the two acrylic samples and of the two wool samples respectively. For the reference [28], only the thermal conductivity coefficients at 10 °C are shown. It can be seen that all examined materials exhibit a thermal conductivity coefficient of 0.037 W/(m·K) mean value, with a standard deviation of 0.005 W/(m·K).

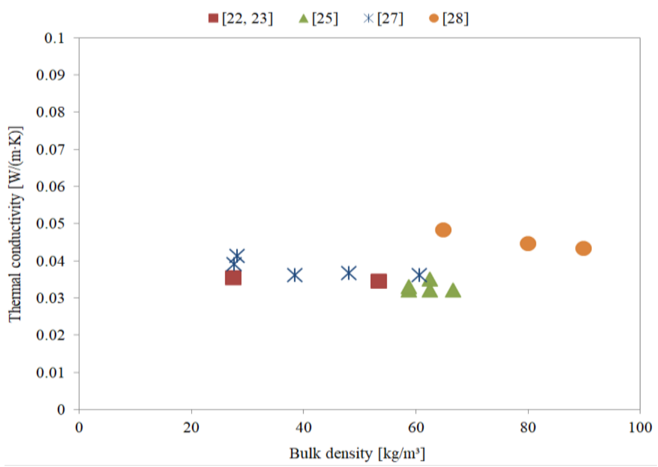

Figure 2. Thermal conductivity versus bulk density for insulating mats

Several authors carried out research to produce innovative insulating sandwich-shaped composite from low cost textile waste and with excellent thermal properties. Ricciardi et al. [29] evaluated the thermal performances of two type of panels differing in central layer thickness. A core of waste paper was glued and pressed between two layers of polyethylene fibers to reach thicknesses of 7 mm and 15 mm. The mean value of thermal conductivity was varying in 0.034-0.039 W/(m·K) range, with higher performance respect to traditional insulating materials. Binici et al. [30] investigated new lightweight composite materials in which a mixture of fly ash, cotton waste and barite was applied between two chipboards. It was observed that when the content of cotton fibers increased, the thermal performances of the chipboards improved. Besides, the use of barite allowed a radioactivity permeability control. Cosereanu et al. [31] simulated the thermal behavior of a sandwich wooden wall with the core filled with different textile waste composite materials. By comparing the innovative wall with the brick wall, was concluded that the wooden structure showed a higher thermal resistance than the brick one at the same thickness.

Trajković et al. [32] and Jordeva et al. [33] produced an insulating material encasing different fabric mixtures in 100 % polypropylene non-woven structure. The mix used for this research were 100 % polyester (blends A and C differing in the size of the waste), polyester/cotton/lycra (blend B: 70/25/5) and polyester/lycra (blend D: 95/5). All tested samples exhibited a thermal conductivity value varying between 0.052 and 0.0603 W/(m·K). The measured λ values were similar to standard insulation materials (0.030-0.045 W/(m·K)). Tests result also showed that the polypropylene structure containing smaller pieces of cutting fabric exhibited the highest thermal insulation. In addition, the presence of lycra decreased the thermal insulation of the structure.

Barbero-Barrera et al. [34] developed building boards by mixing textile waste and lime paste with different lime-water ratios. The authors proved that the insulating performances of the innovative boards increased by decreasing the lime past content.

Aghaee et al. [35-36] focused on the characterization of lightweight perlite and concrete panels for building partition. Woven meshes of glass fibers were used to confine the cotton fibers in the central part of the concrete specimens. The perlite porosity and the textile fiber core allowed to have a thermal conductivity lower than 0.3 W/(m·K).

Kalkan et al. [37] proposed denim powder fibers (DPF) as a new type of mortar reinforcement. Several perlite and pumice mixtures with a different denim waste content were tested. Samples with DPF additives up to 1.25 % in 28 % perlite exhibited better thermal properties and vapour permeability values than samples in 20 % perlite. All tested mortars showed a thermal conductivity varying from 0.084 W/(m·K) to 0.129 W/(m·K) and a water vapour resistance coefficient from 9.2 to 12.8 respectively.

Several researches [38-41] investigated the use of textile fibers to produce lightweight bricks. They reported thermal conductivities and water absorption values. Figure 3 shows the water absorption values of some examined bricks. Rajput et al [38] investigated the hygrothermal effects of the addition of recycled paper mills waste (PW) and cotton waste (CW) to cement bricks. Three types of bricks were produced by mixing different percentages of cotton waste (from 1 % to 5 % b.w.) and paper mills waste (from 85 % to 89 % b.w.) with 10 % of cement by weight. Results indicated that with the increase of the cotton fibers waste the porosity increased from 0.18 to 0.29. A more porous structure allowed an improvement of the thermal performances (λ decreased from 0.32 to 0.25 W/(m·K)) and an increase of the water absorption.

Binici et al. [39-40] examined the thermal properties of cement bricks reinforced with cotton waste (CW) and textile fly ash (TW) and compared them with commercial concrete bricks (CB). They built and monitored two model house with same size but different envelope material. Experimental investigations revealed that the innovative bricks were more lightweight than the ordinary one, thus they showed better insulation capacity, i.e. the thermal conductivity coefficient was 29.3 % lower than CB. This reduction explained the rapid increase of the heating temperature of the model house constructed with cotton waste and fly ash bricks compared to the same model house made with traditional concrete blocks. As shown in Figure 3, the water absorption of the innovative bricks decreased with the increase of the content of cotton fibers. Algin et al. [41] used cotton wastes as lightening fibers for bricks. The work concerned the hygric properties of lightweight composite materials developed by mixing the cement with different combinations of cotton waste (CW) and limestone powder waste (LPW). Figure 3 showed that the water absorption and the CW percentage content were directly proportional. Substituting of 40 % LPW volume with CW, was achieved a water absorption 27.2 % b.w. that is a satisfactory value compared to other lightweight building materials. Similar results were obtained in the work of Agrawal et al. [42]. Their research was on the use of textile fibers in the manufacturing process of clay bricks. Four different combination of polyester/viscous blend (PV), polyester/cotton blend (PC), 100 % polyester (POLY) and PV+PC+POLY were incorporated in clay bricks. Test results indicated that the samples containing textile fibers exhibited a lower water absorption than the clay sample without textile_waste, as shown in Figure 3. It was also concluded that the increase of textile fibers content increased the water absorption of the samples.

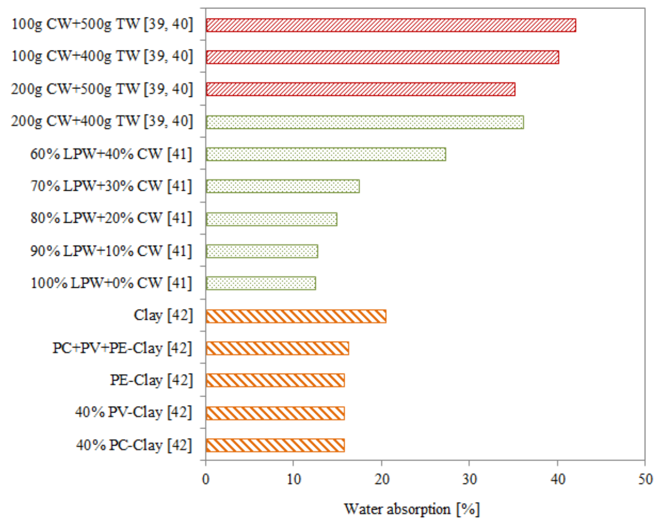

Figure 3. Water absorption values for bricks

The U-factor value, is an important parameter for evaluating the performances of building insulators. Briga-Sà et al. [43] and Paiva et al. [44] carried out an experimental work to determine the U-factor of an external double wall with the air cavity filled by woven fabric waste (WFW) and woven fabric subwaste (WFS). The results indicated that the double wall with the air cavity filled with WFW and WFS exhibited a thermal resistance higher than the double wall with the empty air cavity. Authors stated that WFW and WFS can be considered alternative sustainable insulating materials with thermal properties comparable to usual insulating materials as EPS, XPS, mineral wool, granule, vermiculite or expanded perlite.

3.2 Acoustic properties

Porous materials can convert the energy of sound wave to heat when the sound travels through them. Sound propagation takes easily place in porous matrix characterized by a network of interlocking pores where acoustic energy is dissipated by viscous effects. Fibrous structures are good examples of sound absorbing materials. For this reason most of the textile post-consumer waste and textile industrial waste are mainly used in the form of acoustic absorber [45]. The sound absorption coefficient α is the usual parameter utilized to define the acoustic performances of a porous material and its assessment commonly refers to ISO 10534. In some cases, sound absorbing performance is evaluated by means of Noise Reduction Coefficient (NRC) defined as the mean of the absorption coefficients at frequencies from 250 Hz to 2 kHz.

Several authors proposed the use of polyester in construction materials. Polyester is the most used textile fiber in clothing, thus it is the dominant waste component of the garment industry. Lee et al. [46] proposed the use of recycled polyester fibers to produce innovative sound absorbing non-woven materials by thermal bonding method. The influence of diameter, content and orientation angles of the fibers on the absorption coefficient was investigated. Authors pointed out that by increasing the diameter and the content of fibers, the coefficient α of the non-woven improved as a consequence of the greater possibility of intercepting the sound wave. They stated that the orientation angles of the fibers did not affect the acoustical performances of the innovative materials. Drochytka et al. [28] concluded that the sound absorption coefficient of innovative polyester waste thermal insulators was dependent on the bulk density value, in the higher frequency band between 1000 and 1600 Hz. Trajković et al. [32] and Jordeva et al. [33] observed that the α value of all tested materials was maximum in the range of 1000-2000 Hz and the NRC value was similar to that of other commercial building insulator (NRC was in the range from 0.55 to 0.75).

Tiuc et al. [47] investigated the improvement of the NRC of rigid polyurethane foam (RPF) by incorporating textile waste (TW). Results showed that the rigid polyurethane foam including a 60 % of waste textile fibers exhibited a NRC that was twice as the foam without textile waste.

According to Patnaik et al. [25], the thickness of non-woven materials significantly affected their sound absorption performances. The cause was that a higher thickness lengthens the path of the sound wave through the voids in the material creating more frictional losses with the fibers, with a sound energy damping. The authors carried out a research on new needle-punched non-wovens with good acoustic absorption properties in the overall frequency range (50–5700 Hz). The DWP sample showed a higher sound absorption value than the RPET sample due to the rough surface of the wool fibers that improved the friction phenomena by increasing energy losses. In addition, test results indicated that the fibers length also affected the acoustic performances of the material. About that, DWP showed a higher α value because of the long length of the included fiber that created a very uniform pore structure for sound wave interaction. Similar conclusions were drawn by Seddeq et al. [48] and Ricciardi et al. [29]. Seddeq et al. [47] investigated different non-woven materials containing natural textile fibers (jute, cotton and wool) mechanically connected with synthetic textile fibers (polyester and polypropylene), using the needle punched technique. All tested samples showed a good sound absorption coefficient at mid and high frequencies, but a lower sound absorption coefficient at low frequencies. Test results demonstrated that adding air space behind the sample increased sound absorption at low and mid frequencies. Ricciardi et al. [29] studied that when the thickness of insulating panels decreased, the α coefficient decreased and the peak value was shifted towards the low frequencies. The NRC of the tested samples varied from 0.25 to 0.40 based on the thickness of the layers.

Figure 4 displays and compares the NRC of some textile composite materials examined above.

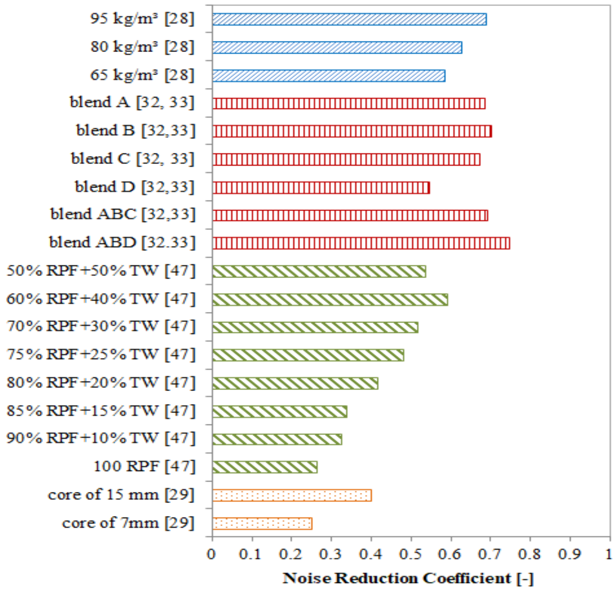

Figure 4. Noise reduction coefficient for same examined composite materials

Barbero-Barrera et al. [34] investigated the effects of the construction water content on the acoustic performances of textile waste-lime panels. It was observed that α increased with a higher water to lime ratio, due to the increase in the amount of pores in which sound waves could easily penetrate.

Segura-Alcaraz et al. [49] analyzed the improvement of the acoustic properties of two type of polyester non-woven by adding a microfiber fabric layer. Results showed that when one or two layers were added, a significant increase in absorption coefficient of the non-woven materials was obtained.

Curtu et al. [50] analyzed the acoustic properties of innovative textile composite materials with a potential role in the urban habitat. The materials tested in the research were produced by mixing wood and textile waste with different binders as acrylic copolymer, clay solved, gypsum solved and formaldehyde. The influence of the type of binder on the acoustic behavior of the samples were investigated. Results pointed out that samples manufactured with acrylic copolymer as a binder exhibited a great sound absorption value at high frequencies, unlike the samples produced with formaldehyde performed a not classifiable acoustic behavior and they were the most reflective composite materials due to the flat and smooth surfaces. Samples blended with clay solved in water exhibited a constant sound absorption coefficient in the frequencies range 800-3200 Hz. Increasing the density value of the materials produced a decrease in the sound absorption coefficient.

Del Rey et al. [51] focused on the characterization of innovative acoustic insulation materials developed from several combination of cotton fibers, polyester fibers and bico PET fibers mixed with phenolic resins or recycled PET fibers. A prototype of a noise adsorbing barrier was designed using the new insulation materials as a core of a metal structure with a drilled plate at the side exposed to the noise source. The new fibrous materials barriers exhibited sound absorption coefficients and airflow resistivity values similar to other commercially available absorptive noise barriers.

Binici et al. [52] examined the acoustic performances of new insulation materials produced by grinding and by mixing agricultural and textile waste. Plaster or epoxy was used as binder. The obtained boards were applied to walls of a test room and sound insulating properties measurements were carried out. An improvement of the sound insulation performances of the walls was proved.

Binici et al. [30] comparing sandwich-shaped chipboards including textile fibers with control chipboards, concluded that the presence of fibers improved sound insulation.

3.3 Mechanical properties

In order to classify a material as a construction material, it must show suitable engineering properties that attest to its quality and convenient application field. The mechanical properties define the structural or non-structural use of the materials.

Umar et al. [53] used yarns derived from textile waste to produce sustainable composite materials that could replace fiberglass materials in low strength structural applications such as door panels or partition panels.

Aghaee et al. [35-36] developed a textile composite concrete with absorbed strain energy about twenty five times higher than the lightweight aggregate concrete without textile fibers. This was due to the orientation of the tensile mesh glass fibers in the direction of the tensile forces. A material with a great ductility and bending ability was achieved. The use of the innovative panels led a reduction in the specific weight of the internal partitions by about 20 %. The lesser weight reduces the damages and the possibility of collapse of the panels in case of an earthquake. Deformation testing showed that the samples exhibited good bending capacity because of the large amount of absorbed energy.

Zou et al. [54] developed composite materials from PET/cotton blend fabrics in order to find a suitable application of PET containing textiles. The fabrics were sprayed with a solution of ethanol and glycerol or 2-phenyl phenol to reduce the melting PET temperature. Results showed that the use of plasticizers allowed to reduce the composite manufacturing time and temperature, but decreased the mechanical performances of the tested composites.

Ramamoorthy et al. [16] concluded that the increase of the compression temperature and time caused the increase of the mechanical properties of the materials. A further increase of these processing parameters produced the degradation of the cotton fibers.

According to Athijayamani et al. [55] the contact of a composite material with water affected the interfacial adhesion between the fibers and the matrix, weakening the bond and worsening the mechanical properties of the composite material. Binici et al. [52] demonstrated that the insulating panels developed from agriculture and textile waste materials showed high porosity, thus exhibiting low compressive strength. Barbero-Barrera et al. [34] retained that the mechanical properties of lime-based insulation boards were affected by the water content that influenced their porosity. A high water content meant high porosity, thus low hardness and low flexural strengths. Rajput et al. [38] tested bricks with good compressive strength (21±1 MPa) to propose as not-load bearing partition walls. They concluded that the amount of fibers used for producing the bricks influenced their mechanical properties due to the nature of fibers to be water-absorbent.

The bricks tested by Agrawal et al. [42] showed a higher average compression value than regular bricks. The compressive strength of all tested materials decreased severely by adding more than 20 grams of PV, PC or polyester additives. Binici et al. [39, 40] produced textile waste and textile ash bricks which allowed to reduce the thickness of the load-bearing walls because of a high compressive and flexural strength. The compressive strength values of all tested materials varied from 8.95 to 13.40 MPa and the flexural strength values was estimated at about 3 MPa. Algin et al. [41] showed that brick samples containing high CW percentages could be used preferably for non-structural applications due to low compressive and flexural strength values. Results proved that with the increase in the CW replacement, the mechanical performances of the analyzed samples decreased.

Kalkan et al. [37] showed that samples with 20 % perlite and DPF percentage content up to 1.25 % by weight exhibited a higher compression and flexural strength than those with DPF reinforcement above 1.25 %. Pinto et al. [55] proposed wool and acrylic thread waste as sustainable alternative reinforcement fibers for cement-based renders. The effect of fiber content and fiber length on the mechanical properties of the new render were investigated. Results showed improved mechanical performances by increasing fiber content and decreasing fiber length. Dos Reis et al. [57] produced an innovative polymer concrete reinforced with textile fibers using different percentages of cotton, polyester, silk and rayon. By comparing the composite material with the simple polymeric concrete, it was concluded that the addition of textile fibers did not improve the mechanical behavior but reduced the brittleness.

Binici et al. [30] proved that by increasing the content of textile waste and the thickness of the panels, the increase in bending strength could be achieved. Liu et al. [58] prepared foamed gypsum blocks from flue gas desulfurization gypsum and textile fiber waste. Results indicated that at 3 % of the textile fibers content the samples showed the maximum compressive strength of 1.6 MPa. Temmink et al. [59] used post-consumer denim waste bounded with thermo set bio-resins (bio-epoxy and acrylate epoxidize soybean oil resin) to develop innovative composite materials. Results displayed that both resins were suitable for manufacture material with structural applications.

4. CONCLUSION

Collect textile waste without recycle can become a serious problem for the health of the environment. The reuse of these leftover materials in new building materials is a solution to the problem of pollution and allows to preserve natural resources for future generation. The different type of textile construction materials and their properties have been examined in this work. Textile fibers can be used to produce sustainable thermal and acoustic insulators in the form of mats or panels, energy efficient bricks, innovative concrete or plaster mortar. Textile materials are comparatively acoustically efficient, with higher thermal performances than conventional building materials. Textile fibers increase the mechanical properties of plaster mortars. The application of textile waste as a secondary raw material is an interesting practice for developing environmental friendly composite materials as substitutes for conventional one. In summary, textile materials are promising materials for buildings, although there is still a lot of work to do. This work can help to have a global idea on the topic and can be a starting point for future research developments.

REFERENCES

[1] Marino C, Nucara A, Nucera G, Pietrafesa M. (2017). Economic, energetic and environmental analysis of the waste management system of Reggio Calabria. International Journal of Heat and Technology 35(4): S108-S116. https://doi.org/10.18280/ijht.35Sp0115

[2] Slater K. (2003). Environmental impact of textiles. Woodhead publishing. Cambridge England, 69-89.

[3] Lalmi D, Bezari S, Hocine, Guermouai MB, Rabehi A, Abdelouahab B, Hadef R. (2018). Analysis of thermal performance of an agricultural greenhouse heated by a storage system. Modelling, Measurement and Control B 87(1): 15-20. https://doi.org/10.18280/mmc_b.870103

[4] Nautiyal H, Shree V, Khurana S, Kumar N, Varun. (2015). Recycling Potential of Building Materials: A Review. In: Muthu SS. Environmental Implications of Recycling and Recycled Products. Springer, Nederlands.

[5] Raut SP, Sedmake R, Dhunde S, Ralegaonka RV, Mandavgane SA. (2012). Reuse of recycle paper mill waste in energy absorbing light weight bricks. Construction and Building Materials 27: 247–251. https://doi.org/10.1016/j.conbuildmat.2011.07.053

[6] Bories C, Aouba L, Vedrenne E, Vilarem G. (2015). Fired clay bricks using agricultural biomass wastes: Study and characterization. Construction and Building Materials 91: 158-163. https://doi.org/10.1016/j.conbuildmat.2015.05.006

[7] Sutcu M, Ozturk S, Yalamac E, Gencel O. (2016). Effect of olive mill waste addition on the properties of porous fired clay bricks using Taguchi method. Journal of Environmental Management 181: 185-192. https://doi.org/10.1016/j.jenvman.2016.06.023

[8] Barreca F, Fichera CR. (2013). Use of olive stone as an additive in cement lime mortar to improve thermal insulation. Energy and Buildings 62: 507-513. https://doi.org/10.1016/j.enbuild.2013.03.040

[9] Liuzzi S, Rubino C, Stefanizzi P, Petrella A, Boghetich A, Casavola C, Pappalettera G. (2018). Hygrothermal properties of clayey plasters with olive fibers. Construction and Building Materials 158: 24-32. https://doi.org/10.1016/j.conbuildmat.2017.10.013

[10] Zonatti WF, Baruque-Ramos J, Duleba W. (2016). Brazilian Scope of Management and Recycling of Textile Wastes. In: Fangueiro R, Rana S (eds) Natural Fibres - Advances in Science and Technology Towards Industrial Applications. Springer, Netherlands.

[11] Hawley JM. (2006). Textile recycling: a system perspective. In: Wang Y (ed) Recycling in textiles. Woodhead publishing.

[12] Korhonen J, Nuur C, Feldmann A, Birkie SE. (2018). Circular economy as an essentially contested concept. Journal of Cleaner Production 175: 544-552. https://doi.org/10.1016/j.jclepro.2017.12.111
[13] Nunes LJR, Godina R, Matias JCO, Catalao JPS. (2018). Economic and environmental benefits of using textile waste for the production of thermal energy. Journal of Cleaner Production 171: 1353-1360. https://doi.org/10.1016/j.jclepro.2017.10.154
[14] Avelar NV, Passos Rezende AA, de Cassia Oliveira Carneiro A, Silva CM. (2016). Evaluation of briquettes made from textile industry solid waste. Renewble Energy 91: 417-424. https://doi.org/10.1016/j.renene.2016.01.075
[15] Lee Y, Joo C. (2003). Sound absorption properties of recycled polyester fibrous assembly absorbers. Autex Research Journal 3(2): 78-84. http://www.autexrj.com/articles/33/118
[16] Ramamoorthy SK, Persson A, Skrifvars M. (2014). Reusing Textile Waste as Reinforcements in Composites. Journal of Applied Polymer Science 131(17): 1-16. https://doi.org/10.1002/APP.40687
[17] Asdrubali F, D'Alessandro F, Schiavoni S. (2015). A review of unconventional sustainable building insulation materials. Sustainable Materials and Technologies 4: 1-17. https://doi.org/10.1016/j.susmat.2015.05.002
[18] Liuzzi S, Sanarica S, Stefanizzi P. (2017). Use of agro-waste in building materials in Mediterranea area: a review. Energy Procedia 126: 242-249. https://doi.org/10.1016/j.egypro.2017.08.147
[19] Smith DS, Alzina A, Bourret J, Nait-Ali B, Tessier-Doyen N. (2013). Thermal conductivivty of porous materials. Journal of Materials Research 28(17): 2260-2272. https://doi.org/10.1557/jmr.2013.179
[20] Stankovic SB, Popovic D, Poparic GB. (2008). Thermal properties of textile fabrics made of natural and regenerated cellulose fibers. Polymer Testing 27(1): 41-48. https://doi.org/10.1016/j.polymertesting.2007.08.003
[21] Hadded A, Benltoufa S, Fayala F, Jemni A. (2015). Thermo physical characterization of recycled textile materials used for building insulating. Journal of Building Engineering 5: 34-40. https://doi.org/10.1016/j.jobe.2015.10.007
[22] El Wazna M, El Fatihi M, El Bouari A, Cherkaoui O. (2016). Thermo physical characterization of sustainable insulation materials made from textile waste. Journal of Building Engineering 12: 196-201. https://doi.org/10.1016/j.jobe.2017.06.008
[23] El Wazna M, Gounni A, El Bouari A, El Alami M, Cherkaoui O. (2018). Development, characterization and thermal performance of insulating nonwoven fabrics made from textile waste. Journal of Industrial Textiles 6. https://doi.org/10.1177/1528083718757526
[24] Gounni A, El Wazna M, El Alami M, El Bouari A. (2018). Thermal performance evaluation of textile waste as an alternative solution for heat transfer reduction in buildings. Journal of Solar Energy Engineering 140(2). https://doi.org/10.1115/1.4038786
[25] Patnaik A, Mvubu M, Muniyasamy S, Botha A, Anandjiwala RD. (2015). Thermal and sound insulation materials from waste wool and recycled polyester fibers and their biodegradation studies. Energy and Buildings 92: 161-169. https://doi.org/10.1016/j.enbuild.2015.01.056
[26] Hassanin AH, Candan Z, Demirkir C, Hamouda T. (2018). Thermal insulation properties of hybrid textile reinforced biocomposites from food packaging waste. Journal of Industrial Textiles 47(6): 1024-1037. https://doi.org/10.1177/1528083716657820
[27] Sedlmajer M, Zach J, Hroudova J. (2015). Possibilities of development of thermal insulating materials based on waste textile fibers. Advanced Materials Research 1124: 183-188. https://doi.org/10.4028/www.scientific.net/AMR.1124.183
[28] Drochytka R, Dvorakova M, Hodna J. (2017). Performance evaluation and research of alternative thermal insulation based on waste polyester fibers. Procedia Engineering 195: 236-243. https://doi.org/10.1016/j.proeng.2017.04.549
[29] Ricciardi P, Belloni E, Cotana F. (2014). Innovative panels with recycled materials: thermal and acoustic performance and life cycle assessment. Applied Energy 134: 150-162. https://doi.org/10.1016/j.apenergy.2014.07.112
[30] Binici H, Gemci R, Kucukonder A, Solak HH. (2012). Investigating sound insulation, thermal conductivity and radioactivity of chipboards produced with cotton waste, fly ash and barite. Construction and Building Materials 30: 826-832. https://doi.org/10.1016/j.conbuildmat.2011.12.064
[31] Cosereanu C, Lăzărescu C, Olărescu C, Laurenzi W. (2012). Ecological solutions for low energy building walls. Pro Ligno 8(1): 28-34. http://www.proligno.ro/ro/articles/2012/1/cosereanu_full.pdf.
[32] Trajković D, Jordeva S, Tomovska E, Zafirova K. (2016). Polyester apparel cutting waste as insulation material. The Journal of The Textile Institute 108 (7): 1238-1245. https://doi.org/10.1080/00405000.2016.1237335
[33] Jordeva S, Tomovska E, Trajković D, Zafirova K. (2014). Textile waste as a thermal insulation material. Tekstil 63(5-6): 174-178. https://hrcak.srce.hr/index.php?show=clanak&id_clanak_jezik=210294.
[34] Barbero-Barrera M, Pombo O, Navacerrada M. (2016). Textile fibre waste bindered with natural hydraulic lime. Composites Part B 94: 26-33. https://doi.org/10.1016/j.compositesb.2016.03.013
[35] Aghaee K, Foroughi M. (2012) Construction of lightweight Concrete Partition Using Textile Waste. International Conference on Sustainable Design, Engineering and Construction, Texas 793-800.
[36] Aghaee K, Foroughi M. (2013). Mechanical properties of lightweight concrete partition with a core of textile waste. Advances in Civil Engineering 2013: 1-7. https//dx.doi.org/10.1155/2013/482310
[37] Kalkan SO, Gündüz L. (2016). A study on the usage of denim waste as reinforcement element in composite mortars on exterior building application. 12 International congress on advances in civil engineering, Istanbul 1-7.
[38] Rajput D, Bhagad SS, Raut SP, Ralegaonkar RV, Mandavgane SA. (2012). Reuse of cotton and recycle paper mill waste as building material. Construction

and Building Materials 34: 470-475. https//doi.org/10.1016/j.conbuildmat.2012.02.035

[39] Binici H, Gemci R, Aksogan O, Kaplan H. (2010). Insulation properties of bricks made with cotton and textile ash wastes. International Journal of Materials Research 101(7): 894-899. https//doi.org/10.3139/146.110348

[40] Binici H, Aksogan O. (2015). Engineering properties of insulation material made with cotton waste and fly ash. Journal of Material Cycles and Waste Management 17(1): 157-162. https//doi.org/10.1007/s10163-013-0218-6

[41] Algin HM, Turgut P. (2008). Cotton and limestone powder wastes as brick material. Construction and Building Materials 22(6): 1074-1080. https//doi.org/10.1016/j.conbuildmat.2007.03.006

[42] Agrawal SK, Watile RK, Mohata PV, Makwana SC. (2013). Utilization of textile apparel waste in clay brick. International Journal of Advanced Research in Engineering & Technology 4(7): 48-52. https://www.iaeme.com/MasterAdmin/UploadFolder/IJARET_04_07_006/IJARET_04_07_006.pdf.

[43] 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: 155-160. https//doi.org/10.1016/j.conbuildmat.2012.08.037

[44] Paiva A, Varum H, Caldeira F, Sá A, Nascimento D, Teixeira N. (2011). Textile subwaste as a thermal insulation building material. 2011 International Conference on Petroleum and Sustainable Development, Singapore 78-82.

[45] Patnaik A. (2016). Materials Used for Acoustic Textiles. In: Padhye R, Nayak R (eds) Acoustic Textiles. Springer.

[46] Lee J, Joo C. (2003). Sound absorption properties of recycled polyester fibrous assembly absorbers. Autex Research Journal 3(2): 78-84. http://www.autexrj.com/cms/zalaczone_pliki/5-03-2.pdf

[47] Tiuc AE, Vermeşan H, Gabor T, Vasile O. (2016). Improved sound absorption properties of polyurethane foam mixed with textile waste. Energy Procedia 85: 559-565. https//doi.org/10.1016/j.egypro.2015.12.245

[48] Seddeq HS, Aly NM, Marwa AA, Elshakankery MH. (2012). Investigation on sound absorption properties for recycled fibrous materials. Journal of Industrial Textiles 43(1): 56-73. https//doi.org/10.1177/1528083712446956

[49] Segura Alcaraz MP, Bonet-Aracil M, Segura Alcaraz JG, Seguí IM. (2017). Sound absorption of textile material using a microfibers resistive layer. IOP Conference Series: Materials Science and Engineering 254. https//doi.org/10.1088/1757-899X/254/7/072022

[50] Curtu I, Stanciu MD, Coereanu C, Ovidiu V. (2012). Assessment of acoustic properties of biodegradable composite materials with textile inserts. Materiale Plastice 49(1): 68-72. http://www.revmaterialeplastice.ro/pdf/CURTU%20IOAN%201%2012.pdf.

[51] Del Rey R, Bertó L, Alba J, Arenas JP. (2015). Acoustic characterization of recycled textile materials used as core elements in noise barriers. Noise Control Engineering Journal 63(5): 439-447. https//doi.org/10.3397/1/376339

[52] Binici H, Eken M, Dolaz M, Aksogan O, Kara M. (2014). An environmentally friendly thermal insulation material from sunflower. Construction and Building Materials 51:24-33. https//doi.org/10.1016/j.conbuildmat.2013.10.038

[53] Umar M, Shaker K, Ahmad S, Nawab Y, Umair M, Maqsood M. (2017). Investigating the mechanical behavior of composites made from textile industry waste. The Journal of the Textiles Institute 108(5): 835-839. https//doi.org/10.1080/00405000.2016.1193

[54] Zou Y, Reddy N, Yang Yang. (2011). Reusing polyester/cotton blend fabrics for composites. Composites: Part B 42: 763-770. https//doi.org/10.1016/j.compositesb.2011.01.022

[55] Athijayamania A, Thiruchitrambalamb M, Natarajana U, Pazhanivel B. (2009). Effect of moisture absorption on the mechanical properties of randomly oriented natural fibers/polyester hybrid composite. Materials Science and Engineering A 517: 344-353. https//doi.org/10.1016/j.msea.2009.04.02

[56] Pinto J, Peixoto A, Vieira J, Fernandes L, Morais J, Cunha VMCF, Varum H. (2013). Render reinforced with textile threads. Construction and Building Material 40: 26-32. https//doi.org/10.1016/j.conbuildmat.2012.09.099

[57] Dos Reis JML. (2009). Effect of Textile Waste on the Mechanical Properties of Polymer Concrete. Materials Research 12(1): 63-67. https//doi.org/10.1590/S1516-14392009000100007

[58] Li Y, Zhang Y, Guo Y, Chu PK, Tu S. (2017). Porous materials composed of flue gas desulfurization gypsum and textile fiber wastes. Waste Biomass Valor 8(1): 203-207. https//doi.org/10.1007/s12649-016-9617-y

[59] Temmink R, Baghaei B, Skrifvars M. (2018). Development of biocomposites from denim waste and thermoset bioresins for structural applications. Composites: Part A 106: 59-69. https//doi.org/10.1016/j.compositesa.2017.12.011