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SURVEY ON THE ACOUSTICAL PROPERTIES OF NEW SUSTAINABLE MATERIALS FOR NOISE CONTROL

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ABSTRACT

According to the definition of sustainability, a product can be considered sustainable if its production enables the resources from which it was made to continue to be available for future generations. A sustainable product can thus be created repeatedly without generating negative environmental effects, without causing waste products or pollution, and without compromising the wellbeing of workers or communities. In the last years many new materials for noise control have been studied and developed as alternatives to the traditional ones (glass or rock wool); these materials are either natural (cotton, cellulose, hemp, wool, clay, etc) or recycled (rubber, plastic, carpet, cork, etc.). Various methodologies have been proposed to evaluate the sustainability of materials and products (LCA, Ecoinvent, Ecoprofiles).

The paper presents an updated survey of the acoustical properties of sustainable materials and in particular sound absorption coefficient, airborne and impact sound insulation data, as well as an analysis of the procedures to asses the sustainability of these materials.

1 INTRODUCTION

In 1987, the World Commission on Environment and Development developed a definition of sustainability which became widely known as the Brundtland Report [1]. It stated that "*Sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs.*"

From this point of view a product can be considered sustainable if its production enables the resources from which it was made to continue to be available for future generations and has the lowest possible impact on human health and on the environment.

Materials obtained from synthetic fibres, such as mineral wool, are commonly used for thermal and sound insulation, because of their good performances and low cost. The European building insulation market of a value of approximately 3.3 billion euros has been estimated to [2]:

- mineral wool (glass) : 27%
- mineral wool (stone): 30%
- foam plastics: 40%
- other materials: 3%.

These materials, though widely used, can be harmful for human health if their fibres are inhaled, since they can lay down in the lung alveoli, and can cause skin irritation. Hence such materials must be adequately overlaid if directly exposed to the air. Moreover they can pulverize and are not resistant to water, oil and chemical agents and this can make their application not suitable for absorbing noise barriers.

In recent years, an increasing attention has been turned to natural fibres as alternatives to synthetic ones, in order to combine high acoustic and thermal performances with a low impact on the environment and human health. Natural fibres have very low toxicity and their production processes can contribute to protect the environment. Recycled materials, such as recycled plastic fibres and recycled rubber mats, can even be regarded as a sustainable alternative, as they contribute to lower waste production and use of raw materials. It is however very important to assess the "sustainability" of a natural or recycled material, and to verify the total energy use in its production process.

2 SUSTAINABILITY ASSESSMENT

In the last years a great attention has been focused on "green" materials, especially in the building sector. In Italy, for instance, many Municipalities have introduced into Building Regulations specific recommendations to improve the use of ecological materials in new constructions, allowing a reduction of construction taxes. These Regulations also contain a list of materials that should be avoided (e.g. mineral fibres).

A lot of commercial products are labelled as "green" just because they contain small percentages of natural or recycled materials or because they are not harmful for human health. This kind of approach is too simplistic.

The real sustainability of a product has to be assessed during all its life cycle (from cradle to grave): for this purpose we can use Life Cycle Assessment (LCA) procedures, which analyse the potential impacts deriving from the entire life history of a product. Material extraction, production, transport, construction, operating and management, de-construction and disposal, recycling and reuse have therefore to be taken into account.

For designers and decision-makers, LCA analysis results are available as "*ecoprofiles*"; among these the most known are Ecoinvent, BRE Eco-profiles and Eco-indicator.

Ecoinvent [3] is a Swiss LCA database which takes into account the following impact assessment results: Cumulated Energy Demand (CED) and Non-Renewable Energy (NRE) fraction, Global Warming Potential (GWP) and Acidification Power (AP). A comparison based on the Ecoinvent database between the environmental impacts of some traditional and natural sound insulation materials from cradle to gate is shown in Fig. 1 [4]: cellulose, flax and sheep wool have the lowest impacts on the considered categories.

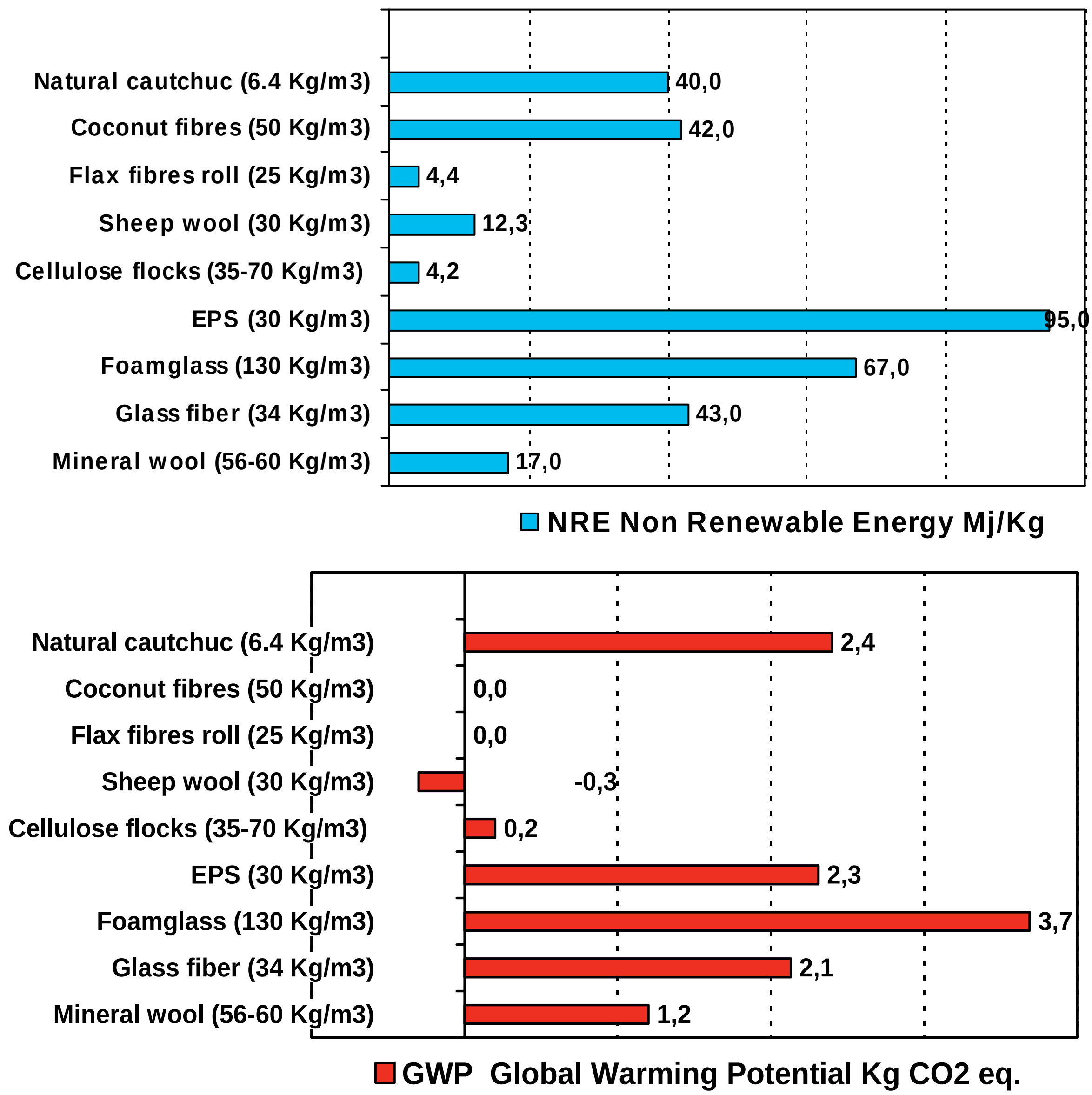

Fig. 1. Ecoinvent. Comparison of environmental impacts of traditional and natural materials. [4]

BRE Eco-Profiles (UK) [5] assign a score (in "eco-points") to a product or a process by weighting normalized impacts on climate change, acid deposition, eutrophication, eco-toxicity, ozone depletion, mineral extraction, fossil fuel extraction, human toxicity, waste disposal, transport pollution. The results for some insulation products, from cradle to their on site installation, are: EPS (15 kg/m^3) 0.028 pt., rock-wool (45 kg/m^3) 0.020 pt., rock-wool (33 kg/m^3) 0.016 pt., recycled newspaper cellulose 0.002 points.

Eco-indicator '99 (NL) [6] supplies a final score by weighting various potential damages: to human health, expressed as number of life years lost and lived disabled; to ecosystem quality, expressed as the loss of species over a certain area in a certain time; to resources, expressed as the surplus energy needed for future extractions of minerals and fossil fuels (Fig. 2).

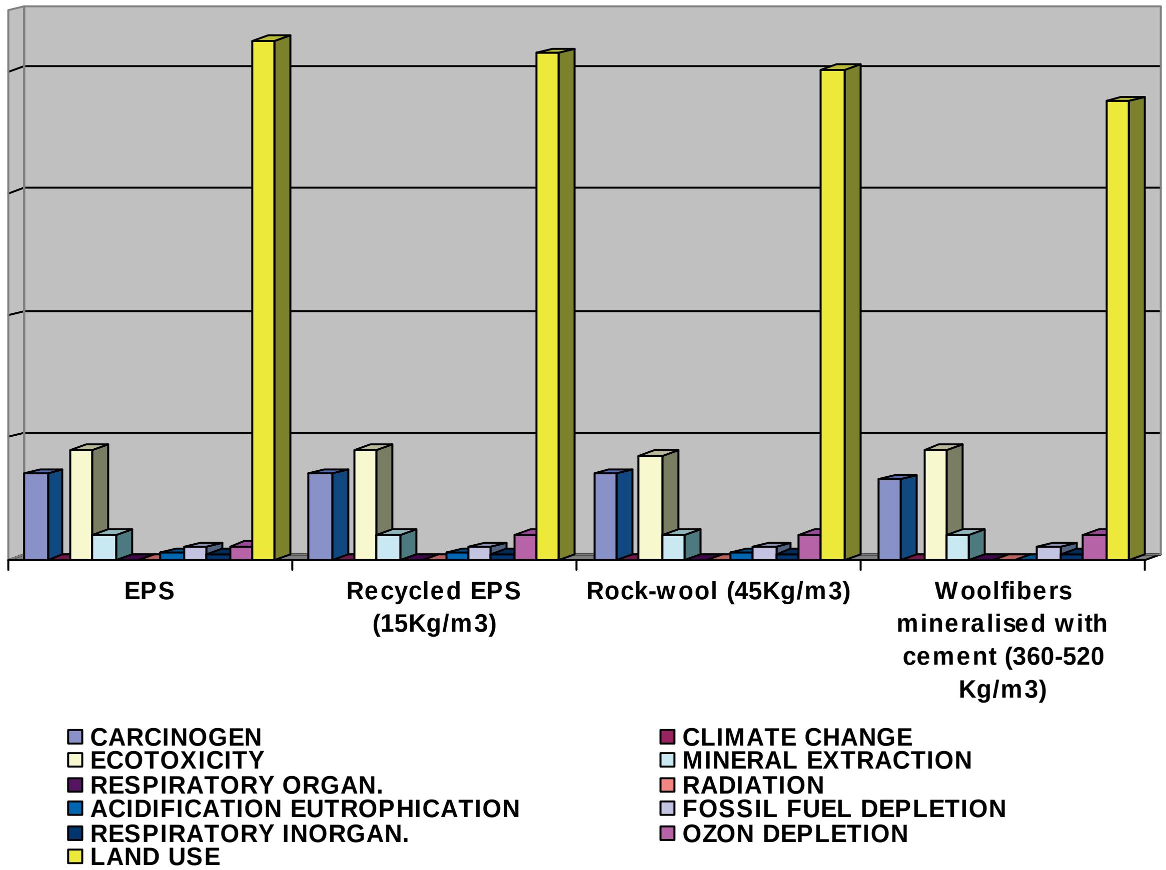

Fig. 2. Eco-indicator '99. Impacts of some sound insulation layers.[4]

An estimation of the use of primary energy for the extraction, transport, production and packing of different insulating materials is reported in Fig. 3 [7]. As it can seen, not always a "green" material (e.g. flax) requires less energy in its life cycle than a traditional one (e.g. rock wool), while synthetic plastic fibres always show the greatest impacts, especially on fossil fuel consumption.

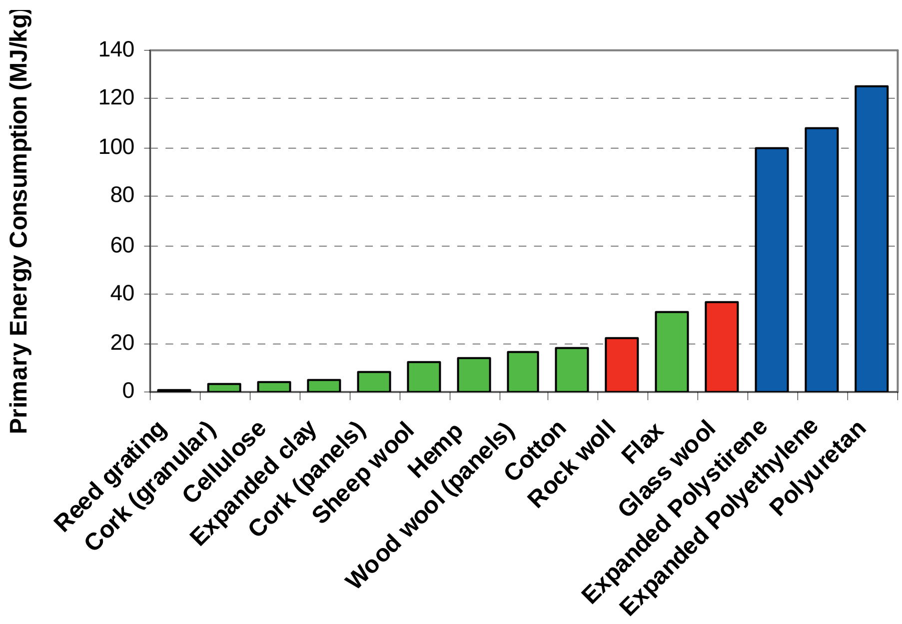

Fig. 3. Estimation of primary energy consumption of some sound insulating materials' life cycles. [7]

3 SUSTAINABLE MATERIALS FOR NOISE CONTROL

In the last years a greater attention for environment and public health has stimulated the research and development of many new materials for noise control as alternatives to the traditional ones. These materials can be divided into two main categories:

- natural materials: cotton, hemp, sheep wool, flax, clay, etc..
- recycled materials: rubber, plastic, cellulose, carpet, etc..

Recent Literature reports a wide variety of materials, from the most common [8], [9] to the most bizarre solutions [10], [11]. Some LCA studies are also available, showing that natural fibres composites appear to be cheaper, lighter and environmentally superior to glass fibres composites [12].

Sustainable materials are in many cases comparable to traditional ones as far as thermal and acoustic performances. Though for many products physical properties have not been deeply analyzed and are not yet certified, they have already reached a technical and commercial maturity; in Italy, for example, many sustainable materials are listed in official prices lists for public tenders.

3.1 Natural materials

As for natural materials, the less treated they are, the higher they perform in energy saving; native materials have to be preferred to reduce transport energy. Moreover natural fibres have negative impacts as far as climate change (CO_2 absorption). Nevertheless other performances have to be considered: vegetal fibres are more subject to fungal and parasites attack and are less resistant to fire than mineral fibres. The non-toxicity of the chemical products used for cultivation must be taken into account too.

The acoustic and thermal properties and costs of some traditional and sustainable natural insulating materials are reported in Table 1. When not specified, absorption coefficient and cost refers to 4 cm thick panels while index of reduction of impact noise refers to 2 cm thick panels.

Table 1. Acoustic and thermal properties and costs of some traditional and natural insulating materials. [4], [7], [8]

	Thermal conductivity λ (W/mK)	Rel. resistance to vapour flux μ (–)	Absorption coefficient α_S at 500 Hz (-)	Index of reduct. of impact noise ΔL_W (dB)	Cost (€/m^2)
Hemp	0.04	2	0.6 (30 cm)	-	5
Kenaf	0.044	2	0.74 (5 cm)	-	-
Coco fiber	0.043	18	0.42	23	-
Sheep wool	0.044	3	0.38 (6 cm)	18	-
Wood wool	0.065	5	0.32	21	12
Cork	0.039	12	0.39	17	19
Cellulose	0.037	2	1 (6 cm)	22	-
Flax	0.040	1	-	-	7
Glass wool	0.04	-	1 (5 cm)	-	12
Rock wool	0.045	-	0.9 (5 cm)	-	6
Expanded polystyrene	0.031	100	0.5	30	10

<u>Sound absorption</u>

Many natural materials as kenaf, flax, sisal, hemp, cork, sheep wool, bamboo or coconut fibres [13], [14] show good absorbing performances and can therefore be used as sound absorbers in room acoustics and noise barriers (Table 1 and Figure 4). At 500 Hz, nevertheless, the absorption coefficient of synthetic materials is generally superior to the one of natural materials. Expanded clay, which may be also considered a natural product, shows good sound absorption performances in a wide frequency range (higher than 0,80 in the range 500-5000 Hz) [15].

<u>Airborne sound insulation</u>

Several natural materials are commonly used as thermal and acoustical insulation in multi-layered walls: among these flax, coconut, cotton, sheep wool and kenaf mats are the most present on the market [16]. Their sound and thermal insulation performances are in many cases as good as those of traditional materials (Table 1 and Figure 5): many studies have demonstrated that the sound insulation of double-leaf walls with low density animal wool (sheep wool) or heavy vegetal wool (latex-coco) is equal or better than the one of walls with mineral wool or polystyrene of the same thickness [4], [17].

<u>Impact sound insulation</u>

This is probably the most common use for many natural materials (cork, coconut fibres, wood wool). Resilient layers made of natural materials can be very good for floating floors to increase impact sound insulation [18]: when the panels are accurately designed and installed, their performances are as good as other traditional materials. The impact sound reduction for some materials tested at the Acoustic laboratory of the University of Perugia is presented in Figure 6 [19].

3.2 Recycled materials

Many recycled materials, such as waste rubber, metal shavings, plastic, textile agglomerates can be used to prepare acoustic materials. It can be useful to mix various recycled materials of different granulometries to obtain the desired performances; in these cases a binder or glue have to be added in a proper proportion.

Sound absorption

The recycled material mostly used to correct the sound environment in enclosed spaces is cellulose obtained from used newspapers, added with flame retardants and biocides. Wet cellulose fibres are generally sprayed directly on walls or ceilings and their sound absorption properties are even better than those of mineral wool (Figure 4). Other promising materials are metal shavings and textile agglomerates [20]. Rubber crumbs are good acoustic materials with a broadband absorption spectrum and are particularly suitable for traffic noise barriers, also due to their durability [9], [21].

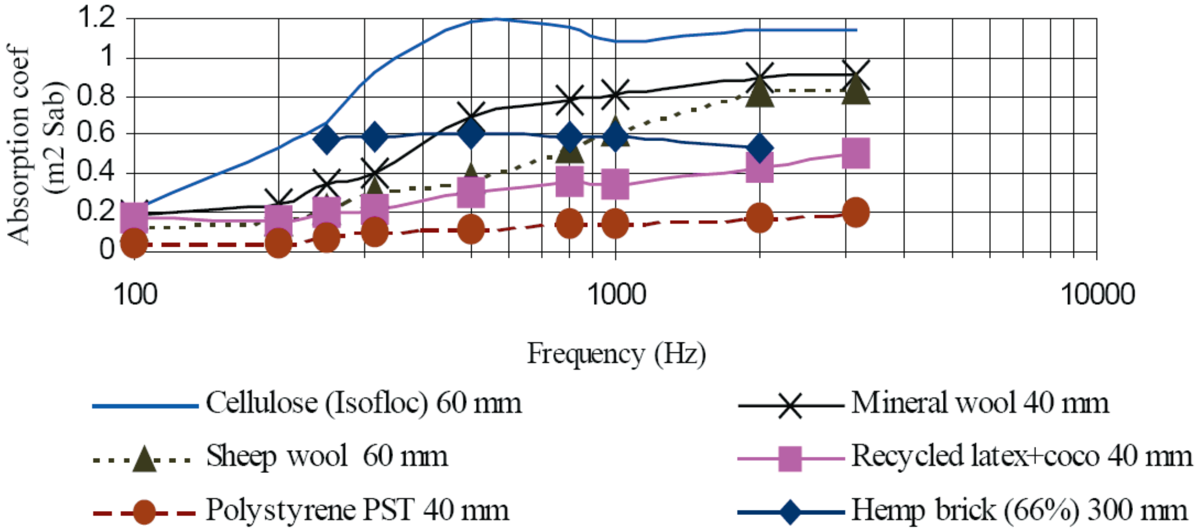

Fig. 4. Sound absorption coefficient of natural and traditional materials [4]

Airborne sound insulation

Dry loose cellulose fibres are already commonly used for thermal and acoustical insulation by filling the cavities in walls and roofs, especially in the United States. When it is obtained from recycled newspapers, it appears to match energy and raw materials savings and health issues. As for the acoustical properties, they are as good as traditional ones (Figure 5).

Impact sound insulation

For this application, recycled rubber layers made of waste tyres granules are an interesting alternative to traditional materials, especially now that tyres are banned from landfills; stockpiles are, indeed, dangerous for the risk of fire and vermin infestation. Because of the large amount of used tyres available worldwide, new applications have to be found and their use as impact sound insulating layers is very promising [19]. Various products are already available on the market, with properties similar to the ones of traditional materials (Figure 6).

Also recycled carpet wastes are interesting materials as far as impact sound insulation, especially if made of a mixture of fibrous and granular waste. The acoustic properties of these underlay materials compare favourably with those of commercially available ones [22], [23].

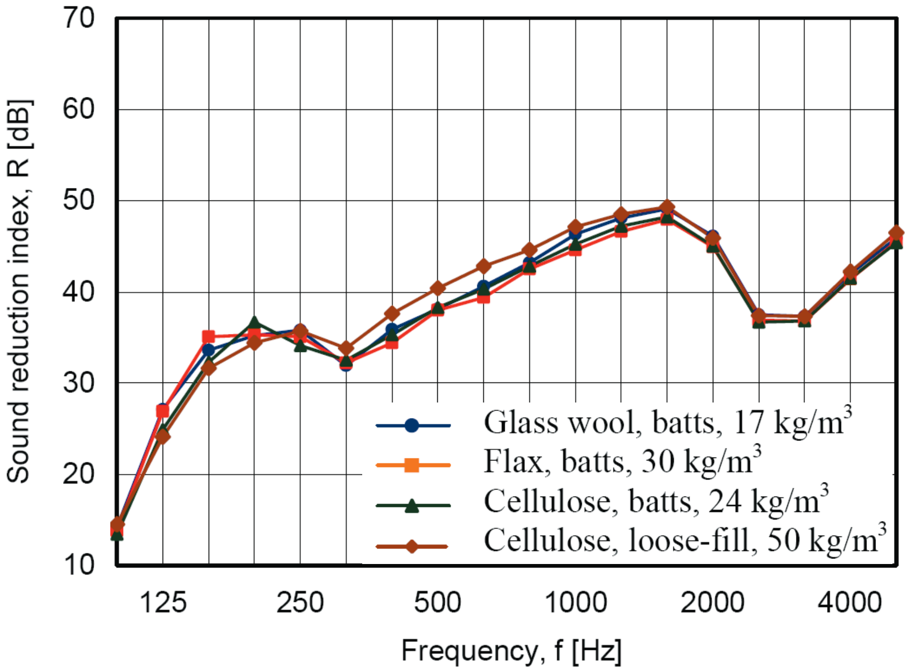

Fig. 5. Sound reduction index for a 125 mm thick wall with 100 mm insulation material.

4 CONCLUSIONS

Acoustical sustainable materials, either natural or made from recycled materials, are quite often a valid alternative to traditional synthetic materials. Airborne sound insulation of natural materials such as flax or of recycled cellulose fibres is similar to the one of rock or glass wool. Many natural materials (bamboo, kenaf, coco fibres) show good sound absorbing performances; cork or recycled rubber layers can be very effective for impact sound insulation. These materials also show good thermal insulation properties, are often light and they are not harmful for human health.

The production of these materials generally has a lower environmental impact then conventional ones, though a proper analysis of their sustainability, through Life Cycle Assessment procedures, has to be carried out. Also the total energy demand has to be accurately evaluated, since not always an "ecological" material requires less energy in its life cycle than a traditional one.

Furthermore, many of these materials are currently available on the market at absolutely competitive prices.

There is however a need to complete their characterization, both from an experimental and a theoretical point of view, and especially to propose a standard and unique procedure to evaluate their sustainability.

The paper presents an updated survey on the acoustical properties of sustainable materials, as well as an analysis of the main methodologies for sustainability assessment, and is completed by a selection of recent related bibliography.

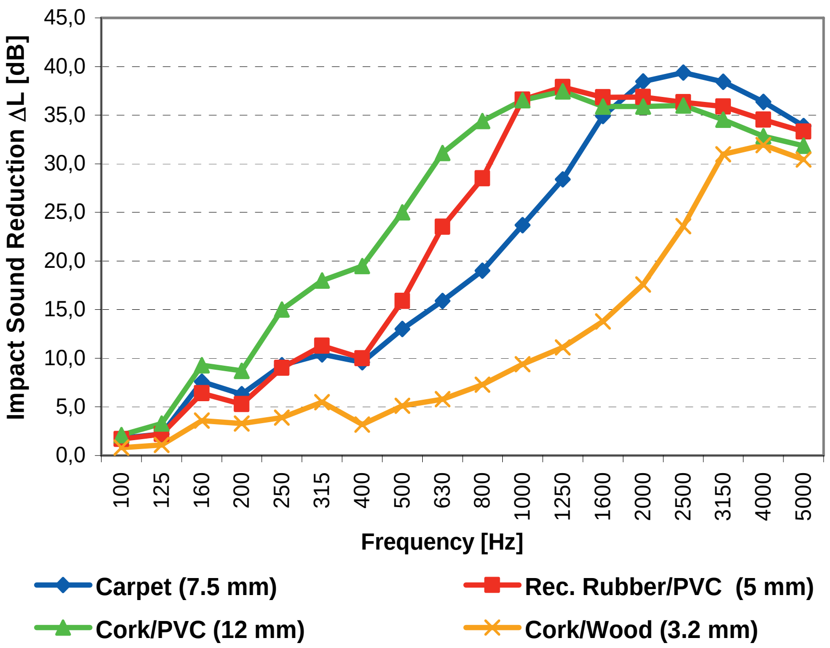

Fig. 6. Impact sound reduction of some traditional and sustainable materials.

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