Construction and Building Materials 140 (2017) 221–228

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Characterization of eco-efficient acoustic insulation materials (traditional and innovative)

M. Pedroso [a], J. de Brito [b,*], J.D. Silvestre [c]

[a] CERIS, ICIST, Instituto Superior Técnico, Universidade de Lisboa, Av. Rovisco Pais, 1049-001 Lisbon, Portugal
[b] CERIS, ICIST, Department of Civil Engineering, Architecture and Georresources (DECivil), Instituto Superior Técnico, Universidade de Lisboa, Av. Rovisco Pais, 1049-001 Lisbon, Portugal
[c] CERIS, ICIST, DECivil, Instituto Superior Técnico, Universidade de Lisboa, Av. Rovisco Pais, 1049-001 Lisbon, Portugal

HIGHLIGHTS

- Current and alternative materials to control noise in buildings.
- Evaluation of the environmental, economic and social sustainability.
- Characterization in terms of embodied energy, acoustic behaviour and costs.
- Alternative materials are perfectly viable to replace the currently used products.

ARTICLE INFO

Article history:
Received 29 January 2016
Accepted 22 February 2017

Keywords:
Acoustic insulation
Embodied energy
Sustainable construction
Natural materials
Eco-efficiency

ABSTRACT

There is a growing awareness towards using materials with less social, economic and environmental impacts in the construction and rehabilitation of buildings. However, the evaluation of the sustainability of acoustic insulation materials in these three dimensions has not yet been presented in reference publications. This paper presents these results for the first time for materials used currently and alternative materials available in the construction market to control noise in buildings.

An exhaustive review has been performed, focused on the most used insulation materials at the European level in construction and rehabilitation. The characterization at the level of embodied energy, acoustic behaviour and costs of these materials is presented, so that the most eco-efficient can be selected and applied.

It is concluded that there are alternative materials that, from the acoustic behaviour, embodied energy and costs points of view, are perfectly viable to replace the currently used products.

1. Introduction

There is a growing awareness towards using materials with less social, economic and environmental impacts in the construction and rehabilitation of buildings. Since the divulgation of the quantitative environmental impacts of thermal insulation materials [1] is now a common place, there is a need to proceed with a similar characterization of the materials whose main function is to promote a better acoustic insulation. An exhaustive review has been performed and, from the long list of materials with that function that were identified, the ones more often used at the European level in construction and rehabilitation and that simultaneously have an acceptable performance in terms of acoustic insulation in walls were identified. This paper thus reflects the technological solutions available in the construction market to control noise in buildings, namely through their use in walls, considering both currently used and alternative materials.

The need of acoustic comfort, besides being a compulsory legal requirement in Portuguese buildings, is also essential for the well-being of their users, since the World Health Organization (WHO) refers that leisure areas must have such insulation that it allows a Sound Pressure Level (SPL) of no more than 30 dB to 40 dB. Therefore, this is the goal to reach, since according to the WHO the effects of noise on Man may be classed in three main levels:

- The physical level is characterized by lesions of the auditory organs, disruption of the blood flow and induction of fatigue;
- The physiological level is characterized by an increase of irritation, stress and discomfort;

* Corresponding author.
E-mail addresses: marco-pedroso@sapo.pt (M. Pedroso), jb@civil.ist.utl.pt (J. de Brito), jose.silvestre@tecnico.ulisboa.pt (J.D. Silvestre).

http://dx.doi.org/10.1016/j.conbuildmat.2017.02.132
0950-0618/

- The social level is characterized by the disturbance of the communication and decrease of the work output.

It is thus understood how from the social point of view and in the sustainability plan acoustic insulation of the noise sources gains special interest and importance, directly interfering with the individual's well-being.

Besides comfort in the use of buildings, there is a growing need of evaluating and certifying them from the environmental point of view. Several countries have developed their own environmental evaluation and certification systems for buildings (e.g. BREEAM, in the UK; LEED, in the USA; HQE, in France; LiderA, in Portugal), and there is also a growing pressure to quantify the environmental impacts of current and alternative materials in order to select those with lesser impact.

This paper presents the characterization of the economic and environmental dimensions of improved acoustic performance materials. The comparative evaluation presented allows, based on previous works [2–6], various actors from the construction and rehabilitation sector to choose and apply the most eco-efficient materials.

2. Literature review

There are various published research works that relate the acoustic performance with some environmental sustainability indicators for acoustic insulation materials [2–6]. This section summarizes the main results from these studies.

One study evaluated the environmental advantages and the acoustic performance of alternative acoustic insulation materials with "sustainable" properties, relative to current acoustic insulation materials. The first group included natural materials such as cotton, cellulose, hemp, and stone or vegetal wool, and recycled materials of rubber, synthetic fibres and cork [2]. The materials acoustic performance was evaluated in terms of their sound absorption coefficient at various frequencies and the insulation to impact noises of two natural materials was characterized. It was concluded that preference should be given to natural acoustic insulation materials given their lower environmental impact in production and because they offer an identical performance to that of current materials for different uses. When current materials are used, their easy maintenance and the deconstruction ability of the constructive system should be guaranteed, so as to maximize their recycling potential.

The acoustic performance of alternative materials was evaluated in another study, which also considered natural (cotton, cellulose, hemp, stone or vegetal wool, and clay) and recycled (rubber, synthetic fibres, plastic, and cork) materials [4]. The environmental performance results of the previous study [2] were considered, along with the embodied energy of some more acoustic insulation materials (i.e. granular and cork panels, expanded clay, wood and cotton wool, hemp, expanded polyethylene and polyuretan). The analysis was complemented with the cost of half the solutions under analysis and the insulation to impact noises of two recycled materials by comparison with existing cork-based solutions. Even though it is greatly based on the previous work [2] in what concerns the environmental performance of the materials studied, this research concludes that the natural or recycled acoustic insulation materials are a valid alternative to synthetic traditional materials, because of their acoustic performance and the fact that they are already available in the market at competitive prices. However, the lower embodied energy of the alternative materials relative to that of the traditional ones must be confirmed for each application. This work was later complemented with a more detailed characterization of the insulation to impact noises of alternative and current materials and of the acoustic absorption performance of alternative and current materials at four frequencies and for a single index that summarizes this performance (see NRC in Section 3) [5]. This analysis was extended in a later work to thermal insulation materials and whole buildings [6].

Even though the studies described relate the acoustic performance with some materials sustainability indicators, they do not include the economic characterization of all the insulation materials analysed, which would allow completing the analysis in the three sustainability dimensions – economic, social and environmental. Therefore, the inclusion of the economic vector in our paper represents a novel contribute, as does the characterization of the economic and environmental performance of construction materials that are normally used in the execution of building walls.

3. Methodology

Sustainable Construction can be defined as the "creation, rehabilitation and responsible management of a healthy built environment, based on resources efficiency and ecologic principles that contribute to a social and economic balance" [7]. Therefore, the procurement, transformation and maintenance contribute to the sustainability of the materials used in construction, which makes their analysis pertinent to maximize the use of materials that cause less environmental impacts but have acceptable technical and economic performances. The methodology proposed in this paper allows thus to characterize improved acoustic performance materials in the social (acoustic performance), economic and environmental dimensions.

The analysis of the acoustic performance characteristics is based on the noise reduction coefficient (NRC). This coefficient dilutes the individual sound absorbing coefficients of the different materials. However, it would be very difficult to evaluate and compare all frequency bands of the materials presented, conjugated with the other characteristics considered, thus losing some objectivity regarding the main scope of this paper. In order to characterize the element's acoustic absorption, data from laboratory tests made available by the manufacturers were used. These tests give the value of α – sound absorption coefficient of the material, corresponding to the ratio between the sound intensity absorbed and the incident sound intensity of the material, which normally changes with the frequency [8]. NRC is defined as the arithmetic ratio between the sound absorption performance of a material, based on four frequencies (250, 500, 1000 and 2000 Hz), in octave bands [9], and is used to have a general idea of the absorption in the frequency range of human speech, i.e. it must be used carefully since it does not represent the material's behaviour for the whole hearing frequency range [10]:

$$NRC = \frac{\alpha_{250} + \alpha_{500} + \alpha_{1000} + \alpha_{2000}}{4} \quad (1)$$

The environmental performance uses embodied energy (EE) as the reference parameter. EE may be defined as the energy used in the life cycle of a product [11], including the transportation of raw materials, the extraction, manufacture, assemblage, installation, dismantling-deconstruction and/or disintegration. There are various methodologies to define the scale, scope and type of EE, and there is no international consensus about the adequacy of these evaluation methods [5]. The energy units typically used are: MJ/kg (Mega joule of energy needed to make 1 kg of product).

4. Scope

The choice of materials to be analysed was preceded by the perusal of the technical files of alternative materials with similar application scope, in order to compare with materials already