APPLICATION OF “MET MATRIX” METHOD IN OUTLINING THE ENVIRONMENTAL ASPECTS OF A NEW INSULATION COMPOSITE MATERIAL

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ABSTRACT

Most of the insulation materials used in construction has a huge impact on the environment throughout their life cycle. Therefore making a product of improved operational and environmental performance indicators is a real challenge for the designers. The widespread usage of composite materials gives more opportunities to achieve this goal. This article describes a conceptual model of an insulating material obtained on the basis of rubber crumbs and expanded perlite of improved environmental and functional performance indicators. The MET matrix is used to determine significant and problematic areas in terms of the environment. The results show that the material under investigation meets the eco materials established literature operational and environmental requirements.

Keywords: eco-design, eco-design tools, composite materials, MET matrix.

INTRODUCTION

The world is recently facing a number of challenges in the field of energy and environmental protection such as growing dependence on imports and insufficient diversification of energy sources, high and unpredictable energy prices, globally growing demand for energy, security risks affecting both producing and transit countries, increasing threats associated with climate change, slow progress in energy efficiency, challenges associated with the use of a large amount of non-renewable natural resources, as well as need for greater transparency and better integration and interconnection of energy markets.

One of the ways to achieve sustainable development by the households themselves refers to the improvement of the buildings energy performance (energy efficiency) and the use of passive heating and cooling. In recent years, the heating of buildings has become a serious economic problem. Solving this problem can be sought through buildings construction on the heat transfer physics principles, so that to assure microclimate normative parameters of the premises with less thermal energy. This is impossible without the use of insulation materials. Apart from having good heat-, moisture- and sound insulation, they must:

- meet the requirements concerning the provision of health and safety for the people working and living on the premises such as:
  - fire-safety - increased resistance to ignition; in the event of a fire, toxic emissions should not be above the norm;
  - sanitary requirements - biological resistance to the emergence of flora and fauna harmful for the human.
- have a reduced environmental impact throughout their life cycle. They are expected to
  - use recycled materials and a negligible amount of energy in the manufacturing process;
  - increase the lifespan of the insulating elements, which will decrease the frequency of repairs, and hence there will be less pressure on the environment;
provide re-usage with negligible processing without generating construction waste.

These and other issues determine EU policy on energy efficiency which is based on Directive 2012/27/EU of 25th October 2012, concerning Energy Efficiency (EF) [1]. The aim is to direct the Member States on the way to achieve the goals of 2020 for sustainable development.

The majority of the problems pointed above can be solved by using eco products. They can play a key role in the pursuit of science and technology to minimize materials impact on the environment, to increase the possibility of recycling and improve the material and energy efficiency [2, 3]. Eco materials are defined as materials that reduce the environmental impact throughout their life cycle, whilst fulfilling their essential purpose [4].

In 2000 Prof. Yagi [5]) offered one of the most comprehensive definitions of eco materials. According to him eco materials must have one of ten specific properties compared to conventional materials. They are expected

• To save energy - the ability to reduce total energy consumption throughout the life cycle of a system or a product;
• To save resources, i.e. to be able to reduce the total amount of materials used throughout the life cycle of a system or a product;
• To provide repeated use, i.e. to allow reuse of the collected products for similar purposes;
• To provide recyclability, i.e. to allow the use of processed materials as feedstock;
• To provide structural reliability, i.e. ability to preserve their basic mechanical properties;
• To provide chemical stability, i.e. ability to be used a long time without chemical decomposition;
• To provide biological safety, i.e. ability to be used without causing negative effects on ecosystems;
• To provide substitution, i.e. ability to be used as an alternative to the “bad” materials;
• To provide urbanization ensuring comfortable working environment;
• To provide removal ability, i.e. ability to be separated, identified, removed and neutralized as a contaminant in the process of environmental protection.

The evolution of the materials constituting the external building constructions (which divide the building into separate premises and provide protective functions (sound, moisture- and heat insulation)) has been extremely dynamic in recent years. The development of polymer chemistry [6] made possible the emergence of technologies for the production of insulation materials including elastomers which add new useful thermophysical, absorbing and waterproofing properties to the products.

The purpose of this work is to study the environmental impact of a new insulating material for incorporation into external structures obtained on the basis of an elastomeric composite with the application of MET matrix.

EXPERIMENTAL

The object of the study was a flat surface (a slab) with open pores with a length, width and thickness of 0.25 m, 0.25 m and 0.03 m, respectively. It was made of rubber crumbs (the phase forming the matrix) in the form of cylinders with a radius $r_k \approx 0.001$ m and length $l = 0.002 \div 0.003$ m and perlite (filler) in the form of spheres with a radius $r_p \approx 0.001$ m. They were glued together by a binder of thickness of 0.0001 m of a polyurethane base (Fig. 1) [7].

Method of study

The designers’ work is facilitated by using methods which present the data in a simplified form [8, 9]. Such is the instrument MET matrix which classifies the categories of environmental impacts into three main groups: material flows (cycles) (M), use of energy (E) and toxic materials, emissions and waste (T). In essence,
the MET matrix is a qualitative or semi-quantitative analysis and is applied to provide a general view of the inputs and outputs of each stage of the life cycle aiming to determine the key aspects and options for environment protection [10].

The relatively simple structure of the matrix provides the design team with the possibility to analyze all phases of the life cycle (vertical analysis) as well as the various environmental impacts associated with each phase (horizontal analysis) [11]. For the purposes of the horizontal analysis, the method divides the life cycle into five main stages: extraction of raw materials and resources, manufacturing, transportation and logistics, end of the life cycle / disposal, Fig. 2 [12].

RESULTS AND DISCUSSION

When using the MET matrix, the following question must be answered “Does the product meet its main and auxiliary functions?” and then the product characteristics, strengths and weaknesses, energy and materials consumption at every stage of the actual lifecycle must be described. The type, the size and the relationship between the materials and the components constituting the product are defined.

Raw materials

The investigated insulating material consists of rubber crumbs, expanded perlite and soft two-component polyurethane.

Rubber crumbs

The environmental aspect of using rubber crumbs as a raw material for the production of various products is quite controversial. On one hand, the fragmentation of disused rubber products requires a large amount of energy. For the insulation product under discussion, the negative effect is reduced by the possibility of reuse. On the other hand, however, the global problem of disused tires can be thus solved.

Expanded perlite

Perlite is a mineral that is obtained by hydration of obsidian which is a natural product of volcanic eruptions. It does not rot and is resistant to weather and pests. Reuse is very easy. In operation it does not emit substances harmful to environment and humans.

Soft two-component polyurethane

This is the only raw material in the case studied that is not recyclable. The thickness of the adhesive polyurethane film, however, is very small (0.0001m), which predetermines the relatively low consumption of the new raw materials.

Production

The production of the insulating material under discussion goes through several stages: dry mixing of the rubber crumbs and the expanded perlite, adding the two-component polyurethane and pressing the whole mass at a temperature of 60°C - 70°C. The process is carried out with a minimum expenditure of energy (just heating to the temperature required) with no release of any harmful emissions into the environment (air, water, soil). The waste material left after obtaining the desired size and appearance of the products can be used as a feedstock for the production of new products with minimal effort and cost. In this respect, the technology for the preparation of the insulating material under discussion is virtually waste-free.

Transportation and distribution

Along with energy and technology, transport is one of the most polluting industries. Therefore, the optimization of logistics and transport systems is very important from an environmental perspective. The specifics of the
application of the building materials (construction sites within the residential areas, relatively small amounts for a single project) identify the road transport as the most suitable for the delivery of these products. The appearance, the low density and the dimensions of the insulating material sheets provide the tight covering of the vehicles used. It is thus possible to transport large volumes of the product with a small number of transport units. On one hand, this leads to a decreased use of fossil fuels, while on the other - to less harmful emissions and less solid particles release to the atmosphere.

Use
This stage of the life cycle is conditioned by several factors: first, the product must fulfill the requirements of its primary purpose so that it can replace analogous materials harmful to humans and environment. Furthermore, it has to meet certain sanitary requirements and last but not least must not have a negative impact on nature.

The functional characteristics of insulating materials are determined by their physical and mechanical properties. They are also expected to be heat-, noise- and moisture-proof.

The thermal conductivity of a given material refers to its ability to transfer heat due to the movement of the molecules in absence of any microscopic movements of the substance. The material thermal conductivity coefficient $\lambda$ (W/m$^2$K) is considered as one of its most important insulation properties. For example, the normative benchmarks for the heat transfer coefficient for internal enclosing structures is $U = 0.5$ W/(m$^2$K). The measurements show that the analyzed elastomeric composite has a thermal resistance $R = 0.5$ (m$^2$K) / W and a thermal conductivity coefficient $\lambda = 0.085$ W/(m K). In combination with the other elements of the external construction, the thermal conductivity coefficient of the structure meets the requirements referring to the energy efficiency as well as the building’s heat and energy saving. Consequently, the product can be used as an insulating building material [13].

The acoustic characteristics of a product are determined by three main factors: the sound absorption coefficient ($\alpha_w$), the sound reduction index ($R_w$) and the levels of noise impact ($L_{nw}$) [14]. The results obtained in determining the acoustic properties of the investigated composite insulator ($R_w = 53\div55$ dB, $L_{nw} = 68$ dB) show that it meets the minimum requirements in respect to insulation against atmospheric noise.

The coefficient of water vapor passage is used [15] to determine the material’s moisture-proof properties. The results obtained show that it meets the normative requirements in accordance with BS EN 13499 “Main technical characteristics of the thermally insulating composite system used for buildings external walls” [16], namely the coefficient of vapor permeability is $\geq 20$ g / m$^2$.

The material physical and mechanical properties largely pre-determine its durability and reliability. The determination of the behavior of the tested product under compressive load is conducted in accordance with BS EN 826: 2003 “Thermal insulation products for building applications” [17]. The compressive strength ($\sigma_{10}$) at 10% relative deformation ($\varepsilon_{10}$) to the initial cross-sectional area of the tested specimen is determined. The results show that the modulus of elasticity (E) of the tested specimen is equal to 10 mPa, which is a prerequisite for high strength and high mechanical hardness during exploitation.

Environmental characteristics
The raw materials used for the preparation of the investigated insulating material determine also its inertness with respect to the environment. None of the components used releases harmful emissions into the air, the water or the soil during exploitation and its good physical and mechanical characteristics increase the material’s durability and reduce the need for frequent repairs which can contaminate the environment.

End of life cycle
The last stage of the life cycle occurs when the product cannot perform its functions as intended or the time has come for planned repairs. What will happen to the already unnecessary product depends largely on its structural composition and structure. The raw materials put into the insulation product under investigation undergo almost no chemical or physical changes during exploitation. This makes them suitable as components
of a new product. The thickness of the adhesive polymer film (0.0001 m) is a prerequisite for easy, low energy consumption grinding of the disused product. Consequently, almost no waste is disposed of in the environment.

**CONCLUSIONS**

After the analysis of the environmental aspects of the composite insulating material investigated carried out at each stage of its life cycle by MET matrix, the following conclusions can be drawn: (i) The obtained results related to the functional indicators show that the tested product meets the requirement for energy efficiency, heat and energy savings in residential and commercial buildings and it can be used as an alternative to analogues harmful both to humans and the environment; (ii) The almost waste-free manufacturing process improves the environmental performance indicators of the product; (iii) The possibility of easy recycling of the disused products as well as the use of the resulting materials as feedstock reduces the negative impact on the environment.

“Extraction of resources and raw materials” and “Transportation and distribution” are the stages of the life cycle of the greatest impact on the environment and this is the field requiring additional efforts by the designers.
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