www.ees.uni.opole.pl

ISSN paper version 1642-2597
ISSN electronic version 2081-8319

Economic and Environmental Studies
Vol. 18, No 1 (45/2018), 93-102, March 2018

Sustainable materials in ecological buildings

Piotr CZOPKA

University of Economics in Cracow, Poland

Abstract: Ecological building means creating and sustaining environmentally healthy construction based on sustainable development principles, economic and ecological effectiveness. The market of building materials has become a pioneer in adapting the idea of sustainable development in the construction sector. As a result of that process "sustainable building materials" have been created. They are defined as materials with superior performance during their whole life-cycle, which meets requirements of sustainable development principles. The following article presents the essence of sustainable building materials. The paper contains an exposition of the whole life-cycle, as well as discusses the advantages and disadvantages of the materials. Besides, the article includes comments on usage of sustainable materials in ecological buildings.

Keywords: sustainable development, building materials, ecological building, product life-cycle

JEL codes: Q01, Q20

https://doi.org/10.25167/ees.2018.45.6

1. Introduction

The building process parameters, its quality, and impact on the environment depend profoundly on building materials and construction techniques. Aspects as the kind of building materials used in construction process, their parameters and sourcing, crucial resources and way of utilisation at the end of their life-cycle should be taken into consideration. In other

Correspondence Address: Piotr Czopka, Wydział Towaroznawstwa, Uniwersytet Ekonomiczny w Krakowie, ul. Rakowicka 27, 31-510 Kraków, Polska.

E-mail: piotr.czopka@gmail.com

words, materials should be analysed in the context of their whole life-cycle. Building any object is a long-term investment, therefore materials constitute the critical factor in fulfilling their role in a long period of time.

The construction sector uses 30-40% electrical energy in the European Union. Therefore, it can be concluded that it is a highly energy-consuming sector, but also one with a high potential in reducing energy consumption. Sustainable construction, which uses sustainable building materials, exploits the idea of sustainable development (Boczek, 2013).

Sustainable building materials involve three aspects: economical, ecological, and social. It means that they minimise the impact on the environment and maximise social benefits at the lowest possible economical cost throughout the whole life-cycle. Maximising social benefits is realised through creating new jobs, creating healthy environment and developing local businesses.

The goal of this paper is to present more environmental friendly alternatives to standard building materials.

2. The essence of sustainable materials

The evolution of sustainable development has posed quite a serious challenge to manufacturers of building materials, who have had to face the requirements of sustainable development in the field of construction. According to Błaszczyński (2012:95), the building materials market was the first market which started to adjust to the idea of sustainable development and develop in compliance with its goals. The new idea enforced application of a new approach, which analyses building materials usefulness in a much broader perspective.

Sustainable building materials are defined as products with specific phases of life-cycle, such as acquiring raw materials and their processing, embedding with transportation, exploitation, demolition and reuse, supposed to meet requirements of sustainable development (Błaszczyński et al., 2012: 95). That definition is broad and does not expressly determine, which material is sustainable and which is not. While evaluating the given building material life-cycle, assessment and other multi-criteria methods, such as BREEAM (Building Research Establishment Environmental Assessment Method), LEED (Leadership in Energy and Environmental Design) and SBMI (The Sustainable Building Material Index), are applied.

3. Life-cycle assessment of building materials

In order to fulfil the conformity assessment of procedures and construction techniques, including sustainable development requirements, adequate assessment tools were created. Definitions of a life cycle of technical making, element or object LCA (Life Cycle Assessment) were instituted, and the method of calculation was written down in international norms ISO 14040-14044. Life-cycle assessment involves every phase of material life and impact on the environment (Affelt, 2011: 51-52).

In order to carry out construction activities according to sustainable development principles it has to meet numerous economic conditions and ecological requirements as well as take into the account social aspects. Particular emphasis should be put on the following issues:

- energy consumption,
- necessary transportation for assurance of regular functioning of object,
- usage of resources in conformity to the rule "3R" ("Reduce – Reuse – Recycle"),
- minimisation of the influence of construction on environment.

On that basis, three life phases of materials have been derived: pre-construction, construction and post-construction.

The pre-construction phase is one, wherein materials production and their transportation to the place of use, take place. It includes acquisition of raw materials, processing, fabrication of final products along with their packaging and transportation to the construction site. The pre-construction phase generates the greatest environmental damage, which is connected with mining of resources. It often requires a major interference in the ecosystem, for example extensive deforestation, ground water pollution, destroying wildlife habitats. On the other hand, transportation of materials causes exhaust emission which contains, among others, carbon oxides, carbon dioxide and sulphur oxides, and influences higher usage of fossil fuels, petroleum in particular. All those activities lead to deterioration of environment and increase in general expenditure, which is connected with the necessity of bearing costs in the field of restoration of ecosystems.

The construction phase starts when the material is being introduced in an object. It primarily requires reducing waste generated during the building process. The costs generated at that phase are connected with the installation process, building-in of the material, exploitation, maintenance, and repairs of the object. Through suitable selection of building materials, substantial reduction in the amount of construction waste is possible. It is crucial to

use only materials, which can be recycled or reused in another building process directly after demolition. In addition, building materials impact on the health of residents should be taken into account, since the duration of operation of and prolonged exposure to some chemical compounds may threaten health. Sustainable construction requires selection of building materials, which include the aspect of people's health.

The final phase of material's life-cycle is management after the time of exploitation. That phase is called post-construction phase. Sustainable construction indicates the need for recycling and re-use of material in building another object without complex processing. That approach allows evading utilisation of construction waste and saving a significant amount of energy, which is used in the process (Błaszczyński et al., 2012: 93-95).

4. 4. Methods of assessment of building materials

One of the most well-known and widely used method is the Sustainable Building Material Index (SBMI). SBMI is a simple method of assessment of materials and building products, used in order to understand the nature and scale of their sustainable impact on the environment. The innovativeness of this method is based on the approach which includes socio-economic aspects in the assessment process. Those aspects have not been included in current assessment tools until now. However, the method does not take into considerations the details that can be found in life-cycle assessment.

SBMI allows for quick obtaining, presenting and comparing crucial aspects of the sustainable influence of building materials. It makes the method highly useful and effective for architects and customers who support the idea of sustainable development (Gibberd, 2014a).

The data used in the assessment process were obtained from manufacturers of building materials and products. Where necessary, the possibility was used of visiting production facility in order to obtain the data or verify them on the spot. Thereafter, the data were analysed and standardised in order to ensure their compatibility with the SBMI format.

In the case where there was no existing data or the data was of poor quality, evaluation of the worst case scenario was adopted. It helped to avoid a too-optimistic evaluation, which significantly differs from the reality and encourages producers to develop their own systems of collecting data. If the data was estimated, it was marked by the letter "E", but when the data were based on records delivered to an assessor, it was marked by the letter "R" (Gibberd, 2014b: 8).

SBMI analysis assesses a product by splitting it across ecological indicators and human development indicators. The following indicators are included in the group of ecological ones (Gibberd, 2014a):

- raw materials demand – defines the amount of raw materials used in production of the building material or product,
- carbon dioxide emission – defines the amount of carbon dioxide emitted during production of the building material or product,
- water consumption – defines the amount of water used in production of the building material or product,
- land use – specifies the amount of land used for production of the building material or product,
- waste – specifies the amount of generated waste during production of the building material or product,
- pollution – specifies the amount of emitted pollution during production of the building material or product.

The indicators of human resources development involve (Gibberd, 2014a):

- employment – specifies the workforce size necessary to produce the building material or product,
- employment in related enterprises – specifies the employment in related enterprises, such as transport, security industries and cleaning, used in the production of the building material or product,
- formal training – specifies employee training and education during the production of the building material or product,
- formal mentoring – specifies employee mentoring during the production of the building material or product,
- health and safety – specifies quantity of health and safety incidents experienced to produce the building material or product,
- ill health per year – specifies absenteeism resulting from ill-health experienced to produce the building material or product.

Each of those indicators is assessed on the scale from 0 (the worst grade) to 5 (the best grade). At the end, the overall rating is calculated. The overall rating is the arithmetic average of the average grade of ecological indicators and human development indicators.

Furthermore, building materials were assessed during eco-certification of building, such as BREAAM (Building Research Establishment Environmental Assessment Method), LEED (Leadership in Energy and Environmental Design), DGNB (Deutsche Gesellschaft für nachhaltiges Bauen). A system of certification allows comparing investments through their compliance with the idea of sustainable development in an objective and rational way. Building materials are assessed on the basis of declared composition, but also many other factors, which decide about their influence on the environment. Among the most important factors taken into account during a building material assessment are their (Muratorplus, 2011):

- composition,
- durability,
- method of obtaining,
- absence of waste in process of gathering, production and building in construction,
- method of packaging,
- influence on residents,
- availability,
- simplicity of disposal,
- ease of use.

Despite the fact that certification systems differ slightly from each other, the scope of the assessment of materials and broad outline are nearly identical.

5. Building materials in ecological buildings

Ecological buildings, also called sustainable buildings, differ considerably from standard ones. During the process of planning and building, economical, ecological and social aspects are taken into consideration. Those buildings have better thermo-insulation properties, consume less electric energy to maintain comfortable internal climate and are made of different materials. Moreover, the building process of sustainable buildings is well thought-out and planned. with taking account of every phase of construction, exploitation and waste management process (Pluta, 2012).

Materials, which are qualified as sustainable, should be durable and have particular characteristics. They should be reusable, recyclable or contain recycled materials in their composition, if it is possible. Sustainable materials not necessarily have to be natural, even though, most of them are. An example of non-natural sustainable materials can be composite

material composed of wood and recycled plastic bottles, which is more durable and stiffer. Also recycled materials use less energy and chemicals in the process (Raney, 2017).

One of the most important features of sustainable materials is no negative influence on residents. It means that they cannot contain toxic substances, which could be released into the environment. When it comes to natural materials, they should be obtained from sustainable sources. Sustainable sources are the sources, which do not deplete natural resources. It mostly refers to sustainable forestry, which is certified by Forest Stewardship Council (FSC). Some materials regenerate very quickly and can be gathered many times from the same plant. The best example is the bamboo and the cork tree, which are not chopped down, but only peeled from layers of their bark (Autodesk, 2014).

Sustainable materials should be obtained from local sources to the largest possible extent. By local materials it is understood materials which are grown or produced at a certain distance from the construction site. Local materials can also be called regional, because their distance can be substantial (around 800 km). The purpose of using those materials is supporting local economy and avoiding a negative impact on the environment, resulting from transportation of the material (Faludi and Lepech, 2012).

The material used for construction of outside partition should be characterized by high mechanical strength and resistance to external conditions. To build external walls, the following sustainable materials are used:

- straw bales – natural, locally occurring and lightweight material, which provides perfect thermal-insulation,
- hempcrete – bio-composite created from the woody inner fibres of the hemp plan. The hemp plant is bounded with lime and pressed into concrete-like shapes, which makes it durable and lightweight,
- bamboo – good extension resistance, lightweight and fast growing material, used in constructing the framework of a building,
- wood – the most popular sustainable material, available in many variants, characteristics may vary depending on the type of wood,
- stone blocks – available in many colours and gradient variations,
- metals from recycling, especially steel,
- rammed earth,
- bricks from recycling and bricks baked on the sun.

The most common material used for construction of buildings is concrete. Despite the fact that concrete itself is not sustainable material, its composition can be enriched, which enhances its properties and reduces waste. Steel ash can be added to concrete compound in order to strengthen it and also absorb and lock carbon dioxide during the process of desiccating and hardening. Another additive used to enrich concrete is ash, which reduces the temperature of setting, or sawdust, which makes concrete compound lighter. The content of recycled materials in concrete may be as high as 97% (Peckenham, 2016).

Materials used in insulation should be characterised by the best thermal insulation, relatively good acoustic insulation, moisture resistance, antimicrobial resistance and fire resistance. Sustainable materials are alternative to styrofoam, foam glass and polyisocyanurate.

The following can be used as sustainable insulation materials (Fix, 2015):

- cellulose – provides continuity of insulation at assembly of any thickness, perfectly isolates thanks to its porous structure, high fire resistance thanks to proper impregnation, good sorption properties and possibility of draining surplus of accumulated moisture,
- mineral wool – this material consists of basalt rock and recycled slag. It is characterised by non-inflammability and fire resistance, vapour permeability and thermal and acoustic insulation,
- cotton – recovered from jeans and other sources of cotton. The content of chemical compounds is low,
- agricultural products – such as sugar cane, corn or soybean. Those materials may be in the form of rigid boards or spray foam,
- sheep's wool – excellent thermal insulation and good sorption properties, which do not cause a negative impact on users' health,
- cement – mixed with water and frothed with air, has porous structure, which increases its thermal insulation and ability to "breathe". The material is moisture-resistant and antimicrobial-resistant.

During interior finishing, sustainable material can be used as well. Materials that are commonly used are certified wood, bamboo, cork or carpets from natural fibres. Those are natural materials, which have no negative impact on users' health and come from renewable source, thereby natural environment is not degraded.

6. Conclusion

Sustainable building materials comply with the idea of sustainable development. During the process of production and acquiring materials, three aspects are taken into consideration: economical, ecological, and social. In comparison to standard building materials, they are usually cheaper and more environmental friendly. This is caused by the fact that among other things, they are produced close to the place, where they are needed or recovered from waste. It means less pollution emission from transportation and significant reduction of generated waste stream.

Sustainable building materials are safe for users, because they do not emit harmful and toxic substances into the environment. They are mostly natural materials, which come from waste recycling or sustainable sources, which should be certified, for example certified wood and paper products from responsibly managed forests.

To sum up, utilisation of those materials in the construction process contributes to reduction of natural resources usage, prevents overexploitation of resources, reduces pollution emission to the environment and supports local economy. Sustainable building materials are also safe for health and life of their users.

Literature

Affelt W. (2011). *Budownictwo zrównoważone* In: Nowoczesne rozwiązania konstrukcyjno, materiałowo technologiczne : budownictwo ogólne : XXVI Ogólnopolskie Warsztaty Pracy Projektanta Konstrukcji. Szczyrk, 9-12 marca 2011 roku. T. 1, Wykłady.

Autodesk (2014). *Green Building Materials*. Available at: https://sustainabilityworkshop.autodesk.com/buildings/green-building-materials. Accessed 17 June 2017.

Błaszczyński T.; Dyzman B.; Ksit B. (2012). *Budownictwo zrównoważone z elementami certyfikacji energetycznej*. Dolnośląskie Wydawnictwo Edukacyjne, Wrocław.

Boczek Z. (2013). *Budownictwo Zrównoważone*. Available at: http://www.architektura.info/index.php/architektura_zrownowazona/aktualnosci/budownictwo_zrownowazone. Accessed 16 June 2017.

Faludi J.; Lepech M. (2012) *Ecological payback time of an energy-efficient modular building*. Journal of Green Building: Winter 2012, Vol. 7, No. 1, pp. 100-119.

Fix (2015). *Sustainable from the Bottom Up*. Green Material Guide. Available at: https://www.fix.com/blog/build-a-sustainable-house/. Accessed 18 June 2017.

Gibberd J. (2014a). *The Sustainable Building Material Index (SBMI).* Available at: http://sustainablebuildingmaterialindex.blogspot.com/. Accessed 16 June 2017.

Gibberd J. (2014b). *Sustainable Building Material Index Assessment and Recommendations for Informal Brick Manufacture in Alliwal*. North, Eastern Cape, Gauge, Pretoria, South Africa.

Muratorplus (2011). Materiały budowlane w zgodzie z ideą zrównoważonego rozwoju. Available at: http://www.muratorplus.pl/technika/zrownowazony-rozwoj/materialy-budowlane-w-zgodzie-z-idea-zrownowazonego-rozwoju_69787.html. Accessed 17 June 2017.

Peckenham E. (2016). *11 green building materials that are way better then concrete*. Available at: http://inhabitat.com/11-green-building-materials-that-are-way-better-than-concrete/. Accessed 18 June 2017.

Pluta A. (2012). *Budownictwo zrównowazone – powszechnie obowiązujący standard*. Available at: http://www.inteligentnybudynek.eu/artykul/article/budownictwo-zrownowazone-powszechnie-obowiazujacy-standard/part/1/. Accessed 17 June 2017.

Raney R. F. (2017). *10 Cutting-edge, Energy-efficient Building Materials*. Available at: http://home.howstuffworks.com/home-improvement/construction/green/10-cutting-edge-building-materials7.htm. Accessed 17 June 2017.

ZRÓWNOWAŻONE MATERIAŁY W BUDOWNICTWIE EKOLOGICZNYM

Streszczenie

Budownictwo ekologiczne to tworzenie i odpowiedzialne utrzymanie zdrowego środowiska budowlanego w oparciu o zasady zrównoważonego rozwoju, efektywności ekonomicznej i ekologicznej. Rynek materiałów budowlanych jako pierwszy rozpoczął dostosowywanie się do idei zrównoważonego rozwoju. W wyniku tego procesu powstały tzw. zrównoważone materiały budowlane, definiowane jako wyroby, do których pozyskania surowców i proces ich przetwarzania w produkt finalny, wbudowanie wraz z transportem, użytkowanie, rozbiórka oraz ponowne wykorzystanie, spełniają wymogi rozwoju zrównoważonego.

W niniejszej pracy przestawiono istotę zrównoważonych materiałów budowlanych. Omówiono fazy cyklu „życia" wyrobów budowlanych oraz ich wady i zalety. W artykule uwzględniono również wykorzystanie zrównoważonych materiałów w budownictwie ekologicznym.

Słowa kluczowe: zrównoważony rozwój, materiały budowlane, budownictwo ekologiczne, cykl życia wyrobów

Kody JEL: Q01, Q20

https://doi.org/10.25167/ees.2018.45.6