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Ecological Assessment of Building Materials in Serbia: Constrains and Possibilities

Saja Kosanović*, Milica Jovanović Popović

*Faculty of Technical Sciences, Kosovska Mitrovica
Faculty of Architecture, University of Belgrade
Kneza Miloša street No. 7, 38220 Kosovska Mitrovica, saja.kosanovic@pr.ac.rs

Abstract

Building materials make significant impact on the environment, hence their ecological performance became one of the key sustainability topics. To determine environmental impact of a material, it is necessary to examine the phases of its life cycle, by using the established method. Unified assessment methodology enables comparison between different materials and the selection of more ecologically friendly option. The practice has already been applied internationally and the diverse models for ecological assessment of building materials are in use. In Serbia, on the other hand, various constrains impede researchers' efforts to develop an assessment system. Undeveloped legal regulation in the field and the lack of quantitative data which describe the ecological quality account for the main aggravating circumstances. Within the existing conditions, ecological assessment may be conducted rather by using descriptive method and general knowledge on building materials and their impact, than by applying approach based on impact measurement. In accordance with this thesis, the set of criteria which may be used in current situation, and which are derived after aligning with the life cycle phases and predicted impact, are proposed. In respect to the criteria development, following issues were considered: Use Efficiency; Durability; Eco-Sign; Availability; Construction Waste and Alternative Building Materials. Transitional ecological assessment model represents a step towards sustainable national building practice and may be used until the database with measured impact of all nationally produced building materials is formed.

Keywords:	Life cycle analysis, National regulation, Ecological assessment, Ecological criterion

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1. Introduction

Building materials make significant impact on the environment, hence their ecological performance became one of the key topics in the field of sustainability. From architectural point of view, the use of building materials is found to be one of the critical factors of environmental pollution and degradation [1]. A study of the environmental impact of building materials is based upon the examination of their behaviour from the process of getting raw materials and concluding all operations until the final return to the natural environment or to the repeated production/installation process. This series of processes represents "the life cycle of building materials" [2]. The rule of thumb is that a building material has potential negative environmental impact in every phase of its life cycle, depending on: origin of raw materials, method of production, distance between the production and construction sites, method of transport, content and features and possibility of re – use / recycling [1], [2].

Different methodological approaches are used to determine the ecological quality of building materials. Assessment may be conducted independently, where materials are the only subject of the analysis, or as a part of overall evaluation through which all segments of ecological performance of a certain building type are examined.

To-date, a series of approaches have been developed for the environmental assessment of building materials: LCA (Life Cycle Assessment) studies, eco-labelling, eco guides, environmental concepts, etc. It was found that different approaches answer different questions and that stakeholders may need to use different tools for external communication, external decision-making support, and internal development [3]. With the harmonized indicators, unified LCA methodology could be considered as the approach which is offering comparable results. To achieve this, "it is important to extend, adjust and harmonise the existing inventory

databases of construction materials to the characteristics and peculiarities of the construction industries in each country", where the manufacturers are obliged to provide standardised information based on the LCA of the real impact of every product [4]. "...In this sense, there would be accurate information on the impact of each product, which would facilitate a correct assessment of the impact of a building from an LCA perspective. Without this information, this impact can only be estimated approximately using existing inventories that, on occasions, are difficult to adapt to the reality of a specific geographical area" [4].

In international systems for overall environmental assessment of buildings, building materials are examined to the variable extent, again by using different methodologies. In German DGNB (Deutsche Gesellschaft für Nachhaltiges Bauen), for example, there exist a series of established environmental criteria and supporting indicators based on which the parts of building structure, such as walls, are assessed [5]. System BREEAM (Building Research Establishment Environmental Assessment Method) calls upon another data base, named Green Guide to Specification, according to which materials can be assessed [6]. Other evaluation systems put an accent on specific materials. Construction waste is also assessed, as well as material re-use or recycling. Advantage in selection is given to prefabricated, long-lasting, regionally available materials, and materials with eco certificates [7].

While setting the base for the first national system for overall environmental assessment of defined building type [8], there were significant specificities observed in the field of building materials. In the process of information gathering and analyzing, materials were labelled as "unexplored" content. Detected peculiarities were found to be independent from the building type and, to the large extent, from the territory for which the system is designed. This paper, in relation to the said, aims to overcome the present state in the domain of building materials on national level, by proposing the transitional ecological evaluation method that fits present conditions, but also represents the base for further scientific and institutional work in the field. Proposed criteria are applicable as independent or may be embodied in national assessment systems for different building types.

2. Analysis of national conditions

The interest in sustainable architecture in Serbia is best visible in scientific and educational domains, whereas green buildings are still rarely built. The same is true for building materials, and for both, national legal regulation is insufficiently developed.

2.1. State on market

Study of the Serbian market indicates the availability of many nationally produced building materials: ceramic bricks, blocks and tiles; building stone; cement and other binders; aggregates - gravel and sand; wooden, PVC (polyvinyl chloride) or aluminium frames for doors and windows; glass products; tin products; prefabricated concrete components; facade and interior mortar products; thermal and hydro insulation materials; rubber products; paints; decorative materials, etc [8]. But, not all raw materials (components) of produced materials originate from Serbia. This fact points to a more complex life cycle and, consequently, to quite certain difficulties in determining the environmental impact in phases.

In most cases, data on nationally produced material behaviour through the phases of life cycle are unavailable. Occasional and isolated available data are not harmonized and very difficult to use. There aren't available data on ecological effects of production process. In general, it is, however, certain that this phase make significant impact on the environment [1]. Additional causes for potential impact increment are: weak pollutants control; solid waste generation and its weak management; energy inefficiency; lack of control of waste water quality; usage of non-renewable energy and material resources; obsolete production technologies; inadequate environmental management in production; lack of financial support for clean production introduction; lack of regulations for clean production introduction, etc.

National manufacturers do not issue valid certificates nor declarations which could mark previously examined and proved ecological quality of a purchased material. Occasional notes which indicate good ecological performance of a material and which are put on package following the producer's own initiative, most often carrying not more than the advertising message, may lead buyers to wrong purchase decisions.

Usage of recycled and re-used materials for construction is rare and not considered as typical, but is potentially achievable to the large extent.

Ecological effects of use of domestically produced building materials are neither known. Many of produced materials are not tested on presence of harmful substances. Effects of various substances in materials are still not examined or proved.

2.2. Legal framework

To-date, a national legal document which would relate to the regulation of ecological quality of building materials is still not brought. Domestic *Law on*

Environmental Protection [9], brought on 2004 and amended on 2009, defines environmental protection standards in domains of imported or domestic technologies, processes, products, half products and raw materials. According to the Article 52 of mentioned document, Producer or Distributor is obliged to warn on environmental pollution or harm on the human health, which certain product or its package causes or may cause, and this by issuing the declaration of half product of product. In another article, Law on Environmental Protection defines the *Eco-Sign*, and separate derived regulation from 2009 [10] defines the terms for obtaining, awarding and usage of the Eco-Sign, intended for different products, processes and services, including here building materials.

The most important national document which regulates the environmental assessment of buildings [11] refers to general guidelines, but doesn't consider building materials separately. Some aspects of materials' environmental considerations, related to life cycle phases, are regulated with broader national legal documents on environmental protection [12], [13], [14]. Analyses of the studies on several mid and large-scale projects [8], developed in accordance with these regulations, clearly indicate that there exist the lack of important quantitative information in regard to environmental impact of building materials, as well as the reference list, i.e. the database which would enable the comparison of different materials, based on their environmental performance.

Domestic Law on Enhancement of Construction Industry in Conditions of Economic Crisis [15] obliges all stakeholders involved in project realization process to use domestically produced building materials at a minimal rate of 70% of total material used.

Governmental *Strategy on Waste Management for Period 2010-2019* regulates a series of actions related to the waste management [16].

2.3. Voluntary assessment of building materials

"The absence of national legal regulation in the field of reduction of negative environmental impact of building materials has as a consequence relied on the exclusively volunteer devotion and efforts of architects and other participants involved in the processes of the design and construction of buildings. It is the architect who has an assignment to point out to Investors all the advantages of the selection of ecologically correct options of, not only basic, but also of alternative building materials" [1]. The current praxis of voluntary assessment of building materials in Serbia, therefore, before all relates to the appropriate material selection. In this sense, it can be further concluded that the current assessment represents rather the thinking process based on knowledge about ecology of building materials, than the established quantitative approach application. The fact indicates the need for the assessment methodology development.

Not long ago, Association of Consulting Engineers of Serbia started an initiative in order to create the "GREENBASE" with green building materials (both nationally and internationally produced) [17]. To-date, however, the number of materials which found their place in the base is still minimal.

3. Proposal for criteria development

According to the analysis of national conditions (chapter 2), it can be concluded that there exist aggravating circumstances which influence the formation of criteria for the environmental assessment of nationally produced building materials:

- Unavailability of information regarding ecological quality,
- Unavailability of information regarding environmental impact over the life cycle phases, and especially during the production ("gate") phase, and
- Insufficiently developed legal regulation.

Mentioned problems are in relation to missing quantified input and output data, which should be included in LCA assessment framework. This further impedes the definition of ecological indicators and their environmental weight, where the both present a base for quantitative approach to the assessment of environmental impact of building materials [18].

Based on the scope and content of existing national legal framework (chapter 2.2.), it can be concluded that it is not possible to establish a significant relation between the regulations and criteria for environmental assessment. Few of the mentioned legal documents, however, may be embodied or used as initial guidelines.

Within the explained conditions, ecological assessment of building materials on national level may be conducted rather by using qualitative method and general knowledge on materials and their impact, than by applying impact measurement based approach. In accordance with this thesis, the set of criteria which may be used in current situation is proposed.

Proposed criteria are derived after aligning with life cycle phases and predicted impact [1]. From the above said reasons, integration was not an easy task. In relation to LCA, following cycle phases and belonging ecological issues were taken into consideration for the criteria defining:

- Raw materials (material origin),
- Transport (distance),
- Installation (construction waste management),
- Use and maintenance (durability / long-lasting, impact on environmental pollution and partially health impact),
- Decommissioning (construction waste management),
- Re-use (previously used materials), and
- Recycling (possibility of recycling).

Finally, achievable ecological objectives were defined and six categories for the ecological evaluation of building materials are derived (Table 1). Every proposed category contains one or more criteria which enable ecological evaluation (Table 2).

4. Conclusions

Reduction of operational energy consumption in buildings (energy efficiency) accounts for the best regulated environmental aspect, both on national and international level. It is, however, estimated that the set goals of this aspect will in near future be fulfilled to the largest extent. The attention is, therefore, gradually moving towards other segments of buildings, such as building materials.

Different internationally developed methodological approaches are used to determine the ecological quality of building materials. Assessment may be conducted independently, where materials are the only subject of the analysis, or as a part of the overall evaluation through which all segments of ecological performance of a certain building type are examined. In Serbia, on the other hand, various constrains impede researchers' efforts to develop an assessment system. Unavailability of information about the ecological quality and the environmental impact over the life cycle phases, as well as the insufficiently developed national regulation in the field, account for the significant aggravating factors.

After analyses of national conditions, it was concluded that the ecological assessment of building materials on national level may be conducted rather by using qualitative method and general knowledge on materials and their impact, than by applying impact measurement based approach. Therefore, the set of criteria which may be used in current situation were proposed. Shown criteria are derived from six proposed categories for environmental assessment of nationally produced building materials, and these are derived after defining realistically achievable ecological objectives.

Beside meeting present conditions and at the same time aiming to overcome them, proposed transitional ecological evaluation method also may be used as a base for further scientific and institutional work in the field. Presented criteria are applicable as independent or may be embodied in national assessment systems for different building types, where the additional detailing in terms of indicator values and environmental weight determination are needed in both cases.

In a wider perspective, paper aims to enhance the development of new environmentally friendly building materials, ecologically correct methods of production and construction, and the introduction of certificates for ecological quality of building materials.

The results urge all involved in design and construction sector: architects and engineers of other profiles, legislative institutions, manufacturers, researchers, etc, to direct their efforts towards the formation of database with measured environmental impact of nationally produced building materials.

Table 1. Proposed categories for environmental assessment of nationally produced building materials

No	Category Name	Ecological Objective
I	USE EFFICIENCY	To decrease negative environmental impact and resource consumption by reduction in material use
II	DURABILITY	To reduce the demand for new materials by promoting durability / long-lasting
III	ECO-SIGN	To promote selection of materials with enhanced ecological characteristics and the development of legal aspect
IV	AVAILABILITY	To reduce transport energy consumption by locally/regionally available material selection
V	CONSTRUCTION WASTE	To reduce construction waste generation and to promote its re-use
VI	ALTERNATIVE BUILDING MATERIALS	To promote eco-friendly substitutes to some conventional building materials with significant environmental impact

Table 2. Proposed criteria for environmental assessment of nationally produced building materials

No	Criterion Name	Criterion Definition	Supporting Indicators/Evidences
I 1	Building Area	Usable area of a building is reduced, in accordance with regulations and comfort demands	% of reduction; Reference values (m^2) for subject building type
I 2	Floor Height	Clear floor height is reduced, in accordance with regulations and comfort demands	Space height (cm); Reference values (cm) for subject building type
I 3	Open Plan	Open plan dominates building's spatial organization	Inspection of project documentation
I 4	Volume Mass & Dimensions	Applied materials/components are with reduced volume mass and dimensions	Weight (kg) per unit area (m^2) of built space; Material specification
I 5	Concrete Use Reduction	In the above-ground part of a building, measures for concrete use reduction have been applied	Ratio between concrete volume and the built area (%); Reference values for subject building type
I 6	Wall Finishes	External/internal wall finishes with solely decorative character are exempted	% of exemption in relation to total wall surface (m^2)
II 1	Protection from Moisture	The set of measures for protection [a] from moisture have been applied	Inspection of project documentation
II 2	Service Life	Main structural parts of a building [b] are made of materials with prolonged service life	Durability (in years) for every main structural part of the building; Applied methodology for service life estimation
III 1	Eco-Sign	Applied building materials are labelled with Eco-Sign	% of materials with Eco-Sign in relation to total materials used, measured by weight
IV 1	Distance to the Production Facility	Building materials applied in main structural parts of a building are locally/regionally produced	% of locally/regionally produced materials in relation to total domestic materials used, measured by weight; Maximum distance radius (km)
V 1	Re-Use	Materials applied in certain parts of building structure [d] have already been used before	% of re-used materials in relation to total materials used, measured by weight
V 2	Recycling	Certain parts in building structure [e] are made of materials that may be recycled	Minimum number of parts of building structure, where a part relates to all applied components of the same kind
V 3	Prefabrication	There exist prefabricated structural building parts [f]	Minimum number of prefabricated parts of building structure, where a part relates to all applied components of the same kind
VI 1	Thermal Insulation	Materials selected for envelope thermal insulation have vegetal origin	% of vegetal insulation materials in relation to total insulation material used, measured by envelope surface (m^2)
VI 2	Mortars	Selected mortars by type are: lime, plaster or lime-plaster	% of lime/plaster/lime-plaster mortars in relation to total mortar used, measured by covered surface (m^2)
VI 3	Polyvinyl Chloride (PVC)	There are no PVC components present in building structure [g]	Visual check and inspection of project documentation
VI 4	Finishing Coats	Applied finishing coats on exterior and interior surfaces are water-based, additionally of natural origin	% of surfaces covered by water-based, additionally natural coats, in relation to total surface area (m^2)

[a] Measures for moisture control in criterion II 1 relate to: adequate hydro and thermal insulation; envelope waterproofing; water diffusion and condensation control; application of moisture-resistant materials, especially in wet areas; adequate water drainage / water management; protection of porous materials; adequate material storage; underground space levelling, in accordance with subterranean waters; comfort demands

[b] Structural parts of a building in criterion II 2 relate to: foundations, foundation and basement walls; above-ground structural elements (columns and beams in skeletal, i.e. walls and ceilings in massive structural system); floor in contact with the ground; external walls; staircases; roof structure and roof cover

[c] Main structural parts of a building in criterion IV 1 relate to: foundations, foundation and basement walls; above-ground structural elements (columns and beams in skeletal, i.e. walls and ceilings in massive structural system); floor in contact with the ground; external walls; staircases; roof structure and roof cover

[d] Parts of a building structure in criterion V 1 relate to: foundations, foundation and basement walls; external walls, interior supporting walls; interior wall partitions; roof structure; roof cover; floor in contact with the ground; ceilings; staircases; floor finishes and outdoor materialized surfaces

[e] Criterion V 2 relates to: main structural elements; thermal insulation; roof structure; walls; roof cover; staircases; windows and doors; installation pipes; flooring materials

[f] Prefabricated structural parts in criterion V 3 relate to: ceilings; main skeletal structure; main roof structure; panel walls; panel roof system of prefabricated cells and small mobile structures

[g] Structure components in criterion VI 3 relate to: windows, doors, partition walls, flooring and solar protection systems

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