ENVIRONMENTALLY-BASED STRUCTURAL DESIGN CRITERIA FOR BUILDINGS

by

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Activities related to buildings contribute to a large degree to environmental degradation. It is necessary to reduce the negative environmental impact and resource consumption throughout the life cycle of the building. The aim is to optimize building performances in accordance with the integrated design objectives. The building structure, along with other elements of architectural space, determines the performances of the building. The building structure should be designed and evaluated as a sub-system of the building, whose behaviour is directed towards the aim of system-building – ecological quality. This paper deals with the analysis of structural design in accordance with integrated design objectives, which are derived from quantitative and qualitative indicators of ecological quality of building, within the criteria of environmental protection throughout the life cycle of the building. The overall objective is to reduce harmful emissions to the air, water and soil, as well as to increase the efficiency of resource use, that is, to reduce the intensity of their use. Based on subject analysis, the environmentally-based criteria for the design and evaluation of building structures are derived, in the function of creating the environmentally acceptable building solutions. The present analysis points to the necessity of applying a complex and systemic approach to structural design, in function of achieving the ecological quality of buildings.

Key words: *environmental quality indicators, integrated design objectives, structural design, environmentally-based criteria*

Introduction

Activities related to buildings contribute to a large degree to the environmental degradation. It is necessary to reduce the negative environmental impacts and resource consumption throughout the life cycle of the buildings [1]. This can be achieved through optimisation of buildings performances in accordance with the integrated design objectives derived from the environmental protection indicators [2].

The building structure, along with other elements of architectural space, determines the performances of the building, that is, its quality throughout the life cycle. The building structure should be designed and evaluated as a sub-system of the building, whose behaviour is directed towards the aim of system-building – ecological quality [2]. This paper deals with the analysis of structural design in accordance with integrated design objectives, which are derived from the quantitative and qualitative indicators of ecological quality of the building, within the criteria of environmental protection throughout the life cycle of the building. The overall objective is to reduce harmful emissions to the air, water and soil, as well as to increase the efficiency

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of resource use, that is, to reduce the intensity of their use. Based on the subject analysis, the environmentally-based criteria for the design and evaluation of building structures are derived, in the function of creating the environmentally acceptable building solutions.

Structural design in accordance with the criteria of environmental protection

Harmful emissions to the air, water and soil

When it comes to the harmful emissions to the air, water and soil, environmental protection indicators refer to the potential for: global warming, ozone depletion, acidification, eutrophication, and photochemical ozone creation. The aim is to reduce harmful emissions.

Emissions of gases that contribute to global warming occur in the processes of production of energy, based on the combustion of fossil fuels and wood needed for the operation of buildings and for the production of building materials and products, and then during the combustion of solid waste and chemical reactions during the production of certain materials. In order to reduce harmful emissions, the following is needed: more efficient energy use and the use of energy from renewable sources; adequate choice of materials; reduction of impact during transportation, which implies local sources and production of materials and energy efficient forms of transport. The concrete-cement industry is responsible for 8% of total CO_2 emissions on the planet, accompanied by steel industry, which is responsible for 5%. Besides the reduction of overall consumption of concrete, it is possible to reduce the amount of cement in the mixture by simultaneously increasing the amount of aggregate and reducing the amount of water. Furthermore, the amount of cement can be reduced by the use of:

- larger size aggregate and coarser sand,
- alternative raw materials in the production of cement clinker [3], and
- materials from industrial waste with the similar characteristics, such a granulated blast furnace slag, fly ash, silica dust for the partial substitution of the cement clinker.

In this way, negative environmental impact related to disposal of industrial waste in the landfills is reduced, with the simultaneous reduction of primary non-renewable raw materials consumption. Reduction of the emissions related to steel structures can be achieved by using recycled steel, considering the fact that during the recycling of the steel the emissions of CO_2 are up to 80% lower, compared to the emissions from steel production from iron ore.

Emissions of gases that cause ozone depletion are related to the processes of space cooling, but also to the processes of production of certain building materials, as well as to the processes of combustion of fossil fuels. In order to reduce the harmful emissions, it is necessary to:

- reduce the use of cooling systems based on the refrigerants with high ozone depletion potential,
- reduce the operational energy needed for building cooling, and
- choose adequate building materials.

Certain materials in structural assemblies can be based on the use of CFC, HCFC, or HFC agents, which have a negative effect on the ozone layer.

Emissions of gases that contribute to the acidification occur in the processes of energy production based on burning of fossil fuels. In order to reduce harmful emissions, it is necessary to use energy more efficiently, that is, to reduce embodied and operational energy of buildings, as well as to use energy from renewable sources.

The process of eutrophication is related to the increase of nutrients in the soil and water as a result of wastewater discharge and the result of combustion of fossil fuels. It is necessary to introduce a system for wastewater treatment, in order to reduce the outflow of nutrients into water systems. Also, a more efficient use of energy is needed, as well as the use of energy from renewable sources.

Photochemical ozone potential refers to the emissions of HC during the transport and emissions of NO_x during the combustion of fossil fuels, which create ground-level ozone that has negative health effects. Given the uneven distribution of resources, as well as the expansion of urban areas, raw materials and building products are often transported over long distances. Heavy weight of certain raw materials and products (stone, gravel and sand, clay products), used to produce building structure, creates additional pressure on the environment, due to higher fuel consumption. It is necessary to reduce the transportation impact, by the use of local raw materials and products, as well as use of more energy-efficient forms of transport. What is also needed is a more efficient use of energy and use of energy from renewable sources.

Energy demand

When it comes to energy demand, environmental protection indicators refer to the non-renewable primary energy demand, total primary energy demand and to the share of renewable primary energy. The aim is to reduce the share of energy provided from non-renewable sources, to reduce the requirement for total primary energy and to increase the share of primary energy provided from renewable sources. Energy consumption during the life cycle of the building includes energy consumption in phases of production of materials and products, of building construction, of building use and of the end of life of the building. The goal is to achieve minimum energy consumption, consisting of embodied and operational energy, throughout the life cycle of the building.

When it comes to load-bearing structure, reduction of the initial embodied energy of the building can be achieved in the following ways:

- through reduction of total material consumption,
- structural design characterized by a higher possibility of building reuse, higher space efficiency, higher level of functional integration of spatial elements and by higher structural efficiency,
- greater share of materials obtained from less energy-intensive processes of raw material extraction the use of less processed materials and structural elements, *i. e.* materials which imply less energy-intensive production,
- use of materials and elements obtained from secondary raw materials, *i. e.* use of reclaimed structural elements, use of already used products from other industries without prior processing, use of materials obtained through recycling processes and use of by-products,
- use of materials and elements obtained from local raw material sources and local production,
- use of materials and elements of lower transport weight,
- use of materials and elements which imply less energy-intensive form of transport, and
- use of materials and elements whose installation is not based on the use of heavy machinery.

Reduction of embodied energy during the use phase of the building, which refers to materials and elements needed for maintenance, repair, renovation, adaptation or reconstruction, can be achieved by ensuring the durability of load-bearing structure, with a minimum of maintenance, as well as via structural design which ensures space adaptability without the need for radical intervention at the level of building structure.

The energy needed for heating, cooling and ventilation of buildings, which account for 50% of total operational energy [4], can be significantly reduced by design interventions. During the design of the building, it is necessary to analyse the building as a whole, that is, to view it as a thermal system that interacts with the environment through a process of heat transfer and fluid-flow. Interventions at the level of structural form and applied materials in order to optimize heat transfer and fluid-flow and to minimize temperature fluctuations in the indoor environment refer to the combination of reduction of heat conduction and convection, and adequate thermal mass.

Evaluation of the energy performances of structural assemblies is primarily based on analysis of their thermal resistance. Thermal resistance of the entire surface of the structure can be significantly reduced in the case of assemblies with high framing factor, *i. e.* with high share of surface of structural members in the entire surface area of the wall, particularly when the structural members are made of material of high thermal conductivity, such as steel. The regulations of certain countries define the maximum allowable values for thermal bridges, they can significantly increase the energy requirements for heating and cooling in building [5].

The new standards related to energy efficiency of buildings insist on a greater air-tightness of buildings with the aim of reducing the heat losses that occur as a result of air leakage. Air leakage most commonly occurs in the area of connection between individual elements of the structural assembly. In that sense, when it comes to the air leakage, non-monolithic load-bearing structures are more sensitive, especially ones that are made of materials which are sensitive to the effects of wetting and drying in terms of dimensional stability, such as wood.

In addition to the reduction of heat conduction and convection, one of the strategies for saving energy needed for heating and cooling of buildings, as well as for minimization of temperature fluctuations in the indoor environment, is the formation of load-bearing structure with adequate thermal mass. The building structure made of material with high heat storage potential (concrete and clay-based materials), can effectively regulate a daily heat flow, if it is properly thermally insulated from the external space, exposed to internal space (without suspended ceilings, gypsum coverings, polystyrene interjoists) and adequately dimensioned and positioned. In the case of moderate continental climate, in winter, within the strategy for heating, the building structure accumulates heat during the day and radiates it to the inner space during the night. In summer, within the strategy for cooling, the building structure accumulates excessive heat during the day. During the night, the building structure is cooled by contact with the outside cold air, which is achieved either by natural or by forced ventilation. Inadequate use of thermal mass of the load-bearing structure of the building can impede realisation of desired thermal comfort and increase the operational energy consumption of the building, especially in conditions of prolonged high temperatures, *i. e.* in conditions that do not allow efficient cooling of the building structure. In addition, thermal mass of the load-bearing structure can increase the energy requirement in winter mode, where there is not enough solar gain. In that sense, in order to adequately use thermal mass, it is necessary to consider a number of parameters during the design of the building. These include: local climate conditions, orientation and geometry of the building, level and method of building insulation, windows location and size, type of shading devices, position, size and purpose of spaces, mechanisms of ventilation, types of lighting, colour of surfaces.

Total material demand

As the construction sector is the largest consumer of primary raw materials in Europe [6], the aim is to reduce the total materials demand throughout the life cycle of the building, that is, to reduce the pressure on the environment during the extraction of resources. The aim is to increase resource productivity.

One way to reduce the total material demand is to reuse the existing buildings, which may require adaptation or reconstruction, or replacement of building elements. When it comes to building structure, restrictions related to the reuse of the building can refer to the following: poor physical condition of the structure; inability to adjust the building space to the new purpose due to inadequate disposition of structural elements; unconformity of existing structure to new standards. In this sense, during the design of new buildings, emphasis should be given to building reuse, with special attention to the issue of structure's durability and issue of space adaptability based on the structural system form. Furthermore, the solution should ensure robustness, that is, minimum vulnerability of the building structure during the various actions.

The reduction of the required material amount can be achieved through space efficiency, which depends on the structural design. The key question is the question of adequate dimensions and position of structural elements. Greater freedom from load-bearing elements leads to greater net usable surface area of the space [7]. Also, building structures that enable integration of the installations in their zone provide greater net usable volume of space. In this way, savings in the surface of the building's envelope can be realized.

Total material demand can be reduced through the functional integration of spatial elements. Surface structural elements, in addition to load bearing function, can take over the function of the building's envelope, as well as the function of the final interior surfaces, which eliminates the need for interior coatings. In that case, special attention should be given to the realisation of adequate structural form and to adequate treatment of the final surfaces, that is, to the realisation of adequate texture and colour of the structural materials. When considering the possibility of using structural material as the outer layer of the building, its resistance to the aggressive effects of the environment must be taken into account, as well as the amount of the material that will be required for the maintenance of structure throughout its life cycle.

Reduction of the required amount of material can be achieved by increasing structural efficiency, which is measured by the degree of utilization of materials in terms of carrying the load. It should be noted that structures are more efficient when the loads cause axial forces in the system, instead of bending [8]. Generally, the geometry of the cross-section and longitudinal structural element geometry affect its structural efficiency. Achieving savings in the amount of material in the case of single structural element leads to progressive material savings within the overall assembly. However, the greatest savings in material consumption can be achieved through adequate shaping of the entire building structure. In order to increase structural efficiency, structural form should be such as to provide more direct load paths and to prevent stress concentration.

In the case of application of composite structural materials savings in the amount of material can be realized through optimal design of materials. In the case of reinforced concrete, savings can be achieved by establishing an optimal relationship between the amount of concrete, reinforcement and concrete strength, as well as by optimizing the reinforcement disposition in structural elements in accordance with the expected stresses in the structure.

Share of secondary raw materials

When it comes to the share of secondary raw materials in total material amount, the aim is to increase it through direct reuse, reuse with prior processing or reuse with prior recycling. This reduces the need for virgin raw materials and embodied energy of materials, but also reduces the amount of waste that is sent to landfills, and by that a potential soil and water pollution.

Structural elements can be reused or recycled when they reach the end of their life [9]. In order to use them again, structural elements need to have adequate durability and need to be adequately maintained. Also, it is necessary to implement a careful deconstruction of the building in which they are embedded. The structural assembly should be such that it enables deconstruction without significant damage of elements. In that sense, structural assemblies made of easily separable prefabricated components are more suitable. Reuse is more common in the case of standardized components and connections, as in the case of components of a larger cross-section, given that they are less prone to damage during the process of deconstruction of buildings [10]. Prior to reuse of structural elements, it is necessary to conduct control of their load-bearing capacity. When it comes to reuse of wooden structural elements, a limiting factor may be a reduction in their cross-section after the removal of damaged parts, nails, bolts, screws and zones with holes. In this context, reuse is more common in the case of wooden elements of larger cross-section [11]. When it comes to reuse of steel elements, a limiting factor may be the problem of corrosion and the problem of material fatigue [12]. In the case of monolithic reinforced concrete structures, reuse of components is rare, given the difficulty in deconstructing them without major damage [13].

Reducing the request for primary raw materials can be achieved by using already used products from other industries, without prior processing, within the building structures. Plastic bottles, baled plastic bags and other plastic materials from waste may be used as lost formwork in concrete structures. Materials obtained by the process of recycling of waste may also be used within the building structures. The primary problem concerning the use of recycled materials for the production of structural elements refers to the potential impairment of materials quality. As steel does not lose its quality during recycling, it can be successfully applied for production of new steel structural elements. In the case of concrete structures, it is possible to use the recycled structural materials as aggregate.

The application of recycled aggregates should be based on their previous testing, given that aggregate characteristics affect the mixture design and properties of concrete [14]. It should be borne in mind that the presence of recycled aggregates in concrete can have negative effects on the workability, strength and durability of concrete, which is one of the reasons that limits their wider application. The reduction of the quantity of primary raw materials within the building structures is achievable through the use of by-products. Cement may be partially replaced by by-products such as fly ash, blast furnace slag, silica fume and other complementary cementitious materials. It is possible to replace up to 50% of cement by fly ash, and to thereby achieve a better workability, greater long-term strength and greater durability of concrete [15], with improved mechanical properties [16]. The problem that limits wider application of concretes with complementary cementitious materials is that their performance and quality vary according to class. In this sense, earlier testing is necessary, which can be economically unprofitable. Fly ash and slag can be incorporated into concrete masonry units, with possible share of up to 35% [17]. Blast furnace slag can be used as a substitute for cement and as a substitute for coarse sand in concrete, along with improving the properties of concrete, such as compressive strength and permeability to water vapour and gases [18].

In order to reduce the requirement for primary raw materials during the design of composite structural materials and composite load-bearing components, the potential of materials and components for future recycling should be kept in mind, which is largely conditioned by the possibility of separation of component materials. The aim is to enable later separation of materials with low energy use.

Share of primary raw materials from renewable sources

Given the construction sector still uses primary raw materials from non-renewable sources in the highest percentage, the aim is to increase the share of primary raw materials from renewable sources.

Consumption of gravel and sand for the needs of concrete industry in Europe exceeds the rate of creation of new reserves. In this context, the trend is to move to the crushed and recycled aggregates, regardless of the low embodied energy of the natural gravel [19]. Again, wood is a renewable, bio-based structural material, whose reserves can be maintained at an adequate level by afforestation. However, it should be noted that, in the case of young forests, problems related to the formation of the structural elements of the required cross-sectional dimension, as well as problems related to the poor quality of the wood from fast-growing species might occur. These problems can be overcome by the use of structural composite timber elements instead of sawn timber.

Share of materials from responsible sources

Exploitation of primary raw materials causes the degradation of natural environment, the disruption of ecological balance and health damage of biological resources. Those effects are particularly accentuated in the case of illegal exploitation. The aim is the use of certified materials from the sources that are responsibly managed.

The primary problem related to use of certified materials is the lack of a certification system or insufficiently developed system of certification. During the design process is necessary to apprehend the effects of exploitation of raw materials on the environment. When it comes to raw materials needed for the realisation of the building structures, it is necessary to understand the impacts that occur in the case of exploitation of forests, sand, gravel, limestone, clay and iron ore, given their extensive consumption. The uncontrolled exploitation of forests, primarily leads to deforestation, soil erosion, changes in the composition of the soil and to biodiversity reduction. Exploitation of sand, gravel, limestone, clay and iron ore, primary implies occupation of large areas of land, disturbance of natural environmental values, habitat loss and pollution of water, air and soil. Particularly unfavourable exploitations are the ones that exclude re-cultivation [20].

Waste disposal and share of hazardous waste

All material inputs during the life cycle of the building will eventually be transformed into material outputs. If they end up in landfills, material outputs jeopardize environmental sustainability by disrupting the ecosystems through land occupation and through possible ecotoxic effects. The aim is to reduce the quantity of construction waste, that is, the amount of material that will end up in landfills, as well as to reduce the share of hazardous waste.

Construction waste, which is largely inert and non-toxic, is generated during the construction, maintenance, reconstruction or demolition of buildings. The largest quantities of the construction waste are generated during the demolition. When it comes to reduction of construction waste, it is essential to consider the aspects related to the reduction of total materials demand. In the case of building structure, an especially significant aspect is structural efficiency, as well functional integration of spatial elements. When it comes to the reduction of the amount of the structural materials that will end up in landfills, in addition to reduction of the amount of embedded materials, it is necessary to increase the share of structural materials that can be directly reused, used with prior processing or recycled. In order to realize this aforementioned, it is essential to consider the following: structure's durability; connections between the elements; standardization of components and connections; potential for future recycling of materials and components. Reduction of waste in the construction phase is possible to achieve through application of systems that do not involve the use of packaging, cutting components on-site, as well as the use of formworks with small number of usage [21]. In order to reduce the share of hazardous waste, it is necessary to avoid materials that contain hazardous substances (oils, paints, coatings, adhesives, by-products, *etc.*).

Freshwater demand and the amount of wastewater

In order to reduce the intensity of water resources degradation and to maintain an adequate supply of fresh water of appropriate quality, the aim is to reduce the required quantity of fresh water and to reduce wastewater in all phases of the life cycle of the building. It is necessary to increase the efficiency of water use and to collect and store water (rainwater and wastewater) with the aim of its reuse (with or without purification).

When it comes to structural materials, the largest water consumption is related to the production of concrete and steel. Reducing the water-cement ratio, with appropriate mixture design, can decrease water consumption during the production of concrete. The amount of the required water can be reduced by adding fly ash to concrete mixture [22]. Given the increased application of concrete and the problems related to the availability of fresh drinking water, the possibility of using recycled water in concrete are currently explored [23]. When it comes to steel production, in addition to high water consumption, special problem is the storage and reuse of wastewater due to the presence of contaminants (organic substances, oils, metals, acids, phenols, cyanides, *etc.*). The same problem exists in the case of wastewater during the production of concrete, because it also contains harmful substances.

Demand for valuable land

The aim is to reduce the amount of valuable land (*greenfield*) that is degraded. It is necessary to use materials for which one the exploitation of raw materials does not involve loss of valuable land, as well as to improve the process of obtaining raw materials (reclamation).

Share of already used building land

The aim is to increase the share of already used building land (*brownfield*), that is, to increase the share of recycled or revitalized locations (abandoned or underutilized building lots and buildings). It is necessary to provide the possibility for buildings reuse through the following: optimal durability of building structure; space adaptability; the ability of adaptation of the building structure to the new standards; structural robustness.

Impact on local ecosystem

The aim is to minimize the impact during the life cycle of the building to the local ecosystem, through the reduction of harmful effects.

When it comes to building structure, the imperative is to minimize or eliminate the emission of harmful substances that have toxic effects on bioresources. Particular risk is related to new materials, whose health effects are not sufficiently tested. Certain materials may emit toxic and carcinogenic substances. Certain materials may contain radon. Radioactive may be materials that contain industrial waste, fly ash and slag. Concrete with fly ash and other complementary cementitious materials may contain heavy metals. Processed wood-based materials may have a high content of volatile organic compounds. Concrete admixtures may also have toxic effects. Toxic effects are possible in the case of application of pigments and coatings for concrete, wood and steel.

Environmentally-based structural design criteria for buildings

On the basis of the conducted analysis of principles of structural design in accordance with the integrated design objectives, that is, on the basis of understanding of the possible forms of integration and interdependence of building subsystems, building structure and structural materials, and the behaviour of these subsystems directed towards achieving the objective of system-building – ecological quality, the environmentally-based criteria for design and evaluation of building structures are derived. These criteria are given in tab. 1.

Table 1. Environmentally-based structural design criteria for buildings

Environmental protection criteria for the building		Environmentally-based structural design criteria
Harmful emissions to the air, water and soil	Global warming potential [kgCO$_2$-ekv/m^2 p. a.] Ozone depletion potential [kgR$_{11}$-ekv/m^2 p. a.] Acidification potential [kgSO$_2$-ekv/m^2 p. a.] Eutrophication potential [kgPO$_4$-ekv/m^2 p. a.] Photochemical ozone creation potential [kgC$_2$H$_4$-ekv/m^2 p. a.]	– Reduction of embodied energy (obtained by burning of fossil fuels) • reduction of material consumption (see the requirement for total material demand) • greater share of materials obtained from less energy-intensive processes of raw material extraction • greater share of less processed materials • greater share of materials from less energy-intensive production • greater share of materials obtained from secondary raw materials • greater share of materials from local sources (local raw material sources and local production of materials and products) • lower transport weight • less energy-demanding forms of transport – Reduction of operational energy (obtained by burning of fossil fuels) • higher thermal resistance of the assembly • minimization of thermal bridges (framing factor) • greater airtightness of the assembly (type of connections, material's dimensional stability) • adequate thermal mass • adequate colour of exposed structural elements • higher level of spatial and functional integration of spatial elements – Maximized use of energy from renewable sources – Reduction of consumption of materials with intensive emissions during production due to chemical reactions – Use of materials whose production does not involve chemicals with the potential for ozone depletion – Wastewater treatment

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Table 1 (continuation)

Environmental protection criteria for the building	Environmentally-based structural design criteria
Energy demand [kWh/m^2 p. a.]	– Reduction of share of energy provided from non-renewable sources – Reduction of total primary energy • reduction of embodied energy • reduction of operational energy – Increase of share of primary energy provided from renewable sources
Total material demand [kg]	– Greater possibility of building reuse • optimal durability and adequate maintenance of the structure • space adaptability (based on the structural system form) • ability of adaptation of the building structure to the new standards • structural robustness – Greater space efficiency • adequate dimensions and position of structural elements • spatial integration of building installations and structural system – Higher level of functional integration of spatial elements – elimination of coatings • adequate structural form and form of structural elements • adequate texture and colour of structural materials • resistance of building structure to aggressive environmental actions • effective maintenance – Higher structural efficiency • adequate geometry of building structure (direct load paths; reduced stress concentration) • adequate longitudinal geometry of the structural elements and adequate geometry of their cross-section (direct load paths; reduced stress concentration) • optimally designed materials (optimum ratio of component materials)
Share of secondary raw materials [kg]	– Reusable structural elements (direct reuse or reuse with prior processing) • optimal durability and adequate maintenance of the structure • possibility of deconstruction without significant damage of elements • possibility of deconstruction without energy and time great expenditure • higher level of component and connection standardisation • greater dimensions of the cross-section – Greater share of already used products from other industries, without prior processing – Greater share of recycled materials – Greater share of by-products – Higher potential of materials and components for future recycling (possibility of separation of component materials)
Share of primary raw materials from renewable sources [kg]	– Greater share of primary raw materials from renewable sources (rate of consumption does not exceed the rate of formation of new reserves) • greater share of crushed and processed aggregates from recycled materials • greater share of structural composite timber
Share of materials from responsible sources [kg]	– Use of certified materials – Use of materials with milder effects of raw material exploitation on the environment

Table 1 (continuation)

Environmental protection criteria for the building	Environmentally-based structural design criteria
Waste disposal and share of hazardous waste [kg]	– Total material demand reduction • higher structural efficiency • higher level of spatial and functional integration of spatial elements – Greater share of materials obtained from secondary raw materials – Reusable structural elements (direct reuse or reuse with prior processing) – Higher potential of materials and components for future recycling (possibility of separation of component materials) – Application of systems that do not involve: packaging, cutting components on-site, formworks with small number of usage – Eliminations of materials containing hazardous substances
Freshwater demand and the amount of wastewater [l]	– Greater efficiency of water use – Collection, storage and reuse of waste water (with the possible recycling)
Demand for valuable land [m^2]	– Use materials for which one the exploitation of raw materials does not involve loss of valuable land – Improved processes for obtaining raw materials (reclamation)
Share of already used building land [m^2]	– Greater possibility of building reuse (optimal durability of the structure; space adaptability; ability of adaptation of the building structure to the new standards; structural robustness)
Impact on local ecosystem [location's environmental value]	– Elimination of materials and products that have toxic effects on bioresources

Conclusion

This paper deals with environmentally-based criteria for design and evaluation of building structures. These criteria should be the basis for design of buildings with various quantitative and qualitative properties, with one common higher feature – ecological quality. This type of building design implies early iterative exploration of interdependence of integrated project objectives and design constraints, in a process aimed at multidisciplinary optimization of design solutions based on multiple analyses of many aspects of ecological quality. Given its complex nature, a further research related to development of strategies for implementation of this design concept in engineering practice is needed. In addition to improving the educational process and to developing strategies of communication between disciplines, implementing the concept of ecologically oriented design in engineering practice implies further development of legal framework, as well as introduction of appropriate standards, which will include a general framework for assessing the ecological quality of buildings.

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