Reconsumption and Recycling in the Ergonomic Design of Architecture

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Abstract. One of the characteristics of human activity is the ability to transform the environment and create new structures. Such actions include various forms of building activities. The adjustments of the whole of material surroundings to the needs and possibilities of man is dealt with by ergonomics. The practical and specific application of the general principles of ergonomics, on the other hand, is dealt with by architecture, i.e. architects designing the *material framework for human life*. The quality of this "framework" determines the quality of human life. A widely understood design more and more often goes away from creation of the defined, finished work – object, to initiate and sustain the development process and different activities connected with the space creation. This way is related to sustainable design that is generally defined as design that meets the needs of the present without compromising the ability of future generations to meet their own needs.

Much of waste comprises valuable raw materials for further utilization and the best way to do it is to reuse the waste at the same level of this original usage. The measures to reduce material consumption in the construction industry are to be sought in the implementation of novel renewable materials of natural origin as well as the non-renewable materials, yet possible to regenerate and reuse, that is in reconsumption and recycling applied, among others, in ergonomic design of architecture.

Keywords: building activities, architectural ergonomics, sustainable design, reconsumption, recycling.

1 Introduction

One of the characteristics of human activity is the ability to transform the surrounding environment and the ability to create new structures. The manifestation of such activity comprises various forms of building activity.

The domain which deals with adapting the whole of the material surroundings of man to their needs and capabilities is *ergonomics*. Architecture, however, and architects designing material frames for man's life, whose quality determines the quality of that life, deal with practical and specific application of principles of ergonomics.

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A widely understood design more and more frequently is departing from the creation of ultimately defined objects towards initiating and sustainable development processes and varied activities oriented towards the creation of architectural space. That way is related to the so called *sustainable design*. An effective implementation of sustainable design strategies requires an integrated approach to the building design, the environment surroundings and people's activity inside and outside of a structure, and this is a feature of *architectural ergonomics*.

Much of building waste becomes a valuable raw material for further use and the best thing is when it is reused at the same level as its previous use. Avoidance of disadvantageous and heterogenic storage of the waste can lead to changes in the manner building structures have been demolished so far. This will encourage a careful deconstruction and segregation of components.

Ways to diminish material absorptiveness in the building industry should be sought in implementing both new renewable materials of natural origin and the non-renewable ones but regenerative and reusable, that is in reconsumption and recycling applied in the *ergonomic architectural design*.

2 Ergonomics and Ecology in Architecture

Architecture has always reflected changes taking place in the process of evolution of societies and socioeconomic needs of human environment at a particular stage of its development, and functions and norms of architecture were moulded through centuries. Also, the underlying principle of architecture has always been creating new spatial solutions. The history of architecture, in turn, comprises a constructional order and the history of forms being a logical consequence of technical development that is a technical progress. As through the ages, when architecture was treated as a synthesis of arts, these days it is also considered one of the forms of humanization of technology and man's industrial and urbanized environment. As opposed to the past practices, when architectural objects were usually a work of one author, today's architecture is the result of works of interdisciplinary teams. [2]

Architecture, as it has been mentioned above, is a reflection of socioeconomic needs of man's environment at a particular stage of its development and also a reflection of forms of the contemporary life. It is one of the creative and conscious elements of influence on the processes of shaping a building, its surroundings, and on shaping settling arrangements, and finally whole regions. This art and its accompanying skills serve the purpose of protecting and creating optimal conditions for man's life in the direct contact with the surrounding environment. Architecture understood in that way, as art and a craft whose task is to solve specific problems, reaches into resources of various disciplines, particularly humanistic, technical, scientific, sociological, and economic – depending on a scale and complexity of analysed problems. Therefore, it has to adapt itself to a complex forms of man's life, to the fast pace of technical progress, which results from achievements of civilization, to the socioeconomic development of population and psychological tendencies specific to particular social communities. [3]

One of future trends in architecture – apart from exposing aesthetic qualities – is more effective implementation of utilitarian contents consisting in general inclusion of principles of ergonomics (e.g. "friendliness" of architecture to the handicapped) and ecology (friendliness towards the natural environment).

It is ergonomics that deals with adapting the shape of the material surroundings to man's needs and abilities in both types of environment. This domain determines the principles of proper adjustment of elements of the system: *man – technology – natural environment*. Architecture, however, that is architects who design man's material framework, deals with practical and specific application of the general principles of ergonomics. The quality of those framework determines the quality of man's life.

Transmitting the ergonomic knowledge to architects in particular is of special importance, since it is they who shape man's environment beginning from an industrial scale to a scale of a single interior detail (an industrial form), and whose design errors are for decades severely suffered by a large group of structure users.

The fundamental purpose of the contemporary and future architecture should be shaping the material environment in a manner ensuring the man appropriate standards and a comfort of life with simultaneous respect to nature – its needs and possibilities, thus with the application of the principles of ergonomics and ecology.

Interrelations between ergonomics, ecology and architecture are the easiest to notice when analysing objectives of activity and domains of interests of the above mentioned disciplines.

A widely understood ergonomics deals with adaptation of the whole of components of the material environment (abiotic environment) to man's needs (biotic factor), which is one of the elements of the global ecosystem. In other words, ergonomics aims at ensuring man safety, health environment of proper quality, and life comfort in the ecosystem of nature.

Ecology, in turn, deals with the whole of phenomena concerning interrelations between biotic elements of nature and both their animate and inanimate environment. In short, ecology concerns functioning of the animate nature in relation to the abiotic environment with particular concern for protection of ecosystems against man's destructive activities.

Concern for man and the natural environment and developing ergonomic consciousness in society is the primary task of designers in all specialities. For the sake of specificity and range of professional activity, a particular role, however, falls to architects in this respect. [1]

A shared goal of ergonomics and ecology comprises activity related to the protection of man's health and the improvement of health quality and safety of the human environment. Thus, an analysis of problems should be carried out concerning both the aspect of ecological and ergonomic design, structure building and their use. Taking the whole nature's and man's good as a direction of the ecologic and ergonomic activity it becomes clear that the overriding objective of all participants in an investment process should be a harmonious cooperation leading to building a structure fully adapted to its users' needs and abilities and to the natural environment. Therefore, ergonomics issues in the building industry should be considered in the context of such a wide cooperation, because they are not only a matter of comfort and safety of an individual man, e.g. a contractor or a user, but mainly a matter of public responsibility for the quality of performance of each participant in an investment activity.

Architectural design has always included, though with mixed effects, the context of nature. The traditional ergonomics, however, initially was concerned only with the relation *machine – man,* certainly in the anthropocentric approach.

Ergonomics of the future, in my opinion, is *eco-ergonomics* which allows for not only man's needs, but also the needs and abilities of the natural environment, whose only component he is. Hence, the historical model of the holistic ergonomics system needs to be modified into a widely understood system *man – technology – natural environment*, which will enable a more holistic view of multiaspect effects of man's technical activity.

A particularly responsible role in this respect falls to architects shaping man's material surroundings from the microscale to the macroscale, that is from the scale of an individual interior to urban and regional scales.

3 Architecture as a Generator of Building Waste

At present times, a question is raised whether architecture is still art in the traditional understanding or – as it is comprehended contemporarily – "engineering". All premises speak for the second option. Future trends point at a growing role of the economic and engineering factor, and the essence of the contemporary engineering is also – apart from an ability to create allowing for the principles of aesthetics (art) – the ability to predict effects of exploitation of technical creations and their recycling. The contemporary engineering encompasses constructing, production technology (realization), exploitation (system organization and management), and utilization of exploited technical products.

The problem of waste comes up in every dwelling and concerns all of us. As unaware consumers, we choose products affecting environment in some way or another. Analogies should be sought in the world of designers - architects responsible for taking decisions in the design process every day, in the act of building a house, a housing estate or a city. An image of a *consumption society* provides an appropriate background for considerations over the contemporary architecture whose purpose is to mould man's and nature's friendly urbanized society, ensuring a high quality of life. Designers, as part of a squandering society, are subject to similar market mechanisms and manipulations. Therefore, finding mechanisms for moulding a rational level of consumption in harmony with the surrounding natural environment comprises a challenge for architects implementing the principles of ecodevelopment. [4]

In the natural environment, there is no concept of waste. A continuous flow of matter takes place in the organic ecological cycle. The contemporary waste management in a settlement environment lacks the logic the natural flow. Waste material is still considered inconvenient in the elimination of litter which a municipal sewage facilities cannot handle. Until now, waste has not been considered as "material located in an inappropriate place" and the natural principle of transforming the waste material from one biological process into a recyclable material for another process is not accepted as well.

In the building sector, the phase of investment realization acts as the principal focus of architectural design, while the stage of use and utilization of a planned structure is given much less attention. The willingness of winning existing components of a building, recycling of building materials or whole structures is not common practice while getting rid of a building waste in "wild" dumps appears to be a standard in a building reality.

In highly developed countries, as a result of the development of social ecological consciousness, the implementation of the principles of sustainable development on the scale of the whole economy requires change in thinking, expanding the area of design decisions into a study of their environmental implications. The law on responsibility of perpetrators of environmental damage, if plainly specified and effectively enforced, changes the outlook on design and forces to seek optimal solutions harmless to the natural environment.

Ecologically conscious decisions will be connected with the sustainable resources management. This management should include both non – renewable original materials and extisting waste that would be treated as equally valuable material suitable for further processing and reusing in an investment process. Designers aware of the decisions should at the same time minimize production of non-renewable waste, adopting wasteless technologies based on existing, even already owned materials and products.

Lack of a holistic view of an investment process is the primary reason for disregard of ecological aspects in design and leads to "the surface architecture" and speculative forms of space development depending on fashion, economic situation, and ways of financing. Possibility of architect's influence on limiting investment's effect on the environment depends on how early he has become involved in the programming and designing phase of an undertaking. The earlier the environmental criteria are allowed for in the design (for example the criteria of minimizing the use of building materials or generated waste), the easier is to achieve the effect of zero influence.

Therefore, an environment-friendly design, called *holistic*, includes the whole of an investment process and the full life cycle of a structure (with the demolition phase, waste utilization and waste and material acquisition). It is design integrated with major circulations of nature management, including water, energy, air and materials, and based upon a decentralized circulation economy.

In the history of architecture, the industrial era has recorded engineering objects, factory buildings, mass housing buildings, and public utility structures all reflecting the culture of both the nineteenth and twentieth century societies. A characteristic of the architecture of that time was exploitation of the natural environment (struggle against nature), squandering natural resources in the name of civilization progress. Invariability of the planned function of buildings and its immobility characteristic to that architecture and town-planning, now – in the age of information technology civilization – has become an outdated assumption.

Buildings which enable function mobility and are easy to adapt have a prolonged technical life cycle and should not be qualified as structures for demolition. For this reason, they should be deemed environment friendly, for fundamental building constructions, used through decades, do not cause a flow of resources and generation of building waste in the course of transformations of their elements.

A form of a building imposed by an architect frequently determines potential possibilities of a structure and its capability of adaptation. A well planned building should be sensitive to social changes, sociological determinants, and changing configurations on the labour market. This is the challenge for a flexible architectural design.

Still, majority of buildings is designed with the thought of their prospective users, of their individual financial capacity, and the necessity of adaptation and adjustment of space to the users' individual needs. Majority of buildings, however, or maybe except for spectacular monuments of architecture, undergoes the process of adaptation resulting from changing habits and ways of their use. Dwellings occupants adapt and arrange space according to their own cultural models or either their own or imposed ideas concerning home or office interior. It is physical engagement of occupants that makes home live.

Perception of the user's role in an investment process changes from passive to active, particularly in the design process. The adaptation process appears to be a crucial element in the life cycle of a structure. The adaptive architecture enables the user transforming the surrounding space, meeting their expectations and current needs, diminishing considerably a useless waste stream. Prior to planning architecture of this type, first we have to plan and programme a prospective user's "design", create a proactive environment, open to a large extent. [5]

The adaptation need evidently appears in the use phase. Adaptation is a continuation of both the design phase and the construction phase. The more friendly and open a system is, the easier is to carry out transformations and make changes. When the system is closed and little flexible, it discourages from adaptation actions or even makes them impossible. It leads to the moral death of the system – we do not want to use it, despite its good technical condition. It is connected with squandering the resources, generating waste, and as a result – with a high cost of the life cycle of a structure. Therefore, the predesign, the programme phase is so important.

4 Reconsumption and Recycling in the Ergonomic Design of Architecture

An essential characteristic of design in compliance with the sustainable development is economy of natural resources and their responsible management. New technologies, capable of creating new materials and combining conventional materials in a new way, give a designer much more choices than ever before.

Such an approach is reflected by "design for minimizing waste", where a designer has to exhibit knowledge concerning the life cycle of products and materials used for production and possess information not only on a type of the materials at different levels of the product transformation chain, but also on possibilities of the usage of components obtained from recycling or elements acquired in the secondary circulation.

A crucial consequence for environment is an increase in the complexity of the applied materials. Advanced material engineering, chemistry, developing connection technologies cause that at the production stage a complex material is created, frequently with a complex structure, difficult to decompose into single elementary components.

Use of materials of that type on a wide scale will curtail the possibilities of their recycling or further processing without bearing high costs. The complexity of materials and complex technologies applied in a construction may make the structure exploitation difficult cause problems connected with repair or replacement of individual elements. The complexity concerns not only the material and technological matters, but also space design. The suggested architectural forms may be characterized by either simplicity or complexity of solutions, and frequently by unnecessary complication of form and function. This, in turn, is reflected in the amount of the used building material and waste produced.

When erecting a house from confectioned, modular building materials, an irregular plan compared to the compact plan will generate more material waste. Whereas a sensible design of a building shape will favour cutting down on squandering the building material, eliminating generation of unnecessary construction waste.

The opposition of complexity is simplification of applied solutions and elements in a manner which makes them generally comprehended, easier to replace, repair and potentially use further. Both complexity and simplification are related to the issue of material absorptiveness of products and structures. If a designer determined a possibility of using less material to achieve a desired result, the advantages of reduction of a waste stream would be noticeable both at the production and the postconsumption stage. Waste storage, energy emission and consumption at every stage of a product life cycle will drop in proportion to the amount of the product reduced material. New processing technologies, materials of better quality and an enhanced product design may have an effect on more economical use of materials and resources. [6]

In the phase of an architectural project, a choice of technology and building materials affects a construction's structure, form, and aesthetics, and determines a manner and cost of its development, and finally affects the environment.

When making a choice from among a rich assortment of building materials, we can adopt different criteria. The traditional criteria are the price, availability, mechanical durability, and safety. The ecological criteria include the degree of impact on the environment in all life phases of a material, material and energy absorptiveness, emission potential, and health and microclimate considerations. If we narrow down the issue to the waste problem, then the easiness of utilization, the possibility of biodegradation or recycling, durability and easiness of adaptation to new needs become factors of crucial importance. The influence the building materials have on the environment is connected with winning raw materials and exploitation of natural resources, pollution generated during the production process and the raw materials or ready products transportation, energy absorptiveness and emission power in the course of use, and the manner of utilization. These factors determine a list of environment friendly building materials and technologies. The list includes both the original materials, generally biodegradable and succumbing to utilization with ease, and recyclable materials – just from recycling.

It should be emphasized that biodegradable building materials will not replace completely the traditional ones. However, developing awareness of the existence of alternative materials among the investment process participants, which reduce the amount of construction waste, should be an important step towards the economy that effectively makes use of natural resources.

The promotion of "biotechnology" and "biomaterials" in architectural design is accompanied by the question to what extent in the contemporary technological world we should rely on newly obtained materials and natural resources (even if they are renewable and biodegradable resources) and to what degree we should make use of materials already produced, being in economic circulation and possible to reuse.

Promoting and applying building technologies and materials – biodegradable but possible to recycle – is in accordance with strategies of implementation of sustainable development. It is easier to obtain and maintain equilibrium on a local scale, both in the natural and urbanized environment, since obtaining natural materials, based on the local production, affects the environment less than the mass industrial production. As a result, it generates less waste and facilitates their reuse.

Nonetheless, comparing the abundance of natural resources to the potential of existing and possible to recycle building materials, priority of use should be ascribed to the already existing products, components, and objects incorporated in the structures of various buildings. Naturally, taking into consideration mixed building technologies, the use of the two material groups described above (natural resources and recycled materials) should be deemed rational.

One of the answers to the posed problems is provided by *appropriate technology.* The concept of appropriate technology puts emphasis on the implementation of more sensible approach to technology and establishes the culture of technology taking into consideration social and economic conditions in its choice and distribution. The application of appropriate technologies is connected with a right choice of technology in the production process as well as in the course of the investment realization in a specific time and place. The adequate technologies include *intermediate technologies, soft technologies,* and *low-tech technologies* being a certain counterpoint to *high-tech technologies.* [6]

Many of those new technologies are already in existence. They usually do not require a big scale and decentralization, they are capable of rapid adaptation to local conditions and increasing their self – sufficiency, which finally means their maximum flexibility. They are frequently called "soft", since their impact on the environment is seriously curtailed by using renewable resources and continuous material recirculation. These technologies embody principles governing natural ecological systems reflecting at the same time the systems wisdom. The intermediate or soft technology can be described as safe since it does not carry any risk. It relies on the use of natural, renewable materials and the consumption of tiny amounts of energy.

As far as the extent of the influence is concerned, we can distinguish two types of technologies: one of them is the independent *small – scale technology* and the other has a wider range of influence, frequently on a global scale. The first can be applied in small communities without external support, whereas the other one is based upon a social organization on a large scale. The *appropriate technology*, which includes soft techniques, is rather a technology of a small scale. It is based upon the application of processes and materials suitable for a specific climate, socioeconomic conditions and natural resources of a region and a local community.

What is peculiar about the appropriate technology is that it is characterized by creating favourable conditions supporting efficiency and pursuing social self-sufficiency, which particularly wait for scientific support and the influx of the know-how information. The idea of appropriate technologies is based upon local people struggling with every day problems. The locals understand better than experts from the outside the problems most important to them. Therefore, they may aptly suggest or create technological solutions addressing their problems. The locals may also determine priorities of solutions in order to economically and rationally manage the funds they are in possession of. Designers and experts organizing help to local communities should involve inhabitants of a specific area in the project, in its early phase. As a result, the project has a chance to be realized with consistency by the locals, be better used, and, moreover, its success would be of concern to all during the course of the whole investment.

Decisions made at each stage of the design and the investment realization have a long-term consequences. They determine functioning of a building, both in the physical, three – dimensional space-time continuum and the social space of a local community. Searching for methods of reducing harmful influence of buildings on the surroundings, we can head towards two contradictory directions: the development of highly sophisticated technologies which facilitate controlling the functioning of a building inside and outside, or the application of a simple and entirely natural solution.

The architecture of sustainable development uses every kind of technology that will rationally take up the ecological challenge of the present time. *Low – tech* means designing buildings in a simple manner, using natural resources of the local environment and at the same time respecting the laws of nature. *Light – tech*, in turn, comprises the application of original materials in an economic - or even temperate – manner, and preference for materials one hundred per cent recyclable. The solutions *high – tech* can be applied as integrating elements with the view of creating optimal life and work conditions, with the minimum use of energy and resources. Drawing conclusions from the above considerations, the right solutions should be sought within the appropriate technologies based upon the local communities. Relying on the locally obtained construction materials as well as traditional, but improved, building methods rationalizes resources management, reducing the need of transportation of mass building materials at a long distance and generating waste. The appropriate technology, frequently resulting from the process of *participatory design*, is easy to exploit, because it is understandable and accepted by local communities. Taking advantage of an informal structure of information circulation within a network of local connections, accepted technological solutions should easily develop on a regional scale, shaping the art of building of human settlements in accordance with the natural and cultural environment.

In order to create effectively operating system of resources management, it is essential to rely on mechanisms motivating people to active participation in efforts towards minimizing the generation of waste. Human factor, users' mentality and attitude are also of crucial importance. One of the programmes releasing spontaneous cooperation between people is creating more or less formal connections at the local level.

5 Final Remarks

Much of the waste comprises valuable material for further use and the best is when it is reused at the same level as it has been used. The avoidance of unfavourable, heterogenic composition of waste may lead, for instance, to changing the demolition of building structures in favour of deconstruction and segregation. Ways of hermetization of technological processes should be sought, including processes generating little or no waste. Along with emergence of economic processes, encouraging effective use of the existing resources, and introduced legislative acts, an interest in environment friendly technologies, including technologies cutting down on generating waste in the investment process, will increase among building firms and investors.

The reduction of material absorptiveness in the building industry should be sought in the decentralized production as well as the implementation of novel renewable materials (of natural origin) and non – renewable (however possible to regenerate and reuse).

What is extremely important is to study a product final life cycle, since the manner of its processing and effectiveness of use of its components influence the material absorptiveness coefficient. In each phase of a product's life the amount of energy used should be minimized and its usefulness and functionality maximized. Just carrying out the design phase properly may contribute to a considerable decrease in the material absorptiveness (both at the stage of production of building materials and erecting buildings). Also, it may significantly reduce the material absorptiveness during the structure exploitation and enable a proper maintenance of buildings, an increase in the amount of the material obtained from products recycling (evolution of home's function), and easiness of its further processing or adaptation and modernization.

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