Eco- Ergonomics in Architectural Practice

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ABSTRACT

Nowadays, one of the main consumers of natural resources and the biggest waste producers is the building sector. Only in the European Union it generates more than 30 per cent of waste every year. Reducing a negative impact of the building industry on the natural environment is an inter-disciplinary task which requires that the designer has possessed an extended knowledge of construction, materials, ecology and ergonomics. The optimum architectural solutions designed for achieving a comfort of using as well as an adequate microclimate of the interiors must be achieved with the respect towards the good condition of natural environment in which we are to live. And this is ecoergonomics that helps us meet this challenge and can be regarded as one of the key pillars of 21-century ecological architecture. This paper is to deal with the ecoergonomics applied in design practice whose aim is to reduce the negative impact of the building sector on the amount of waste produced and an excessive exploitation of resources.

Keywords: Eco- Ergonomics, Systainable Development, Material Resources, Material Reuse

HOW THE BUILDING SECTOR AFFECTS THE NATURAL ENVIRONMENT

One of characteristic qualities of contemporary economy is its significant influence on the environment which may result in a global threat. All the phenomena and processes within economic structures are marked by an incessant anthropogenic pressure. This is due to the situation in which natural resources and the natural space are continually transformed to comfort the needs of human existence. According to the statistics, the building sector significantly contributes to making this pressure even harder. The impact of the building industry results from the extended exploitation of resources and a huge amount of waste produced, as well as a vast demand for energy used at all stages of the life cycle of building materials. Due to their high durability, usually inordinate technical parameters, heavy weight and large volume, the building materials and the waste left behind contain a huge potential of the so-called “grey energy” used while they are manufactured, shipped and applied in their original life cycle. The environment is burdened by the construction industry as early as the necessary resources for industrial production are obtained. Another threat appears while ready-to-use products are processed, which is accompanied by more or less advanced technology and in most cases results in a very high consumption of energy, water and other raw materials. Another side effect is observed when the industrial sewage, solid waste and toxic gases are released directly to the environment. While the building venture is being done one can observe negative effects on the surrounding at different stages, such as preparing and clearing the building area, the construction of roads or temporary objects and - at times - storing dangerous materials, etc. In the vicinity of the building site there are other repercussions, such as a higher level of noise and vibrations, distortion of the landscape, affecting the level of

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ground water and many other equally disturbing factors. Yet, the natural environment is mostly affected at the later stage when the building is being used, especially if the object has been adapted to meet the users' needs. The consumption of energy necessary to provide the interiors with the comfort of warmth and a suitable micro-climate throughout the whole phase of being used and inhabited, which may take a very long time, in most climatic zones is significantly larger than the energy consumed while materials are manufactured and the construction erected. The building sector in the European Union countries is responsible for consuming approximately 40 per cent of the whole energy produced (this is the demand for the energy needed while the building is being used) and, consequently, for the emissions of huge quantities of carbon dioxide, which is the gas that in 50 per cent contributes to the effect of global warming (Adamczyk and Dylewski, 2010). What also affects the natural environment is the phase of the building demolition, as well as the way in which the flow of waste is controlled.

MODERN STRATEGIES OF ENGINEERING DESIGN

Sustainable Development

The idea of balanced development was first defined in 1987, in the report entitled: „Our Common Future" worked out by the U.N. World Commission for Development and Natural Environment. According to the report, all people would benefit from the development „… which guarantees meeting the needs of current generations and does not deprive future generations of having their needs fulfilled…" (World Commission on Environment and Development, 1987). In the document there were three main areas selected which affect the balance of the world economy: natural environment, economy itself and the society. The meaning of "balanced development" was also explained by the U.N. Conference for Development and Natural Environment, also called 'the Earth Summit", which took place in Brazilian Rio de Janeiro in 1992. The idea was understood as a rational exploitation of continually shrinking resources and keeping a stable growth of the quality of life for current and future generations. Balanced development is a process to be continued for a long time ahead, which must not disturb the ecological and social balance (United Nations, 1993). What plays an important role in the actions to perform the assumptions of the idea of balanced development is the building sector. In December 2007, the LMI- Lead Market Initiative for Europe qualified the idea of balanced construction as one of the six leading sectors of economy in respect of its tendency to be innovative and develop quickly. To meet the requirements of balanced development the building industry, at all stages of the investment and maintenance process, ought to consume the least energy and resources and have a minimum impact on the environment. Thus, innovative engineering solutions should combine economy benefits with the care of health and comfort for the users, with a reduced impact exerted on the natural surrounding by water and land engineering objects.

Double Decoupling of Resource Use, Economic Growth and Environmental Impacts

Every year within the European Union new legal principles are introduced to reduce the pollution of the environment. Adequate tax solutions, as well as other mechanisms are recommended to limit the waste produced. This should enhance the development of reclaimed materials, which helps to limit the areas where the waste is stored. Huge quantities of rubbish result from a consumerist lifestyle of modern societies, which neglects the logic of natural environmental cycle. Due to ecological education and appropriate legal regulations more and more designers respect the necessity to consider the aspect of the materials' lifetime and, consequently, the possibility to include the flow of those materials in industrial processes. The direct connection between economic growth and waste production, resulting in an intensive exploitation of resources, must be broken. This is the key objective declared in a special instruction issued by the European Parliament and the European Council: 2008/98/WE of 19 November 2008. Keeping stable quantities of waste produced does not longer seem efficient enough to combat the more and more serious problem of environmental degradation. Now, the process must be reversed and solutions recommended to reclaim materials, which will improve the balanced use of resources.

Principle3xR

To prevent the progressive environmental degradation, in the late 20th century a hierarchy of solutions to the problem of waste was introduced, which can be summarized by the simple 3-R principle: reduction, re-consumption,

recycling. The first factor (reduction) reminds of the possibility to reduce the waste produced through a limited consumption of the products that are not necessary. The second one (re-consumption) emphasizes that it is possible to use disposable products again, which could limit the scale of environmental pollution caused by industrial side-effects, as well as by waste accumulation. The last factor (recycling) recommends the solution when neither we can resign from the product nor the waste can be used again- this product should be stored for the possible future use in some production processes. The order of the factors mentioned is not accidental. The most beneficial situation happens when excessive consumption has been limited. Of the second importance is the situation when the product is used many times before - as late as possible – it is recognized as waste. Eventually, it is the sensible processing that helps limit the environmental impact while the product is being obtained from original resources and the waste is accumulated. The effectiveness of the strategy described depends mostly on the waste paradigm. A change of the attitude is necessary to start considering waste as valuable raw material which can be used again.

ECO- ERGONOMICS IN ARCHITECTURE

Eco-ergonomic attitude to architectural design ought to involve the rational technological solutions applied, which are compatible with the idea of balanced development. Some academic papers describe this rational attitude as the „3xE" model. Thus, it seems necessary for the investments planned and executed to combine the aspects of ergonomics, ecology and economy. In publications issued by the Polish Ergonomics Society (Skowronski, 2011) it is often emphasized that ecoergonomic architecture is not to be spectacular and does not have to break the records when it comes to the height of objects, the area of glazing in curtain walls or the effectiveness of unique high-tech facade systems applied. Following the idea of balanced development, ecoergonomic architecture tends to be rather low-tech and meeting the need to conform with the current utility requirements, as well as traditional forms of vernacular constructing adapted to the given climatic and cultural conditions of the region. The simplicity and rationality of the design solutions applied is obviously accompanied by the introducing of modern, energy-effective and resource-saving technological solutions, such as: solar collectors, rain water storing systems, etc. Modern buildings should be energy–effective, ecological and planned according to the rules of ergonomic design so that they would guarantee a healthy environment and comfortable surrounding for their users. Thus, the natural environment is not burdened at any stage of the building's life cycle. Consequently, ecoergomics contributes to architectural design through a rational and optimal use of available ecological technological solutions and systems which would guarantee the comfort of using and an appropriate microclimate of the building interiors, while the well-being of natural environment is respected (Wines, 2000). Within a range of available architectural solutions one should mention:

A Smaller Scale of the Buildings Designed

The intentionally limited cubic capacity and utility area of buildings can be regarded as an attractive alternative, specially appreciated in respect of ecology and utility against the excessively large, multi-level buildings which, throughout all the stages of their lifetime, significantly contribute to environmental degradation. The idea of small-scale buildings assumes the limiting of the building height to five levels above the ground, as well as the replacing of an uncontrolled sub-urbanization by compact multi-functional urban structures.

Careful Selection of Building Materials Preceded by an Exact Analysis of Their Life Cycle

The assessment of the life cycle is a scientific method which helps to estimate the energy consumed by a given product throughout the whole existence along with its environmental impact. This must be an analysis worked out for all stages of existence, „from a cradle to a grave", from the moment when the necessary resources are obtained, through the process of production, transportation, industrial exploitation - up to the product utility phase.

Preference for Local Wood Species to Be Used in Construction

Every year around the world the area larger than 9 million hectares of forests is cleared (National Geographic, 2001) in order to obtain a new space for farming and meet the industrial demand for wood, which becomes more and more rare. The progressive degradation could be controlled significantly if only the amount of exotic species of wood

used for construction and furniture manufacturing was reduced to minimum. This indirectly would result in a smaller import of wood, which might give way to the using of the local wood grown for that purpose as renewable property.

Systems for Rain Water Regaining and Storing

Rain water, as well as grey water, could help satisfy the demand for the so-called low-quality water without having to employ costly fitting systems. Yet, to make the using of waste water possible costly investments are necessary as special installations for collecting, retaining and utilization must be built. What may enhance this technology, however, is an encouraging economic analysis which usually determines the size of the enterprise planned as well.

Minimum Energy Consumption and Renewable Energy Sources

The forecasts made at the beginning of 2007 say that alternative sources of energy combined with high standards of energy effectiveness may satisfy a half of the world demand for energy as early as in the 50's of 21st century. This, however, involves the necessity to introduce modern technologies in many industrial branches, including the building sector. Nowadays, as the most popular solutions for obtaining energy from renewable sources and using it in low-energy buildings and passive homes, one can mention: solar collectors, heat pumps, recuperators or ground heat exchangers. Equally important is a thermal insulation of outer walls and an adequately chosen technology of construction which would include all aspects resulting from the location planned

Suitable Location of the Building in the Surrounding Area

When the building designed is properly oriented towards geographical directions and its glazed parts, such as windows and winter gardens, properly exposed to the sun rays, the energy consumption may be even lower. In the so-called 'passive homes' the heat return may reach 30 per cent. The optimal location of the building should also be based on the analysis of the wind rose. When the building is exposed to strong winds, the heat loss may reach 10 per cent.

Public Transport Accessible

If public transport is accessible to many people, the traffic in big urban agglomerations can be vastly reduced. This will bring more benefits, such as cleaner air, a lower level of arduous noise and reduction of CO2 emissions to the atmosphere.

A Significant Reduction of Chemical Substances That Harm the Ozone Layer

The ozone later in the atmosphere protects living organisms from a harmful activity of ultraviolet radiation. To prevent this, it is necessary to limit – as much as possible - the use of chemicals and other substances that may harm the ozone layer in the stratosphere. The prevention can be enhanced by a careful selection of building materials and the use of alternative energy sources.

Protection of Green Areas and the Existing Green Plants Growing

In urban design, the protection of green plants growing is connected with those ventures vastly limited which may result in the decreasing of endangered green areas. To prevent this, the phenomenon of suburbanization should be vastly limited giving way to more compact urban structures. Moreover, contemporary design guidelines emphasize that new green areas need to be created within the urban tissue. Green places in big agglomerations are very important for recreational activities, as well as for ecology and health protection.

Re- Consumption of Materials

Re-consumption or the re-use of materials has a very extended meaning comprising such elements, as: secondary use of the materials which have not been processed, utilization of the existing building structures, revitalization of urban areas, proper selection of materials, mobile functions of building objects, modern strategies applied for

demolition and engineering design. Recycling is an advanced form of re-consumption but, additionally, it closes the loop of the materials' natural cycle. It involves the beginning of a new cycle of life (re-cycle) when the processing of the original material has been accomplished. The technological process itself exerts some pressure on the natural environment, but it is much smaller than in case of a linear materials' flow.

EXEMPLARY ECOERGONOMIC METHODS OF BUILDING ACCORDING TO THE OBLIGATORY POLISH LEGAL PRINCIPLES

Buildings Situated Below the Ground Level

In the world, there are many examples of ecoergonomic architecture, which is sometimes dubbed as ergo-ecological one, which include a lot of advanced design solutions. Their innovative aspect, though in many cases rooted or referring to the building tradition of the past generations, often causes formal and legal problems while the pioneer realizations are being executed in a given region or country. A situation like this can be observed when it comes to an eco-ergonomic method applied for building homes that are dipped into the ground. It may seem that the construction of a simple “dug-out” as a living place is an easy task. Beyond doubt is the fact that in technological respect the construction process itself is not very difficult (unless the object is to be erected in the site where the level of ground water is high but, obviously, in this case the solution is not recommended at all). Yet, the procedure to make this object legal is not so easy, as compared to traditional investment process.

In Poland the rules for erecting objects according to the the art of building were defined in an ordinance issued by the Minister of Infrastructure, concerning technical conditions for buildings and their location. As far as an underground building is concerned, one should pay special attention to the paragraph 3, point 20 and 21, as well as paragraph 73, item 1 and 2 of the ordinance that state: “… Whenever the ordinance mentions *the basement or underground room* , it should be understood as the level of building or a part of that level including rooms in which the floor level, partly or wholly, is situated below the level of the site to be managed but at least from one side where there is a window wall, the floor level must not exceed 0.9 m below the level of the adjacent site (…) *The basement* is also understood as an underground level or the lowest part of it where the floor level on at least one side is situated below the adjacent site level (…) In a dwelling room, the floor level at the window and door walls should not be lower than the ground level of the adjacent site (…) In the rooms for people within the buildings housing welfare or health centers, educational institutions, etc. the floor level should be at least 0.3 m higher than the level of adjacent site ...” (Minister of Infrstructure, 2002). The rules presented clearly show that to make a dug-out legal it is necessary to apply for an exceptional procedure omitting the obligatory legal principles. Thus, the investment process will have to be extended as some extra expertise must be done by building specialists on safety and sanitary conditions (BHP and Sanepid) and attached to a properly prepared application (Skowronski 2011). According to Article 9 of the legal act “The Building Law”, a situation must be considered when the local administration organ refuses to give a permission even if the minister accepted the exception. This will make the design process impossible or lasting very long as new alternative design solutions must be found.

The Use of Reclaimed Materials

While the building projects implementing the idea of reclaimed materials are realized, an extended investment process seems inevitable. It involves the re-considering of the architectural adaptation, different conditions of utility, as well as a new attitude to the future alterations or renovations. A technical documentation assuming the secondary use of an existing building usually requires a professional technical expertise developed by a person possessing a building license which is not limited to any narrow specialty. If necessary, the expertise may be completed by appropriate laboratory studies in order to confirm the utility properties of originally used, in-built components of the building. Those procedures, although they may prolong the realization and complicate the programming phase, are among the design solutions commonly applied.

From a legal point of view, the situation becomes even more complicated when a designer, with the advice of the investor, makes the decision to build a new architectural object with the use of reclaimed materials. For Polish

building market this is not standard practice as such solutions have not been introduced before. The biggest formal obstacle concerning the reclaimed materials built in a new object results from the fact that in the moment of the original object demolition the building product is not valid anymore having lost a legal permit to be used in construction. The question arises if - according to the Polish law - it is possible to carry out a transparent legal procedure as to know how reclaimed material can be re-used.

To answer this question one should first of all examine the legal regulations on building materials, defined in the document ”The Building Law” (Prawo Budowlane, 1994), which states: art. 10- “...the products manufactured to be permanently used in construction, of defined utility properties that ensure the fulfilling basic requirements by an appropriately designed and realized object (…) may only be used for construction on the condition that they have been introduced in the market on the grounds of separate specific regulations...” (according to the Ministry of Infrastructure the phrase *permanently* means that the dismantled product is the effect of building works and results in a lower utility properties of the object in which the product was inbuilt, assembled, installed or applied); art. 20– a basic duty of a designer is to work out and agree on an individual technical documentation mentioned in article 10, paragraph 1 of a legal act of 16 April, 2004 concerning the building products; art. 25– it is the investment supervisor's duty to prevent the use of faulty building products and those which are not licensed to be used in construction; art. 57– along with the notification confirming that the construction has been finished and the application for the permit to the object, the investor is obliged to deliver a certificate given by the manager of the building works confirming that the object has been accomplished according to the law; art. 81– the organs of the architectural and building administration, along with the building works supervision (i.e. the building supervisor for the given district) are to watch and control the materials to be used; art. 81c– the organs mentioned above may require that the participants of the building process give full information or present documents confirming that the building product is licensed or has obtained an individual permit to be used in construction; art. 93- those who, in the whole process of construction, do not respect the regulations of Article 10 are liable to a fine. The regulations presented clearly show that - according to the legal act „The Building Law” - in the process of construction only these products are permitted to be used which have been legally introduced to the market for a common use on the grounds of separate specific rules.The responsibility for that is taken by the chosen participants of the investment process whereas the right to control is vested in the proper organs of architectural and building administration, as well as building supervision. What is a 'building product' according to the legislator? Article 2, point 1 of a legal act of 16 April, 2004 „on building products” states that „a building product is a movable object, regardless of how much it has been processed, which is designed for trade and manufactured for being permanently used in a building object, introduced to the market as an individual item or set of items to be combined in construction and making an integral technical and usable unit to help fulfill the basic requirements. According to art. 5, points: 1, 2 and 3 of this legal act, a building product is suitable for being used in building works (is allowed in the market) if it meets at least one of the following requirements: is marked with CE symbol, which is equal to the assessment of its accordance with the unified standard, European technical approval or an individual technical specification of the member state recognized by the European Commission as concordant with the basic requirements; is included in the European Commission list of products which do not strongly influence health and safety and have a special declaration of accordance issued by the manufacturer (it is still a dead rule as the European Commission has not yet issued such a list);is marked with a building sign whose pattern has been described in Attachment 1 to the legal act „on building products”; has been legally introduced to the market in another EU member state which is not submitted to unified standards or guidelines defining European technical approvals set by the European Organization for Technical Approvals only if its utility properties make it possible to fulfill the basic requirements for building objects. The commonly used legal regulations enable the manufacturer who introduces his products to the market within the borders of the Polish Republic to choose one of those methods to obtain a permit for use.

The procedures presented, however, mainly refer to the methods used by the manufacturers or distributors who want to introduce their newly made building materials to the market. Then the only thing that the participants of the investment process must care about is to check if the components used are approved by a special document or trade mark. The legal regulations do not clearly describe how a reclaimed building material should be brought back to trade. Obviously, no investor will decide to implement the re-consumption idea if this entails the necessity to obtain the CE symbol, any other trade mark or declaration of accordance for individual batch of reclaimed materials. To make things clear a telephone consultation with the General Office of Building Supervision was arranged. Their opinion defined the procedures like those as: non-standard ones and yet not practised in the area of the Polish Republic (only few attempts to use reclaimed materials were mentioned and those referred to the works around the objects themselves); possible to be performed on the grounds of the legal act "on building products" of 16 April, 2004, as well as the ordinance of the European Parliament and European Council, No 305/ 2011 of 9 March, 2011.

At present, the valid law in Poland, on the grounds of Article 5 of the ordinance mentioned above, admits the possibility to use reclaimed materials in construction. Yet, the investment process must be extended as it is necessary to assess the accordance of a given component (or set of components) with the unified technical specification published in unified standards, technical approvals or technical assessments. Thus, if the product comes within a unified technical specification, it is advisable at the stage of the design documentation to apply to the appropriate institution, such as the Technical Assessment Unit, for having the product tested in respect of assessment of the material qualities, and those should be confirmed in a special report. The standard requirements which should be met by building products do not seem discriminatory towards the design solutions which are based on reclaimed materials. Such requirements refer to the projects based on both new and secondary materials. The cost of the test like this depends on the amount of samples tested, as well as the kind of material and the qualities examined. As for demolition brick, for instance, examined in respect of pressing durability, with 10 samples taken from the demolition material, the Institute of Building Technology with (a notified Technical Assessment Unit JOT No 1488 (Instytut Techniki Budowlanej, 2014)) estimated the net price of such service at approximately 2500 PLN (estimation done by telephone on February, 10, 2014). Thus, it seems beneficial to examine enough components selected while a large building project is to be realized as substantial savings and a much lower consumption of energy and resources may be achieved in the future if reclaimed material have been used.

On the other hand, if the product does not come within a unified European standard, technical approval or assessment, it can be introduced only once (for one project) on the grounds of Article 10 of the legal act “on building products” and Article 20 of the act “The Building Law”. The presently valid obligatory principles state that only those building products are admitted to be used in construction which have been manufactured according to individual technical documentation developed by the designer of the object or consulted with him, for which the manufacturer declared the accordance of the product with the documentation and legal principles (in this very case the manufacturer stands for the building contractor). The individual documentation mentioned ought to comprise a detailed description of the technical solution, with materials' characteristic and the information about the utility qualities for the given project, as well as the conditions defining how the product is used in the object and how it is maintained. While the technical documentation is being prepared, it is sound practice to seek the advice of specialist's laboratories. Manufacturer's declaration should include: the name and address of the subject declaring, the name of the building product and place of manufacturing, the identification of technical documentation, declaring the accordance of the product with the technical documentation and legal principles, the address of the building site, date of the declaration issued and the signature of the person who issues the declaration. It should be emphasized once again that the procedure discussed applies only to non-standard products.

Thus, according to the law the reclaimed building material is allowed to be introduced to trade for individual investments. One should remember, however, that due to the innovative character of the solutions and not enough experience of the architectural institutions and building supervisors that are to deal with such investments the realization of such investment may be somehow hampered. Particularly, the local and provincial offices (e.g. the district building supervisor, the province building supervisor) do not yet have enough knowledge concerning the procedures to legalize the re-use of reclaimed materials. Also, it should be emphasized that the Building Materials Construction Unit within the Institute of Building Technology suggests continuing the studies to examine reclaimed and supports this suggestion with an example when a designer's application was approved by the dicstrict building supervisor. On the other hand, the Central Supervision Office regards the procedure as not necessary and not obligatory according to the law. To introduce new solutions in building industry one should smooth the way through administration procedures. It is advisable, before a pilot investment is begun, to apply to the General Office of Building Supervision for an official interpretation of the legal principles, which will help to plan a perfect course of the investment in respect of secondary materials approval. The General Office of Building Supervision is a source of information on building products, obliged to deal with the case within 15 working days. If this is done at the beginning of the investment, many superfluous confusions and delays during the preparation of technical documentation for the given building can be avoided.

The least troublesome while carrying out works including the re-consumption idea is the use of components obtained through the waste recycling. These are mostly new products admitted to trade and general use in the same way as fairly new materials.

CONCLUSIONS

For many decades the world markets have been characterized by the growth of wealth and well-being based on an intensive exploitation of resources. Nowadays, the situation has become much more complicated. Since the economic crisis began in 2008, many industrial sectors have been on the verge of extinction. To cope with a high unemployment the governments have to actively stimulate the growth of the world economy. Fortunately, the stock markets reveal some symptoms of improvement. This time, however, remembering the past experience of industrial revolution, all measures should be taken to ensure that the quality of this growth will sustain a balanced future. The latest development strategies assume a balanced economic growth based on an effective use of resources without any harmful pressure on the environment in the individual stages of the products' life cycle. It is also emphasized that the connections between the economic growth, quantities of resources excavated and the amount of waste left behind must be broken.

The building sector is still one of the industrial branches which affect the natural environment in a very intensive way. Thus, one of the major challenges that 21-century ergonomics and architectural design must face will be the introducing of rational decisions aimed at the improving of human existence while the natural environment well-being is still preserved.

Eco-ergonomics has turned full circle coming back to its origins, i.e. traditional building methods. Such strategies are often supported by modern technologies which enable the introducing of such solutions as: green energy generators, rain water storing systems, independent installations for waste purification. All this will make it possible to build autonomous homes which - regardless of energy supply from the outside– tend to be cheap in construction and maintenance and do not emit pollution to the environment. Ecological solutions for construction and materials may sometimes be hampered by unfavorable formal and legal procedures, especially when a pioneer venture is done in a given place. Nonetheless, it is beyond doubt that the membership of Poland in the European Union has made it possible to implement locally the latest architectural solutions created according to the idea of balanced development.

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