Relation between Energy and Durability in the Context of Sustainability

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ABSTRACT: Modern society has been greatly dependent on energy use. Majority of all our energy is still coming from the non-renewable sources and being used mainly in buildings. Understanding the impact that our actions can have both on increased usage and what is more important preservation we have to analyse the structure of energy and understand boundaries that certain levels are imposing. In buildings (as first elements of urbanity but also on other levels) we can distinguish: primary (construction), secondary (energy of maintenance), energy of usage and induced energy. Apart from energy one of the main aspects of our interventions in surroundings is question of durability. What is the time frame of our actions? Can we meet the needs of tomorrow with our today’s structures? In order to understand this matter we have to realize that durability has its physical but also “moral” aspects. From the physical point of view we can structure the buildings on different levels: primary structure, secondary structure – subsystems, envelope. Each of these has its own aspects which can be further analysed and evaluated. On the other hand moral durability has more complex meaning and it include broader cultural and historical value which can not be analysed on the same level or with the same instruments.

Trying to find correlation between these elements we are coming to the dynamic cyclical principle of life cycle in which each aspect of durability has its own energy influence and characteristic and vice versa. In order to achieve our goal and that is to minimize the energy total of the building we must analyse the building as the complex system trying to establish right mechanisms of intervention. Principle of life cycle can give us dynamic tool specialized for the certain level of the building estimating its influence on the whole structure and what is more important its constrains helping us making right decision.

Energy optimisation must be a result of such a process not a starting point. Inventory of influences and possible results is necessary because process of reconstruction does not have always to be the right one. If a determination of a certain element is final, new construction can be a sustainable approach.

Our society has a variety of structures originating from the different socio-political periods, constructed mainly under the postulates which were not energy conscious. Large building fund represents a great potential for improvement and idea of this paper is to look for the relations which will help formulate some of the guidelines for locally applicable algorithms based on the principles of energy optimisation.

Conference Topic: 10 Reflections on sustainability
Keywords: energy, durability, LCA

INTRODUCTION

Development of modern society based on consumer economy has led towards intensive use of material goods and especially energy, followed by depletion of natural resources and degradation of environment. Process of urbanization, which on a global scale still represents the major principle of human settlement development, is even intensifying this trend bringing contemporary society to the point where certain actions are to be made, because irreversibility of processes are bringing us to the ecological collapse.

Built environment as a base for majority of human activities is directly and even more indirectly influencing total energy and material flow and in context of total balance needs special attention. On the other hand dynamic of life and production cycles is posing ever rising demands for the built structures resulting in process of their abandonment or destruction as a consequence of inability or economic adaptation, and construction of new, for the certain period of time, adequate structures. Starting from the premise that any construction process is energy irrational, question of durability is becoming one of the bases in theory of built environment management.

The aim of this work is to define characteristics of built environment which analysed from the energy conscious aspects based on the theory of sustainable development can help us formulate more adequate
inventory of existing built heritage and define guidelines for newly planned one.

2. RELATION BETWEEN ENERGY AND DURABILITY

Meaning of energy for the mankind can be traced all the way to the first human settlements and mythological representations of "gods of fire" which were in correlation to the development of society symbols and "providers" of existence. Development was, in a way, directly connected with overpowering and controlling of various means of energy so it is no wonder that the level of development of certain society was measured through index of energy use\(^1\).

Structure of energy use is mostly influenced by the way that the human settlements are organized in relation to the climatic and natural rhythms. By simple analysis of human population and its spatial distribution, we can see that in 20\(^{th}\) century urbanization has been the leading principle regarding the level of development. Even more, largest urban structures are located in less developed countries where possibilities for control or energy management are very limited or non-existing. Significance of understanding and management of energy flows is very important if we know that almost 50\% of energy is used in "operation" of buildings and further more 25\% indirectly mainly through transport and supplying\(^1\). Great majority of this energy is still being produced from the fossil, meaning non-renewable sources, through the processes that are all destructive for the environment.

Energy in context of needs of contemporary society and complex meaning of built heritage can not be defined in a single way. It has to be separated from the market meaning of product, guided by the principles of trade, directed by various interests and set as welfare for the humankind.

For the purpose of adequate analysis and understanding of energy in buildings (similar structure can be followed in all urban levels) it can be defined as\(^2\):

- Primary energy (energy of production). This is energy that is "contained" in the building taking into account all elements that are defining it. Primary energy is both energy needed for the construction of the building and production of its sub-elements.
- Energy of usage or energy needed for the reaching and maintaining desired level of comfort.
- Secondary energy or energy needed for the maintenance, changing the structure (internal or external), destruction, disposal and recycling of materials.
- Induced energy or energy that is not used directly in object but is being induced indirectly through transport and supplying.

Apart from energy, question of durability (life-span) or time component of human creations is also becoming one of the main positions for the understanding the processes in contemporary society. Durability as characteristics of built heritage in a world where rhythms of changes are happening in time frame that is always shortening is not easy to define. We can formulate two major aspects of durability as\(^3\):

- Physical and
- Moral durability

Distinguishing these two aspects is not being formulated as a result of technical or technological needs but more as an answer to the demands that are being imposed towards materials and systems by technology and standards form one and society needs form other side.

By Physical durability, we are usually considering long lasting of materials, or their fulfilment of certain characteristics in designated time frame. Focus of this paper are not materials in their physical sense but more as a components of building, parts of much more complex subsystems with autonomous characteristics of durability. For this purpose physical – chemical data and degrading processes that are appearing in the exploitation of building are being subordinated to the more complex one where we can distinguish following levels:

- Primary structure, structural system and basic elements that are defining stability as a precondition for functioning of building.
- Subsystems: Secondary structure – partitions, technical subsystems (thermal, electro, water, central heating, other installations), and coverings. Their significance is usually being through the cycles of technical maintenance providing safe and "healthy" environment for the users.
- Envelope: Envelope is defined as a separate element mainly because of the influences that are defining it. Apart from its functional aspects it also carry great significance in symbolical appearance of the building and, which is for this purpose, even more important is a part of the structure where energy characteristics are most dominant both in positive and negative terms.

By formulating building through this levels we can analyse it through analysing its sub-elements defining specific parameters for each of them and valorising more easily their performance. Assumption is that by structuring the building this way we can divide the rhythms of influences towards the certain elements. In this way we can try to set different standards from the point of sustainability forcing the energy characteristics as a major aspect of valorisation.

What are the time intervals that we are defining for the certain levels? Answer to this question is not very easy to formulate, mainly because of the fact that the desired time frame is constantly changing and that it is very hard to say today what will be the designed life span of the object. Theories that were used so far have mainly been in accordance to the amortization principle based on existing technology and projected life span of the building. Following this we can say for example that the residential structures were designed for the 80\(^{th}\) years, which can be significant benefit but at the same time a great limitation for the future treatment. Question of energy in this matter is defining durability at the different scale, it is not forcing physical durability nor on the other side short-term structures. It asks for the analysis of designing process taking into account sub-
levels of the building as we have defined them. Designing the new structures gains in complexity, asks for the more flexible and open solutions at all levels. This way we leave the process of choosing the elements more open avoiding the fashionable trends of applying certain material or technical solutions.

Consciousness about build structure meaning its significance in wider social context is leading us towards the other aspect of durability: moral durability.

If we understand Physical durability as a group of characteristics of certain spatial elements that have to fulfil designated standards, moral durability is more connected to the meaning of the building as a whole in its surroundings. Here we should distinguish two levels of significance – system’s functions in relation to constant changes of contemporary life and it’s symbolic meanings. The first ones are result of changes in functional and technical demands whereas their symbolic meaning is related to cultural and historical context and is subject to other set of criteria and therefore their energy evaluation can not be the same.

Aspects of changes in parameters relevant for building analysis accelerate in time as technology evolves. As a consequence of intensifying rhythm of contemporary society, often the conditions that determine certain characteristics change faster than the possibilities of adequate response through necessary normative regulations and building activities that follow. In this context, altered perception of dwellings is imposed. They remain sorted by their primary use and technical and technological characteristics, but at the same time emerges need for setting new premises that would enable usability corresponding to dynamic demands. In this context, flexibility becomes dominant in contemporary building concept. Repercussions on wider scale, more directly related to urban planning, implicating structuring and (re)defining more complex urban entities, stretch beyond the outlines of this paper, but they should be thoroughly analysed and processed. Flexibility is not related exclusively to volumetric characteristics implying structure, but also to the other physical elements of a building, understood in a way that was previously described. Naturally, we can not assume that the flexibility should be imposed as a primary motive; functional characteristics still remain dominant in the design process, but awareness of possible changes should become an element of general building process. The term “flexibility” carries a notion of deeper sense that overcomes the simple definition of adaptability. The possibility of efficient replacing of certain element, with minimal energy input and maximal gain in quality and/or usability, with its proper disposal or recycling becomes one of the important aspects that determine valorisation of a structure and building’s subsystems.

Symbolic meaning of a building is related to wider social context, its place in spatial perception, and is subject to different levels of protection. Changes in defining input factors and keeping the existing physical structure result in conflict between energy and function that can be resolved in various ways. Levels of intervention depend on the level of strictness in demands of protection and preservation of all the building’s elements, implying its adaptability. Buildings that carry primarily cultural and historical quality are treated in a different way and their energy aspect, as well as other “regular” parameters are of minor importance, and general social interest has the highest priority. However, if this is not the case, it is necessary to undertake thorough analysis and choose the most adequate intervention. These interventions can stretch from minor modifications on certain subsystems to complex reconstructions where

Diagram 1: Correlation between Durability and Energy in a Building
only the direct carriers of socio-cultural symbols are kept unchanged. Historical authenticity might be compromised by such approach, but so-called "badge architecture" has found its place in contemporary, mass-production esthetical ethics. Traditional postulates of theory of protection and revitalisation of built heritage here are not respected in all points, but it is necessary to understand that the inevitable development of cities and large number of existing buildings often ask for a different approach.

Summarizing the relations between energy and durability, we can determine certain correlations that are shown on the Diagram 1.

Diagram of correlations between the energy and durability is organised as a cycle where the building's life cycle is placed in a centre, as a dominant principle. Cyclic flow presents non-linear and in a way reversible correlation where input factors have simultaneous consequences on different spatial and energy levels, in cause-and-effect system of connections. The balance between certain aspects of durability and energy characteristics shows the determination of characteristics and possible directions of acting in basic elements of a building and its basic energy structure.

3. PRINCIPLE OF ENERGY OPTIMIZATION

Energy optimisation comprises set of premises by which it is necessary, in context of theory of sustainable development and from aspects of durability, to minimize energy values of a certain building in the most appropriate manner. The origins of such approach can not be found in traditional practice where optimisation implies primarily technical and design solutions that result in reduced energy consumption, since such solutions should be the ending point and not the starting point of the optimisation process.

As previously stated, the concept of more complex analysis of energy characteristics demands a different approach. In order to clarify presentation of the idea of optimisation, it is necessary to explain the basic principles of correlations between durability and energy through principles of building's life cycle.

Theory of life cycle is based on the premises that each product (object) throughout its life span undergoes thru several phases that have determined, precisely defined characteristics. As basic stages we can identify: the phase of generation (production), the phase of consumption and the phase of disposal (recycling). Each of these phases is defined by different production and technological processes that have direct or indirect impact on the environment. The life cycle assessment is actually a tool for estimating potential environmental implications. To enable such assessments, the process is divided into the following phases:

- The inventory of possible inputs and outputs for a certain system
- The assessment of potential influences as a result of the inventory
- Interpretation of results – valorisation of influences

Detailed explications related to theory of life cycle assessment is not subject of this paper, but shown method points to new set of premises that changes the traditional way of thinking about durability in architecture and its reflections on environmental influences. Durability (permanence) is becoming more dynamic than static value, it being connected to certain spatial-physical level with its own influences that can be analysed and validated. It creates, as one of the basic parameters, way of creates set of decisions on manner, extent, and probably the most important, the possible modalities of intervention.

What is the position of this theory in context of relations between durability and energy and in the optimisation processes? Optimisation, as a method, has no firm starting point, but only the outcome that is usually quantified through indicators of energy characteristics. Fragmentation of total energy balance of a building and by analysis shown through spatial/physical levels, puts us into position to simplify the processes of intervention and thereby the assessments of influences and directions of intervening. LCA analysis where the correlation durability vs. energy is placed as a primary parameter brings us important information on relation to total balance of a building. This approach is important because it does not produce interventions based on the set of general rules taken for granted, but it rather assumes more detailed analysis that goes beyond short-term reductions in energy consumption. In other words, the importance of certain element is validated through overall building's performance through certain time frame and possible interventions are explored. The fragmentation of physical structure is, up to certain extent, determined by possibilities of these interventions, but it is also analogue to logical building phases and processes. Insisting on valorisation of an influence is important in decision making process since sanitation is not necessarily the best response to the questions of optimisation. In case of final determination of an element – overdemanding in energy aspects and inadequate in context of durability, removing such structure and building of a new one, designed according to the above stated principles, might be the most suitable solution. Naturally, not all the elements are of equal technical and technological importance, but this characteristic does not have to correspond to its energy performance, so that what might seem durable and efficient based on certain experience, in fact might prove to be basic disadvantage of a building.

4. CONCLUSION

The method of energy optimisation is not related to the field of refurbishment and reconstruction exclusively (although it is applied mainly in this domain), but can also be successfully used during the conception of new structures. Basic presumptions remain unchanged, but the questions of proper estimations of future actions and predictions of probability of new demands remain open. In this case, the term "durability" appears in a different context of rhythms of contemporary life style and its real needs.
How much does contemporary man depend on permanent structures? It can be assumed that the new industrial, or, to be more precise, information revolution, does not end on the field of “hardware” – production of various technologies, but will also reflect on other aspects that comprise the contemporary life, many of which already noticeable, but most of them yet to be disclosed. The sense of durability might become subject of different interpretations in the future, but, undoubtedly, its relation towards energy and environmental issues is to be fundamental for treatment of built heritage and (re)structuring of future architectural practice.

REFERENCES

1 Construction of buildings consists of number of activities that directly or indirectly influence the environment. By building, we are assuming formulating the entity (building) using materials, products or systems that also are results of manufacturing i.e. energy use. Final product of this process is structure that has negative energy balance in correlation to its surroundings meaning it requires further energy use for the operation. From this point all phases of construction can be considered as energy intensive or non sustainable.


5 Mirjana Mihajlovic Ristivojevic: “A View on Durability and Life Time of Architectural and Urban Structures”, “Architecture and Urbanism at the turn of the III Millennium”, conference proceedings

6 In post II World War Yugoslavia, “Directed housing strategy” (state planned housing development), has calculated that the structures that are being constructed by Socialist society should last for the period of 80 years.

7 The expression “badge architecture” is used to describe architecture that is not “true” in its appearance, but is reduced to compilation of various elements that seem acceptable at the moment. Its purpose is to give “sure”, acceptable answer to current trends, with no deeper philosophical or esthetical origins

8 It is often in practice that the building is treated in an inadequate way, when primary goal is set of “repairs” that is not followed by more detailed analysis and more complex approach. In other words, interventions such as changes in glazing, openings, or improving thermal insulation result in significant reductions in energy consumption, but if they are not result of overall improvement of a building but remain merely “cosmetic” treatment, in context of dynamism of changes in lifestyle and especially its energy characteristics they are only temporary improvements with questionable justification.

9 Based on ISO 14000 standards:

ISO14041:1998 Environmental management – Life cycle assessment – Goal and scope definition and inventory analysis