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CONCRETE – THE DESIGN OF PUBLIC SPACES IN TERMS OF MATERIAL AND TECHNOLOGY ENERGY EFFICIENCY

BETON – PROJEKTOWANIE PRZESTRZENI PUBLICZNYCH W ASPEKCIE ENERGOOSZCZĘDNOŚCI ZASTOSOWANEGO MATERIAŁU I TECHNOLOGII

A b s t r a c t

Based on executions of contemporary designs in the field of landscape architecture, an attempt has been made in the following article to identify the properties of concrete which can help reduce energy consumption throughout the life cycle of a building and its immediate surroundings. The projects selected for the analysis included such urban public spaces as parks, squares, plazas and passageways, where the basic material, determining their aesthetic appeal, is concrete. To provide the widest possible range of issues discussed, construction works located in different climatic zones have been chosen. The properties of the material described in the text have been compiled with the exemplary executions of designs, depicting a creative approach to issues related not only to functionality and aesthetics but also to energy efficiency of the applied solutions.

Keywords: landscape architecture, prefabrication, concrete, sustainable construction

S t r e s z c z e n i e

Bazując na współczesnych realizacjach z dziedziny architektury krajobrazu, w artykule podjęta zostaje próba wskazania tych właściwości betonu, które mogą przyczynić się do ograniczenia zużycia energii w całym cyklu życia samej budowli oraz jej najbliższego otoczenia. Do analizy wybrane zostały projekty miejskich przestrzeni publicznych takich jak parki, skwery, place czy ciągi komunikacyjne, w przypadku których podstawowym tworzywem decydującym o wyrazie estetycznym jest beton. Aby przedstawić możliwie szerokie spektrum omawianych zagadnień, posłużono się obiektami zlokalizowanymi w różnych strefach klimatycznych. Opisane w tekście właściwości materiału zostały zestawione z przykładowymi realizacjami obrazującymi twórcze podejście projektantów do zagadnień związanych nie tylko z funkcją czy estetyką, ale również energooszczędnością wybranych rozwiązań.

Słowa kluczowe: architektura krajobrazu, prefabrykacja, beton, budownictwo zrównoważone

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1. Introduction

Until the twentieth century, concrete had been used mainly as a construction material. Its aesthetic qualities became recognized relatively late, among other things, owing to Frank Lloyd Wright (textile block houses – 1923) and Le Corbusier (e.g. Marseille Housing Unit – 1947–1952). In recent years, it has been promoted intensively as an environmentally friendly material to comply with a popular strategy for sustainable development[1].

The term "sustainable construction" refers to all industries related to construction and is associated with continuous efforts to maximize energy efficiency, reduce CO_2 emissions, reduce the amount of waste, reuse it, recycle material from demolition sites, etc.

Over the past few years, concrete has earned a reputation as one of the most environmentally friendly building materials. It is difficult to say whether this phenomenon is a result of very efficient marketing efforts or rather intensely developed new technologies that continue to expand the range of its application.

There is no doubt, however, that concrete possesses a number of properties[2], which, used knowingly, can help maintain the eco-efficiency indicators[3] at the level required by the standards of modern construction.

Today, the producers of building materials compete with each other in search for new concrete mixtures increasing the attractiveness of this material at all levels. They are successful in terms of its useful life, product aesthetics and structural strength. Contemporary methods of shaping the forms and textures of the surface caused that concrete has also become a very popular material also among landscape architects.

In spite of numerous advantages[4], small elements in the form of prefabricated blocks, do not necessarily have to be the only common solution. Increasingly more attractive but also more efficient, environmental and human friendly resources aimed at shaping and developing open spaces are being looked for.

2. Useful life of the material

On October 12th, 2010 a public debate "Concrete and sustainable construction" was held in Wisla. **Stefan Kuryłowicz**, an architect present there, said: "In my opinion, there is no such thing as sustainable development and zero harm. We are the aggressor each time and the only thing we can do is to be relatively little less harmful. (…) It is possible to re-use of

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[1] The opening sentence of "Our Common Future" report developed by the WCED (Word Commission on Environment and Development) is a summary of the idea: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [11].

[2] The main advantages include: longevity of the material, the possibility of using additives, high durability, the growing popularity of architectural concrete's aesthetics, the possibility of prefabrication, and resistance to sunlight. All of these issues are further discussed in the article.

[3] Eco-efficiency indicators such as MIPS (Material Intensity per Service Unit), CERA (Cumulative Energy Requirements Analysis), embodied energy indicator, material ballast or carbon footprint [8] .

[4] Among the main advantages of such a solution there are: the ease of implementation and maintenance, durability, product availability, a wide range of colours and the repetition of elements [6].

materials, to reduce the amount of water used, the possibility of providing additional jobs, to decrease the amount of energy consumed or produced" [10].

Indeed, production of cement and aggregates, transport, mixing and pouring concrete are energy-intensive processes and they pollute the environment[5], but in the case of acquisition or manufacture of any building material a huge amount of energy must be taken into account and the environment will suffer to some extent[6]. One must, therefore, consider the long-term benefits: the durability of the building[7] or street furniture and their long-term ability to generate economic and ecological profits.

Due to climatic changes and the increasing occurrence of disasters, durability of the work, might prove to be crucial. Concrete is non-combustible (without any additional chemical impregnates), water resistant and at the same time a still economically competitive material; especially if its long-term exploitation at a low-cost maintenance is considered. In Poland, one still takes into account primarily the costs of construction while starting any investment. Few investors are aware enough to determine the choice of a particular technology based on the experience telling us how the material ages, the extent of its energy consumption in the production, environmental impact and maintenance costs over the next few decades. It is assumed that the life of a concrete structure is about 100 years at a minimum cost of maintenance [7.]. Therefore, even at the design stage, it is worth considering the construction of a permanent object with staged expansion as well as the possibility of demolition allowing for the reuse of the elements without destroying them. By avoiding the need for the next "from scratch" investment there is a chance to protect the environment from degradation.

3. The use of additives

As it has been written in the definition of concrete, its composition may comprise of various types of additives and mineral admixtures. They are improving the properties of the material used, depending on the intended purpose.

The already cited norm: PN-EN 206-1:203 Beton – część 1: Wymagania, właściwości, produkcja i zgodność (Concrete – vol 1: Specification, properties, production and conformity) distinguishes two types of additives:

– Type I – almost inert – mineral fillers (e.g., limestone dust) or dyes/pigments,
– Type II – of pozzolanic or latent hydraulic properties – granulated blast furnace slag, fly ash or silica fume [3].

Both fly ash (formed in combustion processes in coal boilers) and silica fume (formed during the production of metal silicon) or blast furnace slag are by-products of the energy industry and metallurgy. Using them as concrete ingredients is aimed primarily at improving the material properties, such as: resistance to aggressive substances, reducing the shrinkage of concrete, tightness. However, it is difficult not to draw attention to other aspects of the

[5] According to the Earthjustice's report from 2008, 150 cement plants operating in the United States emit approx. 10 tons of mercury compounds into the atmosphere [15].

[6] The report of the World Business Council for Sustainable Development from 2012 states that the industry related to cement production is responsible for up to 5% of the total CO_2 emissions resulting from human activities [12].

[7] Structure – every construction work which is not a building or a piece of street furniture [13].

operation. It uses substances considered as waste, which would cause pollution of the natural environment. Also, being an essential component of the mixture, they reduce the consumption of cement itself and thereby reduce the need for its extraction. In some cases, they also contribute to reducing the necessary amount of mixing water. This reduces both energy consumption and CO_2 emissions of the construction process and at the same time fitting in the strategy of sustainable construction.

4. Durability

Striving to increase the strength of concrete mixes, also has an ecological aspect. High Performance Concrete or HPC is gaining increasing popularity, characterized by an even longer life and greater density [14], due to the addition of a reinforcing fibre, nanomodifiers or reactive powders, which allow the formation of a structure with a much smaller cross section of structural elements. In this way, the amount of extracted raw materials and consequently greenhouse gas emissions are limited. An excellent example of the use of modern concrete UHPC (Ultra High Performance Concrete) is experimental and minimalist in its form of street furniture and is the fruit of the cooperation between two departments of the University of Kaiserslautern. The mix that was used in the casting of the components is a kind of self-compacting concrete with fine aggregate fraction not exceeding 2 mm. The compressive strength is estimated at 100 N/mm^2 and due to the reinforcing steel fibers, the tensile strength is 25 N/mm^2. Such parameters allowed us to make prefab construction, combined with a tongue and groove, with a thickness of only 3 cm.

5. Aesthetics – concrete as a finishing material

Since its invention, in the first half of the last century, concrete was a very popular and readily used building material. However, it had always given way, in terms of nobility, to stone, brick or even steel. It was not until the twentieth century that its aesthetic appeal was fully appreciated. In an article entitled *The ethics of concrete brutalism*, M. Charciarek writes „Le Corbusier and the masters of late modernism created objects which, through the so-called honesty and unfinished material formula spilled viewers into the world of original and pure form of architecture. For the first time they ennobled concrete, saying it is "cast stone", its nobility and rank was recognized, using it in the significant realizations of public facilities" [4].

The aesthetics of exposed concrete surfaces goes hand in hand with the strategy of sustainable development. Resigning with the use of additional finishing materials, one limits their production (and thus the emission of pollutants into the atmosphere) and receives the durable, timeless and stately architecture, since concrete gained a reputation of a noble material. The use of this material, currently fashionable among landscape architects, has resulted in many extremely interesting realizations in recent times. One can include here for example, High Line Park in New York, designed by **Diller Scofidio + Renfro** studio in cooperation with **Piete Oudolf**. The paving used here does not resemble in any way the commonly used small-sized cubes, covering the squares and pavements tightly. There is no clear boundary in the form of curbs, between the pedestrian zone and the lawn. Their form has been so conceived as to create visually interesting smooth transition between the hard, artificial concrete hardscape and the natural planting embedded between them. A completely different approach was presented by Chyutin Architects, designing the square in front of the entrance to the University of Ben-Gurion, in the Israeli city of Be'er Sheba. In this case, the composition, though free, results from very consistent geometric divisions. The authors have used concrete slabs not only as a finishing of sidewalks, but also made use of them to create a modular grid, where strips of lawn interspersed with low perennials, strings of lights, trees and benches in the form of a monolithic concrete blocks are distributed. The whole, due to the material used, fits perfectly with the surrounding buildings.

Ill. 1. Park High Line in New York. Diller Scofidio + Renfro + Piet Oudolf (photo by Iwan Baan)

Ill. 2. The square in front of the entrance to the University of Ben-Gurion. Chyutin Architects (photo by Sharon Yeari)

Ill. 3. Weinerberghaus: an experimental piece of street furniture (photo by Sven Paustian)

6. The advantages of prefabrication

A number of advantages flowing from the initial preparation of building component off-site implementation of the object has already been recognized by the first builders who have had contact with investments carried out on a large scale. It was much more profitable, for example, to prepare the building material in a quarry and transport it, already hewn, without unnecessary ballast and avoiding the subsequent littering of the site. No one called this process prefabrication or sustainable construction at the time. This approach simply seemed the most logical.

The quality of the finished products is among other things, what speaks for the use of prefabrication. They were manufactured in optimal conditions in a facility designed for that purpose. Another very important factor is the reduction of the cost of realization. Serial production, reuse of high quality molds and formwork and almost total mechanization of the production process, greatly accelerate the production while the abandonment of preparing formwork shortens the duration of the object's construction.

All these advantages are not the only economic benefits. The high quality of the product means its long useful life without, the already mentioned, outlay for its maintenance. It is connected with the protection of the environment by reducing energy-intensive maintenance work. Reusable formworks reduce the consumption of material required for their production, which is also part of a sustainable development strategy. Likewise significant savings stem from the possibility of exact calculation of the demand for building material and an ideal balance of ingredients in the concrete mix. There is no waste in a factory operating on a large scale. The amount of prepared material is dictated by demand. There is a slightly different situation on the site. Spare building material is often ordered. Sometimes, though, it also runs out and additional transportation has to be ordered involving a financial and energy outlay. At other times a certain amount, which is difficult to manage, is left and has to be used by force. Prefabrication technology is based on the accurate calculation of the demand for the materials; therefore, it does not generate losses caused by approximate estimates. It also allows the rational organization of transport facilities, resulting in the reduction of its energy consumption.

It is becoming quite widespread in international architecture to prefabricate even these pieces of street furniture which had been designed for a single implementation. This was the case of the Holocaust monument in Berlin, designed by Eisenman Architects. It is a kind of square, filled with 2,770 hollow reinforced concrete slabs with lateral dimensions 238 × 95 cm and 18cm-thick walls. These were arranged in a grid pattern, providing a passage of 95 cm width between them. The slabs, or stelae, differ only in height so their upper surfaces create something like a wavy surface. The formation of such a number of items that have the same dimensions, in accordance with the adopted module, as well as of the same hue of the material, was only possible thanks to the production in the facility designed for that particular purpose [5].

7. Concrete recycling

In accordance with the strategy of sustainable development, one should aim to design durable buildings and equipment, offering the ability to easily adapt to the changing function. There is no doubt, however, that the demolition of existing buildings, of those being built or only designed, will always be necessary. Despite all efforts, nothing will last forever. Trends in architecture, the needs of investors, site development plans, etc. are constantly changing. One must therefore take into account the materials that can be reused. Concrete is undoubtedly one of them. At present, debris from a demolition is most often used as a foundation for roads, squares or filler of excavations. The reasons for this are obvious: "The use of secondary aggregates as a substitute for natural aggregates for concrete production provides mainly environmental benefits, however it is clear that immediate economic benefits are not to be expected soon. As time passes, the landfilling cost will grow. The costs of transport to more distant landfills will also increase. Processing and reuse of concrete rubble will also reduce the costs of restoring depleted areas of aggregates mines, as well as the costs of building new landfills" [1].

It is therefore expected that in the near future the situation will change radically. Technologies that enable the processing of rubble to secondary aggregates, which are a component of the concrete, are being developed (and even already used). This will significantly limit the environmental degradation caused by the extraction of natural aggregates, which are not renewable. An excellent role model here are such countries as the Netherlands and Belgium, where up to 90% of waste from demolition is re-used [3] Yet, we must remember about the deterioration of the properties of concrete with the addition of recycled aggregates – particularly in terms of frost resistance (due to higher water absorption) and compressive strength. Currently, research is conducted and successful in improving the mix with the addition of secondary aggregates.

11. Shield against solar radiation

Good architecture, is not only visually appealing, but it also creates the right living conditions. Interesting aesthetic properties, great capabilities of shaping the form and unusual resistance to weathering, are the main factors that contributed to the popularization of this material among designers involved in the shaping of urban interiors.

An interesting example, illustrating the possibilities of concrete in creating the climate of public space, is the school building: Flor del Campo, along with its surroundings, designed by **Giancarlo Mazzanti**. The basic idea in this case, was to create a complex, as a sequence of cells of a living open organism. The perforated wall, like a transparent veil wraps the school and squares, giving them identity and combining various educational functions into one complex: kindergarten, primary school, lower and upper secondary school. Each of them faces its individual inner courtyard. Four fences arranged in rows seem to divide but not to close square spaces. Thanks to an interestingly and formally designed filing of spans, this solution creates the much desired shade, while allowing the free flow of air. The described wall is both a fence and facade of the building. It is made of prefabricated modular concrete panels in various shades of gray and several widths. Specific perforations were inspired by the model of fences made from branches [2].

12. Conclusions

The results of the research lead to the conclusion that what can help reduce the total energy expenditure of a design execution is not so much the material or technology but rather the way in which they are applied.

Eco-efficient awareness of the designers as well as excellent knowledge of the unique properties of the materials used, turns out to be the basis for such action.

As the above examples illustrate, the use of concrete in landscape architecture can be justified not only by aesthetic considerations but also ecological ones. The most important include:

– reduction in material and energy consumption of products and services owing to prefabricated building elements, an opt-out from additional treatment, finishing or maintenance processes,
– an increase in the amount of recycled materials where as much as 90% of the concrete can now be processed; modern technologies allow to the use of material from demolitions not only as a foundation for squares and roads but also as a valuable addition to the mix,
– an increased product durability such as high resistance to weather conditions allows to use roads and street furniture for many years so the need for their re-production becomes limited.

These actions, "contribute to an increased efficiency of resources obtained from the environment and reduction of pollutants emitted into it" [8]. They are particularly important in the case of concrete, since its energy-consuming production contributes to environmental degradation due to exploitation of non-renewable resources or emission of significant quantities of carbon dioxide and mercury compounds into the atmosphere. With conscious and reasonable design, there are possibilities to reduce these costs while long-term utility of the completed projects constitutes a chance for their partial recovery.

Aesthetically, concrete in the landscape should be considered as an artificial stone. Available technologies have made it in many cases, extremely difficult or almost impossible to distinguish concrete from natural stone. Combined with the tremendous freedom in shaping the form, its excellent structural characteristics and resistance to atmospheric agents, we obtain the ideal material for creating buildings complying with the rules of Vitruvius – beautiful, durable and functional.

It should be remembered that currently promoted energy-efficient construction is not only found in tightly insulated houses with relevant installations or certified office buildings and public spaces. It also entails the energy and raw materials consumption used during their design, implementation and exploitation which can be significantly reduced.

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