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MODELING OF BIOCLIMATIC SKYSCRAPERS' FACADES WITH GENERATIVE DESIGN METHODS

KSZTAŁTOWANIE ELEWACJI WIEŻOWCÓW BIOKLIMATYCZNYCH METODAMI GENERATYWNYMI

Abstract

Today, the architectural design process is based on developing digital technologies, and the interest in „fitting" buildings into a local microclimate is increasing. The article brings up the subject of modeling skyscrapers' facades to present the tendency of the generative design methods in the design process of bioclimatic building. As a result, each individual element is adapted to the local microclimate. The results of the design integrated with modeling based on generative methods are mostly unconventional shaped structural forms.

Keywords: bioclimatic skyscraper, facade modeling, generative design methods

Streszczenie

Obecnie proces projektowania opiera się o coraz lepsze wykorzystanie technologii cyfrowych, a zainteresowanie poszukiwaniem budynków „wpisujących się" w lokalny mikroklimat wzrasta. Podjęta tematyka kształtowania elewacji wieżowców ma na celu przedstawienie tendencji do wykorzystywania generatywnych metod w projektowaniu obiektów bioklimatycznych. W ich rezultacie każdy element budynku może być dostosowywany do warunków istniejących w miejscu jego wbudowania. Wynikiem wprowadzenia generatywnego modelowania są często formy strukturalne o niekonwencjonalnych kształtach.

Słowa kluczowe: bioklimatyczny wieżowiec, kształtowanie fasady, generatywne modelowanie

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1. Introduction

Recently, there has been a growing interest in *bioclimatic design,* which is *"*the passive, low-energy design approach that makes use of the ambient energies of the climate of the locality to create conditions of comfort for the users of the building" [1]. The implication of digital tools facilitates greatly the design of bioclimatic skyscrapers.

The methods of designing the bioclimatic structures are also used in European high-rise buildings. The skyscrapers erected in Europe do not compete with global implementations in the unfolding race of height and their prestige is decided by, among other things, bioclimatic solutions. One of the key issues in the design of a tall, bioclimatic building, is the proper structuring, as well as the technical and technological solution of the elevation. The desired goals are: to maximize access to daylight and use of natural ventilation [2], heating and cooling, to minimize heat gain or loss and to prevent a glare.

The development of digital technologies contributed to the increase of research on the enclosure, defined in the architecture as the boundary between the interior and the exterior of the building. For many historic structures, the cladding of the enclosure defined the finishing layer, covering the actual internal structure of the building. Breaking with the treatment of the elevation as a top layer ("the costume"), determines the technological possibilities and the development in the era of optimization [3]. The enclosure is an integral part of building's structure, constituting the continuation and completion of systems in the building. In many contemporary implementations, the enclosure is an element adapting the building to the changing climate conditions, compared to a *skin*. The multitude of factors affecting the exterior and the functionality of the enclosure, as well as the development of the newest technologies and digital tools, currently make interdisciplinary design one of most interesting trends in shaping bioclimatic elevations.

The implementation of innovative technical surface treatment of elevation structures as an *architectural skin*, is made possible by generative tools of an architect, in which the algorithms play a key role. Thanks to the characteristic iterative structure, enabling to generate multi-option solutions, based on initial data [4], the algorithms are widely used in modeling bioclimatic facades of high-rise buildings, where the relation between climate variables is particularly important. The generative design methods allow to control and interfere with the form, generated by the program. Due to the complexity of the architectural design, architects are now closer to the digital tools, that are based on a program (e.g. for manual modeling) and include features embedded in the application. The application of the generative modeling tools allows for the search and analysis of optimal solutions, regardless of their geometrical complexity. The world's most renowned design studios create their own optimization programs, enabling the creation and implementation of a rational and often unusual engineering solutions.

2. The analysis of architectural examples

The use of generative tools in the process of architectural design, allows connecting many disciplines and issues with a single algorithm. In the complex process of generating a form, more often all possible parameters that affect the final form of the object are taken into account. As a result, the modeled form constitutes a coherent spatial arrangement, the surface of which, separates the interior from the exterior, comprises an active layer, through which the processes, necessary to maintain the comfort of the object occupants, take place.

One of the more interesting examples of generative tools application, in the development process of bioclimatic facades of high-rise buildings, is the *Education Executive Agency and Tax Offices* in Groningen. The building, designed by UN Studio in collaboration with the DUO² consortium and implemented in the years 2006–2011, is the new headquarters for two government offices. The complex includes an office building with a parking lot, a commercial pavilion and a public park [5].

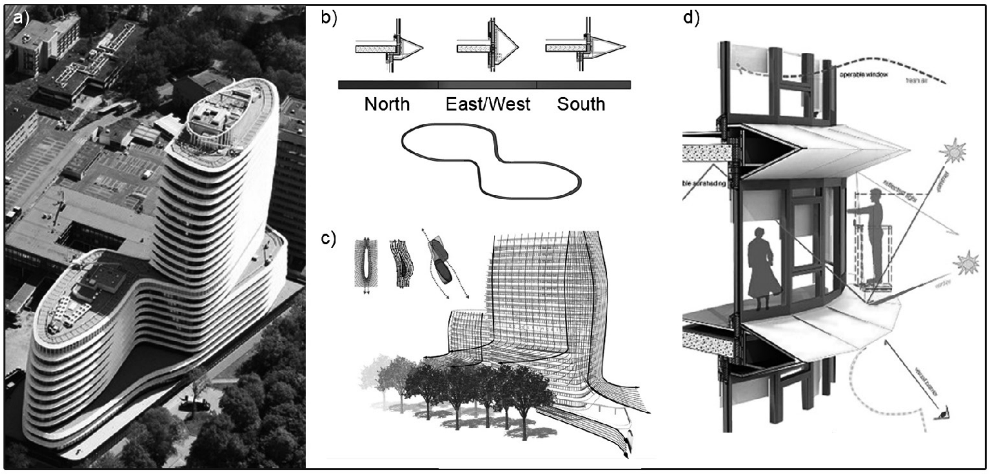

Fig. 1. Education Executive Agency and Tax Offices: a) a bird's eye view; b) shaping of elevation's elements; c) an aerodynamic shaping of building's form; d) a diagram of elevation functions

The object was formed with the use of a parametric methods in a way to obtain optimal exposure to sun rays of the interiors, as well as to enable natural ventilation through windows. A smooth, bionic form was shaped as a result of the aerodynamic analysis, the aim of which was to minimize turbulence around the building. The facade which combines all the necessary features of a bioclimatic "skin" using a relatively simple technology, thanks to the use of generative tools, played a special role in the project. The characteristic elements of the elevation are horizontal ribs, surrounding the building at the ceiling level, the profile of which varies smoothly, depending on the orientation of the corners of the world [6]. These bands are used as elements controlling the gusts of wind, a visual barrier and, depending on the season, reflecting the sunlight outside the building or to its interior. Furthermore, the shaping of the facade prevents the building's overheating process and the specially designed building projection and horizontal bands of windows, allow visual contact with the environment, as well as better lighting of the interior with natural light.

An interesting example of the use of generative design methods is also the building *Tour Phare*, located in the Parisian office district La Défense. The completion of the 300-meter high skyscraper designed by Morphosis is planned for 2017. The building is expected to include a public space on the ground floor, office space and restaurants.

The main objectives of the project were: to maximize the use of daylight, wind energy and to minimize the effect of overheating of the building. As a result, the orientation and the form of the skyscraper have been designed in accordance with the position of the sun. The flat northern facade will be fully glazed and the “waving” east-south-west elevation will be additionally covered with a set of diagonally placed perforated stainless steel panels. The multi-layer skin, thanks to its curvature and construction, will improve the energy efficiency and working conditions [7].

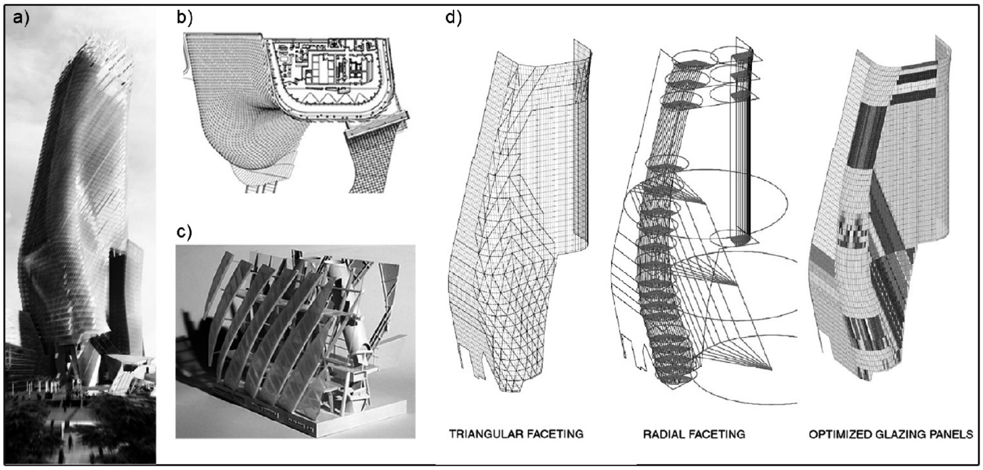

Fig. 2. Tour Phare: a) a visualization; b) the plan of the 65th floor; c) a model showing construction of the waving enclosure; d) diagrams showing the evolution of the waving façade’s glazing

Project was begun on Bentley software form Microstation and a programmer was hired to write scripts for a customized parametric model. Later on, architects finished the project using Digital Projects [7]. The complexity of the waving facade required drawing up of a detailed design regarding, inter alia, the panelization i.e. the division of the facade and the support structure into production elements. Optimizing the form of the panels was made possible by the use of appropriate algorithms for generating divisions, which meet the functional, visual, material and economic requirements. In the pursuit to maximize the amount of repeatable elevation elements, the optimization of both the geometry of the panels and their supporting structure, as well as the method of combining individual elements, was obtained. However, to achieve the greatest possible efficiency, each of the 5000 panels has a different angle alignment. Moreover, the maximum length of steel panels was determined due to a different wind load of the different parts of the building [7].

The generative design methods are a very effective tool for presenting a loose complex architectural form, through the use of an easy to describe geometry and translating it into building elements. An example would be the project of the office building *Bishopsgate Tower* in London, designed by Kohn Pedersen Fox Associates. This skyscraper was designed with the facilities provided by parametric modeling software, namely Bentley’s Generative Components [8]. The geometry of the object was chosen as a result of the generative modeling and it is based on algorithms used to adapt the project to a few simple design restrictions, inter alia, the model of the building was built entirely from lines and tangent arcs.

One of the key issues in design was the solution to the elevation of the building. The object was to be entirely glazed and the double elevation was formed by repeatable rectangular modules. The inner layer of the elevation is a continuous housing, equipped with operable windows, while the outer one is comprised of separated, slightly overlapping panels. In the basement, a curvilinear glass facade creates a canopy over the pavement, which improves the wind conditions at the surrounding ground level.

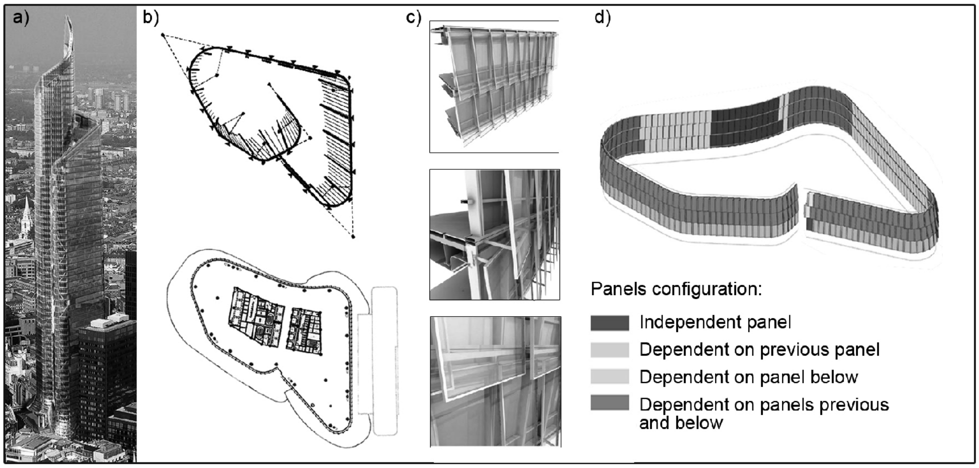

Fig. 3. Bishopsgate Tower: a) a visualization; b) a diagram of the building geometry and a typical floor plan; c) a model of elevation – visualizations; d) a diagram of the elevation panels configuration

The shaping of the facade and the setting of its elements, were generated by a properly "specialized" optimization algorithm. In particular, an iterative process for the purpose of minimizing the voids in the double facade was carried out, which maximized usable space. Furthermore, an important goal was to define such a configuration of panels, which would prevent their collision, in close adjacency and visual continuity, while maintaining the required appropriate vents between overlapping outer panels [8].

3. Conclusions

The European projects, presented in this article, are examples of new generation bioclimatic skyscrapers. Their creation was contingent upon the introduction to the design process of multi-criteria optimization, as a result of which, each element of the building may be adapted to the conditions in the place of its erection. The presented trends in architectural design, involve the use of generative design methods.

Shaping of the "bioclimatic" elevations is an important factor in increasing comfort of tall buildings. Treating the outer divider as an *architectural skin* is a difficult task in finding more effective tectonic and functional solutions, the essence of which results from the microclimatic conditions and the adaptation of the object in given environment. The use of algorithms in the complex process of modeling the form of an object, along with the system of connections and relations, enables to generate heterogeneous structures, which constitute a synergistic solution in an interaction of many disciplines. The use of the generative methods in the design of bioclimatic elevations, pertains not only to the shaping the surface, but also to the systems that are responsible for the processes, taking place between the building and its surroundings.

The search for optimal engineering solutions is becoming an important factor in determining the value of modern architecture. One of the indicators of this trend is the use of generative methods in the design of bioclimatic elevations of tall buildings, which results in interesting and original structural forms, with a considerable degree of complexity that goes beyond the traditional design.

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