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NOVELTY ARCHITECTURE: THE INFLUENCE OF BUILDING MATERIALS IN SHAPING CONTEMPORARY ARCHITECTURE

NOVELTY ARCHITECTURE: WPŁYW MATERIAŁÓW BUDOWLANYCH NA KSZTAŁTOWANIE WSPÓŁCZESNEJ ARCHITEKTURY

A b s t r a c t

The properties of building materials have significantly influenced the shaping of architecture for centuries, and introducing new materials and their conglomerates opens up possibilities for exploring new aesthetic expressions. Design based on the exploitation of material properties, considering the boundary conditions of the physical world, makes it possible to create optimum structural elements that harmonise in the building similarly to organisms found in nature. Novelty Architecture combines unselfconscious beauty and aesthetics, prioritising the search for optimal structures, specified parameters and structural logic. The article analyses the impact of design approaches, often undertaken without the primary guidance of an architect, which captivate with their beauty and technical innovation, highlighting the importance of material selection in contemporary architecture. The conclusions underscore the need for continuous research and exploring new possibilities in the synergistic design of beautiful objects resistant to passing architectural styles.

Keywords: aesthetics, architectural expression, building materials, structural logic, technology in architecture

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

Właściwości materiałów budowlanych od wieków mają znaczący wpływ na kształtowanie architektury, a wprowadzanie nowych materiałów i ich konglomeratów otwiera możliwości odkrywania nowych ekspresji estetycznych. Projektowanie oparte na wykorzystaniu właściwości materiałów, z uwzględnieniem warunków brzegowych świata fizycznego, umożliwia tworzenie optymalnych elementów konstrukcyjnych, które harmonizują w budynku podobnie do organizmów występujących w naturze. Novelty Architecture łączy w sobie nieświadome piękno i estetykę, stawiając na pierwszym miejscu poszukiwanie optymalnych struktur, określonych parametrów i logiki konstrukcyjnej. Artykuł analizuje wpływ sposobu projektowania, często, bez głównego kierowania projektem przez architekta, zachwycając pięknem i innowacyjnością techniczną, podkreślając znaczenie doboru materiałów we współczesnej architekturze. Wnioski podkreślają potrzebę ciągłych badań i poszukiwania nowych możliwości w synergicznym projektowaniu pięknych obiektów, odpornych na przemijanie stylów.

Słowa kluczowe: estetyka, ekspresja architektoniczna, materiały budowlane, logika konstrukcyjna, technologia w architekturze

1. INTRODUCTION

Since ancient times, technological possibilities and load-bearing parameters have defined how buildings are constructed. Architects and builders began their study by recognising the characteristics and plasticity of building materials and then their technical parameters. Historical architectural styles refer to the structural logic and the preferred way of working statically on elements made of specific materials. The ever-increasing mastery achieved by the increasing spans and volumes of building structures is due to the enhanced knowledge of material craftsmanship. The apparent return in the twentieth century to an experimental approach to design, exemplified at the Bauhaus, also developed interdisciplinary design and trained designers as versatile specialists capable of working with other trades. In line with Gropius' guidelines, architecture must reflect the changes in society and not a repetition of the history of previous generations and the achievements of previous eras. Novelty architecture of the 21st century combines the immersive search for beauty and technological coherence, allowing designers to unconsciously search for form based on the absolute criteria of materials selected and structural logic. Comprehensive, in-depth interdisciplinary knowledge enables better use of modern tools and methods in design. Therefore, contemporary architecture should not be limited to knowledge related only to architecture-related fields. The architectural profession requires observing and analysing new developments from many fields such as biology, computer science, mathematics, materials science, chemistry or physics. This paper presents an approach to the contemporary experimental search for logical forms of load-bearing structures of unusual and often experimental architecture, pointing out contemporary trends and developments in design-enhancing technology.

2. BUILDING MATERIALS IN ARCHITECTURAL HISTORY

How architecture and construction are designed is inextricably linked to the technical performance of building materials. Building materials significantly impact structural form, shaping buildings' aesthetics, functionality and durability throughout history. Materials dictate architectural possibilities and constraints, from ancient stone and wood to modern steel, concrete and composites. Starting with the earliest materials available, their significant influence on the shape and aesthetics of building structures is evident. Whether wood, stone, clay or earth, they differ dramatically in their aesthetic finishes and, more importantly, in their properties and preferred mode of static working. While stone can easily carry significant compressive loads, it will not achieve the same flexural performance as wooden beams. Steel and concrete have influenced the development of complex or challenging form design, allowing discoveries regarding exceeding span, load-bearing capacity or structural complexity. However, it is not just these two materials that are currently the focus of architectural experimentation. The historical use of stone in monumental buildings and wood in various architectural styles evolved into the widespread use of bricks and mortar and innovations. The Industrial Revolution introduced iron, steel and reinforced concrete, revolutionising construction and enabling skyscrapers and versatile designs. Contemporary materials and composites offer unique properties that influence structural design, allowing for various forms and aesthetics. Sustainable materials such as green concrete, bamboo, and recycled products are increasingly important in supporting green buildings. Material choice affects load-bearing capacity, aesthetic possibilities and environmental impact, making it crucial for architects and engineers to consider material properties to create functional, attractive and sustainable buildings.

The 21st century is a period of significant technological development and recognition of the properties of traditional materials and material composites based on natural and artificial admixtures. Changing the composition of many composite mixtures makes it possible to discover new, improved load-bearing and insulating parameters for use in architecture. This can be seen, for example, in the increasingly high load-bearing capacity or environmental corrosion resistance of concrete, which is still one of the most versatile building materials. Modern material technologies enable the unconventional use of materials and material composites in the design of structural forms to exceed previous design possibilities.

The most effective way to use building materials is to incorporate their mechanical properties into the calculation algorithms. Because of the properties of specific materials, architect F.L. Wright, already in modernism, saw the need to implement them into the conceptual phase of a project: "Every new material means a new form, a new use if used according to its nature."[1] Technological developments also contribute to the search for more precise placement of building materials while minimising the energy required, the material itself, and the waste generated. The solution to the above conditions is digital printing and fabrication of the finished components in factory-like conditions.

3. AESTHETIC EXPRESSIONS

The search for modern possibilities of expression and communication in contemporary architecture is dictated by the development of modern computer technologies and a change in how we design. The search for expressive forms that follow structural logic, evident at the turn of the 20th and 21st centuries, has created in architecture a design trend whose task is to shock and intrigue the viewer, the passer-by, and the user, using the fundamental laws of physics.

In addition to the increasing familiarity with working with materials and the ability to design selected mix parameters, the development of computer technologies to assist design processes in the architectural and construction sector is also apparent. Modern access to digital tools in design, especially those based on algorithmisation and artificial intelligence, allows the design of complex architectural forms within a structural logic. The lack of an architect does not refer to a real lack of a designer. However, instead, there is a visible change in the way of designing, where, in forms with a wow effect, it is less and less necessary to know the basic principles that students of architectural design learn, such as the history or theory of architecture or the basics of design and composition. Knowledge of advanced structural, material, and installation systems and the ability to cope with innovative and technically advanced structures is becoming essential. Famous in the history of architecture are architects-structuralists, architects-artists, and architects-technologists, who, thanks to their often accompanying studies, can combine architecture with other fields of knowledge and adapt to the requirements of today's client-recipients.

[1] F.L. Wright, *In the cause of architecture: Composition as method in creation* [in:] B.B. Pfeiffer (ed.), *Collected writings*, Rizzoli publishers, New York 1994, pp. 259–260.

Ill. 1. Dancing House, Prague, Czech Republic, project: Gehry&Milunić, photo: Anna Stefańska.

An example of wow-factor design and modern technology facilitating curvilinear forms is the Dancing House in Prague, Czech Republic, whose asymmetrical and free-form shapes are visible from afar, from the other side of the Vltava River. The building combines two alternating parts: a static and a dynamic one, symbolising, according to architects Gehry and Milunić, the transition of Czechoslovakia from a Communist regime to a parliamentary democracy. Dancing House symbolises two dancing figures: the straight one, a male dancer, and the asymmetrical glass represents a female dancer. The apparent use of asymmetrical load-bearing structure layouts has become an indicator of the capabilities of designers in increasingly interdisciplinary studios. The apparent trend towards a return to close collaboration between architect and designer has been enforced through architectural forms that are increasingly less structurally logical.

4. OPTIMUM STRUCTURAL ELEMENTS

The search for tools to support the design of architectural forms that evoke emotion in their audience has been developing over the past decade using digital tools and artificial intelligence. The search for optimal solutions and the close collaboration between architects and designers allows for a two-pronged approach to design, on the one hand achieving significant spans, surfaces or minimising material consumption, and on the other, the possibility of creating geometrically arbitrary objects without the limitations of typical parameters of basic construction materials. An example of a designer who pushes the boundaries of material possibilities using FEM optimisation is Santiago Calatrava. He has repeatedly used significant spans of cantilevered structures in his designs, as in the Museum of the Future in Rio de Janeiro. The possibilities of computational optimisation of the applied geometries and the adjustment of the load-bearing parameters of the structural elements allow the viewer to be amazed by the beauty of the logic of engineering structures, going beyond the design of architectural aesthetics. Contemporary design using advanced optimisations helps blur the distinction between designing for aesthetics alone and searching for logical solutions. This search began in the projects of designers of the last century, who, without using digital computing, created objects that blurred the boundary between architecture and construction. Examples of unique structures using structural logic are usually engineering structures such as bridges, towers or long-span structures such as sports halls. The visible influence of designer-constructors on the design of the above structures was during the transit time between analogue and computer-aided design, during which engineers such as Pierre Luigi Nervi (1891–1979), Frei Otto (1925–2015), Richard Buckminster Fuller (1895–1983), Sergio Musmeci (1926–1981) or Heinz Isler (1926–2009), as well as architects Maciej Nowicki (1910–1950), Antoni Gaudi (1852–1926), Stefan de Chateau (1908–1999), designed. In their reflections on how to design, they believed that 'to shape' (to give shape) describes the process of finding a form under given loads and boundary conditions.[2]

In most cases, the designed objects with bar or shell structures were geometrically advanced shapes. The prototype objects realised were often the result of research explorations based on experimental methods for determining force flows and stress distributions. P.L. Nervi describes the 'beauty' of buildings designed according to the laws of physics: "Form must be the necessary result, not the original underlying structure."[3] The inspiration of bionics and the search for algorithms that describe the pure principles and laws of nature seem to be grounded in it, as the processes that govern living organisms are a matter of survival.[4] Frei Otto describes the process of beauty in architecture as follows: "Aesthetic form emerges at the end of the process. It cannot be achieved through the will to beauty alone. If we have worked honestly, it sometimes comes as an additional bonus."[5]

[2] G. Boller et al., *A proposal for the structural preservation of Musmeci's Basento Bridge in Potenza* [in:] S.A. Behnejad, G. Parke, O. Samavati (eds.), *Inspiring the Next Generation – Proceedings of the International Conference on Spatial Structures*, University of Surrey, Department of Civil and Environmental Engineering, Spatial Structures Research Centre 2021, pp. [1041–1050].

[3] P.L. Nervi., *Concrete and structural form*, "The Architect and Building News" 1955, no. 208(27), pp. 523–529.

[4] R. Finsterwalder., *Form follows nature. A history of nature as model for design in engineering, architecture and art*, Springer, Wien 2011.

[5] F. Otto, *The inverse route*, interview with Frei Otto, March 28 and October 28, 2008 [in:] *ibidem*, p. 102.

Ill. 2. Train station Oriente, Lisbon, Portugal, project: Santiago Calatrava, photo: Anna Stefańska.

The contemporary search for structural optimisation in architectural structures is evident in the work of designers such as Santiago Calatrava, whose design style has become one of the most recognisable since the 1990s. The famous Oriente station building in Lisbon, covered by a steel roof of arborised load-bearing structures, conceals a station hall supported by reinforced concrete arches under the train station slab. The load-bearing elements visible in Ill. 2 are characterised by following structural logic, especially the beam systems – the footbridge in the central part of the photo – whose geometry reproduces the shape of the bending moments on the beam resting on the extreme supports. Not only purely engineering objects created according to structural logic delight with their aesthetic expression. Contemporary interdisciplinary design blurs the boundary between architect and designer in achieving technical innovation and beauty. The role of the architect and the way he or she works is changing: "For the first time in history, architects are not designing but, as it were, 'generating' geometric objects by using a specific set of imperatives encoded in sequences of parametric equations."[6]

5. NOVELTY IN ARCHITECTURE

When designing architectural structures using digital tools, many questions are already posed at the design stage; not only is the optimisation of structures important, but so is

[6] K. Januszkiewicz, *Projektowanie parametryczne oraz parametryczne narzędzia cyfrowe w projektowaniu architektonicznym*, "Architectuae et Arbitus" 2016, no. 3, p. 48 (transl. by A. Stefańska).

their fabrication. The task of computer-aided design becomes the search for the relationship between the spatial form and its optimum supporting structure, followed by the fabrication technology, which can be seen mainly in constructing continuous cross-sections and spatial bar structures. An example of the search in contemporary architecture can be found in formfinding. The design process of 'form-finding' begins with the generation of the initial form of an object, interacting with gravitational forces and external loads. This approach is not a new phenomenon and was used before the era of computer optimisation, as is evident in Ott, Fuller, and Gaudi. The morphology of structures encompasses geometric exploration, the analysis of the relationship between form and the forces acting on it, and the technology of manufacture or prototyping. In the 21st century, digital methods continue to develop, allowing the design, analysis and multidirectional optimisation of structures based on multiple variables. Designers can use digital tools to determine optimal spatial structures for given loads computationally. However, at the moment, there are no structural materials with a variable structure as required. Analysing the dynamics of bionic pattern applications in architecture, it seems that creating such materials is a matter of the near future. Through mathematical algorithms operating based on, among other things, proportionality requirements, minimum or maximum dimensions, the programs analyse individual solutions for the indicated boundary conditions. This is particularly interesting from the point of view of prefabrication, which today is increasingly characterised by the idea of post-Fordism, where the striving for unification is not excluded from the creative search for individual solutions.

Fabrication, which in the last century was associated with medium-quality large-panel buildings made on a significant scale in connection with huge housing needs, today allows the use of a variety of good-quality materials used following preset functional and structural requirements. Today's fabrication possibilities indicate the need for directional action to introduce a qualitative and sustainable architectural and building design process. There is a noticeable trend towards a return to timber structures as a renewable material, with today's factories producing, depending on needs, finished components or even systems entirely in timber, meeting today's energy-efficient design guidelines. More and more prefabricated timber component factories are being built in Europe. The design process for timber structures increasingly involves designers and timber technologists, minimising the influence of architects on the final form of the building, which is created as a result of the technological and production capabilities of the factory.

6. CONCLUSIONS

The algorithmisation of tectonic form-making processes does not take away the creative nature of the architect's work but merely provides new tools for rationalising engineering solutions. Developing in recent decades, 'design engineering' (from Design Engineering) is an interactive medium that combines the design work of the architect and the designer. The development of modern computer tools has significantly improved the quality of design. The shaping of structures no longer takes place a posteriori but is carried out in tandem with work on the architectural concept. Geometrically advanced forms can be designed through algorithmic shaping and simultaneous optimisation in manufacturing technology and materials used. Design, at an initial stage, becomes a holistic endeavour. In the process of designing high-level structural forms, architects and designers are increasingly forced, in the course of being inspired by bionic forms, to be familiar with geometrical laws, mathematical algorithms and the basic working principles of structural systems. What seemed unfeasible in architecture as recently as the 20th century is becoming natural and feasible with the advances of the 21st century.

Computational digital modelling methods open up new possibilities in the creative search for 'eco-efficient' architectural forms and change how we work as the established sequence is reversed. Instead of drawing projections to define the mass to be formed, three-dimensional objects are created that also record information about the building. Thanks to the availability of advanced, generative techniques and engineering achievements, designers can reproduce forms found in nature. In their ephemeral and unique nature, pavilion objects become the subject of an architectural game that subjugates computational algorithms. Architecture becomes more organic, 'gaining' a certain plasticity that the natural world has, and the architect can better use the tools available today to shape it.

When analysing the phenomenon of human-machine collaboration that is taking place in the current fourth industrial revolution, it is apparent that a machine or algorithm is capable of assisting the design process rather than merely performing the mechanical work in question. The trend of algorithmic design for the multivariate optimisation of load-bearing structures and the ability to fabricate them in complex forms is beginning to dominate research related to the frontiers of architecture and construction. The widening gap between architects and builders, apparent for centuries, is slowly beginning to blur with using a machine capable of analysing given parameters. Visible interdisciplinary research in the construction sector points to a renewed need to implement the knowledge of the architect and engineer, expanding the field to include computer science, biology or materials engineering knowledge. This search is particularly evident in research on new production technologies, the optimisation of structures and production, the use of construction materials and, increasingly, those not associated with construction.

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A u t h o r ’ s N o t e

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