

The evolution of the undulating wall



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Expressive buildings based on curvilinear geometry became one of many characteristic elements of contemporary architecture. A fascination with irregular, undulating forms has already been visible in the 20th century. However, the sources of the undulating motifs go back to the Baroque period, when buildings with curved façades were one of the best examples of the natural development of architectural thought.

Introduction

Expressive buildings based on curvilinear geometry became one of many characteristic elements of contemporary architecture. A fascination with irregular, undulating forms has already been visible in the 20th century. Charles Jencks, in the description of the form of Le Corbusier's Church in Ronchamp, emphasised its "curved, unusual shapes", which were connected with the surrounding landscape [1]. The fascination with irregular lines was additionally intensified by the popularization of computer design, which is reflected in the works of i.e. Frank Gehry or Zaha Hadid. However, curvilinear, undulating forms expressing organic movement are not a characteristic motif of the 21st century. Although the contemporary usage of these forms results from the development of architectural thought and technology [2], the motif of the undulating wall has already appeared in Prehistory¹. Nevertheless, the greatest development of this motif took place in the Baroque. The analyses of the historical and modern examples show the evolution of the undulating wall through the ages. This evolution is visible in the usage of forms with regular curvilinear geometry which were slowly replaced with wavy lines with a free character². The Author's research the development of the undulating wall in the Baroque. Then it will be juxtaposed with the realizations and concepts from the 20th century. Additionally, Authors list inspiration from the past, visible in selected projects.

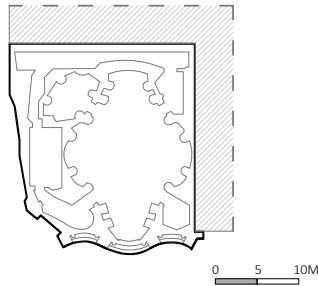


Ph. 1. San Carlo alle Quattro Fontane Church – Francesco Borromini – Author: Paolo Monti [13]

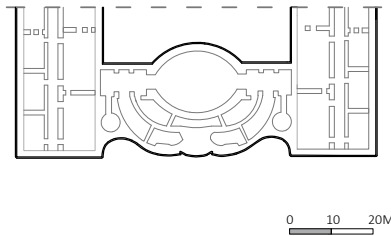
¹ Giedion recalls the first stone temples from the city of Petra in Asia Minor, where the very first steps in creating the curvilinear architecture are visible. The Swiss, however, stresses that due to the fact that the temples were made of stone, it cannot be considered as a pioneering solution that exceeds Borromini's achievements [3].

² According to Kandinsky's systematics in "Point and line to plane". Details are described in "The aim and method of the research".

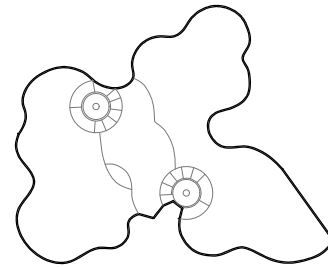
FRANCESCO BORROMINI, SAN CARLO ALLE QUATTRO FONTANE, ROME, 1643



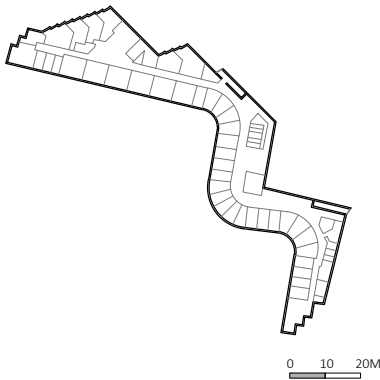
GUARINO GUARINI, PALAZZO CARIGNANO, TURIN, 1679



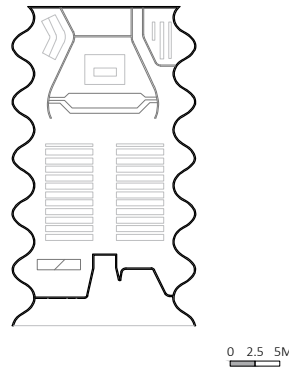
MIES VAN DER ROHE, GLASS SKYSCRAPER, CONCEPT, 1920-1921



ALVARO AALTO, BAKER HOUSE, CAMBRIDGE, 1947



ELADIO DIESTE, CHURCH OF CHRIST THE WORKER, URUGUAY, 1952



HERZOG & DE MEURON, COTTBUS LIBRARY, COTTBUS, 1993

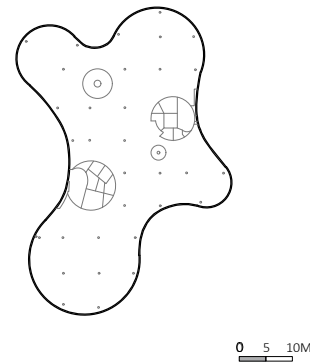


Fig. 1. Author's sketches of the plans of the buildings with the undulating wall

Literature Review

The interest of the motif of the undulating wall is an immanent element of the works of many theorists and historians. 20th-century, expressive buildings are featured in Charles Jencks' "Ecstatic Architecture" [1] and "The Architecture of Jumping Universe" [2]. The fascination of the curvilinear architecture is also visible in the monograph by prof. Tomasz Kozłowski "Tendencje ekspresjonistyczne w architekturze współczesnej" [3], and in the dissertation by Jakub Świerzawski, written under the supervision of prof. Nina Juzwa and prof. Jan Salm, entitled "Krzywoliniowość w architekturze. Historia. Współczesność. Idee. Przykłady" [4]. However, point of view much closer to the Authors' considerations, describing the evolution of the undulating wall, is presented by Sigfried Giedion in "Space, Time, Architecture. The Birth of a New Tradition" [5]. The author focuses on the first applications of the undulating wall and its development from the Baroque to the time of Alvar Aalto. Additionally, Christian Norberg-Schulz in "Meaning in Western Architecture" [6] emphasises the richness of the baroque space, simultaneously focusing on the development of the external wall made by Borromini and his successors.

The aim and method of the research

The main aim of this article is the description of the evolution of the undulating wall.

The Authors analyse Baroque examples of the usage of the undulating wall and its evolution in the 20th century. The starting point is the definition of a wavy line by Kandinsky presented in "Point and Line to Plane": "a curved line is a type of complex curved or wavy-like line, which can consist of geometric parts of a circle, or free parts, or various combinations of these" [7]. Additionally, Kandinsky made a distinction between a wavy line, built of regular or irregular (with a constant or variable radius) segments of a circle, and a freely undulating curve line which loses its geometrical character due to variable tensions [7]. Setting up a wavy line in the frame of its regularity allows distinguishing two variants of curved lines used in architecture. The regular undulating line, with a constant or variable radius of the circle segments and a freely undulating line. Both types of curved lines defined by Kandinsky are the main delimitating factor for the selection of buildings, where the undulating line can be found in the plan of the building or its cross-section. The Authors' considerations will focus on Baroque architecture – mainly represented by a regular wavy line, and on 20th-century architecture, where both types of lines were used and transformed by contemporary architects. The research will include the usage of an undulating wall in the façade of the building, excluding curved elements of the structure of the architectural object. Due to the large number of scientific studies devoted to contemporary ar-

chitecture and parametric trends in 20th/21st-century architecture, the considerations will end in the 20th century, without showing the curvilinear trends of later years.

The origins of the undulating wall – the Baroque

The Baroque is regarded as a turning point in the field of architectural thought by many critics. Christian Norberg-Schulz pointed out that Baroque architecture is characterized by a "synthesis of dynamism and systematicity" and "plastic vitality combined with the richness of space"³ [6]. It is visible in the works of Bernini, Borromini, and Guarini. Although the Norwegian theorist focused mainly on the internal structure of the buildings, he did not ignore the innovative achievements of Italians in creating an undulating wall. On the other hand, Sigfried Giedion emphasised that universalism with a very specific character originated from the Baroque. It "manifests itself in the power of shaping space and the ability to create an amazingly uniform whole from the most diverse elements"⁴ [5]. According to Giedion, the appearance of the undulating elements in the final stage of Baroque, initiated by Borromini in the Church of San Carlo alle Quattro Fontane in 1643, was a nat-

³ [6], p. 149.

⁴ [5], p. 135.



Ph. 2. Palazzo Carignano – Guarino Guarini – Author: Fulvio Spada [14]



Ph. 3. Casa Mila – Antonio Gaudi – Author: Florencia Potter [15]

ural phenomenon, resulting from the development of historical thought. This motif has developed over the next decades and can be observed in Guarino Guarini's Palazzo Carignano from the second half of the 17th century. Another example is the Church of Vierzehnheiligen by German architect Balthasar Neumann from the 18^o century.

Francesco Borromini used stone as the main building material in the Church of San Carlo alle Quattro Fontane (ph. 1.). The façade of the church makes an impression of movement not only by the usage of an undulating line in the plane but also in cross-section. The irregularity of all levels of elevation⁵ creates a unique play of light and shade on the external wall, visible in curved elements.

Guarino Guarini in Palazzo Carignano (ph. 2.) presented a new aspect of the undulating wall which departs from the architectural thought of Borromini in terms of decorativeness and dynamism. Guarini's curvilinear façade, based on a baroque wavy line makes a less dynamic impression than San Carlo alle Quattro Fontane's elevation. The façade is made of static lines without any fracture. Palazzo Carignano is a free-standing building, designed on a square plan. It exceeds the size of the Church of Borromini.

The continuation of the Italians' ideas can be found in the Bavarian Church of Vierzehnheiligen by Balthasar Neumann. The undulating wall used in the central part of the façade emphasised the building's plasticity without showing the dynamism presented by Borromini. It can be perceived as a continuation of the work of Guarini but in a less impressive form.

The analyses of the examples show that in the Baroque the undulating wall resulted from a regular wavy line composed of segments of a circle with a different radius. The above examples show the different scales of the undulating façade, but its decorativeness and dynamic form, achieved by Borromini, did not receive a worthy successor. Both Guarini and Neumann presented a new concept of an undulating façade.

The undulating wall in the 20th century

The analysis of the examples from the 20th century starts with the Casa Mila by Antonio Gaudi. The Art Nouveau building was built between 1906–1910. Gaudi developed his idea of the undulating elements from Park Guell or Casa Batlló. His new masterpiece undulates not only in the cornices but also in the entire stone-made façade. Casa Mila expresses an organic movement (ph. 3.). The undulating wall motif required the develop-

⁵ Borromini used different amplitudes of the undulating line and additionally relocated each of three undulating elements of the façade.

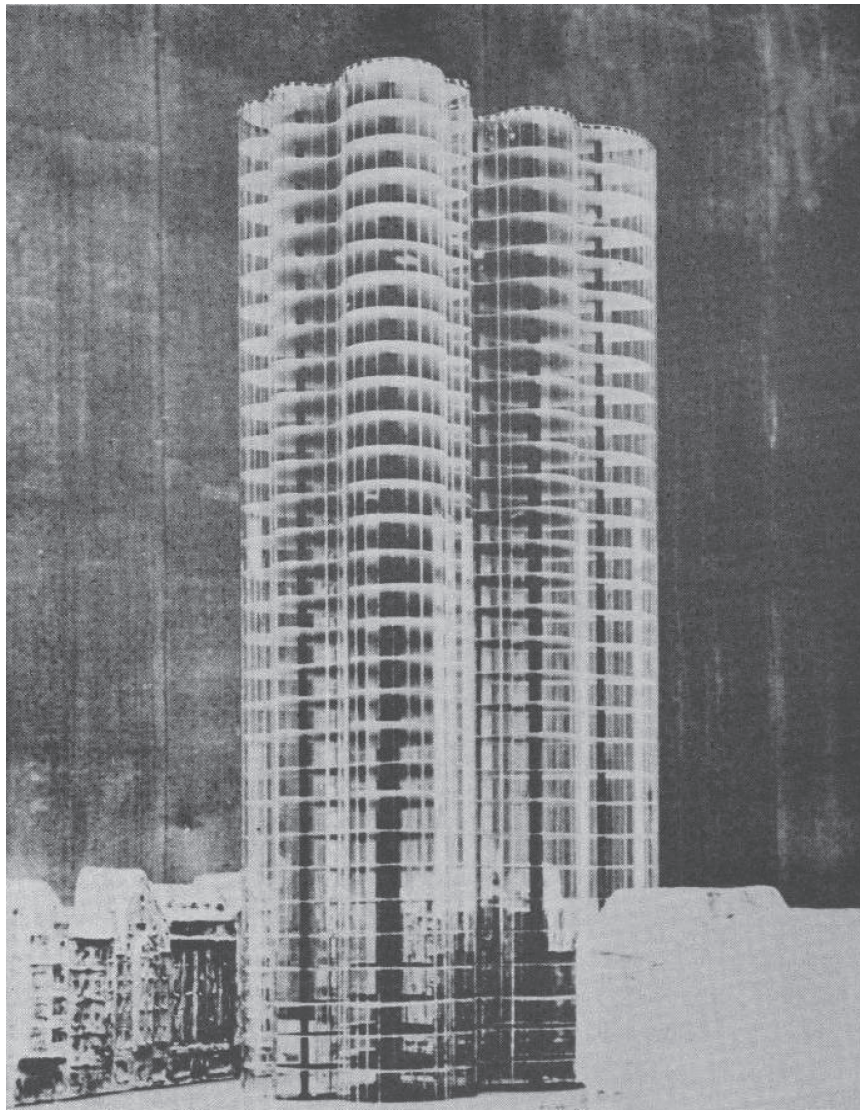
ment of the special building structure system based on the main building material – stone. This material was stripped of its sharp form in favour of delicate, rounded edges which created undulating surfaces. Innovative, on its scale and time, the work of the Spanish architect refers in its curvilinear form to the works of the Baroque. At the same time, Casa Mila showed the new design possibilities of its time and introduced a new type of wavy line, with a free character.

The next example of the continuation of the idea of the undulating wall in the 20th century is the Mies van der Rohe's concept of the two skyscrapers from 1919–1921. The first one, an office building located in Friedrichstrasse in Berlin from 1919, was supposed to be an expressive form inspired by the shape of a crystal. The other one, dating 1920–1921, represented the idea of the undulating wall which is visible in the plan of the building (ph. 4.). Philip C. Johnson, in "Mies van der Rohe", emphasised the influence of the technological progress in both projects by a German architect. The concept of the glass skyscraper was based on an irregular, undulating elevation (ph. 5.) and remains one of the rarest examples of expressionist architecture represented by van der Rohe. The architect stressed that the expressive geometry was influenced by three determinants: "sufficient illumination of the interior, the massing of the building viewed from the street, and lastly the play of reflections" [8]. What is more, the architect emphasised the idea of creating a free plan in which two staircases are the only constant element of the building. The project was a very innovative proposition. Mies van der Rohe's concept differentiates from the historical examples which is visible in the plan which is fully based on the undulating line. A concept is a dynamic form but the new type of wavy line is only visible in the plan of the building.

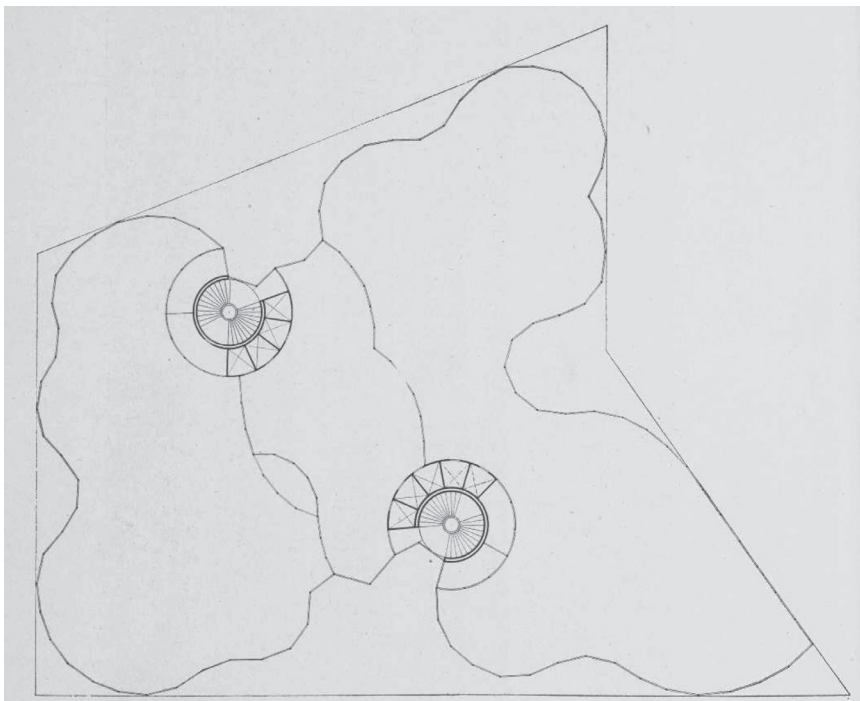
More than two decades later, in 1947, Alvar Aalto designed the Baker House dormitory⁶ (ph. 6.). The gently bent, undulating façade of the brick building was designed to provide a decent view of the river for every user. Proper lighting of the interior of the dormitory allowed avoiding "the atmosphere of an anthill, often felt in such buildings"⁷. Baker House is another example of simplifying the idea of the undulating wall. The façade of the building was made of three sections of a circle which were connected with rectangular elements. The main decoration of the dormitory is the construction material, which gives it plasticity.

⁶ Baker House is the continuation of Aalto's architectural thought from 1938 noticeable in the project of the Exhibition Pavilion for Forestry and Agriculture in Lapua. The plan of the building was inspired by the shape of the Finnish lakes. The Pavilion itself was made of tree trunks, which enhanced the organic character of the building, rooted in the Finnish landscape [9].

⁷ [3], p. 620.



Ph. 4. Glass Skyscraper, 1921 – 1922 – Mies van der Rohe [16]



Ph. 5. The plan of the the Glass Skyscraper, 1921 – 1922 – Mies van der Rohe [16]





Ph. 6. Baker House – M.I.T Student Dormitory – Alvar Aalto – Author: Gunnar Clark [17]

A novel approach to undulating façade was also evident in Eladio Dieste's Church of Christ the Worker (ph. 7.). The building was designed in 1952 and presents the original technology of reinforced brick walls, which were based on an undulating line visible in the outline of the building [10]. Additionally, the irregularity of the undulating walls was emphasised by the expansion of the elements upwards. Like all Dieste's designs, the church maintains a rational idea but also demonstrates the ability to manipulate the experience of space as well as to place an object in the context of a place. Dieste's architecture was described as a synthesis of Le Corbusier's rationalist thought with the fluidity of Gaudi's forms [11]. The church in Uruguay is one of the best examples of this. In 1993, Herzog & de Meuron architectural office won the competition for the project of

the new library in the university campus in Cottbus (ph. 8.). The authors described the concept as: "a solitary landmark within the surrounding urban architecture that would communicate the new spirit of the university and relate to the environment in many different ways" [12]. The library is a very characteristic element of the natural and urbanised surrounding. The authors emphasised that: "in fact, the building looks different from every avenue of approach and yet it remains a single continuous form, a flowing whole" [12].

The architects used the undulating line with the regular, geometric character, to create a very irregular plan of the building. The characteristic tendency from the 20th century can be found in this example. The undulating line is only used in the plan of the building and the form is a static composition that differentiates from Borromini's church. Technological and material progress allowed the architects to create a free plan where staircases and technical rooms are the only constant elements. The ameboid shape of the building is very similar to the concept by Mies van der Rohe from the beginning of the century. Both of the buildings are based on an irregular, free plan.

The evolution of the undulating wall, in the 20th century, was mainly determined by technological progress and the evolution of architectural thought. It can be seen in the kind of curved lines which were used in different buildings. Even though there are examples of regularly curved lines used in undulating elevations, the more common type of this line was the freely undulating one. However, in the 20th century, different determinants can also be found. Architects such as Alvar Aalto or Eladio Dieste did not concentrate only on the aesthetics and functionality of the building. The new determinants were human aspects – visible in the M.I.T building, regional aspect important for Dieste, or the landscape aspect – visible in the concept by Herzog & de Meu-

ron. The projects from the twentieth century are characteristic of the modernist thought what is manifested in the asceticism of the functional solutions. It stands in opposition to the baroque's aesthetics and decorativeness.

Comparative analysis

The analyses of selected, baroque, and 20th-century examples (fig. 1.) show the ideological, material, and constructional evolution of the undulating wall. The Baroque architecture was based primarily on a regular curved line, and architects of that time focused mainly on the decorative character of the façade and the decorative possibilities of the used building material. Borromini as the pioneer of the undulating wall façade in the Baroque [3], modeled an undulating, stone façade, and gave it the impression of movement and undulation in both vertical and horizontal planes. According to Sigfried Giedion, this motif was used again in the 18th century⁸. The pioneering character of Borromini's works, even on such a small scale as the Church of San Carlo alle Quattro Fontanne, turned into an attempt to further development the undulating wall motif for his successors. This evolution was visible in the design of Palazzo Carignano by Guarino Guarini.

⁸ Giedion recalled Lansdowne Crescent in Bath (1794), as an example of Borromini's idea of the undulating wall. [3], p. 186.



Ph. 7. Church of Christ the Worker - Eladio Dieste – Author: Andrés Franchi Ugartemendía [18]

Guarini's brick façade was more than three times bigger than the undulating wall of Borromini's church but no less decorative. Although, the impression of movement in the façade was much less noticeable. However, the usage of bricks to create sensual shapes may be the starting point for further development of the possibilities of this material, visible in the 20th century. The last baroque example is a work on a smaller scale. Balthasar Neumann used classical patterns and calms down the baroque dynamism presented by his predecessors.

Analyses of the 20th-century examples show the development of the undulating wall. The architects of that time often combined both types of curved lines defined by Kandinsky. In the 20th century, buildings were designed with the usage of both regular wavy lines and freely waving lines, which were strongly influenced by technological progress. Gaudi's building was a pioneering example of the usage of a free wavy line that sets the entire façade of a tenement house in motion. On the other hand, Mies van der Rohe's concept presented a modern approach to the dynamism of an undulating line, reaching for expressive values. Alvar Aalto – master of undulating elements in interiors or design, calmed down his characteristic motif⁹ in the Baker House. The dormitory's curvilinear façade was made of three parts of a circle, while the rest of the project consists of rectangular geometry. Eladio Dieste developed his technology which allowed him to design the undulating walls of the church based

on a regular but freely undulating line¹⁰. These elements widen upwards and are connected with the undulating roof which emphasizes the impression of dynamism visible in the form of church.

The last analysed example is the transformation of the thoughts of the predecessors. Prof. Tomasz Kozłowski in his considerations on expressionist architecture noted that architects from Herzog & de Meuron draw inspiration from both Alvaro Aalto and Mies van der Rohe and his unrealized glass skyscraper concept¹¹ [4]. The free form of the library was primarily based on an undulating line made of circular segments which stand in contrast to van der Rohe's concept. The design of the library closes the evolution of the undulating wall motif, which in the early baroque phase was mainly based on the circle sections used in one representative façade. In the Cottbus Library, the entire building is composed of circle sections, undulating in a calm rhythm. The Swiss project opens up a new perspective on the shaping and development of the undulating wall.

Summary

The analyses of the undulating buildings' façades show its evolution over the time of two epochs – the Baroque and 20th century, as well as the development of the basic line used by architects to create undulating walls.

The richly decorated, baroque buildings were based on a regular, undulating line and made of stone or brick. These two materials were used to give a building desired plasticity. The unusual decorativeness of the build-

ings was a characteristic element of its era. The undulating elements of the discussed examples resulted from the regular connection of the segments of a circle with a different radius. The baroque architects most frequently used the undulating wall in the main, most decorative elevation of the building. However, this tendency has changed in the 20th century and the undulating wall motif has evolved. Buildings designed in that time were entirely made of freely undulating lines. It can be observed at the very beginning of the 20th century, especially in Gaudi's works. Casa Mila's façade is completely made of undulating lines in contrary to the baroque buildings where the undulating wall was used only in the part of the building. However, the buildings by Mies van der Rohe, Eladio Dieste, and Herzog & de Meuron show the greatest capabilities of the freely undulating wall. The concept of a skyscraper on Friedrichstrasse was based on the undulating line which was closed in an organic outline of a building. This concept is the best example of the usage of the freely undulating line, which was based on a different amplitude of undulations. The other two projects were made of regular, undulating lines, but architects remoulded the original character of the undulating line. Eladio Dieste used

⁹ Aalto's undulating walls were typically rooted in the shape of Finnish lakes.

¹⁰ Irregular character of the undulating wall is visible both in the cross-section and photograph of Dieste's building.

¹¹ [3], p. 171.





Ph. 8 – Cottbus Library – Herzog & de Meuron – Photo by the Author

regular sections of a circle to create the form of his masterpiece. Simultaneously, the architect remoulded these elements into freely undulating exterior walls which additionally widen upwards to the roof. The architects from Herzog & de Meuron further developed the undulating wall motif which was inspired by the works of Mies van der Rohe or Alvar Aalto. The form and plan of the Cottbus Library are similar both to the Glass Skyscraper concept and the famous Savoy Vase. Its outline is made of segments of a circle, which are connected into an amoeboid shape. This project is the best example to summarise the development of the undulating wall, which in the beginning was just a fragment of a façade made of the undulating wall.

The development of the undulating wall is noticeable while comparing the baroque and 20th-century examples. Even though the 20th-century buildings do not have such rich detail and decorativeness in the facades, their forms reach a completely different expression than historical buildings. Additionally, the analyses of the undulating wall show the diversity in the usage of the motif. The undulating wall can be used as an open form, in the main façade of the building, which is visible in the Baroque. On the other hand, it can be a closed-form, just like in the projects from the end of the 20th century.

These tendencies result mainly from the development of architectural thought and technological progress. These aspects, together with new materials, allowed design-

ers to shape buildings based on the wavy line defined by Kandinsky but also to introduce a new, more free way of shaping architectural forms.

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Streszczenie: EWOLUCJA ŚCIANY FALUJĄCEJ. Ekspresyjne budynki o pofalowanej, krzywokształnej formie stały się jednym z wielu elementów charakterystycznych dla współczesnej architektury. Już w XX wieku widoczna jest fascynacja formami o swobodnym, falującym charakterze. Jednakże źródła motywów falujących sięgają aż do czasów barokowych, w których budynki o krzywokształnych elewacjach stanowiły naturalny rozwój myśli architektonicznej. Ewolucja tej idei nastąpiła na początku XX wieku i przez następne lata motyw linii falistej był używany przez wielu architektów, którzy korzystali z jej regularnego lub swobodnego charakteru. Za pomocą metody analityczno-interpretacyjnej autorzy opiszają ewolucję, jaką przeszła ściana falująca wykorzystująca linię krzywokształną zdefiniowaną przez Kandyńskiego. Analiza wybranych przykładów obrazuje ideologiczną, materiałową oraz konstrukcyjną ewolucję ściany falującej, a także sposób przetransformowania idei linii falistej, który wraca do swoich barokowych korzeni, ale w bardziej nowoczesnym wydaniu. **Słowa kluczowe:** ściana falująca, linia falista, teoria architektury, Kandyński, architektura XX wieku

Abstract: Expressive buildings based on curvilinear geometry became one of many characteristic elements of contemporary architecture. A fascination with irregular, undulating forms has already been visible in the 20th century. However, the sources of the undulating motifs go back to the Baroque period, when buildings with curved façades were one of the best examples of the natural development of architectural thought. The evolution of this idea took place at the beginning of the 20th century. In the following years, the motif of the undulating lines was used by many architects who draw upon its regular or free character. The Authors using the analytical and interpretative method show the evolution of the undulating wall. The Authors use the terms of curved lines defined by Kandinsky. The analysis of selected examples shows the ideological, material, and constructional evolution of the undulating wall, as well as the way of transforming the idea of the undulating line, which returns to its baroque roots, but in a more modern version.

Keywords: undulating wall, curve line, theory of architecture, Kandinsky, 20th-century architecture