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## PHYSIOGNOMY OF STAIRS

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#### Abstract

Stairs, as one of the most important means of expression, have been the subject of interest of architects since ancient times. Nowadays, thanks to the incredible development of technology, it is possible to materialize ideas and projects that previously remained only in the sphere of dreams. The mental meanings and symbolic connotations of the forms of stairs, constituting a continuum of space and a record of the flow of time, may escape assessment only in the perspective of their function and structure. The issues are presented on examples of stairs in historical buildings, as well as modern ones based on new materials and technologies. Regardless of the date of creation, the projects may surprise with their technical advancement, mobility, and sometimes even the possibility of dematerialization in space.

*Keywords: stairs, technology, health, modern materials and technologies*

#### Streszczenie

Schody, jako jeden z najważniejszych środków wyrazu, od czasów starożytnych były przedmiotem zainteresowania architektów. Współcześnie, dzięki niebywałemu rozwojowi techniki, możliwe jest zmaterializowanie idei i projektów wcześniej pozostających jedynie w sferze marzeń. Mentalne znaczenia i symboliczne konotacje form schodów, stanowiących kontinuum przestrzeni i zapisu przepływającego czasu, mogą wymykać się ocenie jedynie w perspektywie ich funkcji i konstrukcji. Problematykę przedstawiono na przykładach schodów w obiektach historycznych oraz nowoczesnych, bazujących na nowych materiałach i technologiach. Bez względu na metrykę powstania realizacje mogą zaskakiwać zaawansowaniem technicznym, mobilnością, a czasami wręcz możliwością dematerializacji w przestrzeni.

*Słowa kluczowe: schody, technika, zdrowie, nowoczesne materiały i technologie*

## 1. INTRODUCTION

Issues related to the ergonomics of stair design have been of interest of architectural theorists since ancient times. In the Renaissance, they were the area of study of Leon Battista Alberti, Andrea Palladio and Michelangelo. Apart from European culture, both in the Asian part and in the Americas, stairs were not only a technical issue, but were closely related to ritual, memory, and religion (Ill. 1). They were an inherent element of imagination and conceptual abilities present in literature and philosophy. Dante Alighieri in “The Divine Comedy” treats

stairs with incorrect proportions as one of the worst punishments of Hell. Similarly, Jorge Luis Borges sees an improperly designed stairs as one of his nightmares:

At first carefully, then indifferently, and finally desperately, I wandered along the stairs and sidewalk of the inseparable palace. I later learned that the width and height of the steps were not constant, which allowed me to understand the particular fatigue they caused.<sup>1</sup>



Ill. 1. The Sun Temple, Modhera, India, 1026–1027 CE, 2023, photo by P. Opalka.

The symbolic or metaphysical meanings and connotations of the forms of stairs, constituting a continuum of space and a record of the flow of time, may escape assessment only from the perspective of their function and structure. Juhani Pallasmaa in her essay *Stairways of mind* sees architecture as an existential metaphor in which “buildings relate us to the world in a particular way and redefine our being in the world, both in terms of space and time” and that “architecture makes the continuum space and the flow of time is conceivable for the human mind.”<sup>2</sup>

As an important element of shaping architectural space, they not only serve to overcome height differences, but also define in a specific way the way of moving around structures and buildings, as well as in districts and housing estates. They can be perceived not only as a spine connecting individual floors, but also as one of the elements providing a physical experience of contact with the matter of the object. Although the scale and form of stairs have evolved since ancient times, the proportions of the dimensions of steps at almost every latitude have oscillated around similar parameters ensuring comfort of movement.

<sup>1</sup> J.L. Borges, *Labyrinths: Selected stories & other writings*, New Directions, New York 1964, p. 113.

<sup>2</sup> J. Pallasmaa, *Encountres 1. Architectural essays*, Rekennustieto Publishing, Helsinki 2012, p. 60.

Contemporary stairs, like a number of other elements that create space, have been transformed. Nowadays, thanks to the incredible development of technology, it is possible to materialize ideas and projects that previously remained only in the sphere of dreams. There is therefore a chance to fill the space with important spiritual and emotional content. The issues in the article are presented on examples of stairs in historical and modern buildings, based on new materials and technologies, the implementation of which may elude not only technical regulations and standards. Regardless of the date of creation, the projects may surprise with their technical advancement, mobility, the possibility of dematerialization in space, an invitation to activity and improvement of health, and sometimes to contemplate a unique space.

## 2. DISAPPEARING STAIRS

Stairs in buildings may dematerialize. In the Glass House (*Maison de Verre*) in Paris, built in 1928–1932, according to the design of the outstanding Parisian architect and furniture designer Pierre Chareau on behalf of Dr. Jean Dalsace and his wife Annie, many innovative solutions were used. The building uses a unique rotating and balancing system for the stairs leading from the living room (*petit salon*) to Mrs. Dalsace’s bedroom on the upper floor. The facility uses a number of other clever solutions in which individual elements can be moved, folded or rotated almost like in a furniture box.



Ill. 2. Stairs with a hydraulically controlled roof, Schloßbergsteig castle, Graz, Austria, 2018, photo by P. Opalka.

Stairs in a historical space may remain neutral to the surroundings. On the Schloßbergsteig castle hill in Graz, the entrance to the underground part, where the theater is currently located, was made in the form of fixed stairs, which, however, remain available to spectators only when the roof above them is raised using hydraulic lifts. On a daily basis, the roof is lowered, creating a rectangular sculptural composition together with three skylights (Ill. 2).

An interesting proposal for a “disappearing staircase” was presented by Aaron Tang. These are single-flight stairs that, thanks to powerful hydraulic pistons, fold up against the

wall and at the same time disappear into the space of the room. Thanks to this solution, access to the upper floor is limited and space on the lower floor is freed up.<sup>3</sup>

### 3. STAIRS AS AN AUDIENCE

Contemporary external stairs, especially in public buildings, combine the functions of stairs with places intended for sitting. These are usually stairs oriented towards a viewpoint – an attractive object, building, square, water or courtyard space. Stairs are often made of a warm, pleasant-to-touch material such as wood, which, unlike stone, concrete, glass or ceramics, as a “slower” material, encourages not only to move slowly, but even to stop and rest.



Ill. 3. Combination of three types of external stairs, EYE Museum, Amsterdam, 2017, photo by P. Opalka.

The external stairs in front of the Eye Filmmuseum building in Amsterdam, designed by the Austrian architecture studio Delugan-Meissl, combine three types of stairs. They were made by varying the lengths of the treads, while maintaining the principles of ergonomics when the treads were several times longer (Ill. 3). The wooden external stairs at the Astrup Fearnley Museum by Renzo Piano, located at the end of the Aker Brygge waterfront in Oslo, encourage people to stop, rest and observe (Ill. 4). The stairs are crossed by a slightly rising sidewalk with an inclination that does not require the use of additional safety elements.

<sup>3</sup> Bianca, *Disappearing staircase: Steps fold into wall* [in:] Trendhunter, 12.11.2007, <https://www.trendhunter.com/trends/disappearing-staircase-wall-stair> (access: 30.05.2024).



Ill. 4. Wooden external stairs leading into the auditorium and connecting with the ramp, Astrup Fearnley Museet, Oslo, design: architect R. Piano, 2014, photo by P. Opalka.

#### 4. STAIRS AS A TOOL TO FIGHT OBESITY

Increasingly, changes in the perception of stairs also result from giving them other functions that may improve health. In 2013, Mayor Michael R. Bloomberg, Deputy Mayor Linda I. Gibbs, Department of Design and Construction Commissioner David Burney and Department of Health Commissioner Dr. Thomas A. Farley announced the creation of the first-ever Center for Active Design, the aim of which is to implement building regulations and design standards aimed primarily at counteracting obesity, as well as promoting physical activity in buildings and public spaces.<sup>4</sup> The program is a response to many years of promoting design solutions that excessively facilitate the movement of people in built spaces, as one of the causes of the obesity problem.<sup>5</sup> The initiative aims to look for design solutions, in particular stairs and staircases, to encourage movement, both in buildings and on the streets. Visible, easily accessible and attractive stairs with safe design solutions to promote movement were considered desirable.

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<sup>4</sup> *Mayor Bloomberg announces first ever Center for Active Design to promote physical activity and health in buildings and public spaces through building code and design standard changes* [in:] The Official Website of the City of New York, 17.07.2013, <http://www1.nyc.gov/office-of-the-mayor/news/250-13/mayor-bloomberg-first-ever-center-active-design-promote-physical-activity-and> (accessed: 30.05.2024).

<sup>5</sup> K.K. Lee et al., *Promoting Routine Stair Use: Evaluating the Impact of a Stair Prompt Across Buildings*, "American Journal of Preventive Medicine" 2012, no. 42(2), pp. 136–141. DOI: 10.1016/j.amepre.2011.10.005.



Ill. 5. Stairs open to the surrounding space: a – Vincent van Gogh Museum in Amsterdam, b – Dublin airport, 2015, photos by P. Opałka.



Ill. 6. Optical interference on the walls near the representative stairs, Philharmonic Hall in Szczecin, 2014, photo by P. Opałka.

Attractive open stairs may be an encouragement for pedestrians, but excessive opening of staircases to the surrounding space may cause unsteady movement of their users, especially if the stairs connect several or a dozen floors (Ill. 5). Stairs of this type cannot be treated as an escape route, but because the users of a given space perceive them as a familiar and fastest evacuation route in the event of danger, they can in fact be interpreted as such. Distraction or excessive concentration of users on the surroundings may cause traffic to stop and ultimately lead to undesirable events that may pose a threat to the health and life of users. Groups that are particularly at risk include people with physical dysfunctions (locomotive organs, motor dysfunctions, deformations of the locomotor organs), sensory dysfunctions (damage to the visual organs, damage to the hearing organs), mental dysfunctions (mental disorders, mental disabilities), as well as with complex disabilities.

Excessive glazing of balustrades and steps may cause anxiety in some users. The certainty of moving up the stairs may also be reduced by optical interference resulting from the finishing of treads, landings, balustrades and elements outside the stairs, e.g. walls (Ill. 6).

## 5. MODERN MATERIALS AND TECHNOLOGIES

The dynamic development of technologies related to materials science makes it possible to construct stairs with forms and physical parameters that have never been seen before. It seems like almost every year these boundaries are pushed further and further.

Concrete is a material that is subject to constant innovation. The construction of more durable and sophisticated stairs is possible thanks to the increasingly common use of High-Performance Concrete (HPC), Ultra High-Performance Concrete (UHPC), Compact Reinforced Composite (CRC), High Performance Lightweight Aggregate Concrete (HPLAC) or Textile Reinforced Concrete. Moreover, thanks to appropriate additives or coatings, concrete can be not only transparent to some extent (LiTraCon, Lucccon), flexible (e.g. Engineered Cementitious Composite) and porous, but also “self-repairing” or electrically conductive.

An innovative example of the use of UHPC concrete are ultra-thin stairs produced by ABT.<sup>6</sup> The stairs designed by the JHK Architekten studio are a kind of hybrid structure in which the materials working together – UHPC concrete and glass – create a durable structure (Ill. 7). Glass glued to concrete essentially increases the stiffness and strength of the entire structure. Thanks to this solution, a flight of stairs without additional supporting elements was obtained, almost 6 m long and only 5 cm thick! The four-times thinner thickness of the stairs required the use of an innovative casting process, ensuring precise compaction of the concrete mixture in a structure with a high reinforcement ratio. Special Si-X architectural glass with a “sawtooth” profile was attached to almost invisible steel strips with small cuts, screwed from the bottom to the reinforced concrete structure. Final strength tests showed above-average strength reserves. The project required close cooperation between glass specialists and concrete producers, both at the calculation, construction and execution stages.<sup>7</sup>

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<sup>6</sup> *Ultra-slim hybrid staircase* [in:] ABT Consulting engineers, <https://www.abt.eu/en/expertise/innovations/ultra-thin-hybrid-staircase.aspx> (access: 30.05.2024).

<sup>7</sup> P. Opalka, *Nowoczesne konstrukcje schodów* [in:] Ł. Drobiec (ed.), *Innowacyjne i współczesne rozwiązania w budownictwie: budownictwo ogólne. XXXIV Ogólnopolskie Warsztaty Pracy Projektanta Konstrukcji, Szczyrk, 5–8 marca 2019 roku*, vol. 1, Polski Związek Inżynierów i Techników Budownictwa. Oddział w Bielsku-Białej, Bielsko-Biała 2019, pp. 99–170.



Ill. 7. Slim and light hybrid stairs by ABT, made of UHPC concrete and Si-X architectural glass, source: *Ultra-slim hybrid staircase* [in:] ABT Consulting engineers, <https://www.abt.eu/en/expertise/innovations/ultra-thin-hybrid-staircase.aspx> (access: 30.05.2024).

A new element of staircases are their interactive functions, which change the way they are used so far. Interactive staircases use sensors to detect movement and trigger specific light or sound effects, which, based on feedback, can stimulate specific user behaviors that can influence specific elements of the space. Interactive features help increase physical activity. Lighting effects can be generated using lasers or LEDs. Creating complex sound effects can involve teams of audio specialists and industrial designers. Using interactive stairs forces users to be more focused, which usually reduces the risk of tripping, slipping or falling.<sup>8</sup> But can't distractions have the opposite effect?

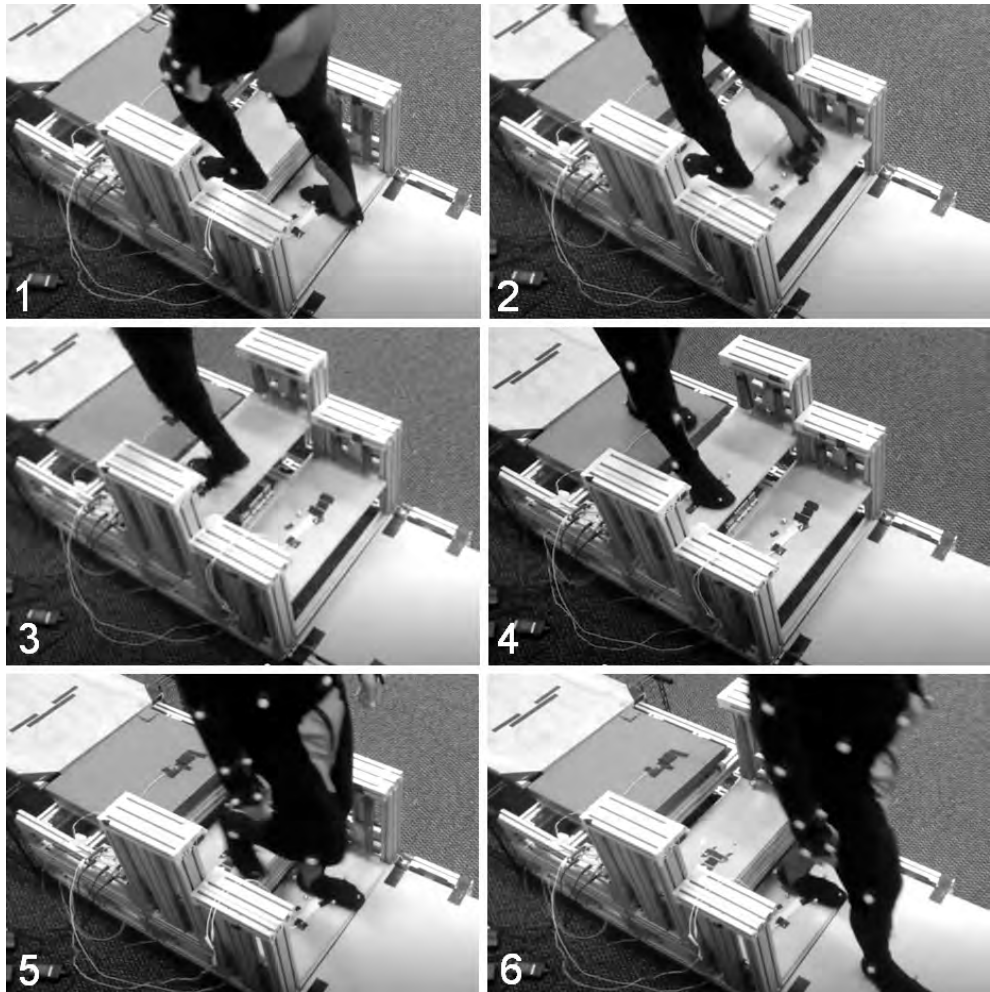
One of the most famous examples of interactive stairs is the “Piano Stairs” at the Odenplan metro station in Stockholm, which in 2009 were part of the Volkswagen Group project “The Fun Theory.”<sup>9</sup> The main goal of the project was to improve human behavior through play. The stair treads are designed in a form resembling a piano keyboard. Users could play musical sounds when entering or going down. Thanks to this approach, unusual stairs were chosen more often than the escalators located next to them. These stairs became an inspiration for many similar solutions. A staircase in the form of a “Piano Keyboard” was installed

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<sup>8</sup> K. Kim, E. Steinfeld, *The effects of interactive stairways on user behavior and safety* [in:] H. Caltenco et al. (eds.), *Universal Design 2014: Three days of creativity and diversity. Proceedings of the International Conference on Universal Design, UD 2014, Lund, Sweden, June 16–18, 2014*, IOS Press, Amsterdam 2017, pp. 157–167.

<sup>9</sup> *10 amazing piano stairs from around the world* [in:] CMUSE, 12.04.2024, <https://www.cmuse.org/10-amazing-piano-stairs-from-around-the-world> (access: 30.05.2024).

outside the metro station in Milan's Dome Square in 2010, also reproducing the sound of a real classical piano. Other playing stairs are located in Shangdu and Hangzhou in China, in Sao Paulo in Brazil and in Rennes in France.<sup>10</sup>



Ill. 8. Prototype of energy-accumulating stairs, source: S. Schrage, *De-icing concrete could improve roadway safety* [in:] *Nebraska Today*, 22.01.2016, <http://www.news.unl.edu/newsrooms/today/article/de-icing-concrete-could-improve-roadway-safety> (access: 30.05.2024).

The dangers posed by interactive stairs may be related to an excess of messages, too dynamic transmission of messages, optical merging of stair elements, creation of optical illusions, interference, and difficulty in reading messages and evacuation signs.<sup>11</sup> Measuring the lighting intensity in the staircase may be a problem. The current lack of regulations regarding

<sup>10</sup> P. Opalka, *op. cit.*

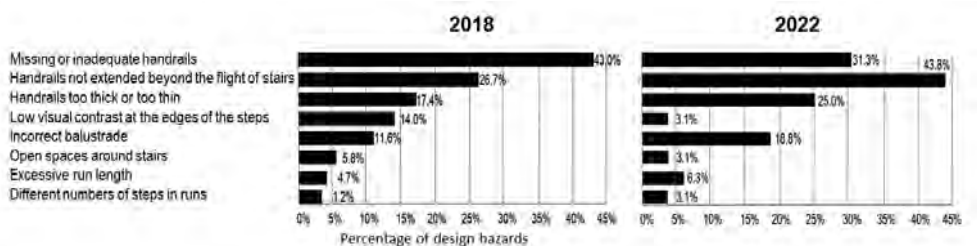
<sup>11</sup> K. Kim, E. Steinfeld, *An evaluation of stairway designs featured in Architectural Record between 2000 and 2012*. "International Journal of Architectural Research" 2016, no. 10(1), pp. 96–112.

the design, construction and acceptance of this type of stairs requires supplementation in this respect. Users of interactive stairs should also be familiar with new solutions, for example by learning the appropriate, standardized signs and messages.

Leny Ting, a professor of biomedical engineering at Emory University and an expert in human kinetics, together with Yun Seong Song, have developed a staircase prototype that could revolutionize the function of stairs.<sup>12</sup> Scientists have noticed that, contrary to intuition, people use more energy when going down stairs because their muscles use (waste) energy to maintain balance so as not to fall. The new staircase prototype accumulates energy while going down the stairs, and then when going up the stairs, the energy is released. Thanks to this, the person entering is much less tired. In the prototype stairs, each step is attached to springs. As you go down, the steps move down, compressing the springs and locking the step with an electromagnetic lock. Compressed springs “capture” and “hold” energy. On the way back, a pressure gauge on each step senses your foot, releasing the lock, and the springs release stored energy to aid in ascent (Ill. 8).

## 6. STAIRS SAFETY TEST

Interesting research into the design of contemporary, modern stair structures was conducted by Karen Kim and Edward Steinfeld.<sup>13</sup> The evaluation included photos of 578 stairs and staircases published over thirteen years (2000–2012) in the recognized scientific journal “Architectural Record”. Based on a checklist identifying the types and frequency of hazards, the stairs were classified from the most dangerous to the safest. The most common design errors were: non-uniform shape of the steps, making walking difficult and disturbing the walking rhythm; shaping the handrails in a way that prevented them from being firmly grasped with the hand; and designing the elements of the staircase in a way that was not very visible to users. The study should be considered valuable due to the fact that the research was limited to high-class facilities designed by renowned architects. Criteria that are ambiguous to verify, such as the assessment of staircase lighting, may raise objections.



Ill. 9. Frequency of threats related to the design of staircases in the surveyed sample of the monthly “Architektura-murator”, source: author’s work based on K. Kim, E. Steinfeld., *An evaluation of stairway designs featured in Architectural Record between 2000 and 2012*, “International Journal of Architectural Research” 2016, no. 10(1), pp. 96–112.

<sup>12</sup> S. Schrage, *De-icing concrete could improve roadway safety* [in:] Nebraska Today, 22.01.2016, <http://www.news.unl.edu/newsrooms/today/article/de-icing-concrete-could-improve-roadway-safety> (access: 30.05.2024).

<sup>13</sup> K. Kim, E. Steinfeld, *An evaluation...*, *op. cit.*, pp. 96–112.

Are stairs and staircases published in Polish architectural magazines safer? A review of photos of stairs and staircases published in the monthly “Architektura-murator” in 2018 and 2022 indicates a different scale and types of threats than in “Architectural Record”. In the study, due to the risk of too subjective assessment, half of the parameters assessed in the American study were omitted. Based on the analysis of iconographic material, a significantly lower percentage of potential threats that may be caused by improper or non-ergonomic design of stairs was found compared to other popular architectural and construction magazines (Ill. 9).

## 7. SUMMARY

A review of new designs and implementations of staircase and staircase structures indicates the priority of aesthetics. The ambitions of investors and architects become the driving force for creating unusual, often unrealistic, stairs. Electronic and traditional media, both professional and non-professional, when dealing with the topic of stairs compete with each other in presenting increasingly glazed or lighter staircases. At the same time, there is a disturbing tendency to marginalize aspects of safety and health. Many stairs and staircases are created either because people are unaware of the risks associated with their use or because they ignore good practice. At the same time, nowadays, for fire protection reasons, stairs are treated almost as one of the elements of technical infrastructure. All this definitely moves us away from thinking about stairs in symbolic and metaphysical categories.

Nevertheless, reflection on the departure from the original meaning of stairs in architecture more and more often finds examples of implementations referring to non-technical meanings. It's good that the motive may be, for example, to improve your health. It's good that thanks to modern research into new materials and new technologies, it is possible to implement projects that were previously only a dream.

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