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THE INTRIGUING STORY OF A CERTAIN STRUCTURE

INTRYGUJĄCA HISTORIA PEWNEJ STRUKTURY

A b s t r a c t

Tensegrity structures are attracting the interest of constructors, architects artists and scientists in many fields of science. The spatial constructions are made of rods and tendons, in which mutual stabilization of the stretched and compressed elements delight in lightness and subtlety of structural elements. *Islands of compression in an ocean of tension.* Spatial sculptures, or perhaps architectural spatial structures that give the impression of magical objects? Spatial structures floating in the air that are not affected by the force of gravity. The story of their creation and the creation of the theory of them is the essence of the questions – rationalist or intuitive way to architecture?

Keywords: architecture, geometry, structure, tensegrity

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

Struktury tensegrity wzbudzają zainteresowanie konstruktorów, architektów, artystów i naukowców wielu dziedzin nauki. Przestrzenne konstrukcje zbudowane z prętów i cięgien, w których następuje wzajemna stabilizacja części rozciąganych i ściskanych, zachwycają lekkością i subtelnością elementów konstrukcyjnych. *Wyspy ściskania wśród oceanu rozciągania*. Przestrzenne rzeźby czy może architektoniczne struktury przestrzenne sprawiające wrażenie obiektów magicznych, struktur przestrzennych unoszących się w powietrzu, na które nie oddziałują siły grawitacji? Historia ich powstania i tworzenia ich teorii stanowi istotę pytania – racjonalistyczna czy intuicyjna droga do architektury?

Słowa kluczowe: architektura, geometria, struktura, tensegrity

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1. Tensegrity structures

Tensegrity structures built of rigid elements, most often rods, and elastic elements, tendons create openwork, light spatial structures whose construction seems to contradict the laws of gravity. They delight, fascinate and intrigue as "impossible"spatial structures, escaping rational reasoning and definition. Objects such as the Needle Tower in Washington (USA, arch. Kenneth Duane Snelson[1], 1968) or Kurlipa Bridge in Brisbane (Australia, arch. Cox Rayner Architects, 2009) amaze and arouse interest of the recipients and users of Architecture[2]. For creators, they are a challenge and often-desirable work that they would like to have in their accomplishments.

According to Richard Buckminster Fuller[3], tensegrity structures can be described as *islands of compression in an ocean of tension*[4]; David Georges Emmerich[5] described them as *self-tensile structures composed of rods and tendons assembled in such a way that the rods remain isolated in the materially continuous set of tendons*[6]; Anthony Pugh defines tensegrity systems as *a discontinuous set of compressed components interacting with a continuous set of tensile components, defining a stable volume in space*[7]; Rene Motro describes them as *systems in a stable state of equilibrium established by a discontinuous set of compression components located within a continuous collection of tension components*[8]. According to Rene Motro tensegrity structures are the spatial structures for the future[9].

2. Tensegrity – a brief history of the idea

The concept of tensegrity is usually associated with the three authors Richard B. Fuller, Kenneth D. Snelson and David G. Emmerich. The first patent regarding the idea of tensegrity, tensional integrity, was reported in 1962 by Richard B. Fuller. In 1964 and 1965 David G. Emmerich and Kenneth D. Snelson reported their patents related to the concept of structure. But in fact, the genesis of tensegrity spatial structures is not derived from the patents and theories developed, but rather from creative spatial activities and the construction of models.

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1 Kenneth Duane Snelson (b. 1927, d. 2016) – american sculptor and photographer. His sculptural works are spatial realizations of tensegrity structures.

2 M. Sroka-Bizoń, P. Polinceusz, *Tensegrity structures – the idea and realization*, Proceedings of the Slovak-Czech Conference on Geometry and Graphics 2017, Bratislava, Slovakia, p. 144.

3 Richard Buckminster Fuller (b. 1895, d. 1983) – American architect, system theoretician, designer and inventor. R. B. Fuller was e.g. a promoter of the geodesy dome concept.

4 V. G. Jauregui, *Tensegrity Structure and their Application to Architecture*, School of Architecture, Queen's University Belfast, September 2004, p. 37.

5 David Georges Emmerich (b. 1925, d. 1996) – french architect, designer and scientist, author of the concept of self-stretching structures.

6 G. D. Emmerich, *Emmerich on Self-Tensioning Structures*, International Journal of Space Structures vol. 11, 1996, p. 29.

7 A. Pugh, *An introduction to tensegrity*, University of California Press, Berkley and Los Angeles, California, 1976, p. 3.

8 G. Tibert, *Deployable Tensegrity Structures for Space Applications*, doctoral thesis, Stockholm, 2002, Royal Institute of Technology, Department of Mechanics, p. 2.

9 R. Motro, *Tensegrity. Structural Systems for the Future*, Kogan Page Limited, 2003.

The calendar of significant events related to the development of the tensegrity structure concept, in the author's opinion, includes the following "milestones":

1921 – at the second exhibition of the "Society of Young Artists" organized in Moscow, the Latvian artist Karl Ioganson[10] presents "self-stretching structures" (Study in Balance), which by some architectural historians are considered to be prototypes of tensegrity systems. The exhibition is visited by a Hungarian painter, photographer, designer Laszlo Moholy-Nagy[11].

1923 – Laszlo Moholy-Nagy and Josef Albers[12] become professors conducting an entrance course at the Bauhaus. Laszlo Moholy-Nagy also runs Metal Workshops, and Josef Albers the Workshop on Wooden Structures.

1929 – Laszlo Moholy-Nagy publishes a textbook entitled *Von Material zu Architektur*, for Bauhaus students. The book includes, among others, photos from the Moscow exhibition of young constructivists, including photographs of Karl Ioganson's works[13]. The publication influences young European artists, including David G. Emmerich, who in his later works recalls the works of Karl Ioganson, which he learned of thanks to that[14].

1933 – The Bauhaus is closed, the university professors largely emigrate from Germany, among them Anni and Josef Albers, who will take over the post of art professor at the newly

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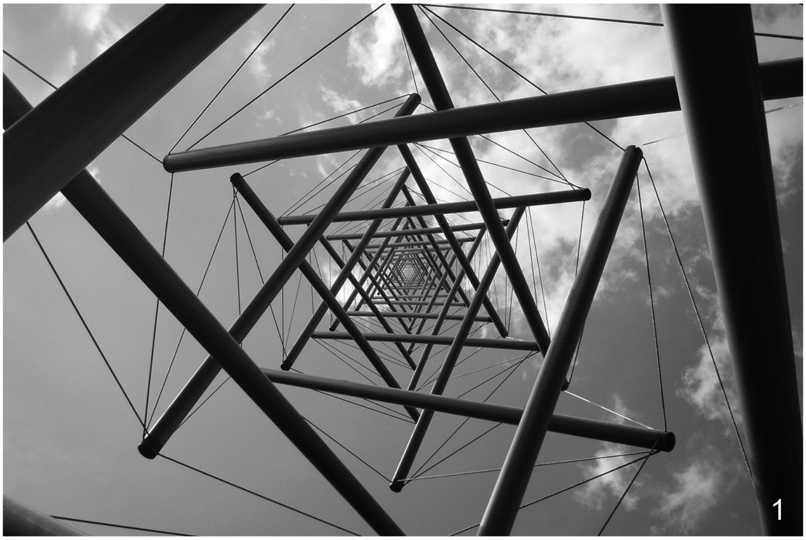
[10] Karl Ioganson (b. 1892, d. 1929) – avant-garde latvian artist belonging to the group of constructivists. Some researchers refer him referred to as a precursor in the construction of tensegrity structures; [in:] M. Gough, *In the Laboratory of Constructivism: Karl Ioganson's Cold Structures*, October, vol. 84, Spring 1998, p. 90–117.

[11] Laszlo Moholy-Nagy (b. 1895, died 1946) – hungarian painter, photographer, designer, professor of Bauhaus, one of the leading creators in the field of constructivism. His most famous work is the *Modulator of light and space* – a complicated mechanism moved by electric motors, equipped with reflectors, which through rasters and filters enables the creation of light presentations. Laszlo Moholy-Nagy's publications interact with other artists – photos from the exhibition of Soviet constructivists, held in 1920, in Moscow, posted in the book *Von Material zu Architektur*, 1929 are noticed, among others, by young Georges David Emmerich. In 1923, Laszlo Moholy-Nagy and Josef Albers became professors conducting an entrance course at the Bauhaus. Moholy-Nagy also runs Metal Workshops. After leaving Bauhaus in 1928, Moholy-Nagy establishes his own design studio in Berlin. In 1934, Laszlo Moholy-Nagy leaves Germany. He continues his creative activity in the Netherlands (in Amsterdam) and the United Kingdom (in London). In 1937, he left for the United States of America, with the recommendation of Walter Gropius, he became the director of the New Bauhaus in Chicago. After closing, due to financial problems, the New Bauhaus college in 1938, Moholy-Nagy opens the School of Design, which in 1944 is transformed into the Institute of Design, which in 1949 was part of the Illinois Institute of Technology, the first a research institution in the United States that has the right to grant a PhD in design; [in:] W. Baraniewski, *Nowa sztuka dla nowego człowieka*, Sztuka Świata, tom 9, Wydawnictwo Arkady 1996, p. 115–136

[12] Josef Albers (b. 1888, d. 1976) – american artist, art theorist and university teacher of German origin. He came from the Bauhaus school, where he learned and worked as a lecturer. In 1933 he emigrated from Germany to the United States of America, where he lectured at Black Mountain College and at the Yale University. He was one of the most influential American colour educators in the second half of the twentieth century. During his work at Yale in 1950, he began working on his most famous series of works entitled Homage to the Square; [in:] D. Homung, *Kolor. Kurs dla artystów i projektantów*, Universitas, Kraków 2009, p. 69.

[13] L. Moholy-Nagy, *Von Material zu Architektur*, München 1929, p. 132–133; https://doi.org/10.11588/diglit.29204#0116.

[14] R. Motro, *Tensegrity. Structural Systems for the Future*, Kogan Page Limited, 2003.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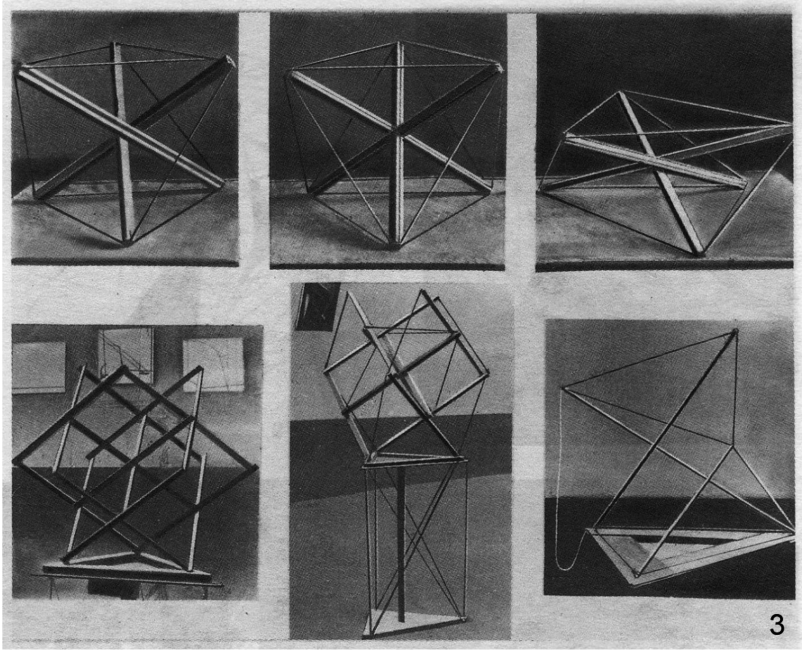
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established art school of Black Mountain College, North Carolina in the United States of America.

1948 – Art student Kenneth D. Snelson develops the X installation.

1951 – Richard B. Fuller publishes a photo of the structure constructed by Kenneth D. Snelson in the *Architectural Forum*, and the *Skylon* installation of the authors Philip Powel and Hidalgo Moyi is created in London as part of the Vertical Feature competition.

1959 – Richard B. Fuller's exhibition takes place at the Museum of Modern Art (*MOMA*) in New York as part of which the tensegrity structure is presented. Thanks to the efforts undertaken by Kenneth D. Snelson, his authorial participation in the work on structures of this type is noted in the description of the exhibition.

1962 – Richard B. Fuller obtains a patent for the structure of *Tensile – Integrity*.

1964 – David G. Emmerich obtains a patent for *Construction de reseaux atotendants*.

1964 – David G. Emmerich obtains a patent for *Structures lineaires autotendants*.

1965 – Kenneth D. Snelson obtains a patent for *Continuous Tension, discontinuous compression structures*.

2.1. Black Mountain College

In the summer of 1948, a second year student of the art department, Kenneth D. Snelson, resigning from summer holidays, took part in a summer course organized at Black Mountain College, North Carolina, USA. The university was established in 1933 and was an extremely innovative art school, which was significantly different from other American universities of this type. The idea of the university was born out of the desire to create a new type of college based on the principles of progressive education of John Dewey[15]. In this aspect, it was an extremely innovative art school, which was significantly different from other American

[15] John Dewey (b. 1859, d. 1952) – american philosopher, educator, leading representative of American progressivism. He was the creator of the concept of a *school of work* (1896–1902) in Chicago. J. Dewey based his pedagogical system on instrumentalism, the direction of pragmatism. He relied on the meaning of the experience as being the truth – the real thing is what works in action as true. Experience is a source of acquiring and verifying knowledge, hence the following slogan was developed in his school of work: learning through action. The main goal of the school was to stimulate the innate abilities of students, interests, enrichment of experiences, independent work, while knowledge was gained in a way "on the occasion".

Ill. 1. Needle Tower II designed by Kenneth D. Snelson, Otterlo, Holland, 1969,
Source: https://commons.wikimedia.org/wiki/File:Kenneth_Snelson_Needle_Tower.JPG, author: Onderwijsgek

Ill. 2. Kurlipa Bridge designed by arch. Cox Rayner Architects, Brisbane, Australia, 2009
Source: https://upload.wikimedia.org/wikipedia/commons/d/dd/KurilpaBridge1.JPG
author: Paul Guard

Ill. 3. Self-streching structures designed by Karl Ioganson, the second exhibition of the "Society of Young Artists", Moscow, 1921
Source: Moholy-Nagy L., Von Material zu Architektur, Monachium, 1929, p. 133; https://doi.org/10.11588/diglit.29204#0116

universities of this type. All members of the university community took part in all works related to the university's activity – in design and construction works, in cleaning works, and even in kitchen work related to preparing meals in the canteen. The time of founding Black Mountain College coincided with the closure of Bauhaus in Germany. Many German university professors emigrated from Nazi Germany to the United States of America, seeking opportunities to continue their scientific and creative activities beyond the Atlantic Ocean. Among them were Anni Albers and Josef Albers, two of the first professors of art at Black Mountain College from 1933. Among the college professors was also Walter Gropius himself. The desire to participate in the lectures of Josef Albers was the main cause for Kenneth D. Snelson, which prompted him to resign from summer holidays. Josef Albers was a professor of art at Black Mountain College, but he also taught spatial design. Two weeks after the beginning of the course, Richard Buckminster Fuller joined the group of lecturers. He was to replace the professor of architecture, who unexpectedly, just before the summer course started, resigned from conducting classes. Kenneth D. Snelson, asked by Professor Josef Albers, assisted Richard B. Fuller in preparing geometric models for Fuller's lectures.

2.2. Spatial structures in the bauhaus spirit

Kenneth D. Snelson describes his own "discovery" of tensegrity as a result of "play" with moving spatial structures. After finishing the course K. D. Snelson returned to his home in Pedlenton, Oregon, fascinated by the ideas presented by Josef Albers and Richard B. Fuller during their lectures. In the autumn of 1948, the young artist passed on the construction of spatial installations, whose inspiration he sought in both lectures by Albers and Fuller. As he relates in his letters, Professor Josef Albers assessed him as a student distinguished by his special talents in the field of construction of spatial installations.

A young creator, uncertain about the choice of artistic direction of education, he saw his educational opportunities as part of a technical university and the winter semester of the 1948/49 academic year he devoted to studying engineering at Oregon State College. The experience gained during the semester in the study of technical sciences confirmed his conviction that this field of education was not in the sphere of his interests. He presented his hesitations and dilemmas related to the choice of further education by letter to Richard B. Fuller. He also sent him photos of the sculptures he made – spatial structures, including the structure titled "X" by the author. The "X" model of Kenneth D. Snelson aroused the huge interest of R. B. Fuller, whose hitherto existing set of spatial models did not include structures with tension elements. The interest in spatial structures built by Kenneth D. Snelson resulted in the publications of Richard B. Fuller regarding tensegrity, (*Synergetics* 1955 and *Tensegrity* 1961), and even his patents describing tensegrity structures. Despite the fact that he did not construct any structure model himself, he based only on the models constructed by Kanneth D. Snelson, his student. This was an example of a particularly understood cooperation, because Richard B. Fuller in his publications did not mention Kenneth D. Snelson as the author of spatial models being an inspiration to formulate the theory.

Independently from the two American researchers of spatial structures, in Paris, David G. Emmerich, in 1958 he constructs the first structures built of rods and tendons. In their description, reference is made to the work of the Soviet constructivists presented in the 1929 book by Laszlo Moholy-Nagy entitled *Von Material zu Architektur*. In this publication he finds a work entitled Study in Balance (authored by Karl Ioganson), which becomes for him the basis for his own research on spatial – bar – tension structures. He constructs and describes models of structures, and in 1964, he reports patents regarding constructions and self-tensioning structures (*Construction de reseaux atotendants, Structures lineaires autotendants*).

According to Kenneth D. Snelson, he did not come across the works of Karl Ioganson during his research on tensegrity spatial structures. But one can assume that by participating in the lectures of Josef Albers on spatial design, he had the opportunity to learn about the constructivist ideas presented to Bauhaus students, including the textbook Von Material zu Architektur, by Laszlo Moholy-Nagy, a close associate of Josef Albers during their activities conducted in Weimar.

3. The rationalist or intuitive way to architecture

The controversies associated with the authorship of the tensegrity concept are constantly present in the scientific discourse and have resulted in numerous publications regarding this issue[16]. Undoubtedly, each of the three tensegrity's artists commonly referred to made their unquestionable contribution to the research, development and dissemination of ideas. Kenneth D. Snelson built spatial structures fascinated by the idea, David G. Emmerich, by building his own models of spatial structures, studied and analyzed the work of other authors, Richard B. Fuller described and disseminated the tensegrity term, thus inspiring subsequent researchers and creators to continue work on tensegrity structures. The young, avant-garde Latvian constructivist, Karl Ioganson, seems to be the great absentee among the well-known creators of the tensegrity concept. The creator who described his own creative process in the following way *from painting to sculpture, from sculpture to construction, from construction to technology and inventiveness – this is the path I have chosen, which will probably prove to be the ultimate goal of every revolutionary artist*. But his absence among the tensegrity creators is in fact illusory. The ideas of constructivism, which he represented in his work, were disseminated through the publication of his works[17]. And through the creative power of teachers such as Laszlo Moholy-Nagy and Josef Albers, these ideas exerted an amazing influence on young art and architecture adepts who often did not know the name of the revolutionary constructor, Karl Joganson. This was the case with Kenneth D. Snelson[18].

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[16] These controversies are described by the authors: Bieniek Z., *Shaping of modular tensegrity structures*, 8th World Congress on Computational Mechanics, June 30 – July 5, 2008, Venice Italy; Jauregui V. G., *Tensegrity Structure and their Application to Architecture*, School of Architecture, Queen's University Belfast, September 2004; R. Motro, *Tensegrity. Structural Systems for the Future*. Kogan Page Limited, 2003; M. Sroka-Bizoń, P. Polinceusz, *Tensegrity structures – the idea and realization*, Proceedings of the Slovak-Czech Conference on Geometry and Graphics 2017, Bratislava, Slovakia, p. 144; C. Sultan, *Tensegrity Structures: Sixty Years of Art, Science and Engineering*, Aerospace and Ocena Engineering Department, Virginia Polytechnic Institute and State University, December 2006, p. 2–5.

[17] This issue was described by Laszlo Moholy-Nagy (L. Moholy-Nagy, *Von material zu Architektur*, Monachium, 1929, p. 132–133) and Rene Motro (Motro R., *Tensegrity. Structural Systems for the Future*, Kogan Page Limited, 2003).

[18] In his correspondence with other researchers of Tensegrity structures, Kenneth D. Snelson mentions this – V. G. Jauregui, Tensegrity Structure and their Application to Architecture, School of Architecture, Queen's University Belfast, September 2004, p. 38.

The creative path of Kenneth D. Snelson can be described as intuitive, but he referred to himself as a sculptor, not an architect. His talent in the construction of spatial structures and interest caused by ideas presented during lectures at Black Mountain College (so, however, a little *ratio* on the creative path can be pointed), have become a contribution to such objects as: Needle Tower in Washington (USA), Needle Tower II in Otterlo (Holland) or Easy Landing in Balitimore.

The path of David G. Emmerich, architect and scientist, perhaps seems more rational than Kenneth D. Snelson. His works are mainly scientific publications, patents. But they arose as a result of empirical studies, the creation of physical models of spatial structures and the study of these.

Richard B. Fuller's path is definitely rational, the adoption of which resulted in a number of publications and the amazing popularization of the tensegrity idea. Richard B. Fuller himself did not build any tensegrity structure, but he saw the intellectual potential inherent in the spatial structure and built its beautiful theory. And as an extremely talented science promoter, a real "dream seller" in this area, he continues to inspire more researchers and developers dreaming about building magical structures, spatial structures floating in the air, which are not affected by the force of gravity[19].

The words of Cornel Sultan testify to the power of this "beautiful theory" – *interest in these fascinating sculptures slowly moves from an intuitive, inspiring world of art to a systematic and rigorous world of science, the world of science and engineering*[20].

Cornel Sultan also indirectly answers the question regarding the intuitive or rational way to architecture? Architecture located on the borderline between art and exact sciences, the creation of which is based **simultaneously** on intuition and rationality.

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[19] About such inspirations are writing N. Veuve, S. D. Safaei, I. F. C. Smith, Deployment of tensegrity footbridge, Journal of Structural Engineering, 141 (11).

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[14] https://www.bauhaus100.de/en/past/people/masters/laszlo-moholy-nagy/.