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THE ART OF CONSTRUCTION WOOD – STONE – IRON – CONCRETE – STRUCTURAL CONCRETE

SZTUKA KONSTRUOWANIA DREWNO – KAMIEŃ – ŻELAZO – BETON – STRUKTURALNY BETON

Abstract

Invented in Assyria, known as Roman concrete during the Roman Empire, concrete was also used in the early Middle Ages. The people behind the 19th century Industrial Revolution took up the idea of using iron and transmutation of concrete as an interpretation of a new form of art. Its latest manifestations include large span bridges, thin-walled coverings, large structures reaching up to several hundred meters. How can one judge the beauty of the engineering structure? Today the questions posed are: How to preserve concrete constructions? While starting a new work today, we want to give the world's most common building material the mysterious power that creates the foundations of the new "wonderful world of concrete". The dream of the transmutation of matterstill inspires minds. The famous 12 principles still give rise to the reflection among contemporary chemists and authors of structural art. The integration of forms and colours of construction materials with nature reveals unexpected associations of arch-holism; it is also linked to the future of the transmutation of structural art integrated with nature – the mother of science and wisdom.

Keywords: concrete architecture, transmutations of structural art

Streszczenie

Wynaleziony w Asyrii beton nazwany w okresie cesarstwa rzymskiego betonem rzymskim, miał zastosowanie w czasach wczesnego średniowiecza. Twórcy XIX w. po Rewolucji Przemysłowej podjęli myśl zastosowania żelaza i transmutacji betonu będącego wykładnią nowej formy sztuki. Jej najnowsze przejawy to mosty dużych rozpiętości, cienkościenne przekrycia, wielkie budowle sięgające kilkuset metrów. Czym jest struktura architektonicznej przestrzeni? Jak oceniać piękno inżynierskiej struktury? Dziś rozpoczynając nowe dzieło, pragniemy nadać najpowszechniejszemu materiałowi budowlanemu na świecie tajemniczą siłę, tworzącą zręby nowego „cudownego świata betonu". Marzenie o transmutacji materii wciąż rozpala umysły. Sławne 12 zasad nadal budzi refleksję obecnych chemików i autorów sztuki konstruowania. Integracja form i kolorytu materiałów konstrukcyjnych z naturą ukazuje nie-

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oczekiwane skojarzenia arcyholizmu, ma także związki z przyszłością transmutacji sztuki konstruowania zintegrowanej z naturą – matką nauki i mądrości.

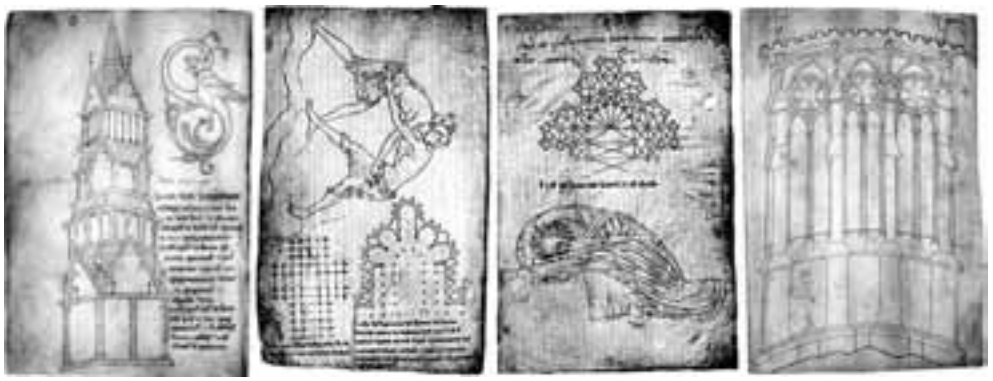
Słowa kluczowe: architektura betonowa, transmutacje sztuki konstruowania

While talking about the art of construction, in our mind's eye, we see the prehistoric megalithic buildings, megara made of clay and Babylonian mud, bound with shoots of branches and leaves from savannah grasslands, constructed from wooden logs requiring a chisel and a biface, made of rock rubble padding communication trails and defence fortification systems. The advanced engineering of roads, bridges, and concrete buildings enabled the construction of a two-wheeled araba – a cart drawn by oxen used for carrying heavy loads with wheels made of concrete or asphalt cement. (ill. 1). The eyes wander towards cellae with statues of deities, Assyria and Cicilia, towards the tops of ziggurats made of sun-dried mud-bricks, they lead us to the view of the mighty pyramids of ancient Egypt and the openwork fronts of archaic and classical Greek temples. Invented in Assyria, known as Roman concrete during the Roman Empire, concrete was also used in the early Middle Ages. It allowed one to create spatial structures made of bricks and large stones bonded with firm concrete mortar, iron anchors, it enabled to arch domes of the oldest temples and structures with plates of tuff rocks, and to erect spatial constructions of thermae, baths and aqueducts.

Ill. 1. A head of a women, polychrome concrete, 1300–1250 BC, Acropolis Museum Mycenae; An araba on massive wheels in Nimrud pulled by hundreds of people; The oldest known Egyptian ivory sculpture, the Predynastic period, Naqada I / Naqada II, 3750–3550 BC; Source: www.google.pl

Although this technology was forgotten in the Middle Ages, the possibilities of carved stone lace-work brought the unexpected effects to the European Gothic art. Awareness of beauty began to demand the sublimity of architecture. The building took on the shape of a structure that gave a new significance for combining aesthetic experience with the function and idea of the developed Middle Ages. The old bulky, stocky, stone-filled monastic temples and monastic communities gave way to the churches of early Gothic. An example is the stone Cathedral of Notre-Dame in Reims, the total floor area 6 650 m², tower height 81.50 m, southern rose window diameter 9.65 m, transept width 30.70 m, western façade width 48.80 m. The work of Jean d'Orbais began between 1211 and 1221 with the construction of the first level of the choir adapted to the ambulatory running around the chancel. It was here that Bishop Saint Remi

baptized Clovis I in 486, who defeated the Roman general Syagrius at Soissons, united all the Frankish kingdoms, conquered the kingdom of Toulouse and most of the Roman Gaul. Paris, Soissons, Reims, Metz and Orléans became the main residences. Today, the cathedral's powerful arches support intersections of the axes of a transept and extensive 50 m long and 15 m wide nave, rising up to 38 m high, opening the interiors of ornamented towers and high lanterns.



Ill. 2 Structure of the Gothic building, a page from Villard de Honnecourt's sketchbook. Source: www.google.pl

Villard de Honnecourt (born *c.* 1200) regularly visited the site, sketching in his album the fragments that began to appear after the laying of the cornerstone by Archbishop Aubrey de Humbert (ill. 2, 3). The north-eastern tower was erected in 1460. The pivotal point of the cross space, where the chancel, nave and transepts converged, was destroyed by the fire on July 24, 1481. This required the development of a bows system so that each arm of the church could be well supported. A few years later, in 1485, the erection of the Angel Tower ended the construction of the cathedral.

During the French Revolution, the rood screen and stained glass windows were destroyed. On October 19, 1914, the cathedral was heavily bombed. By 1918, it was damaged by 300 bombs. In 1926 Henri Deneux undertakes the reconstruction of the rose window tracery, using concrete. The end of the reconstruction of the majestic structure of the cathedral in Reims took place in 1996, when Pope John Paul II visited it on the 1500th anniversary of the baptism of Clovis I by Bishop Saint Remi.

Over the centuries, in the periods of Renaissance, Mannerism, Baroque and Classicism, larger and larger sacral buildings, castles, residences and palace complexes began to emerge, closing the technical capabilities developed in the Quattrocento era by Filippo Brunelleschi, Leonardo da Vinci, Michelangelo and others. After years, the people behind the 19th century Industrial Revolution took up the idea of using iron and transmutation of concrete as an interpretation of a new form of art. Among them, there were Joseph-Luis Lembot, Joseph Monier, and Maksymilian Thullie in Poland[1] (ill. 4).

[1] Maximilian Thullie, professor of Lviv Polytechnic, conducted research on reinforced concrete, built an experimental reinforced concrete footbridge in 1894.

Ill. 3. Notre-Dame Cathedral in Reims – Saint Remigius Bishop Saint Remi before 533 baptizes Clovis I, king of the Franks of the Merovingian dynasty. Source: www.google.pl

Its latest manifestations include large span bridges, thin-walled coverings, large structures reaching up to several hundred meters. Eminent scholars of our school, Professor Roman Ciesielski, Kazimierz Flaga and others, also devoted their lives to this issue.

The history of the building shows us the contemporary aesthetics of suspension bridges in Chicago and New York, the latest examples of the great buildings of the world in Hamburg, in the Austrian Tyrol, the Museum of European and Mediterranean Civilisations in Marseille, unprecedented shapes, structural characteristics and working forces. Their precursors are classic spatial structures, such as the Washington Monument, the Eiffel Tower, the Gateway Arch in St Louis, the Fourth Bridge, the Brooklyn Bridge, as well as the metal forms of the British and American creators, including Telford, Brunel, Eads and John Augustus Roebling.

The beginnings of reinforced concrete date back to first innovative forms of bridges and shell constructions. These are the works by Maillart, Mann, Maillart and Isler. The efforts of Freyssinet, Finsterwalder and Leonhardt constitute the beginnings of prestressed concrete. Structural concrete structures are the most typical examples from around the world, including Warsaw (ill. 4, 5).

Since the time of Viollet-le-Duc, conservators and restorers of works of art and historical monuments benefit from the boon of new materials while making repairs, reconstruction and restoration works. They turn to helpful constructions made of concrete and reinforced concrete. What is the structure of architectural space? How can one judge the beauty of the engineering structure? Today the questions posed are: How to preserve concrete constructions?

Ill. 4. Hamburg, Köhlbrand Bridge, (1970–1974); Austria Ötztaler Achbrücke (2011); Marseille MuCEM designed by Rudy Riccotti (2013), Internet: www.google.pl

Defining this new field of art that appeared at the end of the eighteenth century, Professor Ryszard Kowalczyk wrote that some design engineers consciously practiced this field of art that exists in parallel to and fully independent of architecture[2]. He also wrote: *"The set of lectures >Structural art< developed by Professor David Billington allows one to study the works and ideas of great constructors through the structural evaluation of their works, their structural designs and their aesthetic imagination" ... "The basic elements of structural art are efficiency and economy and its freedom, based on the potential that it offers to the designer in expressing an individual style that is motivated by the conscious search for engineering elegance"*.

Contemporary research concentrates on structural modifications of high-performance concrete, Portland cement structure without modification and with nanotubes additions, flexible concrete (ECC), fiber-reinforced concrete, prefabricated façade elements and Nano concrete. Utility modifications of self-compacting concrete (SCC), architectural concrete, translucent, self-healing and geopolymer concrete are also examined. Microstructures before and after precipitation of calcium carbonate (CaCO3) are revealed under the

[2] R. Kowalczyk, a series of lectures based on David Billington's publications, *The Tower and the Bridge – The New Art of Civil Engineering*, Retrieved at: www.structurae.de.

Ill. 5. 180-metre skyscraper Warsaw Spire, Source: www.google.pl

microscope. Photocatalytic concrete and photocatalytic processes in urbanized areas are subject to Eco-modification[3].

The critical analysis of a number of engineering works shaped by the technology of concrete production has been known for over 200 years. Finding the methods and the new evaluation criteria allows one to follow technological and material progress. The annual consumption of concrete has become more economically efficient, 7 times higher than that of steel and 4 times higher than wood. While starting a new work today, we want to give the world's most common building material the mysterious power that creates the foundations of the new "wonderful world of concrete". The previously unknown structures of a special type of concrete – *ductal* with altered cement composition – are being presented. As a result of a better knowledge of chemistry, a thin concrete with a lace-like appearance was created, having a ten times greater strength. There is water-resistant concrete or another type, based on wet sludge, clay and mud. Innovation is not just new technology. It is also a new, different way of looking at the needs of the modern world. For this purpose, it is necessary to understand matter and to be able to disassemble it to create another matter. This principle was known to Lavoisier and Newton who studied the dispersion of light using the alchemy of corpuscles. Contemporary chemistry combined with quantum mechanics and subsequent ground-breaking experiments of structural art conducted in modern international laboratories go back to the old rules of transmutation among other things (ill. 6, 7).

Brought to Krakow by Michael Sendivogius of the Ostoja coat of arms (1566–1636), the alchemist Sethon, who discovered the 12 rules of transmutation, argued that it was possible to change common metals (lead or mercury) into gold. The so-called philosopher's stone was allegedly

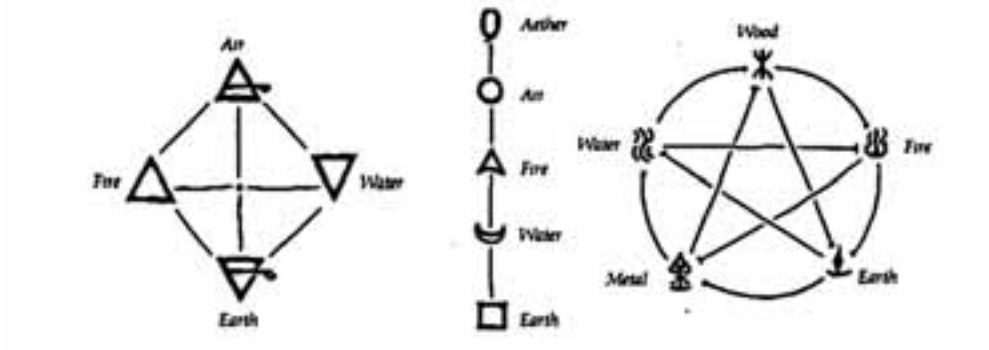
[3] *T. Z. Błaszczyński, Cudowny świat betonu,* [in:] Nanotechnologie w budownictwie, Poznań 2012, Retrieved at: www./3.t_blaszczynski_cudowny_swiat_betonu.pdf.

Ill. 6. Hen's Foot Tower at Wawel Castle in Krakow; Michael Sendivogius' alchemical workshop; alchemical apparatus. Source: www.google.pl

capable of it. A well-equipped laboratory, an alchemical workshop, was needed for that purpose, which King Sigismund II August, the last Jagiellonian on the Krakow throne, made available at Hen's Foot Tower at Wawel Royal Castle in Krakow. It is here that Michael Sendivogius discovered oxygen obtained from KNO3. His book was published in 53 editions until 1778.

1. The dream of the transmutation of matter still inspires minds. The famous 12 principles still give rise to the reflection among contemporary chemists and authors of structural art.calcinatio – roasting of the starting matter into a fragile and powdered substance.
2. solutio – dissolution of the obtained matter.
3. separatio – separation of "basic ingredients", e.g. "four elements".
4. coniunctio – reconnection of components in a "harmonious" manner.
5. putrefactio – decomposition, purification and refining of the substance through the action of heat.
6. coagulatio – solidification of the fluid resulting from the combination of the "spirit" and "first matter".
7. cibatio – feeding the resulting "white tincture".
8. sublimatio – transition from solid to gas and back, catharsis of "white tincture".

9. fermentatio – obtaining a "gold ferment".
10. exaltatio – combining "ferment and spirit" into "red tincture" – "philosopher's stone".
11. augmentatio – enhancement, *multiplicatio*, multiplication of the "transmutation efficiency" of the obtained "stone".
12. proiectio – throwing the "philosopher's stone" into a molten metal to transform it into another superior material. Nuclear physics enables the conversion of certain elements into other ones, including non-precious metals into gold by means of nuclear reactions, e.g. by bombarding the target made of mercury amalgam with neutrons (n), deuterium (D) or protons (p) in the accelerator.



Ill. 7. Comparison of the three alchemical traditions: a. – four Aristotelian elements, Air, Water, Earth, Fire; b. – India, five Vedic tattvas, Ether, Air, Fire, Water, Earth; c. – Five Chinese Elements: Wood, Fire, Earth, Metal, Water. Source: www.google.pl

The styles of national schools are currently present on all continents, presenting examples of innovative construction solutions for high-rise buildings, including cutting-edge Spanish roof coverings and Swiss technological tradition of bridge design. Against this backdrop, there have emerged countless examples of new solutions in the work of outstanding architects and constructors. In their works, each of them strives to overcome the barriers of the elusive principles of alchemical symbology supported by the classic elements of the three alchemical traditions (ill. 7.).

The integration of forms and colours of construction materials with nature reveals unexpected associations of arch-holism; it is also linked to the future of the transmutation of structural art integrated with nature – the mother of science and wisdom.