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Metal and iron construction in sacral space shaping

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Abstract. The article considers the use of innovative materials in the European sacred space of the late 18th - early 20th centuries in particular metal structures as well as the structural basis of reinforced concrete. The chronological framework of stages of this process which consistently master properties of the new building materials offered by an epoch of industrial revolution is established: cast iron, malleable iron, steel, reinforced concrete. The desire to be "modern" in the formation of sacred space, which follows from the artistic decisions of the first consumers of steel and concrete in sacred buildings, is analyzed. The constructive advantages and disadvantages of new materials are revealed. Metal constructions and decorative elements that form a sacred space are presented. A comparative analysis of public spaces, both sacred and secular in terms of the use of metal structures. Possibilities of new materials which demanded aesthetic comprehension are presented. It was found that during the XIX century such comprehension in the architecture of sacred spaces took place in line with two approaches: traditional-aesthetic, when constructive elements made of new material were designed in traditional historical forms in line with the eclectic understanding of styles; and structural and technological, by inventing new design principles for new construction. It was found that in both cases the use of metal and reinforced concrete was a significant factor that influenced the formation of modern sacred space.

1. Introduction. Technological innovations in sacred architecture

Traditional building materials, stone and brick, have allowed the construction of complex and bold structures over the centuries, including the formation of large surfaces of the vault in sacred space. Not only with the use of domes with large spans (examples are the thirty-meter dome of the Church of St. Sophia and the forty-two-meter dome of St. Peter's Basilica), but also in the system of Gothic vaults which could cover areas several meters wide (Alba Cathedral - 18 meters). Only in a few cases, mainly in relation to pilgrimage shrines of transnational significance, in the 20th century there was a need to cover particularly large areas. It can be assumed that from the point of view of construction, the developed building traditions provided the necessary opportunities for the construction of churches throughout the 20th century. Thus, the change in the structures and materials used was not the result of needs formulated by specific construction tasks, although in some cases the motivation to use the new structures was to reduce costs [9].

Undoubtedly, the new materials contributed to the construction of the building itself and the adoption of certain forms of solids and interiors, but all these needs could be met using the old building customs. An important reason for the changes in the sacred architecture of the 20th century should be considered the special mental state of European society at the turn of the 19th and 20th centuries, which manifested itself in the belief in "new times" and included the need to adapt various



forms of culture to this new era. "Modernity" was another era after the "Enlightenment", which was characterized by great self-awareness and admiration of the intellectual elite for the uniqueness of its time. The slogan "modernity" also contained the belief in the progressive nature of modern times and forced to reject many previous formulas of social life and culture. Numerous members of the elite promoted the violent nature of change. This can apply to politics, religion and architecture [6].

Within the Catholic Church, attempts to adapt to the "new times" have been made since the French Revolution in the late 18th century. Church historians considered them insufficient and intertwined with much stronger conservative attitudes, which was manifested, in particular, in the documents of the Catholic Church, such as the so-called Program or anti-modernist encyclical *Pascendi Dominici Gregis* (1907). People and groups who initially worked on the fringes of the Church, seeking to adapt their faith and teachings to changed attitudes and mentality, gained support among Church leaders as well.

Modernization became the official doctrine of the Catholic Church during the pontificate of John XXIII, and under the term "aggiornamento" it found expression, among other things, in the encyclical *Ad Petri* (1959) or in the opening speech of the first session of the Second Vatican Council (1962). However, for a long time the need for "modernity" was primarily a trend of artists, in whose activities the intuitive element motivates them to avant-garde attitudes. The desire to be "modern" is evident from the artistic decisions of the first users of steel and concrete in church buildings [9].

2. Metal structures in sacred space

The oldest sacred building, created with the use of cast iron elements, is the church of St. Chada in Shrewsbury, built in 1790–1792 by George Stewart (Figure 1) [17; 18].



Figure 1. George Steuart, Church of St. Chada, 1790–1792, Shrewsbury.

Because the fragility of cast iron does not allow its use for tensile structures, the main metal element in buildings at this time were columns. The iron columns used in the ground floor almost do

not attract attention, while those used on the galleries have an extremely elongated shape, impossible to obtain in stone or wood, and they gave the opportunity to use tall windows providing excellent lighting for the church. The nave on a plan - more characteristic of neoclassical Protestant churches in continental Europe - is considered a controversial solution in this area and was implemented as a result of a misunderstanding that occurred when selecting one of the four designs submitted by the architect. In this first stage, the interest in cast iron as a structural material in public construction was realized in the design of bridges and industrial facilities. In English factory buildings, the structure of cast iron pillars with brick walls and vaults arose for purely utilitarian purposes to save the area of the shops and from the idea (erroneous) of fire resistance of cast iron - and aesthetically almost did not make sense. View of the columns with Corinthian capitals in the church of St. Chad testifies that the architect's artistic decisions were based on the constructive possibilities of cast iron in the traditional aesthetic vision.

A similar replacement of stone columns with cast iron, especially in porticoes, became more frequent in the late 18th and early 19th centuries in various parts of Europe. Many cast iron details were introduced in an equally imperceptible way. The church of St. George, built between 1813-1814 by Thomas Rickman in Everton (Liverpool) the "fanatical supporter of iron" and John Cragg, specialist in the use of this material (Figure 2-3) [14].



Figure 2. Thomas Rickman, Church of St. George, 1813–1814, Everton, Liverpool, façade.



Figure 3. Thomas Rickman, Church of St. George, 1813–1814, Everton, Liverpool, interior.

The exterior of the church resembles a typical work of a meticulous English neo-Gothic artist, but the stone walls surround the interior, made entirely of cast iron, which indicates a freer use of the material. The prefabricated columns, vaulted ribs, tracery windows and even the doors were all produced in Cragg's foundry and assembled like a machine after being transported to the construction site. On the mainland, a similar church was built only eighty-seven years later, and it was Jules Astruc's Notre-Dame-du-Travail in Paris. Rickman's work through the use of iron brought the gothic system to the ultimate refinement. The whole structure is reminiscent of wire lace as all the elements have been cast very thin. The use of iron is hidden by the polychrome, and the large figural stained glass window behind the altar, filling the entire wall, definitely restores the atmosphere of a traditional church.

In 1842, Edward Blore used similarly slender columns to create the extensive chapel space at Buckingham Palace, and between 1842 and 1844 the iron structure became the base of the large St. Vincent de Paul in Paris by Jakob Ignaz Hittorff, an architect from Cologne [16]. In the mid-nineteenth century, the largest neo-Gothic church, in which columns and vault were made of cast iron,

were created by Louis-Auguste Boileau (Figure 4–5).



Figure 4. Louis-Auguste Boileau, Church of St. Eugène, 1854–1855, Paris, facade.



Figure 5. Louis-Auguste Boileau, Church of St. Eugène, 1854–1855, Paris, interior.

Around the church of St. Eugène (Figure 6) in Paris (1854–1855), a violent polemic broke out in the *Journal des Débats*, even before the building was completed, between the church's architect and Eugène-Emmanuel Viollet-le-Duc [1].



Figure 6. Louis-Auguste Boileau, Church of St. Eugène, 1854–1855, Paris, interior.

Leaving aside the elements of courtesy exchanges, which include the claims that Boileau was an ignorant bungler and Viollet-le-Duc an eloquent but limited supporter of imitation of the old styles, this

discussion shows the limit that was reached in the use of cast iron structures within the Gothic system. It is also interesting because both adversaries were supporters of Gothic and enthusiasts of the use of cast iron. The polemics revealed, however, that iron structures, already commonly used then for roofing stations or markets, had shortcomings that should be taken into account when using them for buildings with more complex plans and intended for long use. Viollet-le-Duc drew attention to the susceptibility of cast iron to rust, which threatens the durability of the structure, especially in connection with the high susceptibility of the material to changes in volume. As an example of the nuisance resulting from the use of iron, he described the case with a metal spire, which crowned the tower of Rouen Cathedral, the work "unsatisfactory, though not entirely hopeless". "With sudden changes in temperature, this iron structure produces a hail of bolt heads, and in rain, a shower of rust despite the use of paint" [1, s. 55]. In addition, Viollet-le-Duc highlighted the dangers of combining materials with different coefficients of expansion, i.e. stone walls and iron structures, and the need to abandon forms of medieval architecture when using new techniques and materials. "When it comes to sharp arches or gothic columns molded in cast iron or machine-made lamellas to resemble the medieval ones, these are all examples of rather childish bad taste. [...] A change of material should entail a change of forms. To achieve this, it takes time and thorough knowledge of the properties of these materials, a long series of experiments. We took the first step, and that's good. [...] But let us beware of under-educated reformers. They only pave the way to ruins, or at best to disappointment [1, s. 55–56].

The church designed by Boileau has survived to this day in good condition, so the cited warnings can be considered exaggerated, but with the problem of the durability of the metal structure and the need for new forms, the architects began to grapple with the growing awareness of the importance of these issues. Further important works of church architecture solved them with unsatisfactory results. Victor Baltard, the author of the Paris halls (Halles Centrales), in the years 1860–1871 created the Church of St. Augustine (Saint-Augustin) with a developed modular structure comparable to Paxton's Crystal Palace. Like the building of the library of St. Genevieve, created by Labrouste in 1843 and 1850, the metal structures here are enclosed in the brickwork of the outer walls. Inside this building, evidence of the use of an iron structure was visible through the sphere of decoration, and an iron dome was also an additional achievement, but from the outside, the wall coating was shaped with Romanesque, Gothic, Baroque and Classicist motifs [2]. An important change was the abandonment of the Gothic Revival in favor of a certain eclectic mix, foreshadowing the charm of Wagner's Vienna railway station.

The fact that the new materials and structures demonstrated their own, albeit crude aesthetics, was revealed with great force by the buildings built for the World's Fair in Paris in 1889 - the Eiffel Tower and the Gallery of Machines. The Eiffel Tower, a hypertrophied neo-Gothic peak made of iron beams, has long been challenged by its ugliness, which seems to be not entirely justified because the tower's prototypes, the Gothic churches, once seemed more ugly, but they do not evoke such emotions. The massive structure and its material were presented as decoration, which was to be considered one of the main distinguishing features of modernist architecture. And if the first tier of the openwork structure of the tower was still "decorated" with cast iron ornaments, then in the Gallery of Machines impressed only the expressiveness of the open metal structures. Only after this work could the Church of Notre-Dame-du-Travail (1899-1901) of Astruca be built, in which the steel structure was used in an exposed form in a manner typical of nineteenth-century stations and hangars, and stripped of any historical decorations (Figure 7–9). As a result, an interior with an unadorned iron structure was created, filled with natural light, but thanks to a clear orientation towards the altar, it retained the atmosphere of the church building.

It can be noted that the stages of introduction of metal structures to the formation of sacred spaces generally correlate with the historical sequence of the use of metal in public buildings for various purposes [15]. During the period under review, the architects of sacred buildings consistently used in their practice cast iron, wrought iron, steel in accordance with how the success of metallurgy introduced these materials into industry and construction, and processed them according to aesthetic attitudes of time (Table 1). Differences in individual stages can be attributed to the large «specific

weight» of specifically spiritual, psychological needs that must be met in sacred architecture. Taking into account the stylistic features of the Gothic, Neo-Renaissance styles in the formation of sacred space based on the use of new materials was based on philosophical, social views on state of society and the position of the church in the dramatic era of the Industrial Revolution.



Figure 7. Jules Astruc, Church of Notre-Dame-du-Travail, 1899–1901, Paris, façade.



Figure 8. Jules Astruc, Church of Notre-Dame-du-Travail, 1899–1901, Paris, interior.



Figure 9. Jules Astruc, Church of Notre-Dame-du-Travail, 1899–1901, Paris, interior.

In general, the decision of the architect, designer regarding the style, design of the object, the materials used and technology is determined by the requirements for objects of a particular purpose [7].

By the end of the 19th century, metal became an integral part of another new building material, reinforced concrete. The use of reinforced concrete brought another change to the construction

industry at the beginning of the 20th century. The history of the use of this material in the architecture of the last few centuries is well known and does not need to be presented in detail. It can only be recalled that its origins lie in the actions of John Smeaton, who during the construction of the lighthouse at Eddystone near Plymouth in 1756-1759 conducted many experiments with the combination of lime, clay, tuff and volcanic ash (pozzolana), as a result of which he managed to obtain hydraulic lime, which is actually natural cement.

Further discoveries by Joseph Aspdin (Portland cement in 1824), Joseph-Louis Lambot (1848) and Joseph Monier (1867) led to the use of reinforced concrete in construction by François Hennebique (in 1892). It was in Hennebique's studio that the possibilities of this material were discovered by artists who later gained fame as outstanding innovators of architecture. Reinforced concrete, which prevented the rusting of steel elements embedded in concrete, based its durability on the fact that both materials constituting it had the same thermal expansion coefficient. The new material could be used in simplified construction systems, reduced to the necessary number of vertical elements (pillars or columns) and a thin reinforced concrete slab directly on them or on horizontal intermediate beams. Reinforced concrete slabs could be shaped into a parabola or structures created in other ways, eliminating the division into load-bearing and lifting elements. Concrete made it possible to create prefabricated elements, increased the possibility of covering large spaces and eliminated load-bearing walls. The disadvantage was the ugliness of the texture and the color similar to dry mud, which initially predestined it primarily for use in engineering buildings. Despite this drawback, concrete was used to build the temple before the end of the 19th century - in the church of Saint-Jeane de Montmartre (1894-1904) by Joseph-Eugène-Anatole de Baudot (Figure 10–11) [4; 13; 19].

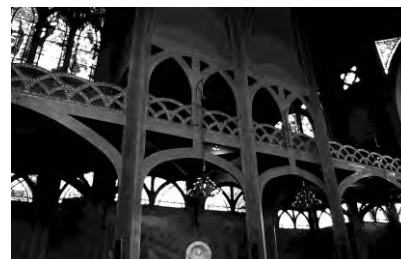


Figure 10. Joseph-Eugène-Anatole de Baudot, Church of St. Jana, 1894–1904, Paris, facade.

Figure 11. Joseph-Eugène-Anatole de Baudot, Church of St. Jana, 1894–1904, Paris, interior.

Although it was not the first church building to use reinforced concrete, it is the first public building in which this was done boldly and openly. The temple was brick-clad on the outside, but inside its concrete structure remained completely exposed and unadorned. Structural arches extend from the floor and intersect in the vault in a manner similar to the net vault. Double shell-rib vault and a layer of air in the walls protect the building against temperature differences and moisture. Another innovation was the use of only square windows, which was mitigated by filling them with traceries. Despite the starting point of the decorative layer of the church situated in the Gothic Revival, the final expression of the building has much in common with art nouveau: sharp arches draped with floral braids, and the facade decorations have a distinct Art Nouveau charm.

Very early experiments with the use of reinforced concrete in sacral space construction began in

Germany. In the years 1901–1903, Gabriel von Seidl built the Church of St. Rupert, in which the concrete skeleton was complemented by brick walls. The Roman Catholic garrison church designed by Adalbert Kelm in Kiel (1907–1910) was made entirely of reinforced concrete, and a concrete shell had an overlap of only 6.5 centimeters. The most important building of the first decade of the 20th century, shaped in the new material, remains the Evangelical garrison church in Ulm, built by Theodor Fischer in 1908–1910 (Figure 12–13) [3; 11; 12].








Figure 12. Theodor Fischer, church in Ulm, 1908–1910, facade



Figure 13. Theodor Fischer, church in Ulm, 1908–1910, interior

From the outside, the work presents itself as a neo-Romanesque building with a powerful vestibule, the lines of which have been softened so that long ago it has allowed researchers to qualify it as Art Nouveau. A single-space hall with a considerable, 27-meter wide, no supports, and its vault is supported by only a few reinforced concrete ribs. Reinforced concrete was used in this building with full awareness of the goals and acceptance of official factors, which was of particular importance in the building, the cornerstone of which was laid in the presence of the rulers of Württemberg - King Wilhelm II and Prince Albrecht. From the description of the church prepared by the architect for the magazine "Christliches Kunstblatt" and another, containing a description of the project, in "Architektonische Rundschau", it clearly follows that the material used was previously considered appropriate and necessary to create an interior that could accommodate 2,000 people (1,3 thousand in the nave and 700 in the gallery), ensuring a clear view of the altar and the pulpit, bringing the preacher closer to the audience and enabling him to contact the organist [5]. In turn, from the report of counselor Johannes von Merz at the second congress of Protestant church construction in Dresden in 1906, it can be concluded that the use of concrete for church purposes was no longer an individual matter. Merz clearly stated that current construction methods are influenced by reinforced concrete structures, which facilitate the covering of large and widely laid out surfaces. Eight years later, Alfred Wanckel spoke positively in a comprehensive publication on German Protestant construction at the beginning of the 20th century. In his opinion, new technologies were the only factors shaping the contemporary style, which was supposed to concern both previously impossible construction solutions and stimulation of the artistic imagination to discover new, virtually unlimited forms of solids and shapes of space. In Wanckel's statements, one can see traces of the exaggeration, typical of supporters of modernism, in emphasizing artistic freedom even in relation to matters related to religion. This is in some contradiction with the deeply religious motivations of Fischer himself, who based the basic shape of his church on the words close to Luther, "The fortress is our God".

Table 1. Historical stage of structural application of metal in sacred spaces.

Stage in sacred spaces	Period	Approach	Example	Stage in secular spaces
1. Supporting constructions from cast iron (columns)	80's XVIII century	<i>constructive and aesthetic</i>		Cast iron structures in industrial construction
2. Various (supporting, decorative elements) made of cast iron within gothic system	The first half of the XIX century	<i>constructive and aesthetic</i>		Introduction of cast iron structures in public architecture
3. Experiments within a mixture of Romanesque, Gothic styles as well as elements of Baroque and Classicism Masked construction	second half of the XIX century.	<i>constructive and aesthetic</i>		Application of cast iron and steel structures in the architecture of public spaces
4. Open steel structures in the interior without historical decorations	end of the XIX - beginning of the XX century.	<i>constructive and technological</i>		Identification of the aesthetic expressiveness of the steel structure
5. Beginning of the use of reinforced concrete	Early twentieth century	<i>constructive and technological</i>		Formation of modern style in architecture thanks to new materials

3. Conclusion

An attempt is made to investigate the historical role of metal in European sacred architecture of the late 18th and early 20th centuries both metal structures and structural base of reinforced concrete. A chronological framework of stages of this process is proposed, in which architects - creators of sacred spaces consistently master the properties of new building materials proposed by the era of the

industrial revolution: cast iron, malleable iron, steel, reinforced concrete to express the idea of modernity. At the first stage, in the 90s of the 18th century, the interest in metal as a structural material determined the use of cast iron elements - support columns in the sacred space. At the second stage in the first half of the XIX century. there is a much wider and free use of cast iron in the frame and for interior design elements within the Gothic system. The third stage in the second half of the XIX century. distinguished by the use of malleable iron and steel elements along with cast iron within a mixture of Romanesque, Gothic styles, as well as elements of Baroque and Classicism. At the end of the XIX century. there is a transition to steel structures with the search for means of identifying the aesthetic expressiveness of the structure and material, which was characteristic of public architecture for various purposes. The beginning of the fifth stage is marked by the turn of the XIX and XX centuries, when the use of reinforced concrete contributed to the formation of modernist views on the architecture of sacred spaces.

The idea of «New Times», the need to modernize the church was a challenge of time and the decision was due in part to the avant-garde trends in the work of artists in the aesthetic understanding of the constructive and decorative possibilities of new materials. During the XIX century. such comprehension in the architecture of sacred spaces took place in line with two approaches: traditional-aesthetic, when constructive elements made of new material were designed in traditional historical forms in line with the eclectic understanding of styles; and structural and technological, by inventing new design principles for new designs. In both cases, the use of metal and reinforced concrete was a significant factor influencing the formation of modern sacred space.

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