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RESEARCH ARTICLE

Centralized Spaces in Hungarian Church Architecture between the World Wars – Historical and Structural Survey of the Dome of Ottokár Prohászka Memorial Church

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Abstract

Architectural research, focusing on Hungarian architecture in the inter-war period so far, have mainly analysed buildings and architects regarding the international modern architecture and the path leading to development of modern Hungarian architecture. The present article undertakes complex research on an emblematic, but less discussed building of the era with the related competition, the sacral buildings with similar structure and space arrangement. The social and art historical research is supplemented with the analysis of the behaviour of the structure and the circumstances of the construction. Besides investigating the era of the construction of the church, a brief description of the planning competition is presented with archetypes of the architectural history and the structures, also showing the construction process. The description is complemented with the results of the examination on the spot and the reconstruction of the presumable original statics calculation.

Keywords

centralized space · church architecture · Székesfehérvár · Ottokár Prohászka · shell · spherical shell · dome · reinforced concrete · inter-war period

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1 Introduction

The architecture of the inter-war period has been evaluated in many ways already. Recently, the atmosphere of publications has been represented mainly by the contest of stereotypes. In this kind of view, the neo-Baroque, Eclectic, neo-Romanesque, neo-Gothic and neo-classical styles were less valuable in contrast to the great emphasis of progressive architecture and the appearance of modern.

Making an attempt to slightly vary the image of this era, by focusing our research on a building that has not been in the centre of interest until now, is an enormous challenge. Probably the Ottokár Prohászka Memorial Church, in connection with the planning competition, provides us with the first example for the plurality of styles of the inter-war period.

Besides the multitude of historical styles, modern architecture design also appeared even in traditional categories of buildings, such as churches. This is the reason why Nóra Pamer called the five years era, between 1928 and 1932 the “time of fermentation” [20].

2 Church architecture between the World Wars

After the trauma of World War I, the awakening Hungarian society had to base its own thinking on new principles. Both art and architecture were affected by this process in parallel. The Great Depression at the end of the 1920s resulted in unemployment and conflicts among generations. It was followed by significant development after 1934, when architects, born in the first decade of the century, struggled against the members of the elder generation for state and public commissions. Several concepts were born to create the reformed style in art. The collective national style was expected to express the state and spiritual representation. The 1930s demonstrate an authentic cross-section of the contest among the above mentioned ideas.

Various movements aimed for ecclesiastical renewal. On the one hand, it meant reforming the dialogue with the society and joining the believers to the Church (like Actio Catholica). On the other hand, it meant educating the priests in which Regnum Marianum community, formed by the followers of Ottokár Prohászka, had a great role. The emblematic Magna Domina

Hungarorum Church, commonly known as Regnum Marianum Church, was built for this community between 1925 and 1931 in the City Park (the so-called "Városliget") of Budapest, and destroyed in 1951. The domed church, designed by Iván Kotsis, had a central space arrangement [5]. By that time, the demand for progression had been formed in the Catholic Church. It partially provided the opportunity for the development of a new style and the representation of the Church supported by modern art.

The churches, as buildings, demonstrated most appropriately the role, the renewal of the Church and the responses to the social problems. The churches also symbolized the prevailing standpoints of the Catholic Church with their style, ground plan and the applied fine art works. Besides, it was necessary to conform to the different regulations and instructions of the Hungarian Catholic Church and The Holy See [2]. The Ottokár Prohászka Memorial Church and the similar Catholic churches with central arranged plan from this era ought to be examined from this point of view.

3 History

3.1 Antecedents

After the death of Ottokár Prohászka, the diocesan of Székesfehérvár (2nd April, 1927), numerous conceptions have arisen, concerning the place and the type of an honour memorial. The decision aimed at Székesfehérvár. With the intervention of Gyula Zichy, archbishop of Kalocsa, the City Assembly decided to build a memorial church which was intended to be put on the territory of the Railway Parish. Meanwhile, Lajos Shvoy, the former priest of the Regnum Marianum Church was nominated as the new bishop of Székesfehérvár, who also supported the church building campaign. The key aspects for choosing the most appropriate place for building the church were: easy access and splendid view both from the railway and the city. At the time of the planning, the chosen place was relatively peripheral compared to the downtown [E]. Nevertheless, such a huge building construction helped the area develop and result in the elaboration of larger-scale urban design concepts. Accordingly, three plots were suitable for building the church on the territory of the Railway Parish: 1. the place of the Civil Rifle Range, 2. the barrack at the corner of Budai Street and Lövölde Street, 3. the free urban area around the hospital for infectious diseases.

Discussions were held with the Association of Shooting for taking the primary plot the Civil Rifle Range, but finally the calculated price was high therefore new alternatives were elaborated for the place of church building. Meanwhile purchasing the plot was kept count as the second possibility because of a two-storey building which would hide the church from the city. The barracks would only be made available to church building if they could manage to set the soldiers elsewhere. The conference held 7th February, 1928 pointed out the free urban area around the epidemic hospital as an appropriate place, and the parish presidency made an application to the city council and the municipal committee for obtaining the plot for the parish for free [E]. The General City Assembly supported the church building with a plot for free of charge, which was chosen by expediency from the three alternatives relating to urban design conceptions [E], behind the stud and the territory of the former epidemic hospital.

The area is distinguished based on the city development plan, where a high school for girls was intended to be built. The most attractive avenue of the city with villas and parks would be led there [E]. Early in February, 1929 the Church Building Committee was set up, led by Lajos Shvoy and mayor Aladár Zavaros, in order to coordinate the collection of the donations. The patrons of the committee were the newly nominated archbishop of Esztergom and Prince Primate, Jusztinián Serédi and the governor of Hungary, Miklós Horthy. It can be suggested that the Memorial Church of Ottokár Prohászka in Székesfehérvár was built with national cooperation and with the support of The Holy See [E].

3.2 The Competition

On 8th February, 1929, a national, private and open design competition was announced. The subject was the Ottokár Prohászka Memorial Church, parish and culture house. The competition generated considerable interest among the Hungarian architects. The contest was open to those architects who were certified members of the Chamber of Hungarian Engineers and the Roman Catholic Church, as well. The competition announcement said: "The church should be planned by the centreline of the 1780 m^2 area bounded by Horváth István Street, Dr. Kuthy József Street and Új-Várkörút Street (under topographical lot numbers of 1448/1, 1449/3, 1450 and 1451/11). The axis of the church should be perpendicular to the axis of Új-Várkörút Street, and the main entrance should open to Új-Várkörút Street." [E]

The announcement specified that the church should have 800 seats and be suitable for 2000 people in total. The Church Building Committee let the designers decide on the architectural and artistic style of the church. Planning a tower or a campanile next to the church with four bells was also necessary. A further requirement was to build a sepulchre inside the church, which can be accessed by the believers even if the church is closed. In addition, the main altar should be seen perfectly from every point of the church. The priest, next to the main altar during ceremonies, should stand 105 centimetres higher than the nave [E].

165 architects from Hungary and 6 from abroad have collected the competition documents but only 33 of them have applied for the contest with their plans before the deadline. Only the fragments of the plans are known, partly from the issues of Magyar Építőművészet and Tér és Forma reviews, and mostly from the collection of the plans recently found in the church.

On 6th June, 1929, the jury started to consider the tenders. They appointed the date of the examination on the spot and the judgement to 21-22nd June, 1929. Diocesan Lajos Shvoy, the chairman of the jury, underlined that: "the judgement of this committee will be a national issue, which will attract the attention of the Hungarian people, and I declare that I will support the cause with all my strength, and I will request the same from the other committee members." [F]. On the date above, the jury judged the applications and awarded the prizes in the assembly hall of the Fejér County Hall in Székesfehérvár. The minutes can be found in the Székesfehérvár Episcopal and Cathedral Chapter Archives. They contain the reviews of all the 32 valid applications [F]. The application 33 was disqualified by the committee for offending secrecy. The minutes also enclose the judgement of the jury as an authentic source, contrary to the partial and doubtful information of the journals.

The variety of plans of the competition indicates the need for the renewal of the Catholic church architecture in the society of the architects. This is supposed to be the first time when the basically functional church architecture appears in large numbers in Hungary using foreign patterns from Germany, the Netherlands and Italy. The architectural style is based on minimal and cubical shapes, using exposed concrete instead of the neo-styles that were propagated in this era. The designer of the prize plan 12 bearing the code-name "Vir Dei" is *Fábián Gáspár* [F], who was the most employed architect by the Catholic society in his era. He was the member of the committee of the church art in Székesfehérvár, as well [A]. The temple was built based on his application plans using symmetric arrangement (Fig. 1).

The parish and the community centre are attached to the domed, circular-plan central space with archways on both sides, forming an organic unity. "*The apse, the chapel of the Holy Sepulchre, the singing-gallery and the memorial chapel of the bishop are located at four different points of the centralized space. The sacristy is behind the apse, and the baptistery is connected to it. The 70-metre-high tower, which was supposed to be a local feature, is at the very back of the church.*" [G] Referring to the non-built detached campanile and the archways, which connect the collateral buildings to the main building, it is true that the prize plan draws inspiration from the pre-medieval Italian traditions. However, the regular hemisphere dome of the temple and the boarded inner design are explicit references to the Pantheon of Rome [B]. Instead of using an opeion, Fábián applied a lantern, which is a characteristic of the Italian Baroque and it can be illustrated with the dome of Saint Margaret High School in Budapest. Its external appearance can be partly related to both the classicist features of the Saint Anne Parish Church of Esztergom and the Baroque archetypes (Fig. 2).

Instead of choosing medieval, Roman, Gothic or modern style, the planner considers the style of the temple to be Baroque. He explains that a different decision would have made a sharp contrast with the appearance of the most splendid Hungarian city. Furthermore, the speaking manner, the gesticulation of the Great Bishop Ottokár Prohászka was closely associated with the Baroque style [C].

"The prize plan met all the requirements of the committee since it fulfilled all the functions determined in the announcement. It aligned the temple, the community centre and the parish to one axis centrally. Its style expressed the memory of the Great Bishop worthily. Some small details had to be corrected, as the apse and the gallery were too small. In addition, the main altar was erected improperly. The arrangement of the steps in front of the altar rail was impractical, because one step would have been enough for the communion. Increasing the height of the space below the dome was indispensable for the perfect spatiality." [F, H] The identical opinion of the jury is reflected by the style of the accomplished memorial church, which is an archaism tracing back to the Baroque.

4 Analogies of the central-domed space of the Prohászka Church

"*It is an interesting symptom that the two-thirds of the applicants support centralized spaces, almost designing a Protestant sermon church, probably with reference to the memory of the orator bishop.*" [I]

From the valid 32 applications, submitted to the Prohászka-contest before the deadline, 21 plans show centralized composition. In contrast, 10 plans are longitudinal. No relevant information is known about the design of one application, because the minutes do not mention the structure of the space and the plan. As the minutes do not contain information about the preferred layout arrangement, most of the awarded plans, including the first prize plan, show centralized composition. The announcement said that "*The plan of the church shall be located centralized.*" [F]. It was found inadequate, therefore, it was officially emended on 22nd April, 1929 by the mayor Dr. Aladár Zavaros and the parish priest Nándor Kéri. They explained that the clause referred to the arrangement of the church on the plot [F]. Moreover, the centralized plan can be traced back to both the national and international architectural traditions, in which centralized shape is frequently used for baptisteries, memorial chapels and for memorial buildings.

Tibor Gerevich, the chairman of the National Committee of Monuments and the founder-director of the Hungarian Academy in Rome, has published a review on the Franz Joseph Votive Church at Rezső Square, Budapest. (The so-called "Magyarok Nagyasszonya" Church was planned by Jenő Kismarty-Lechner. The foundation-stone was laid in 1924 and the church was consecrated in 1931.) He has shown in the essay that in the discussed era, the central-domed configuration and the symbolism of the church was well-known: "*The shape of the dome helps the spiritual expression of the piety memory come into existence, and it symbolizes with ceremonial and serious emphasis.*" [D] The church is a memorial church by name, which intends to be a worthy announcer of the memory of the Great Bishop. This aim needs to be transmitted by the shape of the space, which is represented by the centralized form. Nevertheless, centralized spaces are the less suitable arrangements for the Roman Catholic liturgy. It seems to be verified by the furniture of the

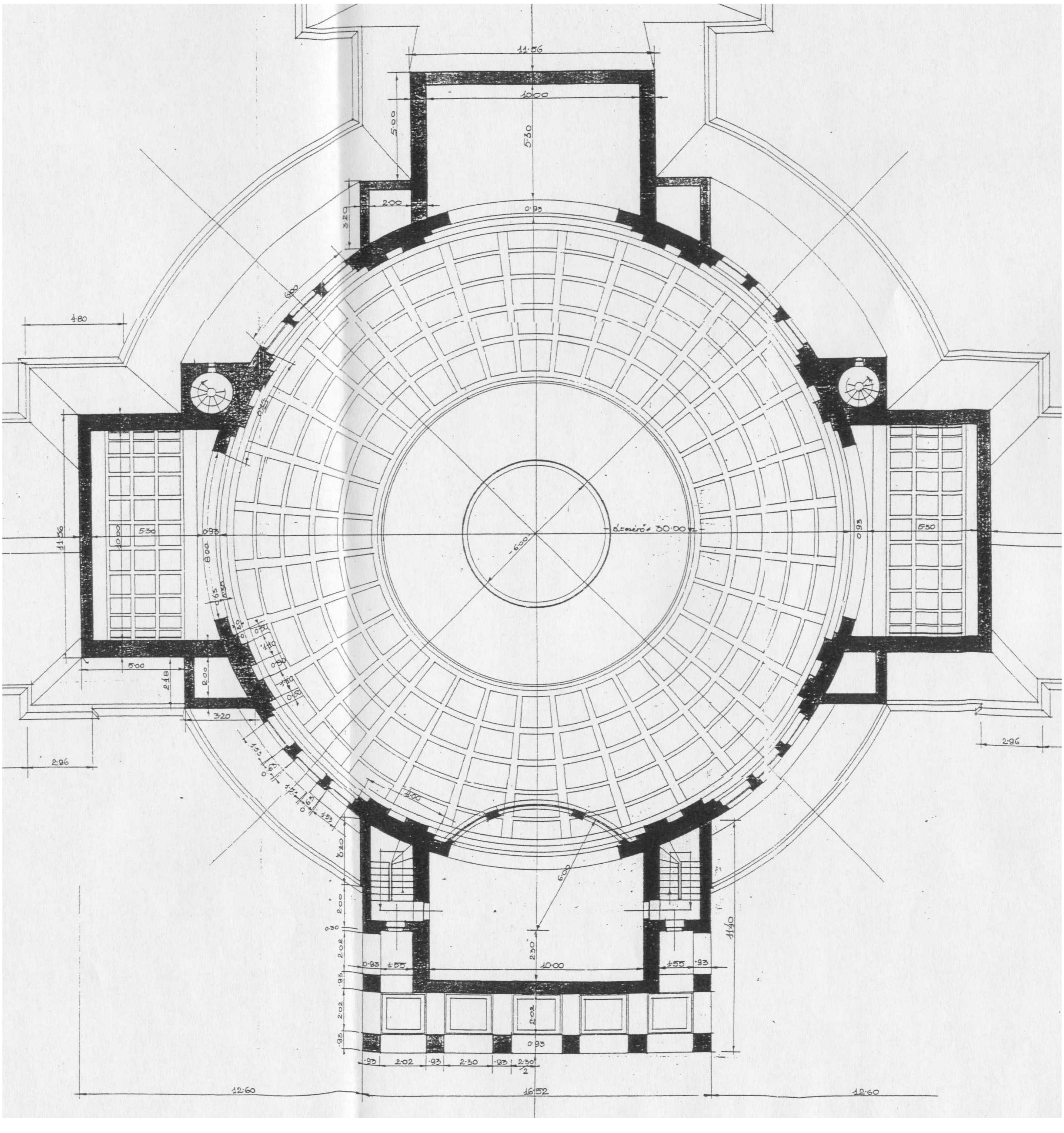


Fig. 1. Ground plan of the central space of Ottokár Prohászka Memorial Church (Szigeti and László Engineer Office, Renovation of Ottokár Prohászka Memorial Church, the building diagnostics plans of the church, 2001)

Fig. 2. The church today (photo by the authors)

temple, as well. On the circular plan, supplemented with additional spaces, the arrangement of the pews is similar to the interior of the longitudinal churches. Therefore, it can be suggested that the liturgy uses the space similarly to longitudinal churches, instead of the centralized tradition. The widespread use of the centralized space order in the Roman Catholic church architecture was inhibited by its difficult adaptation to the liturgy. Contrarily, centralized spaces were suitable for the liturgy of Protestant churches. Thus, the different ground plan types (triangular, Greek-cross, hexagonal, polygonal, circular etc.) became more popular [12]. When searching for the roots of the centralized space of the Prohászka Memorial Church and Roman Catholic temples in general, ancient traditions should be taken into account. The circle is the most exact shape that symbolizes perfection, thus it expresses God [12]. The centralized space, as mentioned by Rudolf Schwarz, is a symbol for the 'open heaven' as it spreads over the altar to pervade the faithful [25]. The circular shape originates from the ancient Rome, where the churches have developed from centralized vaulted spaces, for example Roman baths. Gáspár Fábián, the planner of the church, also refers to the ancient traditions, when he indicates the Pantheon of Rome as the closest source of the space-structure of the Prohászka Church. *"The Pantheon of Rome was always before my eyes indeed. [...] Only this Pantheon-like dome is worthy enough for the Great Bishop."* [C] In another article, he presents his views: *"I consciously designed the dome of the Prohászka Memorial Church based on the Pantheon of Rome in greatness and form. In my opinion it is the most phenomenal space-structured room in the world. No other building can reach it in this regard. The inner diameter of 30 metres is also deliberate. [...] the structures of the domes of the Pantheon and St. Peter's Basilica sit on cylindrical tambours. However, I broke the circular plan of the church crosswise, four times with 10-10-metre-long tabernacles. The tabernacles were closed by semicircular (more precisely, three-centred arches with distorted surface) structures, which were supposed to hold the large tambour with the pierced circular walls among them. [...] The architecture of the interior of the church strongly contrasts with the Pantheon. In the case of the Pantheon, the cylinder-wall that holds the dome has few moulds due to reasonable static causes. In the Prohászka Church, the large-span arches and column-grids render the architecture gentle, consistent and rising."* [B] (The contour of the walls of the Pantheon has many folds [21], as it was mentioned by Hart with reference to ventilation niches that help proper setting of the mortar [8].) Further antecedents can be considered from the era, which are not mentioned by him. The above mentioned Regnum Marianum and the church at Rezső Square, as well as a Hungarian classicist antecedent St. Anne Church of Esztergom and the Round Church of Balatonfüred can stand as examples. Although these churches were built a long time ago, they could serve as archetypes for the so-called inter-war conservative construction tendencies.

5 Structural analogies

The load-bearing capacity and the methods of construction can be the bases for studying the structural analogies of domes. Most of the period of the history of architecture was dominated by construction with small elements (bricks, stones, etc.). Though, it has to be emphasized that in the architecture of the ancient Rome the so-called roman concrete (Opus caementicium) was a known material centuries before Christ [21]. According to [15], the invention of this material can be originated to 3 or 4 centuries before Christ, but [1] states that it was invented in approximately 150 BC. The strength of this material, which was suitable for monolithic construction, could range between 8 and 10 N/mm^2 [8]. In the history of the development of domes the method of construction with small elements was determinant. The problems of this method were solved inventively even in ancient times [4]. The possible methods of construction always depended strongly on the applied material, and it usually determined the fashion of the dome.

In the beginning of the history of domes, mainly corbel vaults were constructed, a classical example can be the Treasury of Atreus in Mycenae. However, the Pantheon in Rome is a real vault made of stone, brick and roman concrete, lightened locally with baked clay tubes. The 43.3 m diameter dome works as a ribbed vault. The structural behaviour of the present-day form of Hagia Sophia in Constantinople is less clear than the previously mentioned examples, but it gives proof of considerable static knowledge. The 42 m diameter dome of the Dome in Florence also includes many structural curiosities. The reason for these special structural solutions was the advantageous static behaviour and the possibility of construction without formwork [21]. Saint Peter's Basilica in Rome, or Saint Paul's Cathedral in London are also important steps in the history of the development of domes. Sainte Genevieve's Church in Paris (built between 1757 and 1812) was the first dome where the architect used the help of an engineer during planning. Nevertheless, the static behaviour of the building is difficult to understand. The Cathedral in Esztergom with a 33.5 m diameter dome and Saint Stephen's Basilica in Budapest (previously: Lipótváros Parish Church) are important for us in Hungary [10, 21].

The domes of the 20th century were mainly built of reinforced concrete, abandoning the formerly used construction method with small elements. The application of reinforced concrete was usually combined with monolithic construction. However, there is a Hungarian example from the beginning of the history of reinforced concrete domes that is presumably made of prefabricated elements [27]. The world's first and second reinforced concrete domes in the history of architecture can be found on the top of the Armeemuseum and Anatomie in Munich, both were built in the first decade of the 20th century [13]. These first two domes were followed by many others, at first in Germany, then at other places in Europe and in the world. The Jahrhunderthalle in Breslau, the Grossmarkthalle in Leipzig [13] and the extremely large-span dome of the Assembly Hall in Illinois, USA, which is still the largest reinforced concrete dome shell in the world, are very important milestones in the history of the development of domes, without mentioning all examples.

6 Construction of reinforced concrete domes

Reinforced concrete was invented in the middle of the 19th century. The earliest reinforced concrete "structures" were the flower-pot of Monier, the boat of Lambot [7], and many other products made of concrete [24]. The new material appeared in building construction at the end of the century. However, this application was preceded by engineering: the material was studied scientifically both in theory and in experiments. Thus, in the last quarter of the 19th century, a large-scale development could be seen in the application of reinforced concrete. New companies were established worldwide, which could gain ground on the market by several ways. They have bought patents, undertaken scientific research, developed their products and published the new knowledge in the topic of reinforced concrete (e.g. the Monier-booklet, published by Wayss) [15, 24]. Mathematical and mechanical knowledge also showed significant development, parallel to the increase of the measure of the new material in building construction. Reinforced concrete structures in education appeared only in the beginning of the 20th century. At the Budapest University of Technology the reinforced concrete appeared first as an elective subject in the academic year of 1903/4 (lectures held by Szilárd Zielinski), the compulsory education, including theory and practice, began in 1906/7 for the architects (held by Adolf Czakó), and in 1907/8 for the civil engineers [18].

Structural planning based on structural knowledge and construction experience became general in the end of the 19th century. The mostly used grapho-analytical methods in structural planning, introduced by Cullmann, were not able to understand the physical behaviour of surface structures, they could not be used for the structural calculation of shells [9, 24]. The so-called membrane theory, which was able to describe the moment-free structural behaviour of shells of revolution, was completed in the 1910s. The membrane theory can be applied to the shells whose thickness is small related to their principal radii of curvature. This property results in small stiffness against bending and thus negligible moments act in the shell. The supports should also be constructed in a way that the reaction forces act in the local tangent plane i.e. the membrane displacements can be attained freely [3]. Reinforced concrete shells can easily fulfil the previously mentioned condition of small thickness, so they can be calculated based on the membrane theory. The condition of supports is not always met, there are methods in the literature [17] to treat the so-called edge effects. The location of edge effects for elliptic and parabolic shells is restricted to the neighbourhood of edges, but for hyperbolic shells they can have an influence on the whole surface. The theory of non-axisymmetric membrane shells was elaborated in the 30s. Dischinger's 1928 work [13] did not contain the complete shell theory, it was available only in the 1950s [24]. The application of shell structures is mainly determined by stability questions. Although buckling studies started relatively soon, the application of the results in engineering practice was limited, one could often experience a considerable difference between theoretical and experimental achievements [11, 26].

Reinforced concrete shells appeared first in civil engineering (containers, silos), mainly planned by German, French and Russian engineers (Intze, Dischinger, Finsterwalder, Hennebique, Coignet, Bonna, Maillart, Suchov) [24]. The name of the Hungarian Szilárd Zielinski should also be mentioned, because he planned, among others, several water towers [6] where axisymmetric shells can also be found. Reinforced concrete shells appeared in architecture shortly after the turn of the century. The structural behaviour of the highly transparent covering of Brunner Bank in Brussels is not shell-like (only at the top), so it is not classified among domes [24]. The building period of shells of revolution (i.e. domes) from this starting time to World War II is important for the present article.

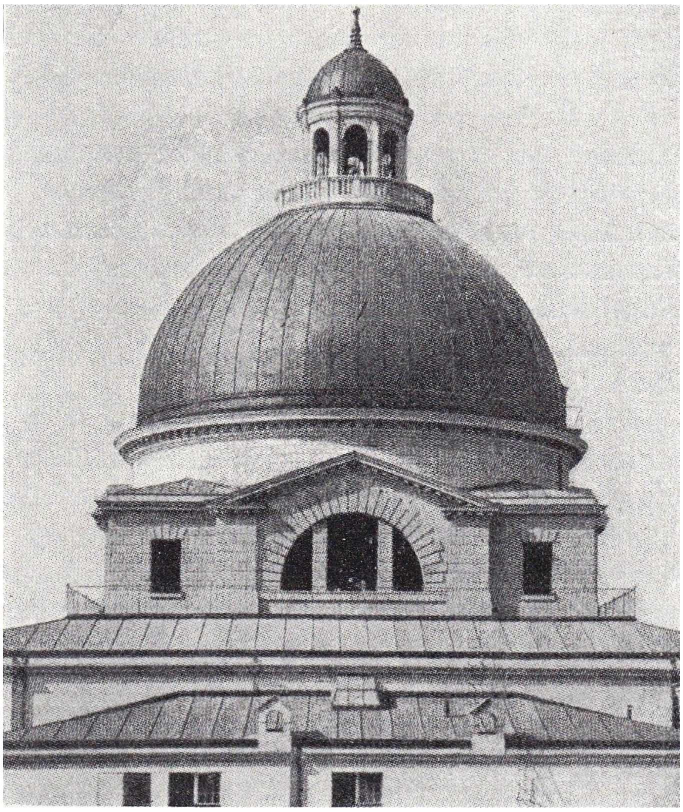


Fig. 3. Armeemuseum, Munich (Kraus-Dischinger, 1928 [13])

The world's first and second reinforced concrete domes, which are real shells from a structural point of view, can be found in Munich [13, 24]. The first one is on the Armeemuseum (Fig. 3), built between 1902 and 1904. It is a 16-metre-span double-layered monolithic reinforced concrete shell with only 6 cm thickness. The structural engineer of the shell, Ludwig Zöllner did not take the load-bearing capacity of the concrete into consideration, he only examined the structural behaviour of the spatial lattice structure made by the reinforcement. The reinforcement of the dome – contrarily to today's construction practice – is not made of steel bars of circular cross-sections but of shaped-steel cross-sections [13, 24]. The second shell, on the Anatomie, built between 1905 and 1907, has a 22-metre-span single-layer shallow shell, also made of reinforced concrete. This shell was also constructed with shaped-steel reinforcement, and the surface of the shell is opened at several points with lighting holes. Further important examples from Germany: Union-Theater (Saarbrücken), Musikpavillon des Fredenbaumsaales (Dortmund), Crematorium (Dresden), the dome of the Ludwig-Maximilian University (Munich), and other – sometimes quite peculiar – structures [13].

All the shells mentioned above were made of monolithic reinforced concrete. The dome of the reinforced concrete church in Rárósmulyad (Mula) was a special structure in Hungary in 1910 with its dome made of prefabricated elements [27]. This method came into general use only much later [19]. There were also other special construction technologies, for example the net structure of companies Zeiss and Dyckerhoff&Widmann (Dywidag). The most important feature of the method worked out by Bauersfeld and Dischinger was that a triangulated spherical spatial lattice structure, made of steel, was built first (with a specific weight of only 9 kg/m^2), then the concrete, made with fast-setting cement, was placed onto this net by shotcrete technology. The machine used for conveying the concrete is the patent of the Hungarian engineer József Vass from 1911 [23]. The first example to this system is the Planetarium in Jena from 1925, but many other buildings, not only planetaria, had a structure like this [13, 24].

Ribbed domes should be examined separated from those without ribs, because their structural behaviour is different. The Jahrhunderthalle in Breslau (Wroclaw) has only a skeleton structure, without shell-like parts. The structural plans were made by Trauer and Gehler. The building was built between 1911 and 1913, and it was at the top of the list of the world's largest „domes" between 1913 and 1930 with its span of 65 metres. The Grossmarkthalle in Leipzig was built between 1928 and 1930. Its ribbed dome (Fig. 4) constructed upon an octagonal ground plan was the world's largest dome between 1930 and 1957 (65.8 m). The structural plans of this building were made by Dischinger and Finsterwalder. The structure has 10-cm-thick shell areas between the ribs, and they play a considerable role in load-bearing. Among the ribbed domes that survived World War II, the pumping station in Duisburg-Beeck, or the dome of Markuskirche in Plauen could be mentioned [13].

Among the Hungarian domes made of reinforced concrete, the shell roof of the church in Rárósmulyad is the first. This was followed by many other reinforced concrete domes, for example the Roman Catholic Church of Muraszombat (Murska Sobota), the Calvinist church of districts VI.-VII., Budapest (the so-called „Fasori" church), the former chapel of old people's home in Székesfehérvár (today it is the Heart of Jesus Church), the Parish Church at Rezső Square, Budapest, the Regnum Marianum in Budapest, the Church of the Oath in Mohács and the dome of the Ottokár Prohászka Memorial Church in Székesfehérvár.

7 Structural study of the reinforced concrete dome of the Prohászka Church

The Prohászka Church has a double-layered covering (Fig. 5). Above the central space of the church, a reinforced concrete hemispherical shell sits with a diameter of 29.40 m, covered with a timber roof structure put on the reinforced concrete surface.

Most of the reinforced concrete shell has a rib system on the inner surface. The height of the ribs is 40 cm, the thickness of the shell zones between the ribs is only 7. . .10 cm, and the upper part of the dome is a smooth shell surface with an increas-

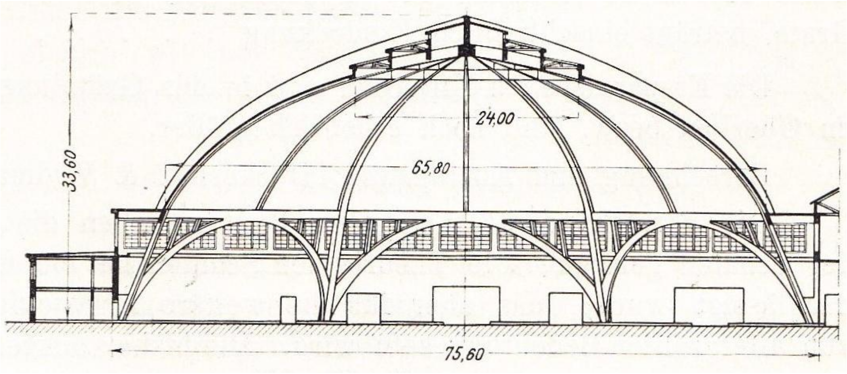


Fig. 4. Grossmarkthalle, Leipzig (Kraus-Dischinger, 1928 [13])

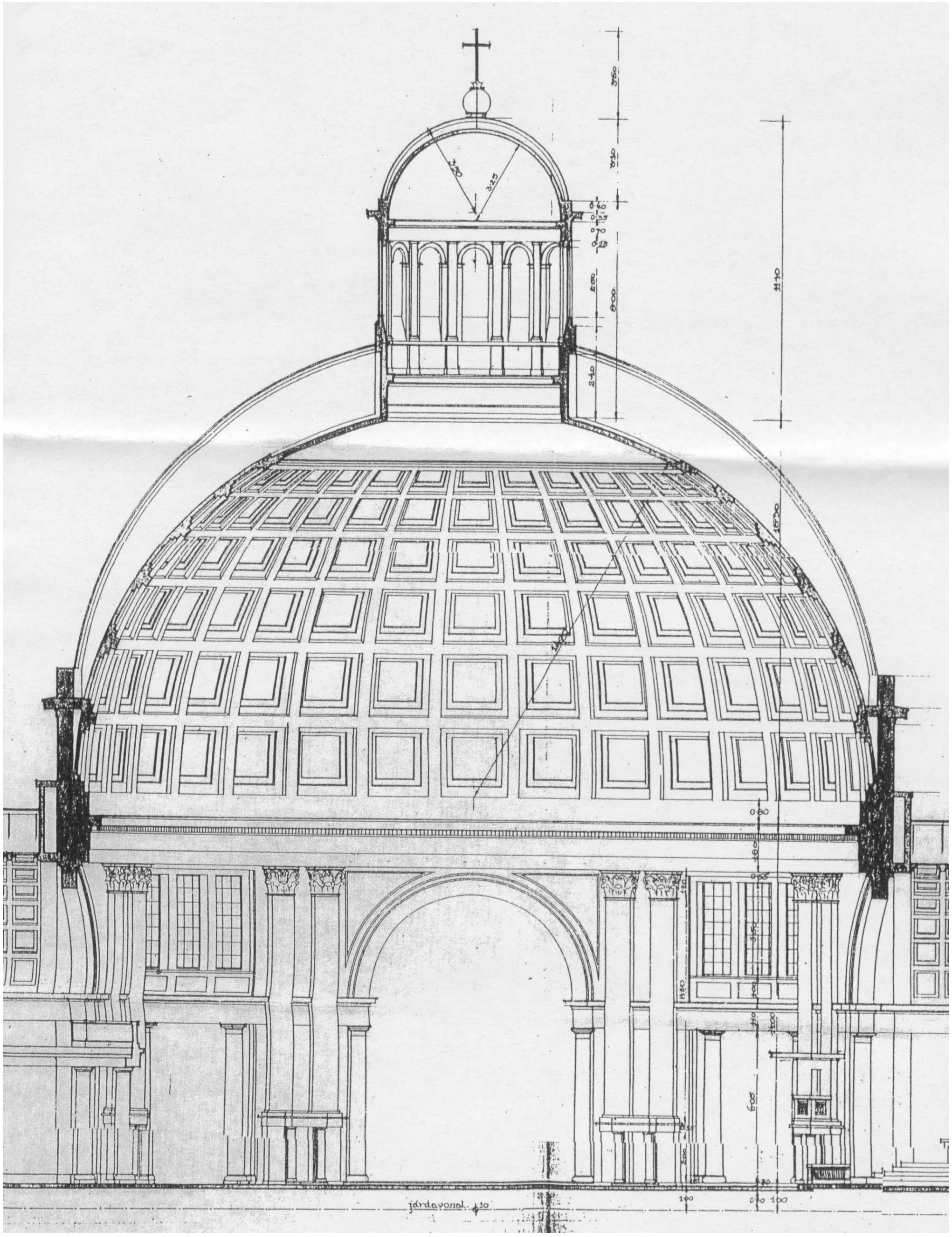


Fig. 5. The section of the central space of Ottokár Prohászka Memorial Church (Szigeti and László Engineer Office, Renovation of Ottokár Prohászka Memorial Church, the building diagnostics plans of the church, 2001)

ing thickness towards the centre. The reason for this change in the thickness is the demand for load-bearing capacity in consequence of the lantern sitting on the top of the dome. The structural calculations of the ribbed part of the dome made by Ferenc Gatterer [B] were probably based on the theory of spatial lattice structures. On the smooth part, however, the membrane theory could provide the solution, because the bending theory of shallow shells was not known in those ages [9].

If the static behaviour of the ribbed part of the dome (Fig. 6a,b) is analysed, based on the theory of spatial lattice structures [13], it can be seen that the behaviour of the dome is similar to membrane shells. An approximate static analysis could have also been made – omitting the ribs from the calculations [14] – because the internal forces of the ribbed dome in the meridional and circumferential (hoop) directions are in close relationship with the meridional and circumferential forces of a membrane shell with a similar shape and loading.

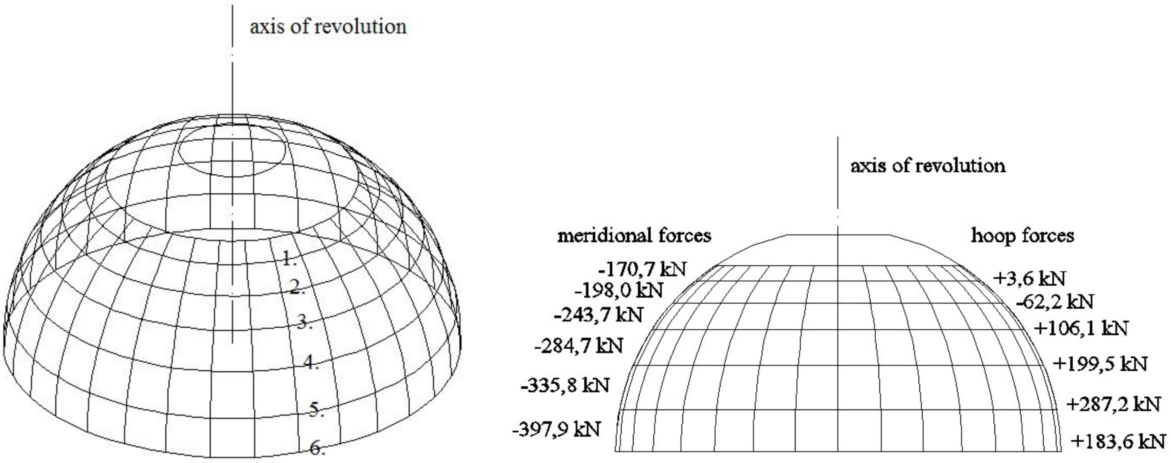
According to our calculations (Fig. 6b), compression force can be seen in the second circumferential rib counted from the top (rib 2.), but in the lower circumferential ribs (ribs 3-6.) tension forces can be experienced. It is a characteristic feature of a spherical membrane shell loaded with a uniformly distributed load over the surface: on the area below the 51.82°meridional angle (in the dome shell it is exactly the zone of ribs 3-6.) the internal forces in the circumferential (hoop) direction are tension. Similarly, a smooth spherical shell with an opening at the top (and taking also the load of the lantern into consideration), the change of the sign of the circumferential forces takes place at approximately 53°, this value is close to 51.82°. In the top circumferential rib (rib 1.), tension force is acting: this is the result of the huge load of the lantern and its neighbouring parts related to the load on the other parts of the shell. The cracks on the concrete surface experienced during the examination on the spot also indicate large tension forces in the circumferential direction at the bottom part of the shell. Vertical cracks can be seen on the shell surfaces between the meridional ribs at the bottom (the places of these cracks on the ground plan are at the openings of the walls that hold the dome). The calculations show increasing meridional forces towards the bottom of the dome, this is also a natural characteristic of the membrane shell. This approach based on the theory of spatial lattice structures does not take into consideration the load-bearing capacity of the shell zones between the ribs: it causes an error that increases the safety of the structure.

It is interesting how the structure under the dome holds the loads. Most of the domes in the history of architecture were placed on a cylinder (or sometimes a frustum of cone), with a vertical axis of revolution. In the case of the Prohászka Church the situation is different (Fig. 5), here the dome sits directly on the top of the walls that have huge openings with spatial arches. A ring-like structure was placed in this building that can help in the distribution of the forces, but, because of its position, this is not so effective. The structure with a 90 cm×260 cm cross-section starts from the bottom of the shell and it runs outside the building as an attic wall. This arrangement and the huge proportion of the openings in the walls caused difficulties during planning [B]. There are structures in this building with shear force, bending and twisting moment acting simultaneously, and these effects could not been handled at that time. The problem was solved with the help of a book which was first published in Berlin in 1929 [22]. The way of structural analysis of reinforced concrete beams with shear force, bending and twisting moment acting simultaneously and of spatial frame systems can also be found in this book. Based on the book, the structure could be planned. This case mentioned by Gáspár Fábián is a curiosity in the history of load-bearing structures, because it is very rare that a new result in science or engineering can be used so soon during the structural planning of a building.

8 Construction of the dome and its state today

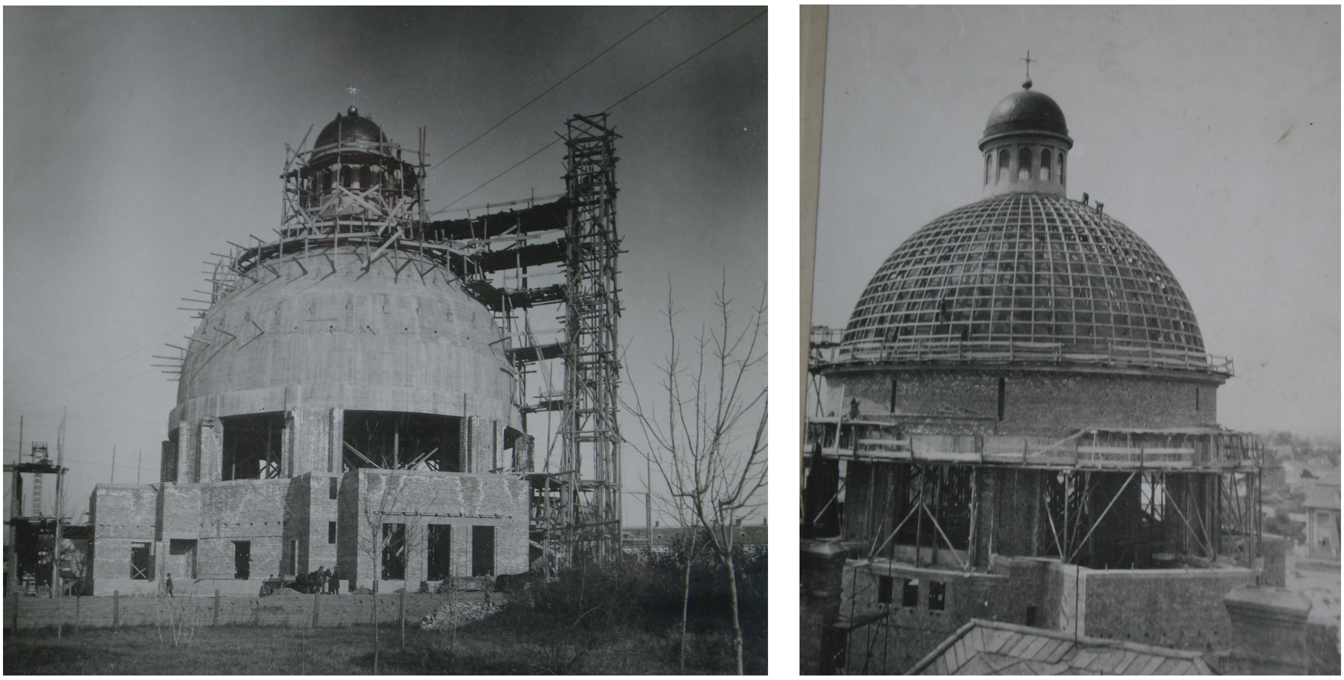
The most interesting part of the construction of the Prohászka Church is the construction of the dome. This work was done by the Ast Company, which made the foundation of the building, too. In the tender announcement it was also prescribed that the concreting of the dome (including the ring that borders the lantern) had to be finished in a week from the beginning. It was also specified that generally in the concreting work a break no longer than 12 hours was allowed. In the concreting of a ring, this time was to be only 1 hour. The joint gaps in the concrete should have been made in a radial direction, and cleared before continuing the work. The construction was done in the summer of 1930, when the water supply of the city was the most adverse. Thus the water needed for concreting was stored in a reinforced concrete container with a volume of 200 m^3 made up of the special foundation structure of the campanile [B]. The foundation of the church caused the planners great anxiety because of the weak soil. The plans of the foundation can be found, showing the special structure of the foundation system.

The dome was concreted on a timber formwork, made with due care, containing the inverse forms of the panels of the inner surface. During the examination on the spot it could be seen that the bottom part of the shell (up to a meridional angle of approximately 45°) was concreted in a double-sided formwork. An amount of 800 m3 of concrete and 48.6 tons of steel reinforcement (circular cross-section with smooth surface) was built in. The concreting work of the dome was completed in a week, in agreement with the prescriptions. The construction was led by reinforced concrete engineer Schütz, who died soon after the work, in consequence of the extraordinary efforts. It is not rare that a totally new structure or a curiosity in building construction technology needs superhuman efforts both from the engineer and the construction works manager. It is an unfortunate event that in this case it cost one person’s life. The demolition of the formwork was made one year after finishing the shell, thus the scaffolding could have been used for the inner painting of the church [B]. During the concreting of the shell, it stood



(a) (b)

Fig. 6. (a) Spatial lattice structure model of the dome of the church, with the numbering of the circumferential ribs. (b) The forces in the meridional and circumferential (hoop) ribs of the dome of the church



(a) (b)

Fig. 7. (a,b) The church during construction (SzECCA, Prohászka Collection / Documents of the Ottokár Prohászka Memorial Church [F]

on relatively slender “legs”, because only the most important supporting walls were standing, the other walls were made later (Fig. 7a,b).

The building was hit by a firebomb in World War II. The whole outer shell of the dome with the timber roof structure burnt down (Fig. 8), and the reinforced concrete shell was also damaged. The repairing of the latter one can be seen on the spot, mainly above the high altar (on the north-northwest part).

Huszonötezren hódoltak Prohászka emlékének a nagy püspök halálának huszadik évfordulóján a székesfehérvári emlék-templomban tartott ünnepségen, a fővárosból, a fehérvári egyházmegyéből és egész Dunántúlról

Fig. 8. The church after World War II (SzECCA, Prohászka Collection / Documents of the Ottokár Prohászka Memorial Church [F]

During the examination on the spot, we had the opportunity of measuring the compressive strength of the concrete of the dome based on its surface hardness by means of a Schmidt-hammer. On the parts where the original concrete could be found, we made 6 examinations, 10 rebounds per each examinations, and the strength values were taken from a design aid about “old” concrete [28], these values were used for evaluation, based on [16]. The compressive strength of the concrete of the dome, according to our examination, which gives only an approximate result, is 5.85 N/mm^2. On the spot we could detect the distance of the reinforcement elements inside the concrete with an inductive steel detector. The distance between the circumferential steel elements is uniformly 30 cm. The distance in the other direction, i.e. between the meridional reinforcement elements ranges between 10 and 20 cm, the reason for this variation can be that these steel bars should have been omitted step by step during the construction from the bottom to the top.

9 Conclusions

The research of non-modern buildings from the inter-war period is undeservedly pushed into the background in the history of Hungarian architecture and building structures. This state of being slighted is quite unusual in the case of an architectural competition that has such a country-wide importance and monumentality as of the Ottokár Prohászka Memorial Church in Székesfehérvár. The examination of the unique material of the design competition, the structural and architectural design and the construction of the dome, which is one of the largest reinforced concrete domes in Hungary, and the connections with literature from abroad make us a clearer view of the architecture of this period. Gáspár Fábián, who had protested against the use of reinforced concrete in church architecture earlier, planned a monolithic reinforced concrete church for the competition in 1929, and tried to make the modern material conform to the elements of historical architecture. The monumental dome with the ring sitting on the load-bearing walls with huge openings could only be solved structurally by a book from Berlin, from the year of the competition: Rausch, E.: *Berechnung des Eisenbetons gegen Verdrehung (Torsion) und Abscheren*. The characteristics of the planning and construction of the Prohászka Church support the fact that during the rather complex design process of architectural planning the considerable knowledge in the fields of structures and building construction is essential.

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