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Inverted Domes of Sports Halls in New Belgrade and Nis: Analysis from the Aspect of Structural Art

Jelena MILOŠEVIĆ*, Miodrag NESTOROVIĆ, Milijana ŽIVKOVIĆ, Marko GAVRILOVIĆ

*University of Belgrade – Faculty of Architecture
Bulevar kralja Aleksandra 73/II, 11000 Belgrade, Serbia
jelena@arh.bg.ac.rs

Abstract

Sports Halls in New Belgrade and Nis represent outstanding twentieth-century Serbian structural engineering examples. The structural systems of both halls were designed by architect and civil engineer George Zlokovic. The roofs of these halls are inverted domes spanning 60 and 70 meters made of prestressed cables suspended between the outer reinforced concrete ring and inner steel ring and stabilized with thin prefabricated concrete plates. This interpretative research discusses the design and construction process and presents a critical analysis of buildings from the standpoint of Structural Art. The study's conclusions were based on literature research, a review of archive documents, site visits, and a recording of the conversation with the author. The paper contributes to the development of structural critique by highlighting lessons learned from specific cases that should not be overlooked in current times, such as (1) the importance of research for design; (2) the significance of comprehensive and integrated treatment of diverse building aspects such as form, function, and structure by the reconciliation of architectural and engineering demands to provide design quality; (3) the benefit of linking rational with creative thinking to achieve design excellence; and (4) the benefits of the nonconventional approach to design and construction aiming to improve building economy and efficiency and produce aesthetically pleasing solutions.

Keywords: structural design, construction technology, structural systems, structural art, historical spatial structures, suspended structures, inverted concrete domes

1. Introduction

Original approaches to construction and series of innovative structures realized in Serbia in the middle of the twentieth century promoted a discussion of structural design from the perspective of a wider cultural framework and revising interrelation between engineering and architecture (Lazarević [1]). Previous standpoint strongly resonates with the concept of Structural Art as a creative subdiscipline of structural engineering (Billington [2]). Starting form this frame of reference, this research aims to identify and fill the missing contribution of Serbian structural engineering in the international panorama of modern architecture. The objective is to improve knowledge on the research topic focusing on two works of academician George Zlokovic (Đorđe Zloković), a prominent twentieth-century Serbian structural engineer (Nestorović and Milošević [3]) – prestressed hanging roofs for the Hall of Sports in New Belgrade (1968), and Hall Cair in Nis (1974), Serbia. Furthermore, investigating this topic should contribute to understanding the importance of the works historically, currently, and specifically from the Structural Art perspective, as well as to contextualize engineering achievements during a specific sociocultural and economic period. Finally, the research aims to raise awareness, promote exploitation and protection of the twentieth-century heritage that these spatial structures represent, and serve as a starting point in possible future identification, rehabilitation, and restoration strategies development.

2. Materials and Methods

The general strategy for performing the research was a case study that combined interpretative-historical and qualitative methods. The interpretative-historical technique was used to research complex spatial-temporal connections, and explain how diverse factors (including socio-cultural, economical, technological) brought about the material expression of buildings. On the other hand, qualitative research was applied to interpret a phenomenon in terms of meaning and value. Since in this type of study, researchers provided interpretation, meaning, and discourse, their expertise with the local context and socio-physical phenomena contributes to the validity of findings presented using narrative and description.

In this study, various documentary materials were used. This range of data enabled the creation of a comprehensive insight and increase in understanding of the author's peculiar design approach. The formed database included diverse types of evidence classified in the following categories: (1) *Determinative evidence* – photographs from the time of construction and data obtained from the interviews; (2) *Contextual evidence* – archival evidence (original project documentation), biographic and bibliographic data; (3) *Inferential evidence* – texts, other relevant buildings form that period; (4) *Recollective evidence* – obtained from the transcripts of unpublished interviews with the academician Zlokovic (first interview was conducted by Milošević as part of PhD studies research, second by Blagojević in 2013 in the form of a recorded public interview during the exhibition in Museum of Applied Arts in Belgrade, Serbia).

The research process included searching, collecting, organizing, analyzing material (sources), and constructing a complete narrative. The following research techniques were employed: (1) *Archive research* which provided extent archival documentation and its interpretation through the review of original projects, sketches, photographs (2) *Research of texts* including books and articles; (3) *Interviewing the author* as a tactic for both collecting and analyzing data; (4) I*n-situ study of buildings*, carried out in Belgrade and Nis, which were documented by photo and video records of buildings, and local information; (5) *Analysis and interpretation* which included reenactment, comparative analysis, descriptive analysis, logical interpretation, and identification of remaining questions.

3. Results

Zlokovic's designs are a direct expression of his principles and views on construction, therefore it is necessary to start their analysis by establishing a connection to the author, bearing in mind the peculiarity of academician Zlokovic as a person, scientist, engineer, designer, builder, and educator (Nestorović and Milošević [3], [4]). Zlokovic's design approach is related to his formal education as both an architect and civil engineer, but also to various influences during the years of his professional formation. From his study stays in Paris, Moscow, London, Munich, and the US in the early 1960s, Zlokovic brought a new set of knowledge. His theoretical points of reference at the time, in thinking about architecture and structural systems, were Buckminster Fuller, Frei Otto, Walter Bird, Pier Luigi Nervi, Robert Le Ricolais and others (Nestorović and Milošević [3], [4]).

Zlokovic belonged to a group of designers that viewed structural design as an autonomous discipline with its own set of rules that integrate science and art. In his work, he placed emphasis on the complementarity between disciplines of architecture and engineering, as well as on developing a rational base, along with the aesthetic values of his structural design. He did this by following a path in between the extremes of both disciplines and between inspiration and intellectual reflection. In addition, Zlokovic skillfully utilized an integral design principle, understanding a building as a unique, organic structure created by reconciling the diverse requirements, and through the complex interaction of form, function, and construction. Both Hall of Sports in New Belgrade and Hall Cair in Nis represent the embodiment of the aforementioned attitudes and principles.

3.1. Hall of Sports in New Belgrade

Built in the second half of the twentieth century, with its position, purpose, scale, and technology, the Sports Hall represents a complementary content to the buildings of administration, culture and trade that form the center of New Belgrade. Organizationally and aesthetically, the Sports Hall fulfills the needs and goals of the structure for the city center based on the Athens Charter. The universal hall was built for the "Partizan" Physical Education Association and sporting events. The project task was to accommodate an auditorium with 5,000 seats, a ground for smaller scale sports, a small hall for martial sports, a sports area with a separate entrance, a separate entrance for spectators with a hall, changing rooms, a buffet and sanitary facilities, within the given and limiting circular plan building, with a diameter of 61,6m. Volumetrically, the building consists of two elements – the cylindrical volume and the canopy following the cylindrical form that covers the entrance staircase. The free treatment of the glazed façade was enabled by the repetition of large-section columns which were equally spaced along the circular axes of the structure, with no additional elements in between them (Zloković [5]) (Figure1).

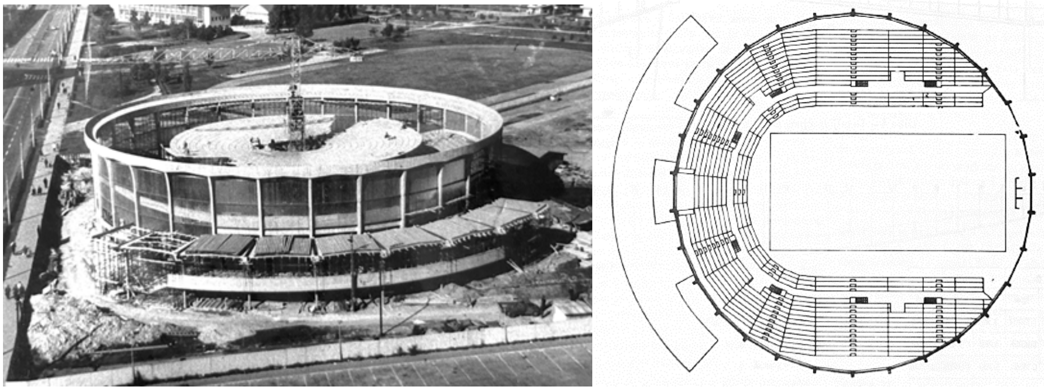

Figure 1: The Hall in New Belgrade under construction (left) and building's plan (right) ([5], 3, 10)

3.1.1. Inverted shallow shell dome spanning 60 meters

The roof of the Hall typologically represents an inverted prestressed dome with a 3-meter arrow. This system features a prestressed radial cable network supported on the outer compressed circular ring made of concrete, and central tensioned ring made of steel. The roof surface is made of prefabricated reinforced concrete slabs which, pre-stressed by cables, form a shell. The outer ring rests on columns stiffened by the tribune structure. The water drainage of the inverted dome was done through an opening at the lowest point of the dome (Figure 2).

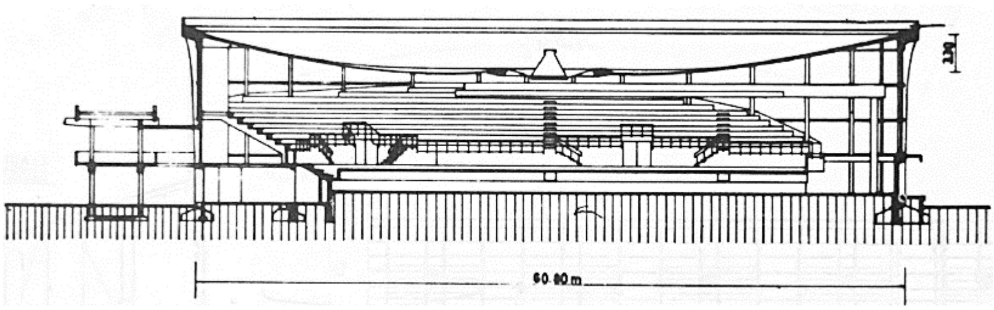

Figure 2: The section of the Hall with showcased span and height of the inverted dome ([5], 3)

The prestressing of the dome was achieved by loading bags with sand over the roof slabs supported by the cables, after which the joints between the slabs were filled with concrete. After the concrete hardened, the sand was removed. The cables then compressed the monolithic reinforced concrete shell. Due to the stresses in the shell, the cables were stiffened, and the deformability of the entire structure was reduced several times compared to a system that is not prestressed. When the concrete in the joints hardens, such a structure becomes a rigid three-dimensional prestressed reinforced concrete shell.

The calculation of the force in the cable was carried out considering the elastic deformations of the cable, which gives a lower force compared to a cable that is assumed to be inextensible. The cable and the compressed ring were calculated for the effects of constant load, snow, and temperature changes. The outer ring is compressed, flexually stressed in the vertical plane and in the direction tangent to the cables, stressed in torsion. The ring stability control shows a very high safety factor. The load from sandbags, used for prestressing, was 200 kg/m^2, which equals the sum of the weights of insulation and snow (90+110kg). The maximum force in the cable is 16.0 t, producing a tension of 69.3 kg/mm^2. The cable consists of a 6Φ7 profile of high-quality steel wire with a strength of 155 kg/mm^2.

The outer compressed ring (Figure 3) is placed at an inclination of 1:5 to the horizontal, which corresponds to the tangent to the curve of the cable at total load. The stresses in this ring are the normal force 605 t, the moment in the tangent plane of the cables -16.7 tm, the moment in the vertical plane -28.6 tm. Temperature stresses give smaller values than when only the total load is considered without these effects, since the heating of the ring occurs when there is no snow, and cooling reduces the diameter of the ring, which reduces the forces in the cables, and thus in the ring. The torsional moment of the ring is a maximum of 2.14 tm. In terms of ring buckling stability, there is a 26-fold safety. Dilation of the compressed ring was enabled by the conical surface on which the ring rests. The elastic joint enables smooth dilation of the ring to the limit, which is required, considering concrete shrinkage and temperature effects. In the case of seismic forces, the reinforcing bars prevent movement perpendicular to the radial direction, and in the radial direction they do not allow the ring to move beyond the limit determined for temperature expansion.

Elements of prefabricated reinforced concrete formwork consist of outer panels, internal panels, and suspended panels. They represent the final visible surface that is not processed further. With the help of these elements, the space for concreting the pressed ring is formed. The elastic joint and the anchors of the outer legs are in a leveling joint that forms a conical surface on which the pressed ring rests. The height of the leveling layer on the pillar axis is 37 cm, and in the middle of the field it is zero. The weight of one prefabricated element could not exceed 1200 kg due to the load capacity of the crane. The mutual connection of the panels was done at their ends by welding the dropped ends of the reinforcement and filling the joints.

The cables were placed radially at 78.5 cm on the inner edge of the compressed ring, where they are anchored with a hook, and for the inner tensioned ring they are fixed with the anchors of the IMS engineering system. Prefabricated reinforced concrete slabs are supported on the cables by means of dropped ends of the reinforcement (Figure 3). After loading the roof with the sandbags, the joints between the plates were filled. The highest pressure in the slab, immediately after unloading from the sand ballast, was 97.5 kg/cm^2, and with constant loading of the finished roof 53.6 kg/cm^2. In addition to radial couplings, parallel circuit couplings are also filled. With the outer ring, a wider coupling is provided for compensating the length in the radial direction.

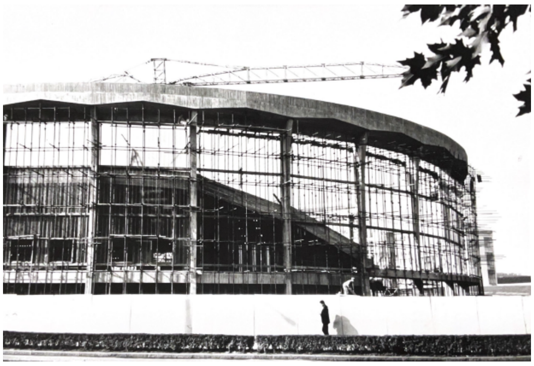


Figure 3: The outer compressed ring during construction (left) and the assembly of the inner ring, radial cables (right) (UB-FA Archives)

The tensioned inner ring is axially stressed both for constant load and when the snow is on one half of the span of the suspended shell. The force in the ring is 645 t if the elastic deformations of the cables are not considered, or 605 t if they are. The ring consists of 6 parallel lamellae 400.20 with a distance between them equaling the thickness of the garter. In this way, a simple continuation is possible using double-sided tourniquets and multi-head screws. The force from the cable to the tensioned ring is transmitted through the bands, which allows all lamellae to be equally loaded. With workshop welding, these elements are fixed in certain places and these seams do not have a supporting role (Zloković [5]).

3.2. Hall Cair in Nis

The Hall of Sports in Nis (Hall 'Cair') represents an advancement in conceptual and structural terms from its predecessor, the Hall of Sports in New Belgrade. Several innovative structural solutions, cable lines' distribution and adjustments, as well as technological procedures, were introduced in the design of this Hall (Zloković [6]).

The Hall structure was based on a circular geometry, placed in a city park Cair, as a natural addition to its general spatial composition and recreational identity. Visually, the building differentiates from the New Belgrade Hall with its form having an outward offset in the upper part, designed with the recognizable rectangular screens in the circular glass façade (Figure 4). The organizational plan of the building was constructed in a way to allow housing for a different set of functions, including: the central multifunctional hall with the capacity of 6500 seats (4000 for sports-related events), a hotel with the capacity of 50 beds, a restaurant with 200 seats, a small training hall, a press center doubling as a conference room, as well as dressing rooms for the referees and coaches [7]. The challenge of the building's structural design was the elaboration of inverted dome roof structure spanning 70 meters. It was configured to be overall more rational than the New Belgrade Hall, considering the total material consumption and construction technology.

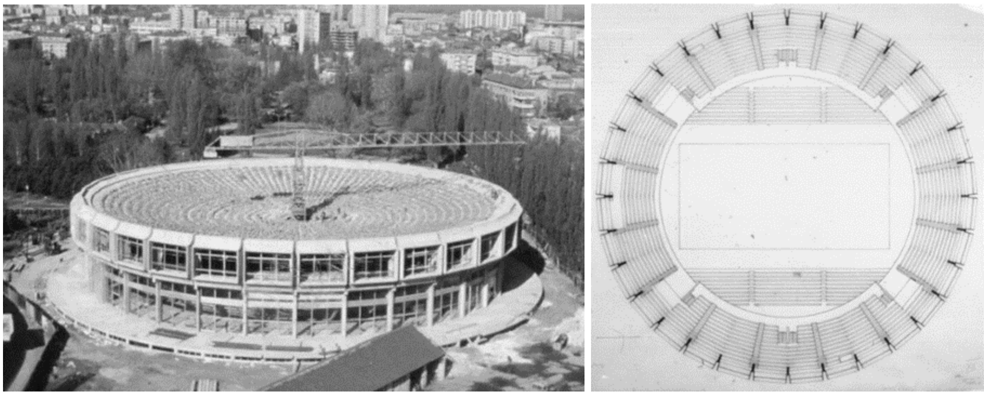

Figure 4: The Sports Hall Cair in Nis nearing completion (left); and building's plan (right) (UB-FA Archives)

3.2.1. Inverted shallow shell dome spanning 70 meters

The structural concept used for the roof is similar to that used for the New Belgrade Hall. It consists of 128 radially distributed steel cables spanning between the outer compressed concrete ring, with a variable cross-section, and the inner tensioned ring made up of steel plates bolted together. The outer ring is at a higher level than the inner, creating the inverted dome geometry, with the arrow of the dome being 4 m. The concrete ring is 160 cm wide with heights varying from 57 to 87 cm. It is supported by 32 radially distributed columns and the special type of elastic joints were used to tie them together. These connections allow for the ring to have a fixed support in the direction of the columns' longitudinal axes, while also being able to slide in the inclined direction of the support base (Figure 5). The inclination of the concrete ring cross section is 30%. The elastic joints were used to prevent the bending of the columns due to the possibility of them being pulled towards the center of the structure as a result of the ring's temperature induced deformations. The prefabricated concrete slabs used for the pressing of the steel cable radial network came with perimetrically placed ribs only 12 cm in height (the slab itself is only 3 cm thick). The slabs were prestressed, and due to that mostly compressed.

Special efforts were made to improve the construction technology. The construction process was highly efficient and based on a low-cost strategy using only one centrally positioned crane with a 40 m span, with scaffolding solely placed in the middle of the structure for positioning the tensioned steel ring. Firstly, the concrete columns and outer ring were cast, with the elastic joints and steel cables placed along the rings' length. Then, the steel ring was positioned using the scaffolding and crane to proceed with the cable tensioning. Later, the prefabricated slabs were placed on the cable network, along with the spacers needed for positioning the joints between the slabs.

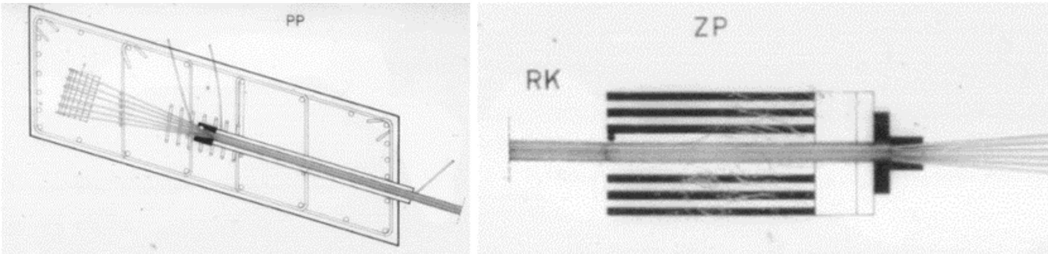

Figure 5: Left: The detail of the prestressed cables' anchorage to the outer compressed ring; Right: the joint between the prestressed cables and the inner tensile ring (UB-FA Archives)

After the slabs were positioned, the cables were once again tensioned and secured by using steel plates in the anchorage points. The circular joints between the slabs were then reinforced and the projected weight was introduced to the roof structure. The weight was created by placing bags filled with sand on top of the roof to prestress the inverted dome (Figure 6). An important aspect of the monolithization process was to maintain the radial symmetry of the load distribution in the roof, by planning out the sequence of the concrete filling in the joints. Lastly, the cables were bent at the end where they are supported by the steel ring and the ring was injected with concrete. The finishing segments of the roof construction were carried out by closing the steel ring with a steel cone, and building the water drainage installations, along with the suspended ceiling (Zloković [6]).

Figure 6: The process of prestressing the inverted dome of the Hall of Sports in Nis (UB-FA Archives)

The hall is still in active use, after it has been reconstructed and adapted to contemporary needs in 2011. The characteristic architectural elements such as the window screens were kept and adapted to the current regulations [8].

3.3. Analysis from the Structural Art frame of reference

Based upon engineering rather than architectural design, structural art is more akin to an idea than the artistic forms commonly found in large constructions (Scipio [9]). The main way that structural art differs from architecture is in the constraints that structural artists work under. In this regard, it is important to address the fact that structural engineers frequently produce works of art that are unknown to the global architectural practice (Hu, Feng and Dai, [10]), by discussing the work of authors like Zlokovic, who is a member of a relatively small community of Yugoslavian engineers and is both an architect and a civil engineer. Regarding David Billington's [2] definition of structural qualities and values that structural art should possess, including economy, efficiency, and elegance, Zlokovic's designs could be classified as such. In support of this claim, and to fully grasp the significance of his works, scientific, social, and symbolic dimensions of his achievements will be further elaborated.

Zlokovic's spatial structures are characterized by conceptual unconventionality, rational consumption of materials, work, and energy per unit of surface area, and well-thought-out construction technology. What unites Zlokovic's projects is his sensibility and characteristic analytical approach. Considering the scale of the projects he worked on, as well as the ideas that emerged from his theoretical work, Zlokovic's methodology included a continuous development and implementation of new design and construction tools. True to himself, he understood and studied the traditional processes of architectural and civil engineering, and innovated in ways which supported the originality of his designs. Reflecting on his work he pointed out the following:

> *The correct application of spatial structures in architecture presupposes knowledge of the static and structural properties of the system, since a huge number of diverse possibilities require an exact analysis when looking for the most favorable system, where in addition to stability, functional, aesthetic, and economic conditions should be optimally satisfied.*

The application of shallow inverted shell domes as an architectural, artistic and engineering gesture, Zlokovic justified by stating the following reasons: (1) Urban requirements that the building should have as little height as functionally possible; (2) Reducing the volume of space (and therefore the air in it) which significantly lowers investments and costs for heating and ventilation; (3) Creating a more pleasant impression on the user by enhancing the natural lighting through the utilization of a concave dome (the internal surface of the dome should be materialized in a way which reflects the natural light to a planned degree).

The shape, organization and, above all, structural system, and construction technology of the Sports Hall in New Belgrade, represented the driving model for the advanced design of the Hall Cair in Nis. These buildings demonstrate the evolution of Zlokovic's work process that extends between projects, demonstrating consistency of practice whose work is based on research, continuous improvement and Apollinarian striving for innovation. The comparison of the main characteristics of two buildings, built 6 years apart (given in Table 1) as well as following discussion, highlight the development of the ideas, and how they address the structural art aspects of economy, efficiency, and elegance.

Table 1: Comparative analysis of the two halls' main characteristics

Hall of Sports in New Belgrade	**Hall of Sports in Nis**
Location: Novi Beograd, Block 5 Year of construction: 1968 Investor: Municipality of Novi Beograd Architectural design: Arch. Eng. Velimir Ostojić, Arch. Eng. Olga Ostojić Structural design: Arch. Eng. Civ. Eng. Đorđe Zloković, PhD Main contractor: "Prostor", company for studies, design and construction, Belgrade	Location: Nis, 9. Brigade Street Year of construction: 1974 Investor: City of Nis Architectural design: Arch. Eng. Ljupka Kovačević Structural design: Civ. Eng. Dušan Stanković (lower part of the structure); Arch. Eng. Civ. Eng. Đorđe Zloković, PhD (roof structure) Main contractor: "Građevinar", construction company
Span 61.1m, boom 3.08m, f/l=1/20	Span: 69.6m, boom 4m, f/l=1/19
Material consumption per roof square meter: 16 cm of concrete 25.4 kg of steel	Material consumption per roof square meter: 11.2 cm of concrete 20.6 kg of steel
Total number of prestressed cables: 240	Total number of prestressed cables: 128
Total scaffolding surface: 323m^2 / 11% of the roof surface (3000 m^2)	Total scaffolding surface: 220m^2 / 5.5% of the roof surface (4000 m^2)
Volumetrically consists of two joint segments – the main hall and the canopy	Volumetrically characterized by the addition of the offset part on the upper part of the building
The prestressed slabs have a trapezoidal shape with the section height of 16cm	The prestressed slabs have a T-shaped perimetrical ribs with the reduced section height of 12cm in the rib zone, and 3cm in the slab zone

3.3.1. Interpretation in terms of economy and efficiency

By selecting a system of prestressed cable networks, a relatively light and rigid large-span roof structure was obtained in both cases. A suspended roof on a circular base with radial cables is an economical solution due to the lowest material and labor consumption, assembly without scaffolding (only used for the inner ring) and with a minimal amount of formwork. The driving force behind the structural solutions was the need for the most economical solutions, low amount of on-site labor (most of the structural elements were prefabricated and mounted on site), fast building process, as well as the least amount of material used.

In the background of these design projects stood extensive scientific research. The project documentation for the Sports Hall in New Belgrade contains a study explaining the theoretical basis for the calculation of hanging roofs and attached excerpt from the literature. Such a studious approach resulted in a series of technical solutions that contributed to the overall efficiency of the construction. The pre-stressing of the roof allows the shell of the prefabricated plates to be always compressed; because of that the movement of the cables due to asymmetric snow loads is small, as well as the deformability of the roof in general. Also, since the adjustment of cable lengths and their anchoring is done as in the case of prestressed concrete elements, joints that require screws made of special steel are avoided. In comparison to the reinforced concrete domes, this solution, in addition to using considerably less formwork and scaffolding is more economic. The analysis of the cost of both types of structures (using the pavilion in Montevideo as a reference for the reinforced concrete dome) showed that the solution with a reinforced concrete dome is 3.75 times more expensive than the inverted dome shell of Sports Hall in New Belgrade. The material consumption in Cair Hall is less per square meter than used in the New Belgrade Hall, because of the technical solution improvement.

The construction technology was leveraged to another level conceptually compared to what has been done before in local context. For example, to achieve prestressing in the cables, additional loads were needed. The quick and economical solution was to use sandbags. These halls were among most inventive structures in Serbia at the time, yet the construction technology was essentially low-tech, making it accessible and manageable to local contractors. The entire process was highly sensitive to local context and state of technology and based on rational principles. When interviewed about his hanging roofs designs, Zlokovic explained that they were built with the help of a single crane, practically without scaffolding, prefabricated like weaving a spider's web:

> *We succeeded because prestressed suspended roofs are extremely rational. This is a single shell of thousands of prefabricated elements placed on a network of cables. Those elements, three centimeters thick with ribs, are very mobile on the cable network, but assembled with concrete joints and prestressed, they form a very rigid and stable whole.*

Precisely controlled design and construction processes, demonstrates the high level of professional ethics, reflected also in a rational approach and self-imposed limitations, synchronization of all participants. This resulted in far greater control of the author during the entire process. This fits beforehand with Zlokovic's view that architecture and special constructions cannot be separated, and that an architect must from the beginning propose forms that are tectonic.

3.3.2. Interpretation in terms of elegance

Given that Zlokovic was formed both as a civil engineer and an architect, his creative thinking, while at the same time being scientifically sound, presents no surprise. Even though his practice was focused on structural design, his approach to unique, non-conventional and elegant structures was rooted in his architectural education. Contrary to the frequent architectural attitude that form represents the goal, which favors its complacency, Zlokovic's halls are the result of the interweaving of different and complex relationships that are set at the beginning of the project (including investor, economy, program, aesthetics, construction, context, environment, construction technology, material, time of realization). Zlokovic's attitude was grounded in the belief that, in architecture, everything must be in balance.

Formally simple, cylindrical buildings are created as a result of Zlokovic's personal search for the ideal Platonic form. Having in mind his overall work, we perceive that both Zlokovic's scientific research in the field of the theory of structures and practice are based on mathematical principles and methods, and understanding of mathematics as the law of the world, beauty, and art. Both the Hall of Sports in New Belgrade and Hall Cair embody the transformation of an archetype referencing to the ancient arenas. The aesthetics of the primary geometry aligns with some of the perspectives presented in Vitruvius' treatise [11], which may not be regarded as a theory of beauty in the strict sense, as Grassi emphasizes [12]. This view of architecture is shaped by mathematical principles and demonstrates an effort to uphold the relationship between ontology and art.

Zlokovic began his book "Co-ordinated Systems of Constructions" [13] by quoting Vitruvius: *Proportio est: ratae partis, membrorum in omni opere totoque commodulatio ex qua ratio efficitur symmetriarum* (Liber tertius, I). This conveys the impression that modern architects are still able to strive for canons in the arrangement of spatial elements and reflects a belief in the timelessness of certain concepts, which need not conflict with notions of modernity and technology. By adopting such an approach, whose naturalness is constructed, a simple and harmonious architecture with a series of perfect details was created. His motto was to achieve the impression of simplicity, create buildings that are lightweight (both in terms of structure and aesthetics), and seem effortless, as if they were naturally assembled and arranged.

Zlokovic maintained that, to simplify the design and building processes, it is essential to establish dimensional harmonization of the structural elements and assemblies, keeping in mind the additive nature of the construction process. Previous has an implication on the buildings' design and aesthetics because it produced a balanced relationship and harmony through systematic and dimensional coordination, which was accomplished by applying preferential sizes of measurements based on the sexagesimal system. The search for balance and harmony of the buildings' structure can be described as their greatest quality – basic geometry, abstract and without anything too narrative in the design.

During the period of socialist Yugoslavia, the process of urbanization was at a high level for most of the Yugoslav cities, including Belgrade and Nis. After the first wave of new construction mainly focused on housing units, reflecting the initial needs of the growing working and middle class in urban areas, it was clear that cultural, recreational, and other amenities were underdeveloped (Blagojević, [14]). It is important to emphasize that AEC (Architecture, Engineering, and Construction) practice in Yugoslavia was highly associated with federal politics and economy, making these types of structures sought after and a good ground for the AEC industry development. Finally, both analyzed halls are public buildings that serve as sports and recreation centers. In addition to meeting space and organizational requirements and standards, they have strong social aspects, and reflect the relationship between architecture and identity in specific local context (time and place). In this regard they also have certain semantics providing people with something that they will be proud of.

4. Conclusion

The Hall of Sports in New Belgrade and Hall Cair in Nis are highly economical and efficiently designed structures that meet the requirements of their architectural program, while displaying Zlokovic's advanced research and design principles. Every detail of these structures has been thoroughly planned and well executed, demonstrating that the innovation in structural design does not necessarily require the use of highly advanced construction technology. The aesthetic value of the projects is seen in their monumental status as landmarks of the cities of Belgrade and Nis. The structures are a result of a holistic approach in which architectural and structural design intertwine and conjoin to form a monumental representation of the engineering capacities of the time. About the time in which Zlokovic worked, can be said that Serbian cultural space was side by side with global design movements. The heroic period of construction in former Yugoslavia left behind several innovative buildings, some of them attracting the attention of the international public. Academician Lazarevic [1] noticed that *constructor lives the full* *life of his time* as well as that *they mutually mark each other.* And time favored an advanced way of thinking, willingness to engage with challenges, while sociocultural and economic conditions facilitated realization of creative ideas, which are all necessary conditions for innovation. Unfortunately, the architectural and construction discourse in Serbia in this sense failed to achieve continuity. In line of Lazarevic's [1] classification of constructors, some constructors working in that time in Serbia could be designated as *modern constructors* – the creators of developmental concepts. Zlokovic's elegant and rational buildings based on the logic of tectonics, proof that by using methods and tools of science, architecture, and art there is a possibility for invention.

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Paper Title: Inverted Domes of Sports Halls in New Belgrade and Nis: Analysis from the Aspect of Structural Art

Author(s): Jelena Milošević, Miodrag Nestorović, Milijana Živković; Marko Gavrilović

Affiliation(s): University of Belgrade – Faculty of Architecture

Address: Bulevar kralja Aleksandra 73/II, 11000 Belgrade, Serbia

Phone: + 318643534893

E-mail: jelena@arh.bg.ac.rs

Printed name: Jelena Milošević

Signature: ____

Location: Belgrade, Serbia

Date: 01.07.2024.