RECONSTRUCTION, MODERNIZATION AND BUILDING OF FOOTBALL STADIUMS IN THE SLOVAK REPUBLIC

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Abstract: *Roof constructions of football stadiums must mainly comply with safety criteria. In terms of security risks, they must therefore meet the strictest criteria. Durability is also an important factor. At the same time, they should also meet architectural requirements, which are often influenced by the budget.*
The development of new technologies and materials is also reflected in various roofing projects for football stadiums in Slovakia.

***Key words**: football stadium, reconstruction, modernization, building*

1. Introduction

The modernization of football stadiums in Slovakia has moved forward significantly in the last ten years. It was a logical development. Almost all football stadiums in Slovakia did not have adequate technical infrastructure. The only stadium that gradually underwent reconstruction was the MŠK Žilina stadium. It was also used for matches of the Slovak national team. Some stadiums were no longer suitable even from the point of view of safety and their parts, or the entire grandstands had to be taken out of use.

Their maintenance, as well as inappropriate structural solutions, had a significant impact on the state of the supporting structures of the stadiums. That is also why the government of the Slovak Republic by its resolution no. 115 of February 27, 2013 approved the financing of the reconstruction, modernization and construction of football stadiums for the years 2013-2022 in the amount of 45,000,000.00 euros. By concluding a contract between the Ministry of Education, Science, Research and Sport of the Slovak Republic and the Slovak Football Association, stadiums were selected that will be able to draw funds for their renovation. Stadiums were still divided according to UEFA criteria. Two stadiums in Žilina and Trnava were included in category 4, the others in categories 3 and 2. It was a significant shift in the modern era of modernization of football stadiums in Slovakia.

2. Safety and durability

Football is becoming a bigger and bigger phenomenon. It is a source of huge funds

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and some gigantic constructions of stadiums are connected with it. Most of the stadiums in the respective countries have been modernized or built new, mainly in connection with the organization of international competitions - European or world championships. The development of new technologies, materials and construction procedures has also significantly affected this sector. In many countries, modern stadiums are their pride and rank among important buildings that testify to the strength of the economy or the maturity of the nation. However, safety and durability are the most important attributes of all types of load-bearing structures.

In football stadiums, this aspect is all the more significant, because in these objects there is a large accumulation of people - in the order of tens of thousands. An important part of football stadiums are the roofs of the grandstands. Most of the stadiums that are included in the highest category with four stars must have all the grandstands covered. It is a significant shift in terms of protection of grandstands from the effects of the weather. Grandstands are the most heavily loaded structures. Therefore, their safety comes first. Whether the constructions of the grandstands are designed from concrete or steel, their roofing does not cause a significant degradation of the materials as with uncovered structures. New technological procedures in the field of concrete prefabs contributed significantly to the safety and durability of tribune structures. Most of the stadiums built in recent years have grandstands made of prefabricated elements made of high-quality concrete. Prefabrication has enabled the realization of elements of various shapes and sizes in recent years, but mainly contributes to increased safety and durability. Even from an architectural point of view, such elements are preferred. The proportion of prefabrication compared to old stadiums is incomparable. However, it should not be forgotten that despite this, it is most important to design the right type of prefab for the given part of the structure and to choose a proven type of detail. When assessing prefabs, their verification at the I. ultimate limit state and II. serviceability limit state is very important. In this regard, the dynamic stress on the grandstands caused by the crowd plays a significant role in safety.

Another important part of the stadium is its roof. In most cases, this forms the main architectural element. In most stadiums, these roofs are realized using steel structures of various types. The type of proposed structure depends on several factors. At the beginning of the design project, the architectural requirements are set and their fulfillment in terms of the overall architectural expression and its integration into the site in question. However, the roof must again meet the criteria set for safety and durability. A properly designed static system and the use of suitable materials is the first prerequisite for a building to be safe and to have the required lifespan. Climatic changes play a significant role in the design of the roofing structure. Even in European conditions, we are already exposed to extreme weather fluctuations, especially the effects of wind. Therefore, we must prepare for situations that cannot be underestimated in connection with the effects of frequent storms or hurricanes. This issue is related to the reliable design of the tribune roofing. An important role is played by the dynamic component of the wind and its flow. For such important buildings as stadiums, it is advisable to prepare a wind study and verify the roof in a wind tunnel. The costs associated with such verification are incomparable to the level of risk that may arise from an inappropriately designed construction. That's why it's important to appeal to investors to have such a wind study drawn up already during the proposal.

An integral part of the project documentation for such important buildings as stadiums should be a statics audit. An independent assessment of the audit is thus another important one a point that contributes to the safety of the building. It is important that the checking structural engineer (Prüfingenieur) - auditor has experience with similar buildings. An example is the established and functioning static control procedures in Germany.

Even if all the conditions associated with the design of the stadiums are met, the building may not meet the criteria of safety and durability if the quality requirements imposed on the delivery and assembly of the building are not met. In order for the construction to meet these requirements, it is necessary for the selected contractor to meet the strictest quality assurance criteria for such constructions, not only during its implementation, but also during the warranty period of the work. These aspects should already be taken into account during the selection procedure of the construction contractor. The same must apply when choosing a designer. The general designer must guarantee not only the quality of the project but also professional author supervision during the entire construction of the work. The same applies when choosing a construction supervisor.
The construction supervisor should have sufficient experience with such constructions. Therefore, in most cases, it is advisable to choose a larger company for supervisory activities.

So, if we can define the main attributes of safety and durability of the supporting structures of stadiums, then they are:
- suitability of the designed static and supporting system,
- appropriate selection of structural elements,
- suitability and type of designed materials,
- performance of control static audit,
- quality of work implementation,
- control activity during the implementation of the work,
- maintenance and care of the building during its lifetime.

3. Supporting structures of the grandstands and their roofs

The design of the support structure of the tribune is primarily influenced by the architectural design. However, it is important that such a structure is also designed safely. A suitable static system of the tribune's transverse structure and global stability in the transverse and longitudinal direction are the basic prerequisites for the reliable transfer of permanent, imposed and climatic (variable) actions. From the point of view of the materials used (with the exception of wooden ones), the support structures of the grandstands can be divided into:
- steel,
- concrete,
- combined.

In the last period, the supporting structures of the grandstands built from concrete are mainly used. The reasons are simple. Concrete is one of the oldest building materials, and in recent years, mainly due to modernized prefabrication procedures, it has been increasingly used. The technical, technological, aesthetic and economic advantages include, for example, permanent color, low maintenance costs and a long durability, which practically coincides with the life of the object. The surface treatment of concrete elements plays an important role here. With a suitable combination of all aspects, brilliant surfaces with surface porosity of up to 1% can be achieved. Fig. 1 shows an example of the combined construction of the western tribune of the City Arena football stadium in Trnava. This tribune was the only one subject to reconstruction. The original main supporting steel frames of the roof were left. The main steel beams of the tribunes were newly realized, on which prefabricated concrete benches for the auditorium were placed. As standard, the benches were equipped with slats for seating. A new ramp was built to install lighting up to a height of 23,788 m.

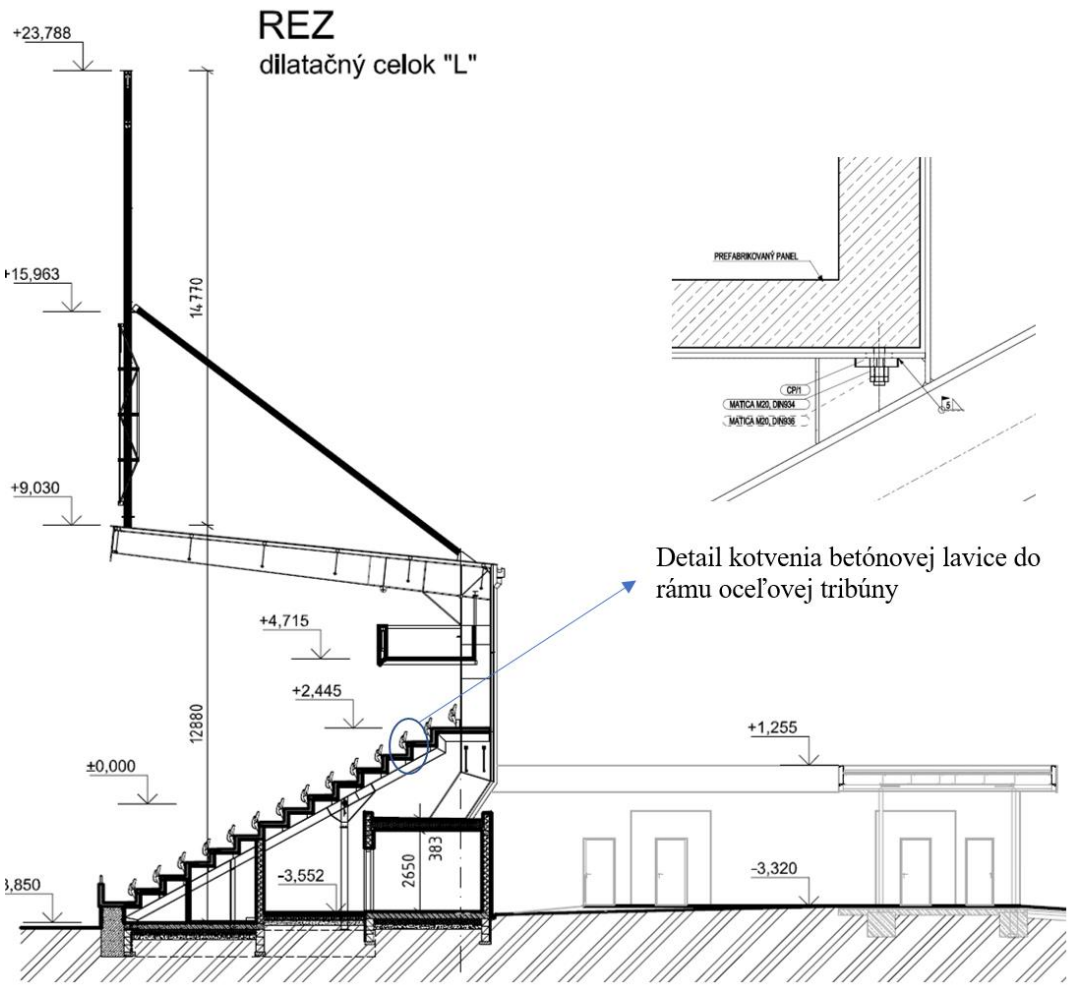

Fig. 1. Transverse link of the combined structure of the west tribune of the City Arena in Trnava. Cross section, dilatation unit L. Prefabricated panel. Detail of the anchoring of the concrete bench to the frame of the steel tribune.

Fig. 2. Example of the structure of the northern prefabricated tribune of the City Arena in Trnava.

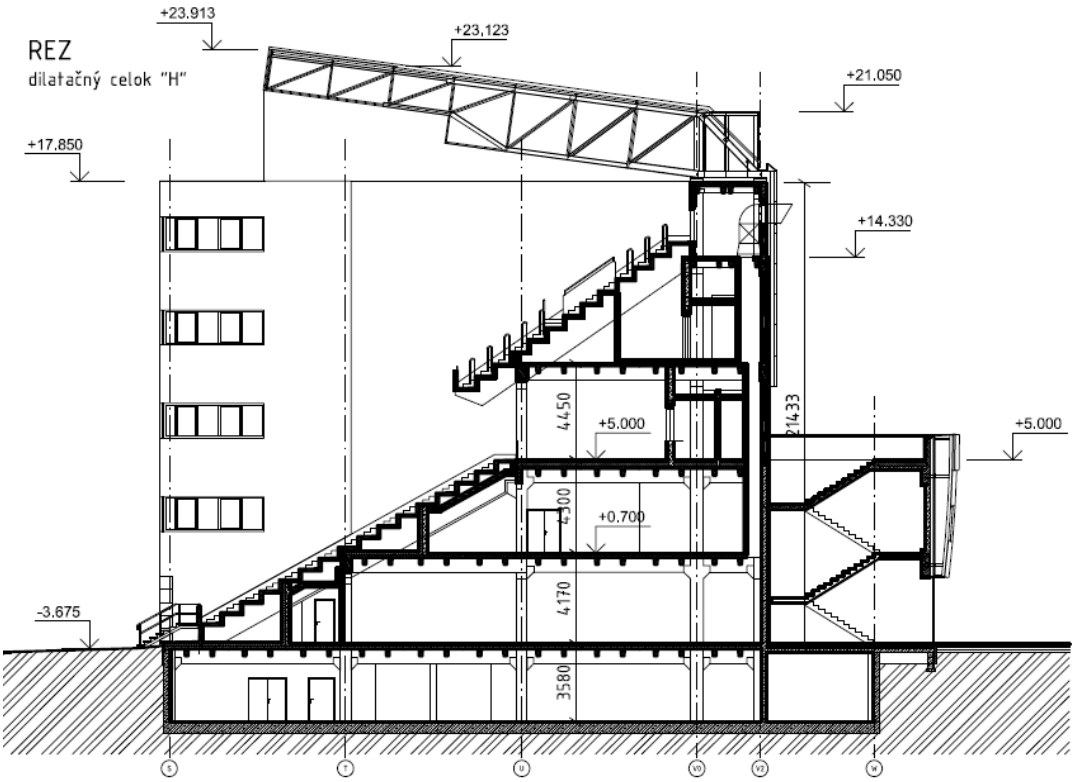

Fig. 3. The supporting structure of the northern tribune of the City Arena in Trnava Cross section, dilatation unit H.

In Fig. 3 is an example of a solution for a multi-storey tribune of the City Arena football stadium in Trnava. A part of the premises serving as parking areas is scattered below ground level.

Fig. 4. City Arena in Trnava, view of the completed building.

Fig. 5. City Arena in Trnava, view of the pedestrian zone – part of a multifunctional building.

4. National Football Stadium in Bratislava

The construction of the national football stadium in Bratislava was the largest and most significant investment in the modernization of football stadiums in Slovakia. The stadium is built on the site of the former stadium (legendary Tehelné pole – Brick field), thus preserving the continuity of the environment. The project is the author's work of Ing. arch. Kállay. The stadium with a capacity of 22,500 spectators meets the highest criteria of UEFA standards for category 4. There are multi-storey VIP zones, SKY-boxes and congress halls. More than 1,000 parking spaces are available in the stadium underground. The construction of the stadium was carried out by the company Strabag Pozemné a inžinierske staviteľstvo, s.r.o. The entire project also includes commercial parts - an administrative building and a residential complex of buildings "Tehelné pole". These buildings were also realized by the firm Strabag Pozemné a inženierske staviteľstvo, s.r.o. The construction was completed in 2019. From the point of view of the project solution, the most modern methods were used on the construction, such as the production and assembly of the steel structure of the grandstand roofing and the roof membrane, or in the field of monolithic reinforced concrete structures, the use of COFRA 220 elements and prefabricated structures. From a static point of view, it was a complicated load action, especially in the assembled state. The most complex phase in this issue was the debugging of structures from the point of view of II. serviceability limit state. The company Stavokov projekt s.r.o. provided the static part of the implementation project for the entire stadium and also for both commercial buildings. Work on the implementation project began in the fall of 2016.

The National Football Stadium won the prize in the Construction of the Year 2019 competition in Slovakia for an exceptional and progressive project solution. The expert jury was impressed by the mastery of the demanding static solution of the steel structure of

the grandstand roof with exceptional loading of the cantilever-like parts of the structure, which forms the largest membrane structure in Slovakia and, for the challenging solution, is atypical of the prefabricated structures of the stadium grandstands. The new football stadium Tehelné pole was nominated for the 'Stadium of the Year' award for the best stadium opened in 2019. The award is awarded in two levels. One is awarded by sports architects, but football fans can also vote. The competition is announced by stadiumDb.com, one of the world's leading websites dedicated to football stadiums. Tehelné pole won 11th place from 21 selected participants of the competition.

Fig. 6. Visualization – National football stadium and complex of commercial buildings. Author: Ing. arch. Karol Kállay.

5. Bearing concrete structures of the upper structure

5.1 Tribune beams

The supporting elements of the grandstand, both lower and upper, are designed as prefabricated. They are placed on supporting monolithic frame structures in the column heads or to brackets on columns. The width of the tribune beams is 500 mm and the static height is 900 mm. They are fitted via end teeth with holes formed by HWR ø 80mm, on elastomeric bearings with thickness 10 mm with the prescribed bearing capacity - for the spikes of the column brackets. Holes or HWRs are thoroughly poured with concrete min. C30/37 finer fraction, or better - Emcekret.

Due to the implementation process, the part of the ceiling at the elevation of +14.0 is solved with a pair of prefabricated beams.

5.2 Tribune benches

Tribune benches were mounted on the tribune beams. The clear width is 800 mm and the step height is 360 mm for the lower grandstands up to level +6.00 and 550 mm for the upper grandstands above level +6.00. There are atypical elements resulting from the technical solution at the edges and near the stairs. The basic shape type of the grandstands is the so-called inverted and double-bent-L so called "double-headed", due to the max.

restrictions of horizontal joints. Where, for composition and structural reasons, it was not possible to preserve this principle, the cross-section is simply turned - L.

The first outermost row from the grandstand and on the gallery has the shape of an unequal-armed letter U due to the creation of the railing border. The uppermost row of benches is supported by a prefabricated railing brace. To better ensure watertightness, the joints of the benches are placed in the upper position of the seats, with placement on a rubber sealing profile in the insertion groove. Statically, the benches act as hinged, simple beams with the possibility of deformation due to temperature effects. The material used was: concrete STN-EN 206-1-C40/50-XC4, XF1(SK)-CI 0.4-Dmax16-S3.

Fig. 7 Assembly of the structure of the western tribune and tribune benches.

6. Basic characteristics of the grandstand roof

The roof of the grandstands of the national football stadium is characteristically divided according to the orientation of the world sides into:

- North grandstand
- East tribune
- The western tribune
- South tribune

The steel structure of the South and East grandstands are structurally identical. The structure of the northern grandstand is placed lower so that it does not cause excessive shading of residential buildings. The structure of the western grandstand is mounted on the load-bearing reinforced concrete structure of the roof. The maximum heights of the grandstand structure were defined in the building permission. From this, the heights of the steel structure were derived, which were increased by the value of the deformation from the structure's own weight and the roof shell. The roof shell is made of a PVC membrane.

6.1 Static action and stability of the structure

The structure of the roof of the grandstands of the national football stadium is designed from steel. The basic static scheme for all grandstands consists of a cantilever. From a static, but also an architectural point of view, only the eastern and southern tribunes have the same shape. The layout of the cantilevers is different for individual types of grandstands:

- North grandstand: 23.30 m
- East grandstand: 29.00 m
- West grandstand: 24.38 m
- South grandstand: 29.00 m

The cantilevers are designed as lattice systems anchored to reinforced concrete structures. The cantilevers on the northern grandstand are hinged to a single-bay steel frame anchored to the load-bearing reinforced concrete elements of the grandstands. The rear part of the structure consists of a bracket and a tie rod for anchoring the shell. However, these elements also perform a static function to balance the system. The cantilevers on the western grandstand are hinged to a two-bay steel frame, anchored to the load-bearing reinforced concrete roof elements.

The cantilevers on the east and south grandstands are hinged to the steel column. In the rear part of this structure, a balancing system is designed, designed from a steel horizontal bracket and a system of two truss rods.

The stability of the roof constructions in the longitudinal direction for all types of grandstands is ensured by lattice braces. In the case of membrane constructions, the upper chords of the trusses correspond to the convex curves of the membranes and are offset with a margin so that they do not come into contact with the membrane, which would cause problems with water drainage. Lattice stiffeners also perform an important function during the assembly stage when tensioning the roof membranes, where large tensile forces occur perpendicular to the longitudinal axes of the upper straps of the trusses due to prestressing. In the front part of the roof in the length L = 12,0 m, a structure for skylight is designed. This construction is designed from rolled IPE profiles and Jäckel profiles, on which full polycarbonate plates with thickness 10 mm were placed.

6.2 Description of the supporting structures of the roof

The upper chords of the truss brackets are designed from Jäckel profiles. The diagonals of the vertical members and the bottom chords are designed from tubes. Vertical lattice longitudinal stiffeners for a span of L = 8,15 m ensure the stability of the brackets in the assembly stage, but mainly perform a stiffening function against the action of the horizontal effects of the membranes. The steel constructions of the cantilevers were made in the workshop, delivered in one piece.

7. Conclusion

This contribution is primarily dedicated to the two largest stadiums in Slovakia. The multifunctional complex City Arena in Trnava won all the awards, including the main prize in the Construction of the Year 2015 competition. The construction of the National Football Stadium in Bratislava received an award in the Construction of the Year 2019 competition for an exceptional and progressive project solution.

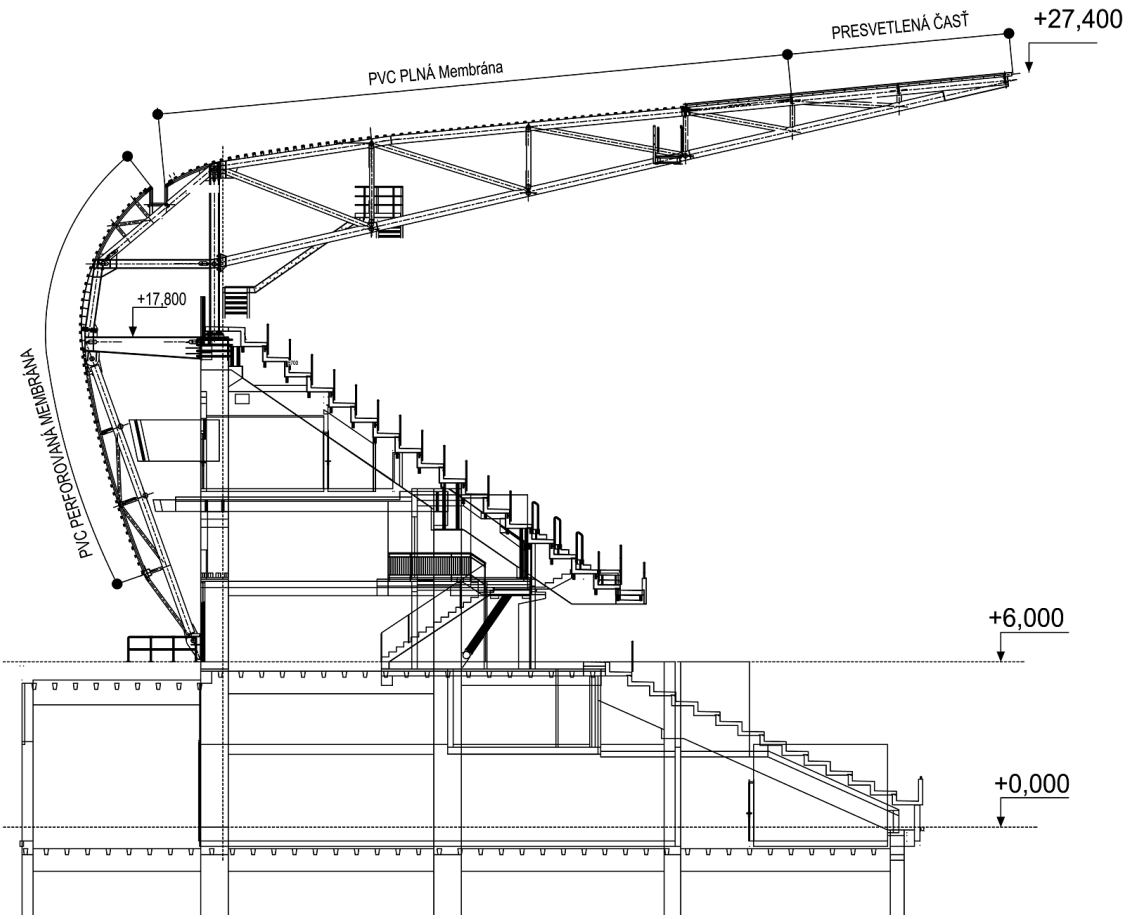

Fig. 8. Schematic cross-section of the eastern grandstand. PVC perforated membrane. PVC full membrane. Lighting part.

Fig. 9 Instalation of the steel structure of the grandstand roof.

Fig. 10 National football stadium, Tehelné pole apartment complex and administrative building.

Fig. 11 National football stadium in Bratislava, illumination lighting.

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References

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