formal "binder" for adequate formation of the future identity of urban design in the history of cities.

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STADIUMS – THE PRESENT AND THE FUTURE

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Stadiums are arguably the most important sport facilities today. Due to their significance, size and popularity, they define the surrounding space and often even the cities and areas they are located at [2]. They become the symbols of the countries they were built in. Stadiums are also architectural objects seen by more people than any others [5]. The number of people who see stadiums on TV is enormous, since sport manifestations are commonly being shown at prime time. Also, stadiums are buildings that gather the greatest number of people at the same time, even more than 100.000. Stadiums owe their public visibility to the growing popularity of sports in the last one hundred years. Other than this, stadiums as magnificent architectural objects also deserve to be in the center of attention. Compared to other types of architectural buildings, stadiums have very long inactive periods, while they retain very high maintenance costs [1]. Thus stadiums need to attract visitors even in the inactive period and in such way ensure their financial sustainability.

Today stadiums are usually built with some type of cover. Cover is an important element of the architecture of the stadium, both esthetically

and structurally. There are several types of structural systems most commonly used for the stadium covers (Table 1.1).

In this research eleven representative stadiums around the world have been analyzed. All of these were built or fully reconstructed after the year of 2000. The average exploitation period of analyzed stadiums is only 4 years, which is very important in the sense that they show the state of the art in this area of engineering. Based on the information and conclusions regarding these stadiums, we can generate some insight about the stadiums of the future. Some of the stadiums for the upcoming championships are already being built, like the ones in Brazil for the World Championship 2014, and the Olympics 2016, while the others are still in the design phase (EC France 2016, WC Russia 2018, WC Qatar 2022, Olympics Tokyo 2020).

Table 1.1

Stadium covers and their structural systems

Structural systems		Covering
Cantilever		
Shells		• Open
Space grid		
Trusses	Straight	• Partially covered
	Arch	
Lightweight	Cable net	• Fully Covered
	Membrane	
Suspended		• Retractable
Pneumatic		
Hybrid		

Analyzed stadiums

The present analysis of stadiums was conducted in several parts. In order to get a complete picture of the stadium, some general characteristics were analyzed first. After this, the focus was given to the cover of the stadiums. Structural system of the covering and the material used were thoroughly analyzed. The average capacity of the analyzed stadiums is about 70000 seats. All analyzed stadiums, except the Olympic stadium in London, have the spectator stands completely made out of reinforced concrete. The stadium in London has one part of the stands that was used only during the Olympics made out of steel. Afterwards, it was dismantled so that it can be used elsewhere. One important issue is the structural connection between the stands and the structure of the cov-

er. If this connection does not exists than these two structures can be regarded as independent from one another, which is important for the calculation of loads. Whether this connection exists depends mostly on the applied structural system of the cover. Structural systems [2] used for these stadiums are: space grid, suspension, pneumatic, arch, lightweight and hybrid systems (Table 1.2).

Table 1.2

Analyzed stadiums with basic characteristics

	Year	Location	Capacity	Structural system	Structural material
ANZ stadium	2000	Sydney	80000/ 110000	Space grid	Steel
Estadio Municipal	2003	Braga	30000	Suspension	Steel cables, RC
Spiros Louis	2004	Athens	70000	Hybrid – arch and suspension	Steel
Allianz arena	2005	Munich	70000	Pneumatic	ETFE, steel
Wembley	2007	London	90000	Hybrid – arch and suspension	Steel
Bird's nest	2008	Beijing	80000/ 90000	Space grid	Steel
Moses Mabhida	2010	Durban	55000	Hybrid – Arch, suspension, membrane	Steel, PTFE membrane
Juventus stadium	2011	Turin	41000	Suspension	Steel
ONSC	2012	Kiev	70000	Membrane	Steel, PTFE membrane
Stadion Narodowy	2012	Warsaw	55000	Membrane	Steel, PTFE and PVC membrane
Olympic stadium	2012	London	25000/ 80000	Membrane	Steel, PVC membrane

Even though space grids were extremely popular in sport facilities earlier [3], in the new millennium their application is decreasing. Their self-weight is relatively small which is a great advantage, but their height is bigger compared to all other systems, which can have negative esthetical consequences. This system is used on the Bird's Nest stadium, but is completely covered with membranes on both upper and lower sides, and thus hidden from view. On the other hand, lightweight structures are rapidly taking over the market. Their first period of domination was in the 70s of 20th century, when cable nets were at their peak. Membranes as

another subtype of lightweight structures are becoming extremely popular today. Their application is more frequent while their characteristics are still being developed and improved. In the segment of structural material used for the covers of analyzed stadiums, steel has the most important role, while reinforced concrete is completely outdated. Timber structures have never found application in covering stadiums.

Stadiums of the future. Stadiums of the future can be divided in two groups, those which are designed based on the existing models, and those which are drastically different from any existing stadium. The stadiums of the first group bring only small changes and improvements to the current level of knowledge of stadiums. These mostly concern the improvement of specific characteristics of the stadium, but do not apply radically new ideas. Possible improvements are in the area of energy efficiency, better utilization of existing structural systems, slight altering of the usual shape of the spectator stands or their cover, or better quality of lighting of the stadium. Stadiums of the second group are true trail blazers in different areas, and they test the application of new ideas concerning the new forms of the stadium, new structural material and systems, new concepts of erection and assemblage. New forms of stadiums can be found in the concept-solutions for some of the stadiums to be built in the near future. Stadiums of the present and the past are mostly symmetrical or even biaxial symmetrical, while the new concepts propose an asymmetrical or discontinuous envelope of the stadium, or amorphous and yet unseen interpretations of the natural forms for the stadium cover.

In the future we can expect the shortening of the construction time, even for the most complex structures and forms, but also new hybrid structural systems that will combine some of the existing and some of the new systems. The advance in the sense of structural materials will most likely shift towards the use of synthetic polymers similar to plastic but with extremely improved properties. These will have incomparably better characteristics compared to steel and other currently known building materials. Such materials will be used for all structural elements and will allow for the reduction of cross sections. This will enable the covering of unimaginable spans by today's standards, and the creation of super-lightweight structures.

A great increase of the capacity of stadiums is not expected since it would lead to bad visibility from the stands. However, the possibility of

expanding the number of seats for certain occasions will become a reality on stadiums. This concept is already seen on the Olympic stadium in London. The number of seats will not be fixed and constant, which will allow for energy and financial savings. The trend of enlarging the screens on stadiums is already present. Until recently stadiums only had scoreboards, and today it is possible to watch the whole match on the screen at some stadiums. By application of new technologies in football, especially the "Hawk eye" system that is already used in tennis, the need for the big screens at the stadiums will increase. One of the possible ideas is to show the whole match on the façade of the stadium. This makes a lot of sense knowing that for the big events there are never enough seats for all potential spectators. In such way it would be possible to watch the game live in a crowd, which would feel almost like the atmosphere on the stands. One of the certain steps in the development of stadiums is the elimination of structural elements holding the huge light sources. With further technology development the required number and size of the light sources will significantly decrease, thus only a few small light sources will be installed at stadiums. Finally, it would be reasonable to expect that all stadiums will be completely covered. This would provide ideal conditions for playing and a higher level of comfort for spectators. At this moment such structural solutions are at the edge of the possible, and are thus very expensive if possible at all. The improvements in the areas of building techniques, structural materials and systems will lead to the easier and cheaper construction of the stadium roofs, so they will become an integral part of the stadium.

Conclusion. Stadiums are one of the most important public facilities today. They symbolize the power of the regions they are located in, and are worldly recognized architectural objects. As a product of connecting engineering with architecture, stadiums are a showcase of state of the art in both of these areas. Their spectacular visual esthetics and the role they have in the everyday life helped them develop faster than other building types and act as models for other buildings around the world.

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SPORTS FACILITIES SUSTAINABLE DESIGN

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Abstract. Construction of sport facilities has always been very interesting for architects. Even in Ancient times, this two disciplines have been related and one depended on other. Architecture was always medium to express importance of sport in everyday life of one man. Because of the special technical requirements, these facilities shape is subordinated to function. Through history, because of lack of technology, these buildings were very expensive and their maintenance was not economically efficient. Even so, building of these facilities was very important for every nation and because of that many experts have been developing strategies to make these kinds of facilities more energy efficient and more sustainable. Today, thanks to the technology development, these facilities are more and more rational built and their construction is optimized. Main accent is on sustainable design and energy efficiency. This paper is about sustainable design of sport facilities around the world.

*Key words***:** sustainable design, sports facilities, energy efficiency, green design

Introduction.