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SPORT ARCHITECTURE TECHNOLOGICAL EVOLUTION MODELS AND PARADIGMS

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ABSTRACT

The paper focuses on technological evolution applied to sports architecture, considered as urban infrastructures. A field of research - that has always been not really considered both by architectural historiography and by technological culture - despite the fact that sports architecture has always represented privileged places of formal, technical and engineering experimentation. Some design experiences in the field of sports venues - from the twentieth century to the contemporary age - have instead represented significant steps of technological development. In particular, the latest generation of sports infrastructures, represent the architectural typology where it is possible to find, concentrated, paradigms such as those of resilience, flexibility, sustainability technologies for adaptive skins and many others innovative parameters.

KEYWORDS

Sport; architecture; technology; urban identity; facade

1. INTRODUCTION

Architectural and historiographical culture has traditionally neglected sport architecture: "A more pronounced neglect characterises the treatment of sporting spaces and stadia in architectural history".[1] It can be considered a paradox if we just think about the general importance that sport has always had in contemporary society and as sports architecture has always been a privileged places for technical, technological and construction experimentations.[2] These places refer to the Genius Loci present in the memorial structure of communities which, as such, identify evocative elements of anthropological experience, representations of material and identity culture which represent a symbolic mark on the context. It is therefore important to note that sports facilities have always possessed the distinctive character that Norberg-Schulz identifies in the existential space that is formed in the fundamental relationships between human beings, environment and landscape. The concept of sports infrastructure expresses qualities inherent to its being an interactive hub in a given territory, of which it becomes the driving force and dynamic expression. In this sense, sports infrastructure must be considered in its material meaning as an element of connection between urban functions, a dynamic system in continuous change. Unlike the terms "sports facility" or

"installation", a sports "infrastructure", as such, cannot be traced back to an exclusive typology[3] of buildings, fully expresses the role these architectures have acquired in the evolutionary dynamics that structure the contemporary city. It is true that with a few very particular and qualified exceptions, since the end of the nineteenth century, the stadium-building landscape has been substantially dominated by the engineering culture, which has brought and limited its essence within the realm of pure structural 'functionalism', so much so that stadiums have long met Bernard Rudoksky's concept of "architecture without architects".[4]

2. OBJETIVES

The aim of the article is to report, through a schematic historical-evolutionary overview, the importance of sports architecture on the one hand in the technological evolution of large building infrastructures and on the other in the urban development of cities which was, since ancient times, references in terms of material and construction culture and from the symbolic, cultural and social point of view. In recent times, the latest generation sports infrastructures constitute a really unique case in contemporary cities for their symbolic and media value and, again, as symbols of the excellence of technological development in architecture.

3. SPORT ARCHITECTURE. SYNTHETIC HISTORICAL EVOLUTION

If we analyze the timeline of generational development[5] from a specifically technical/technological point of view, we can further highlight some moments where sports architecture manifests itself as an emblem of experimentation and innovation. In a very schematic and synthetic way:

a) in antiquity (late republican and imperial) the modern stadium type (or arena type) was actually canonized with the construction of the Flavian amphitheater (better known as the Colosseum). In it the construction innovations are notable and can already be found: use of large masses of pozzolanic cement, a geometrically advanced basin in its development in plan and section (attention to the visual comfort of the public in the c-value of the steps);

b) a complex and rigorous system of functions and access flows capable of guaranteeing perfect management of the stadium machine; an achieved harmony and unity between architecture and construction technology expressed in the external fronts;

c) and finally, the most surprising requirement, the application of the modern concept of flexibility of use, in particular in the explanation of the construction techniques of the velarium (for the coverage of the stands) and the setting up of the *naumachie* in the center of the arena.[6]

In the Colosseum and in general in the megalithic arenas of imperial Rome, the basin (or cavea or steps), in its mirrored yet essential and stripped-down linearity, defines in every way an architecture in which *venustas*, *firmitas* and *utilitas* are closely connected, thus materializing the perfect synergy between structure, function and aesthetics. Stone, wood, "mixed" concrete and natural fabrics are the recurring materials that the large dimensions of these artefacts force us to use according to ante-litteram principles of large-scale modularity and stressing their mechanical characteristics to the highest levels.

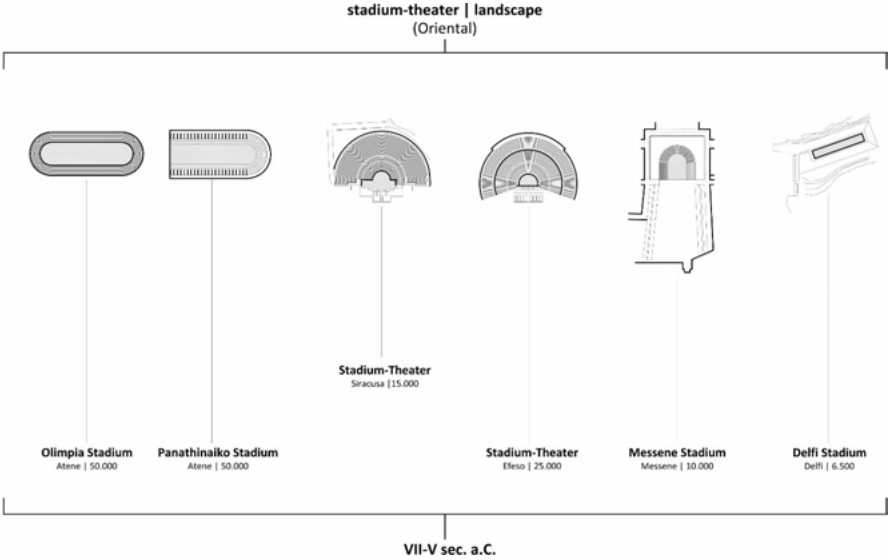

Figure 1.

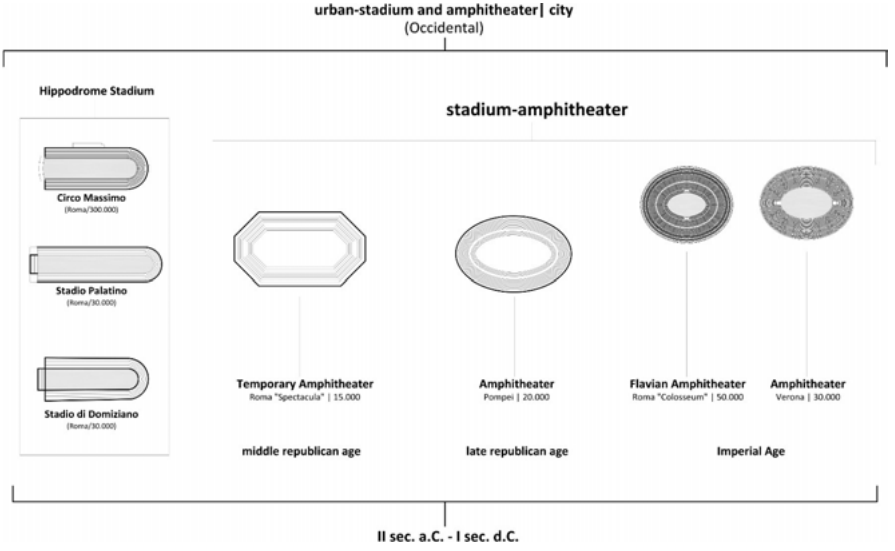

Figure 2.

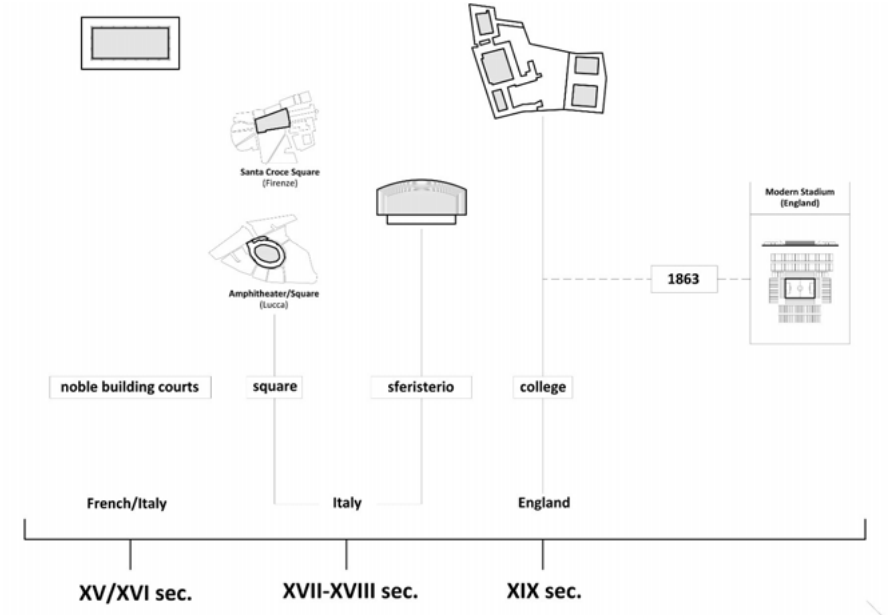

Figure 3.

4. THE MODERN ERA AND TECHNOLOGICAL INNOVATIONS

In the Modern Era (1st generation | 1863-1920) iron and cast iron were used in the United Kingdom for the first stadiums in the world designed specifically for football and for the first time a "specialist" designer established himself in this field: Archibald Leicht was not an architect but a hydraulic engineer, specializing in iron shipbuilding. He applies his hydraulic knowledge to access and construction flows to create increasingly capacious stands and large roofs, structures with a spartan and skeletal lightness, almost Gothic-like, not separated from a decorative style that characterized the main stands, real buildings urban. The large-scale application of techniques, materials and construction systems deriving from other industrial sectors - which is defined as *technology-transfer*[7] – will become a constant practice in the field of sports infrastructures.[8] The second generation (1920-1960/70) is characterized by the massive use of reinforced concrete for the regime's sports infrastructures and according to different declinations: a more "mass" one (e.g. like the Berlin stadium built for the Olympics in 1936 as a symbol of the greatness and construction wisdom of the Nazi regime) and another more "architectural" one which is highlighted in the masterpieces of Pier Luigi Nervi between the Thirties and Sixties. The large roof spans and the need to host an increasingly mass audience are ideal prerequisites for Nervi who can unleash all his construction wisdom and genius in the field of sports architecture, also designing specific systems to improve and optimize the construction processes.[9]

During the III and IV Generation (1960/70-1992) various sports facilities once again became privileged places of experimentation, innovation and technological transfer. The Olympic Stadium in Munich (1972) undoubtedly represents an emblematic case in the field of research on geodetic, light and reticular structures by Buckminster Fuller and on Frei Otto's membranous tensile structures. "The 1972 Munich stadium project is the first large-scale project whose static analysis empirically carried out starting from physical models is supported by electronic computing equipment. The term *Form-Finding* is coined which will effectively become a design technique which, combined with the synthesis skills [of some designers] will give life to architectural creations of high expressive and technical capacity."[10] In the Montreal Olympic Stadium (1976), a mobile roofing system in a tensile structure with a *Teflon* membrane (textile fiber reinforced with glass fibre) with packing in the center, system (based on the model of the ancient Roman *Velarium)* adopted for the first time on such significant dimensions[11] while the stadium of Spalato (1979, designed by Boris Magaš) is characterised by roofing in high-performance polycarbonate (used here on a large scale for the first time). The polycarbonate sheets rest on a three-dimensional 'MERO system' grid and were purposely designed and manufactured to withstand loads and ensure performance levels of diffuse lighting consistent with the sport function of the facility.

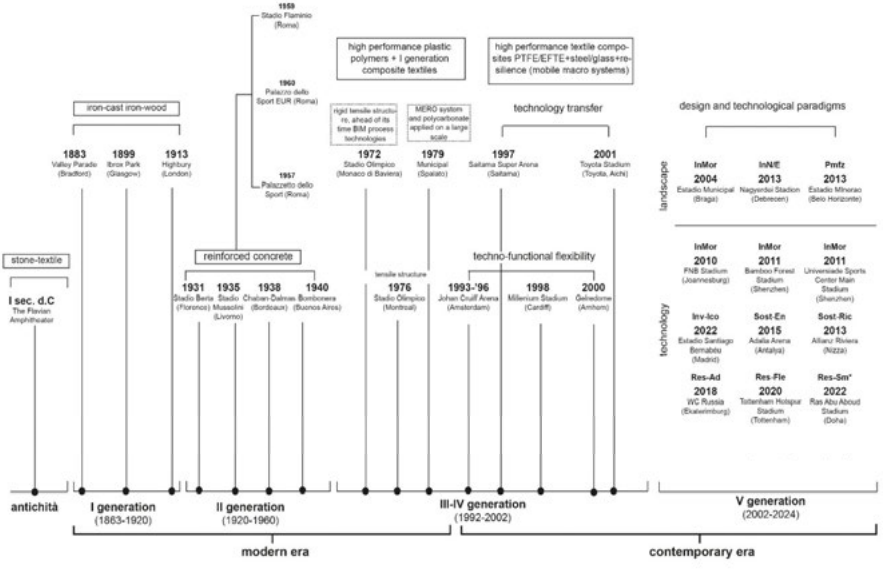

Figure 4.

5. THE CONTEMPORARY ERA AND THE LAST GENERATION OF SPORT ARCHITECTURE. AESTHETICS AND HYPER-TECHNOLOGY

Since the mid-1990s, the theme of resilience - expressed in functional and use flexibility - has begun to be a constant element in new constructions (indoor stadiums and arenas) to adequately respond to management and economic needs. Also in this case, sports architecture becomes the field of application of technical solutions never before tested in the construction sector; just think - to give just a couple of examples - of the technological transfer from the aeronautical sector in the Saitama (1997) and Toyota (2001) stadiums to move entire parts of the arena in the first case and thus configure different functional layouts and, in the second, to move the large cover through a complex system of moving air bearings. Other examples of this new generation are the Millenium Stadium (Cardiff, 1998); the Gelredome Stadium (Arnhem, 1998), the first European example with a pitch that can be totally moved outside; the Sapporo Dome (Sapporo, 2002) with movable stands and field (the latter rotatable and removable) and, to close this first New-Age phase of resilient sports infrastructures, the Arizona Cardinals (Glendale. 2006), designed by the studio Peter Einsenmann Architecs, first example of a mega-stadium pitch that "slides" out of the stadium.

Figure 5.

Figure 6.

Figure 7.

Figure 8.

The evolution and complexity of the architectural reality and its management, economic and social processes has favoured the spread of a new generation of multifunctional structures designed to guarantee environmental quality, safety and multifunctionality. As consolidated paradigms of the current concept-constructive scenario, multiscalarity and multidisciplinarity are essential references for an innovative design approach. Considering sports buildings and architectures as equivalent to infrastructures in the traditional sense means placing them within the complexity of the organization of the contemporary space that surrounds us. The word infrastructure evokes the dynamic concept of "integrating", adding something to obtain a complete and functioning system. Adding the word "sport" means, from a semantic and operational point of view, defining a new approach aimed at achieving a global rethinking of the role of sports facilities within society. It also means integrating and connecting currently isolated spaces and places, defining new settlement systems, reordering scattered fragments of cities, creating new levels of experience. Trends in thought, research and development point towards an integration of architecture and urban planning to achieve high-quality and environmentally sustainable design.

Since the beginning of the 2000s, major sporting events have dictated the times and rhythm of constant and exponential innovation in the field of sports architecture: major events which, like the Universal Expositions of the twentieth century or the recent Expos, constitute, for the host countries, the ideal "windows" to show the whole world one's political-economic power, one's culture and the level of technological innovation achieved. Since 2002 we have in fact been able to identify the latest generation sports infrastructures: the new contemporary ones are characterized by innovative technologies and materials, a renewed sensitivity to ecological-environmental aspects; architectural morphologies that interact with the landscape or systems that infrastructure and innervate the city, providing it with new services for the community; macro-scale design objects with technologically advanced and luminescent skins that make these architectures the new landmarks of the contemporary city with dreamlike symbolism.

Figure 9.

Figure 10.

Making a quick overview of some of them: the 2002 World Cup football championships in South Korea and Japan are characterized by the use of technologically advanced materials - in particular lightweight composite membranes (textile and reinforcing fibers of various types) with high performance (Teflon, EFTE, PTFE, etc.) which during this great sporting event are used extensively for the first time and applied with easily interchangeable and recyclable modular systems. Materials that also lend themselves well to defining organic and "metabolic" forms directly influenced by the construction tradition and experimental research of the *Metabolism* current of the Seventies, reaching an extraordinary level of refinement and technical-formal complexity in the definition of the technological nodes both in the facades and in roofing.[12] The 2004 European Football Championships in Portugal are instead characterized by the use, albeit in a contemporary key, of traditional materials and construction techniques referring to the material culture of the place, such as for example stone coverings, colored ceramics (the typical azulejos) or structures "poor" in cast-in-situ concrete, however skilfully integrated into the delicate morphology of the Portuguese territory. There is a clear reference to a certain regionalist constructive and figurative tradition which Portuguese architecture continuously draws on, also through the prolific work of some contemporary masters. The 2006 World Football Championships in Germany are instead a symbol of the eco-technological turning point in terms of large sports facilities. If in the Portuguese experience environmental compatibility is more clearly expressed in the relationship between materials-morphology-landscape, in the German one the emphasis is placed extensively for the first time (as a guiding paradigm for the organization of the event and its communication) , on the theme of environmentally sustainable management of buildings, through the production of energy from renewable sources, the recovery of rainwater (which will become a consolidated technological and design paradigm in large structures in general) and the reuse-recycling of materials. An objective certainly facilitated by the cultural and political-social sensitivity towards the theme of energy and environmental sustainability in Germany in those years. The infrastructural experience of the European Championships in Switzerland and Austria in 2008 is along the same lines, in continuity with a strong "techno-ecological" approach: the facilities, smaller in size, nevertheless present a high technological concentration in terms of refined solutions, extensive use of energy production systems from renewable sources and traditional materials with low environmental impact such as wood. Furthermore, the Swiss approach in particular is based on the typological-functional model of the urban stadium (or stadium-neighborhood). The 2010 World Championships in South Africa instead offer a different panorama, less coherent from the point of view of programmatic objectives, also reflecting a cultural and political context that is certainly more difficult to manage. South African stadiums thus oscillate between hyper-technological ambitions that characterize new stadiums and more poor and traditional solutions, which involve simply bringing existing stadiums up to standard from the point of view of safety and capacity or, at the most, a façade restyling capable of making the structures medially appealing. In some ways a similar discussion can be made for the 2014 World Championships in Brazil: both these events have in common a self-celebratory bigness[13] which led to the creation of mega-systems which were then difficult to manage and exploit in the post-event phase. The situation was different for the World Championships in Russia 2018 and those in Qatar 2022 whose infrastructures are conceived as media icons, symbols of new geo-political and economic balances and powers even before technological ones,

not necessarily directly connected to a consolidated sporting context of reference. In some ways they represent the risk that self-celebration and hyper-technological exaltation lead, on the one hand, to the drift of a "DisneyWorld effect" (symbol of an *Augé-style-non-lieux* and of an *prêt-à-porter architecture*) and, on the other, to the "*tabula-rasa* effect" which, in the case of the event in Qatar, led to the creation in a semi-desert area, in a sort of duplication of the "Dubai-effect ", of a sort of Stadium-City, founded on the construction of seven new stadiums (plus one redeveloped) around which as many "neighborhoods" for entertainment were born (linked however only to the duration of the event), connected by new infrastructures road systems.

Figure 11.

At the same time to this explosion of the big sport-events just mentioned above, another interesting trend should be noted which affects the field of sports architecture and which essentially concerns their monumental immanence which is given, in addition to the aforementioned dimensional data (generally of the "out-of-scale" compared to the morphological conformation of the urban fabric) by the absence of resilience of these artefacts, rigidly constrained in their own archetypal conformation which makes them, in their historical meaning, basically monofunctional. Precisely these elements underline its monumental meaning which once again contributes to the construction of the city as "a large artefact, a work of engineering and architecture, more or less large, more or less complex, which grows over time",[14] or, as Guido Nardi writes, "from a cultural point of view, the aspect that most characterizes the construction of a sports facility is the monumental role it plays both within the fabric of the city and within the collective imagination and therefore of the social unconscious".[15] This aspect of historical stratification, almost "archaeological" in its vertical reading, which characterizes many sports architectures, constitutes a sort of "barometer" of the construction and changes of the city.[16] Esse, come i tracciati infrastrutturali, sono permanenze costanti nell'evoluzione della città e alla stessa stregua dei tracciati infrastrutturali una volta abbandonati diventano elementi di critica discontinuità nel tessuto urbano. Also for this reason there are many projects completed and underway which outline a clear trend in the design approach with respect to these sports "monuments": their maintenance of the structures and identity of the places and at the same time a profound restyling in technological terms -typological and morphological that can guarantee their use in accordance with the most recent international regulations and performance parameters. Usually these operations focus on creating new multifunctional spaces under the stands delimited by new facade and the introduction of new high-performance roofs that provide lighting and environmental comfort for the public and, in some cases, on the insertion of mobile elements (pitch, stands, roofing itself) to allow the holding of events of different nature. Among the many here we mention, just as an example: the Bernabeu stadium (Madrid, nearing completion), with the construction of a new fully closed mobile roof and the insertion of a new skin characterized

Figure 12.

by curved blades in stainless steel that flow around the structure creating an asymmetric pattern at the same time sculptural and dynamic, which generates different plays of light throughout the day and seasons. To complete the façade was also provided a retractable roof, which will allow the stadium to be used throughout the year and for different events. And at night an LED lighting system will project multimedia content on a large scale.[17] In addition to this, the stadium has been equipped with a "packable" mobile pitch to make the most of the arena for concerts and other events. Also in Spain, the Camp Nou stadium (2024, under construction), where a more evident perception of the original structure is maintained, and a more "traditional" covering is inserted on all the stands. A new EFTE skin has been designed for the Johan Cruijff Arena (Amsterdam, 2024) which allows the addition of new commercial spaces. Other less "invasive" interventions can be considered the one on the Berlin Olympic Stadium (2006) - with the restoration and philological consolidation of the existing structure (reinforced concrete and cladding stone) and the insertion of a new light roof with a steel structure and composite textile skin – and the one, similar in approach, on the Luzhniki Stadium (Moscow, 2018). Specifically in the Italian context, the approach on existing stadiums usually involves the maintenance of the main stand (almost always subject to historical-architectural constraints) and the addition of three new stands with relative new coverage.[18]

Figure 13.

6. FUTURE PERSPECTIVES: BIG SPORTING EVENTS AND INCREASINGLY TECHNOLOGICALLY ADVANCED INFRASTRUCTURES

At the end of this general overview, we can therefore state that the field of sports architecture is in constant and continuous evolution, both from a technological (process and product) and functional and social point of view.[19] Sport in its general sense is becoming increasingly important in contemporary societies and its places are evolving very rapidly at the same time. The so-called Big Sports Events take place every year becoming extraordinary opportunities for innovation at every level and, at the same time, the need to renew and redevelop the existing architectural heritage or to build new places for sport to accomplish an more and more increasing sport-demand, will make sports architecture (and its design, construction and management) increasingly strategic. Suffice it to say that in recent years the focus is increasingly shifting from the hard infrastructure (the large stadium or arena) to the soft one, the latter understood as that set of activities and places for sport which are widespread, widespread, spontaneous, directly connected and integrated with urban public space. This means that the physical place itself loses importance in favor of an increasingly expanded, permeable and fluid use of spaces for sport, without a solution of continuity between parks, open spaces, public squares and the stadiums themselves which thus become nodes and service hubs only if considered within this network of relationships - material and virtual - that innervate our cities and our landscapes.[20]

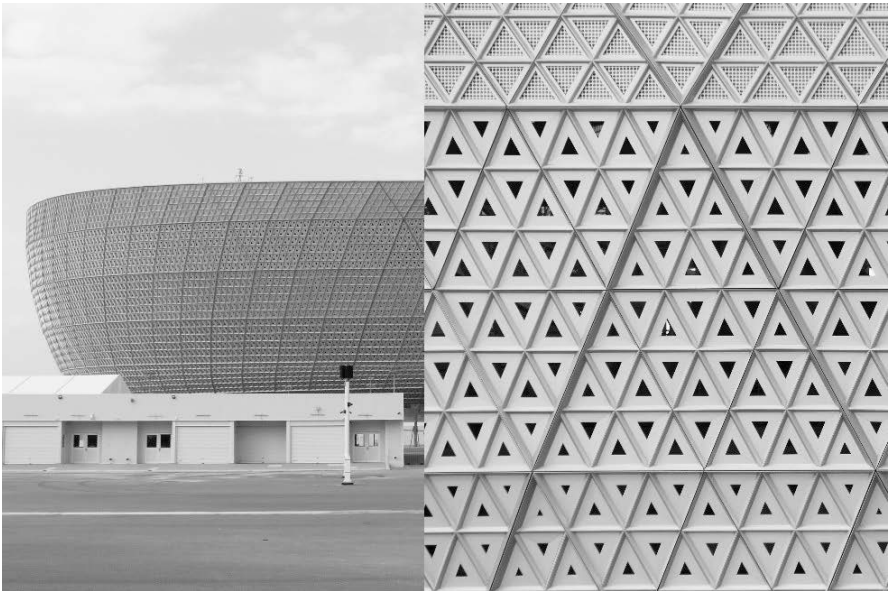

Figure 14.

NOTES

[1] Benjamin Flowers, *Sport and Architecture*, (London: Routledge, 2017), 3.

[2] The size of these artefacts, such as their large structural roof spans, has been a challenge for designers and builders since ancient times.

[3] For a study of the "stadium-type" see also the fundamental text by Giuseppe De Finetti: *Stadi. Esempi Tendenze Progetti*, (Milano: Ulrico Hoepli Editore, 1934). «Lo studio delle ragioni formali degli stadi moderni ci riconduce agli esempi di due popoli mediterranei, i Greci e i Romani, che in questo campo erano giunti alla creazione di architetture definitive ed esemplari, durate utili per secoli, tipiche per la loro armonia mirabile tra necessità e forma», *Prefazione*.

[4] Bernard Rudowsky, *Architecture without Architects. A Short Introduction to Non-Pedigree Architecture*, (New York: MoMA Press Release, 1964).

[5] "From the second half of the nineteenth century, it is possible to recognize the passage between traditional and modern games. From 1863 onwards (the year of establishing the modern rules of football), the generational division is as follows: Generation I (1863–1920): birth of modern soccer and mass sport sociology; Generation II (1920–1960/70): large arenas as a representation of power; Generation III (1960/70–1989): low-tech tin and concrete architecture; Generation IV (1992–2002): the post–Taylor Report New Deal for stadiums; Generation V (2002–2016): Great Events and the establishment of the stadium as a high-tech identity icon on a global scale; Generation VI (2018–2023–?): design and technology for sports and leisure theme parks", Davide Allegri, *Contemporary project and technological innovation. Architecture, engineering, design*, in Emilio Faroldi, *Sport Architecture.*

Design Construction Management of Sport Infrastructure, (Siracusa: Lettera Ventidue, 2020), 25-45.

[6] In fact, the *Colosseum* also stood out for the innovative use of the volume located below the stage, a choice that forced the ancient builders to adopt complex waterproofing and water discharge systems. Even previously, in the Republican era, temporary arenas had been built with a sophisticated and complex construction system of wooden elements, somehow anticipating the theme of flexibility which is now a fundamental theme (see the structures just completed for the Paris 2024 Olympic Games).

[7] See on the concept of *technology transfer*: Ingrid Paoletti, *Una finestra sul trasferimento. Tecnologie innovative per l'architettura*, (Milano: Libreria CLUP, 2000).

[8] See for example Tony Garnier's design for the Stade de Colombes for the 1924 Paris Olympics, with reinforced concrete stands and iron roofing.

[9] See also: Micaela Antonucci, Annalisa Trentis, Tomaso Trombetti, *Pierluigi Nervi. Gli stadi per il calcio*, (Bologna University Press, 2014).

[10] Aldo Capasso, *Architettura atopica e tensostrutture a membrana. Segno e segni del nuovo archetipo costruttivo tra etica e forma*, (Napoli: CLEAN, 2019).

[11] A system then adopted in several other cases in more recent times, in particular by the GMP Von Gerkan Murg and Partner studio.

[12] Almost all the stadiums built for this event also have a reference - in the form, in the materials used, in the techniques - to the material culture and to the constructive and popular translations of the places.

[13] About this concept see also: Rem Koolhaas, *Junkspace*, (Macerata: Quodlibet, 2006).

[14] Aldo Rossi, *L'architettura della città*, (Milano: Il Saggiatore, 2018), 23.

[15] Guido Nardi, *La tecnica nell'architettura per lo sport: note intorno all'auspicata fine di un culto monumentale*, in *Impianti Sportivi Parchi Giardini*, (Milano: Electa, 1990), 53.

[16] Emilio Faroldi, *Lo sport: indicatore culturale di rigenerazione fisica e sociale. Architetture, paesaggi, lineamenti*, (Mendrisio: Espazium, 2023).

[17] Lucia Brandoli, *New facade for Real Madrid's Estadio Santiago Bernabéu nearly complete*, (Milano: Editorialedomus, Domusweb, 18 settembre 2023).

[18] See for example the cases of the Bergamo and Udine stadiums.

[19] In a recent document produced as part of research on the prospects of the "Stage of the Future", a sort of decalogue of paradigms was formulated which outline the main development themes (in the original document all of them are extensively described, here they are reported as only the precise list is known): Stadium-Accessible, Stadium-Urban, Stadium-Smart Stadium-Sustainable, Stadium-Multifunctional, Stadium-Resilient, Stadium-Technological, Stadium-Safe, Stadium-U.E.F.A., Stadium-Cultural.

[20] The complexity and specificity of the sports infrastructure sector requires excellent training programs capable of preparing sector professionals for the design, construction and management of sports venues. The *International Master in Sport Design and Management*, held since 2017 at the Polytechnic of Milan, directed and coordinated by Emilio Faroldi and Davide Allegri in collaboration and synergy with the Graduate School of Management (Gsom-POLIMI), is placed in this perspective.

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