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ARCHITECTURAL RENOVATION OF STADIUMS AS A NEW VISION FOR SUSTAINABILITY CASE STUDY (RENOVATION OF CASTELÃO ARENA STADIUM, BRAZIL & SOLDIER FIELD STADIUM, CHICAGO)

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Abstract

By reviewing the current situation of some existing stadium buildings, many stadiums are not applicable to sustainability requirements, with the absence of the required principles in this field, where sustainability is considered now as one of the important current trends. Rehabilitation of existing Buildings considers a crucial contributor to most sustainable development aspects. It is a starting point for the redevelopment which promotes social, economic and environmental aspects of sustainability. Both FIFA and UEFA support the need for sustainable stadiums. They set out some of the objectives which can achieve sustainability in stadiums. These objectives include efficient use of energy, reduction in water consumption and using local materials. So the research works on the possibility of renovating existing stadiums by making some architectural changes to meet the requirements of sustainability. From this point of view, this paper sheds light on two key issues; firstly: study and analysis of the existing stadiums, the applicability to meet LEED Certification and to achieve these requirements, secondly: assessing and analyzing some of international case studies in this field (Renovation of Castelão Arena stadium in Brazil and Soldier Field stadium in Chicago),both of them received LEED certification for their sustainable features , where the new changes give continuity to the original project . The research concludes the most important change items that can be used to develop the current stadium buildings and aims to provide an architectural framework to renovate the existing stadium buildings to achieve sustainability.

Keywords

Architectural design, stadium renovation, stadium design, sustainable design, sustainability.

ARCHITECTURAL RENOVATION OF STADIUMS AS A NEW VISION FOR SUSTAINABILITY

CASE STUDY (RENOVATION OF CASTELÃO ARENA STADIUM, BRAZIL & SOLDIER FIELD STADIUM, CHICAGO)

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ABSTRACT

By reviewing the current situation of some existing stadium buildings, many stadiums are not applicable to sustainability requirements, with the absence of the required principles in this field, where sustainability is considered now as one of the important current trends. Rehabilitation of existing Buildings considers a crucial contributor to most sustainable development aspects. It is a starting point for the redevelopment which promotes social, economic and environmental aspects of sustainability. Both FIFA and UEFA support the need for sustainable stadiums. They set out some of the objectives which can achieve sustainability in stadiums. These objectives include efficient use of energy, reduction in water consumption and using local materials. So the research works on the possibility of renovating existing stadiums by making some architectural changes to meet the requirements of sustainability. From this point of view, this paper sheds light on two key issues; firstly: study and analysis of the existing stadiums, the applicability to meet LEED Certification and to achieve these requirements, secondly: assessing and analyzing some of international case studies in this field (Renovation of Castelão Arena stadium in Brazil and Soldier Field stadium in Chicago),both of them received LEED certification for their sustainable features , where the new changes give continuity to the original project . The research concludes the most important change items that can be used to develop the current stadium buildings and aims to provide an architectural framework to renovate the existing stadium buildings to achieve sustainability.

KEYWORDS

Architectural design, stadium renovation, stadium design, sustainable design, sustainability.

RESEARCH PROBLEM

Many existing stadium buildings do not meet their goals to supply a safe and healthy environment for occupants, through programs that enhance reducing energy and water consumption, reduction in waste and promoting recycled materials. The Earth Summit Conference in 1992 had confirmed some of key considerations for hosting sporting events to meet sustainability requirements. Therefore, there's an urgent need to develop stadiums by utilizing architectural design to achieve sustainability.

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RESEARCH GOAL

Research goal is to provide a framework for the renovation of existing stadiums to obtain sustainability by architectural design.

RESEARCH METHODOLOGY

The research methodology is based on two approaches: theoretical and comparative analytical studies. The theoretical component requests to identify the concepts of sustainability, its advantages, sustainable design, renovation to achieve sustainability and its relation with LEED. This is followed by an applied study of the most successfully renovated stadiums that provide some strategies and techniques which based on principles of sustainability, Castelão Arena is the first eco-friendly stadium has been received LEED certification in Brazil and Soldier Field in USA which preserves the past and protects the future through some strategies to achieve sustainability consider as an architectural masterpiece to achieve LEED Existing Building certification.

1. INTRODUCTION

The design of the stadiums has been developed significantly over many periods and the status of modern stadiums shows a development in its design with increasing of the spectators numbers.

There is an increased need to design and construct of new stadiums with the impact of architectural design trends on the design of these stadiums, such as achieving sustainability requirements which will be considered in the design and construction of football stadiums that will receive the FIFA World Cup 2022 (FIFA, 2017) and also there's an increasing trend towards renovating existing stadiums to meet sustainability requirements.

The World Commission on Environment and Development defines sustainable development that "it meets the present needs without compromising the ability of future new generations to meet their needs". (Wikipedia, 2015) In September 2015, a number of sustainable development goals were identified to obtain better life like access to clean affordable and sustainable energy and increased use of renewable energy sources. Other goal is related to sustainable cities and communities (goal no.11) which include energy, buildings, urban and social development, improving resource use and reducing pollution. (UN, 2015) For the goal of climate change, a road map to address climate change problems was agreed by reducing carbon dioxide emissions and building resilience to climate change. (UN., 2015)

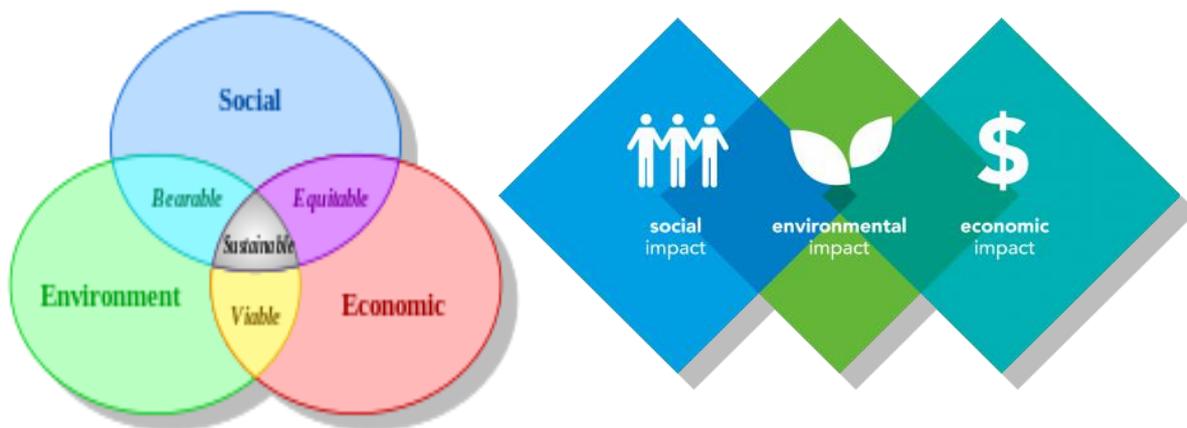


Fig.1 Ideas of sustainability, Reference (Wong, 2013)

There are many factors that drive to achieve sustainability in buildings, a sustainable building is well corresponded to the environmental aspects, uses local available resources and is healthier for users (Hagan, 2004). This sustainable building is more economic than other building, it uses less energy during different operation and less running cost, it can also use recycled materials and its materials can be reused in other buildings (Williamson, 2004). In 1998, John Elkington defined the idea of sustainability as social, economic, and environmental considerations (as shown as in fig. 1) (Wong, 2013).

2. SUSTAINABLE DESIGN

The definition of sustainability by American Institute of Architects (AIA) is "the ability of society to continue to operate in the future without being forced to retreat by depletion or overloading the main resources on which this system relies".(Wong, 2013). Sustainable design refers to some characteristics to reduce demand for the environment components because of building characteristics like low energy and water use, decreasing carbon dioxide production and emission. (John, 2007).

3. SUSTAINABLE BUILDING DEFINITION

A Sustainable building is the result of a design that associates in increasing resource efficiency like water, energy and materials, through minimizing the effects of building on human health and the environment during the building's life cycle, by improving design, construction, operation, and maintenance.(Srinivas,2015) .

4. THE NEED FOR SUSTAINABILITY IN STADIUMS DESIGN

The design of stadiums is currently achieving a major development with the growing need for sustainable buildings (Sheard, 2004) , as the stadium building is influenced by the existing architectural trends , there is a recent trend to build sustainable stadiums, and to develop architectural design ideas to build more sustainable stadiums, while increasing the architects awareness of sustainability trends, so the design of stadiums that meet the sustainability requirements is considered as an important issue (Szokolay, 2008) . There're many sustainable stadiums will be established in this period in many areas like Qatar State which is preparing for the World Cup in 2022 (as shown as in fig. 2).



Queen Elizabeth Olympic Park stadium
Reference: (Meyers , 2012)



National Stadium in China
Reference: (Davies, 2015)



MetLife stadium in New Jersey
Reference: (Dublick, 2016).

Fig.2 Some Sustainable Stadiums

- The design trend of Dalian Shide stadium in China depends on sustainable design by generating of renewable energy, using maximum natural lighting and recycling processes of water (Meyers , 2012).
- Rectangular stadium in Melbourne, Australia was opened in 2011, the design is based on the formation of the roof that helps to regulate the internal building temperature and stadium design can save up to 500,000 gallons of water each year by the rainwater collecting system (Meyers , 2012).
- The New Meadowlands Stadium in New York works to conserve energy and water, improves waste management, and addresses environmental requirements. Some recycling systems had been developed to decrease about of 1.7 tons of carbon dioxide during the construction process (Meyers , 2012).
- MetLife stadium in New Jersey(as shown as in fig. 2) has been developed to achieve sustainability, by reducing energy consumption, reducing water consumption, reducing pollution, and improving waste management, also the design of MetLife stadium reduced energy consumption by 30%, it used turf in playground and low water consumption toilets to reduce water consumption, by these methods water consumption had been reduced by 11 million gallons per year. In 2013, a renovation was made to reduce energy consumption, 14 micro wind turbines and 11,000 solar panels were added to generate electricity from renewable energy (Meyers , 2012).
- The design of Century Link Field stadium in Seattle, USA was based on the use of energy-saving lighting units throughout the stadium and to encourage the public to move by internal electric vehicles to reduce pollution (Meyers , 2012).

- The design of M&T Stadium in USA considered the sustainability requirements. It uses a method of sustainable, non-polluting cleanliness, provides more than 3 million gallons of water with water-saving latrines, recycles more than 30% of normal waste and provides more than 5,000,000 KW/hour since 2005 to 2017 (Meyers , 2012).

5. RENOVATION TO OBTAIN SUSTAINABILITY

Buildings renovation to obtain sustainability can be defined as a design that deals with different fields (social, environmental, and economic) which utilizing of the advantages and improvements of these fields, increasing comfort, quality of life and decreasing the waste production (Trachte,2013).The renovation of a building to achieve a certain objective, like sustainability, can be less costly in some cases than rebuilding a new one (Paradis,2016). Renovation of buildings to achieve sustainability is carried out by studying the current status of the existing building like energy efficiency and operating cost, identifying its weaknesses to achieve sustainability , then making a proposal including an architectural design vision for all required modifications to renovate the building , in order to achieve the sustainable process to the building ,while maintaining the structure of this existing building, and considering the environmental aspects.

The required proposal and architectural development is carried out for the existing building renovation to meet the sustainability requirements, including the reduction of energy consumption ,reducing the operation cost , using water efficiently, using efficient irrigation systems, reusing of recycled water, collecting rainwater, maintaining different resources, using of recycled materials, developing a plan for recycling operation waste , recycling waste resulting from renovation process as much as possible and adding a plan to recycle the demolition and construction debris from the renovation process (Rabertson , 2014). The required modifications are for external façade, roofs, interior spaces, finishing materials, electrical and mechanical systems, water and sewage systems and energy systems, and also using the innovative architectural solutions to comply with environmental climatic considerations, generating and using of renewable energy to achieve part of the energy required for the building, using of the maximum natural lighting, energy-saving lighting units, Improving the internal environment, maintaining air quality and reducing carbon dioxide emissions (Bauer ,2010).

6. SUSTAINABILITY RATING SYSTEM AND LEED APPLICATION

LEED (Leadership in Energy and Environmental Design) is one of the international rating systems for green buildings. U.S. Green Building council (USGBC) ,which is based on enhancing sustainability in building design, structure, construction and other related operations ,considers LEED certificate is an international known tool that indicates for achieving sustainability (USGBC homepage) ,this council assures to reach to a sustainable future through LEED principles (Patel, 2015). According to LEED application, the evaluation rating system is based on 100 points, which are divided into main categories like: sustainable sites, water efficiency, energy and Atmosphere, materials and resources, indoor Environmental quality, and innovation in Design.

The LEED certificate is given according to the number of points obtained by the building, at least 40 points must be obtained by any building to award LEED certificate. The building is classified into one of four levels according to its points, the building awards LEED certified if its points are between 40 to 49 points, it awards a LEED Silver certificate in case of its points are between 50 to 59 points, it also awards a LEED Gold certificate in case of its points are between 60 to 79 points and it awards a LEED Platinum certificate in case of the points are 80 or above (Usgbc, 2017).

7. SUSTAINABLE RENOVATION AND LEED

LEED certificate is recognized for sustainability achievement, it has a framework for sustainable buildings including design, maintenance, construction and operations of new and existing buildings. (Usgbc, 2017) LEED has a system to rate green buildings in different phases like design, construction and operation (Bauer, 2010).

Buildings which obtain LEED certification (as shown as in fig. 3) save energy, water, resources, and support people health ,as an example Mercedes-Benz stadium is the first sports stadium has obtained the platinum LEED certificate that was awarded in 2017 (Robertson, 2014). The renovation of a building to achieve sustainability by performing the sustainability requirements enables this building to obtain a score for LEED certificates, this certificate type, whether platinum, gold or silver, depends on the extent to which the requirements are achieved (Vashon,2014).



Lincoln Financial Field
Reference: (Dublick, 2016)



Levi's Stadium in San Francisco
Reference: (Davies, 2015)



National stadium in Brasilia
Reference: (Malaymail, 2014)

Fig. 3 Some stadiums had obtained LEED certificates

7.1 Lincoln Financial Field stadium in USA was opened in 2003, after that many renovations were made to stadium to comply with the sustainability requirements, including recycling operations for materials and waste, and generating electricity by solar panels and wind turbines on stadium facades. Lincoln Financial Field stadium had awarded LEED certification in 2013 (Dublick, 2016).

7.2 Levi's Stadium in San Francisco had obtained a golden LEED certificate, 85% of the water used in project is from recycled resources, and the total consumption of lighting has decreased by 15-20% due to the use of led lighting (Davies, 2015).

7.3 National stadium in Brasilia had obtain platinum LEED certificate, it had been built using the demolition of a previous stadium, the design used fiberglass membrane to protect spectators from ultraviolet, 9,600 solar panels were installed on the roof of the stadium which are capable of providing the full electric power needed, the design allows good natural ventilation, as well as it uses a sustainable irrigation systems to reduce water consumption, the design encourages spectators to go to the stadium with their bicycles in order to reduce pollution, it offers 3500 bicycle parking places, the design allows to use the stadium in other functions such as concerts and conferences (Malaymail, 2014).

8. CONSTRAINTS THAT CAN AFFECT THE STADIUMS RENOVATION

Many constraints may affect the renovation of stadiums that include:

- Site constraints and neighboring properties.
- Market demand and its requirements.
- Financial funding.
- Laws and regulations.
- Stakeholders and their conviction of renovation.

9. INTERNATIONAL CASE STUDIES

9.1 *Castelão Stadium, Fortaleza, Brazil, Architect: Vigliecca & Associados*

Castelão stadium is a football stadium constructed in 1973 in Fortaleza, Brazil, shown in fig. 4. It was selected to be one of the playing venues of the 2014 World Cup, so that they started to think how to make it more sustainable. This stadium redeveloped for the 2014 World Cup and now it is the first stadium to receive a (LEED) certification according to the integration between the existing structure and the new one to achieve sustainability. Therefore, the main objective of Castelão stadium is to renovate the stadium in a sustainable manner to be an architectural landmark not only a sport avenue (Dynamo, 2012).



Fig.4 Location of Castelão stadium in Fortaleza, Brazil Reference: (Dynamo, 2012)

At the beginning of the construction, Castelão stadium contains one small oval-shaped tier, which holds about 70,000 spectators. In 1980, the second tier was constructed over the full stadium to hold more spectators, after renovation the seating capacity increased to 63,903 spectators. All the seats are resistant to UV rays, fire and retractable. There is a building in the center of the stadium designed for changing rooms; the stadium also has 85 toilets and 44 bars.

9.1.1 *Renovation of the stadium included the following:*

a. Renovation of the Elevation

The façade was made of stainless steel sheets and also was covered with an external frame “glass skin” to minimize heat by reflecting sun light (as shown as in fig. 5), but the original columns are kept. The stadium has been redeveloped, but its identity was well preserved. In addition, 60 steel columns were installed around the structure to reduce the vibrations from the stands and to support the new structure.



Fig.5 Stainless steel sheets & glass skin in the renovated elevation (Dynamo, 2012)

b. Renovation of the Roof

According to the renovation, the old roof was removed with a large new one to cover all the fans and coated it with a soundproof and a heat-resistant material to make the stadium cooler and to improve the circulation of the air (as shown as in fig. 6).

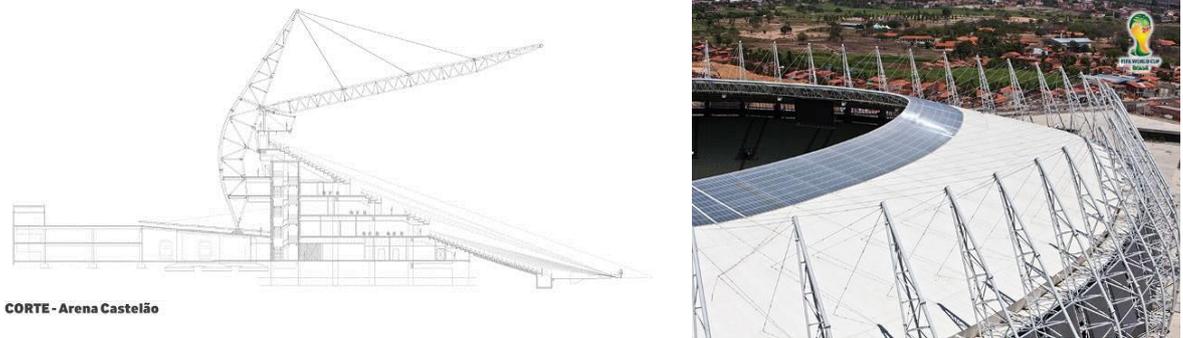


Fig.6 The new roof covers all the spectators Reference: (Dynamo, 2012)

c. Renovation of Park Lots

According to increase the capacity of the stadium to 63,342, an underground car park was added with over 4000 spaces (as shown as in fig. 7), access has also been upgraded, four bus lanes were created to the stadium, two metro stations and light rail vehicle line make it easier for spectators to reach to the stadium. Car parks also include spaces for bicycles. In addition, some commercial and recreational facilities were developed surrounding the stadium like cinemas, restaurants and an Olympic center (Woosley, 2011).



Fig.7 Plan of the stadium with a view of park lots Reference: (Woosley, 2011).

9.1.2 Sustainability features in Castelão Arena's:

The stadium was renovated with focus on sustainability and considered that efficiency and design are parts of the future. We will shed light on some of Castelão Arena's sustainability features:

a. Reducing Water Consumption

“There is a reduction of 67.6% reduction in drinkable water consumption by simply using steel and water saving technologies, and a 71.9% reduction in the volume of potable water directed to the local sewer system. Low flow plumbing fixtures - such as sinks, toilets, urinals and showers - will reduce water consumption by more than 52 percent.” (Green, 2014) .According to water runoff the new roof also can collect it and reused to clean the bathrooms and for irrigation landscape.

b. Reducing Energy Consumption

The major areas in energy consumption are the Performance of using ventilation, lighting and air conditioning.

- **Lighting system:** Smart lighting system has been used in the stadium such as using Automatic light sensors, which provide a 12.7% reduction in annual energy consumption. Also Lighting design system enables 100% of all spaces in the stadium to be independently controlled, this system reduced energy consumption by 25% which mean that the annual energy consumption in the stadium reduced by 12.7% (Zimmer ,2014).
- **Air conditioning system:** The Air conditioning system designed to consume minimum energy. Most spaces have automatic shutdown to save energy of the stadium. It does not also use refrigerating gases which consider the main cause of ozone layer.

c. Waste Reduction

- **Construction Waste Reduction:** 97% of the waste transferred from landfills during the construction and recycled.
- **Event Waste Reduction:** “Strategically positioned central waste disposal units are set to store and recycle event waste, including paper, cardboard, plastic, glass and metal.” (Zacheo, 2014).Furthermore old subjects like chairs, boards and canopies were denoted to other smaller stadiums. All the new seats are resistant to fire and UV rays (as shown as in fig. 8).



Fig.8 New seats which resistant fire and UV Rays in Castelão Arena Reference: (Zacheo, 2014)

d. Promoting Sustainable and Recycled Materials

One of the main trends during construction of the stadium is to use local materials that saved on tons of concrete and steel, according to that:

- 20 % of the construction materials, which used in the stadium, were made with recycled content and about 47% were fabricated locally.
- o “To further reduce CO2 emissions, higher percentages of fly ash were substituted for cement to construct the concrete portions of the project” (Castelão, 2014).
- o The concrete waste of the construction was recycled on site and the recycled material was later used to build a sub-base parking.
- o 36 thousand tons of concrete, generated from the demolition of part of the old stadium, were reused to pave the new car park.

e. Improving Indoor Environmental Quality

- "A monitoring system ensures the continuous thermal comfort of guests, Low VOC volatile organic compound materials were used throughout, such as sealants, paints and coatings used to improve the indoor air quality for the building occupants" (Zacheo,2014).
- Ninety percent of regularly occupied indoor spaces provides occupants with natural daylight and views to the outdoors

f. Enhancing the Site and its Surroundings

The area of the arena developed with better accessibility, including four bus lanes, two metro lines, a light rail, hotels and restaurants (as shown as in fig. 9).



Fig.9 Developing the surrounding site of Castelão Arena Reference: (Castelão, 2014)

According to the renovation strategies of Castelao Arena which based on principles of sustainability (Reducing Water Consumption, Reducing Energy Consumption, Waste Reduction, Promoting Sustainable and Recycled Materials, Improving Indoor Environmental Quality, Enhancing the Site and its Surroundings) , Castelão is the first eco-friendly stadium has been received LEED certification .

9.2 Case study, Soldier Field stadium, Chicago, Architect Holibird and Roche

Soldier Field is an American football stadium in Chicago, Illinois, (as shown as in fig. 10) owned by the Chicago Parks District. It is one of the most historic sports venues in the United States. This stadium named Municipal Grant Park Stadium designed by The architect Holibird and Roche who designed the stadium in 1919 and the stadium was renamed in 1924 (Soldier Field,2012). the stadium renovated in 2003, it increase the capacity to 103,000 and became the first North American stadium to achieve LEED Existing Building certification in 2012. It has a vital addition of the sustainable building movement.

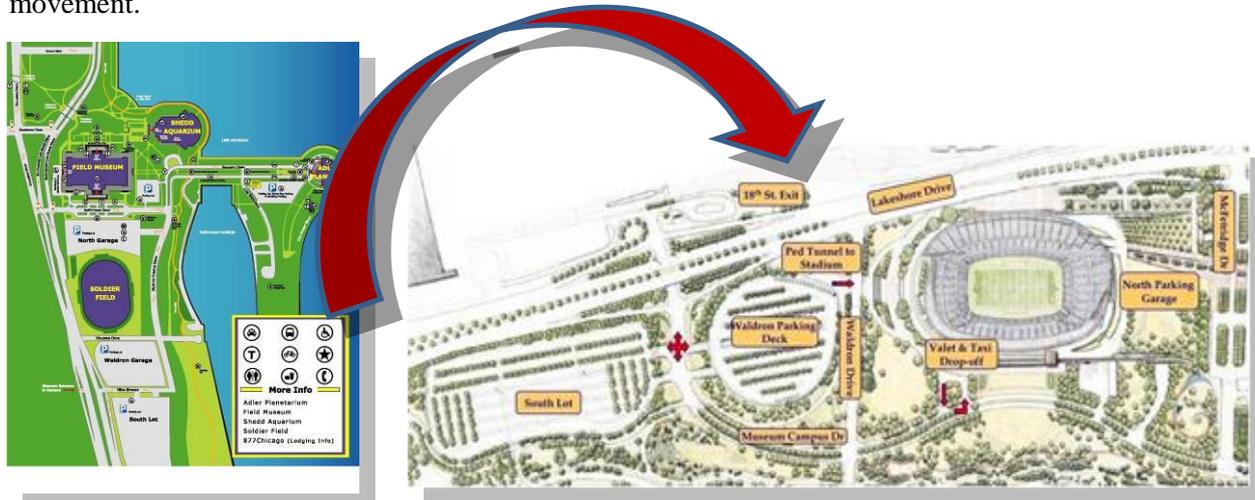


Fig.10 The site of Soldier Field in Chicago, Illinois, reference : (Soldier Field, 2012)

LEED certification provides some strategies: sustainable site development, water savings, energy efficiency, materials selection and indoor environmental quality. According to the renovation of the stadium, the Chicago Parks District main goal is to improve the efficiency by decreasing the environmental impact of Soldier Field stadium through some strategies (as shown as in fig. 11) for human and environment like: (reducing water and energy consumption, creating waste management programs and reducing waste and harmful greenhouse gas emissions). The main objective of renovating the stadium is to preserve the external wall and reconstructed the stadium's interior that is called 'facadism'.



Fig.11 Aerial view of the stadium in 1926 and 2003 Reference: (Soldier Field, 2012)

9.2.1 Sustainability features in soldier field:

The stadium was renovated in 2003 with focus on sustainability and considered that efficiency and performance are parts of the future. We will shed light on some of soldier field sustainability features:

a. Reducing water usage:

Collect water from bathroom sinks, showers, laundry and baths for non-drinkable water (irrigation and landscape) to save annual water bills.

b. Reducing Energy consumption:

- Using solar panels:
 - o 1162 solar panels were installed on the western roof of soldier field .These panels can generate 375 kilowatts of electricity.
 - o The renovation of the stadium include three Charging stations for electric vehicles in the North Parking Garage which are free to all the users to enhance the use of energy efficient vehicles To promote energy-efficient vehicles, the stadium has three electric vehicle charging stations that fans can use at no cost (Soldier,2012).
- Lighting system:
 - o Traditional lighting was replaced (as shown as in fig. 12) by an energy saving LED lights including on the historic columns of the stadium to decrease the stadium’s annual energy consumption.



Fig.12 Lighting system (LED lights) in Soldier Field Reference: (Hogan, 2004)

- Heating System: Soldier Field does not receive much sunlight. Therefore, they installed a heating system to provide warm for the turf and the soil. “The heating system was installed 9 inches deep underneath the root zone using more than 40 miles of 3/4-inch tubing (as shown as in fig. 13). Radiant heat will warm a combination of water and glycol as it is pumped through the tubing” (Hogan, 2004). As a result, this heating system will melt snow and will keep the field warm and keep the turf healthier and grow in the winter.

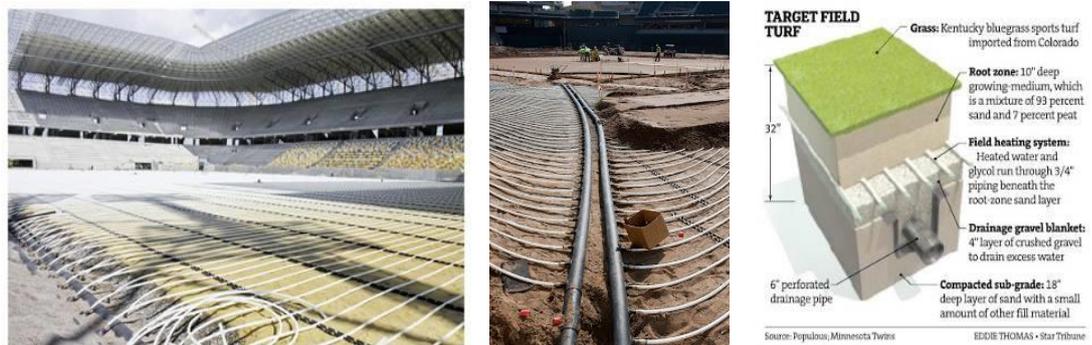


Fig.13 Heating system under playing surface, reference: (Hogan, 2004)

c. Reusing and recycling materials:

According to recycling programs many items were implemented in soldier field as follows

- Reusing of soil removed from the field during re-sodding and repurposing for landscape projects.
- Reusing of all containers & bottles used for green cleaning chemicals and products through container refill stations.
- Recycling of all aluminum with Soldier Field's 30-yard aluminum compactor.
- Recycling of cardboard with Soldier Field's cardboard bailer.
- Recycling of all plastic bottles in a 30-yard open-top dumpster on event days and special plastic pick-ups on non-event days.
- Recycling of office paper.
- Recycling of glass.
- Recycling of all light bulbs and batteries.
- Recycling of all lost cell phones and eyeglasses.
- Recycling of all delivery pallets.
- Recycling of all toner cartridges from office printers and fax machines (Soldier Field, 2012).

d. Participating and encouraging fans:

Participating spectators and public in the environmentally practices to reduce, reuse and recycle their environmental footprint. “They are encouraging and facilitating participation by patrons in the stadium’s greening initiatives to take an active role in reducing its carbon footprint. Only by educating and offering opportunities for staff and patrons to participate while visiting the stadium and the museums can we make a more positive impact on our community and environment” (Vashon,2014).

e. Improving the Site accesses:

Soldier Field is located near the Chicago downtown area so there are many accesses to soldier field like CTA’s Red, Orange, and Green lines stop, CTA Buses, Metra Trains and water taxi.

f. Renovation the roof:

The original concrete roof, which covered just some seats in the upper ring, was replaced with a fiberglass-tensioned membrane to cover 95 % of the seats inside the stadium (as shown as in fig. 14).

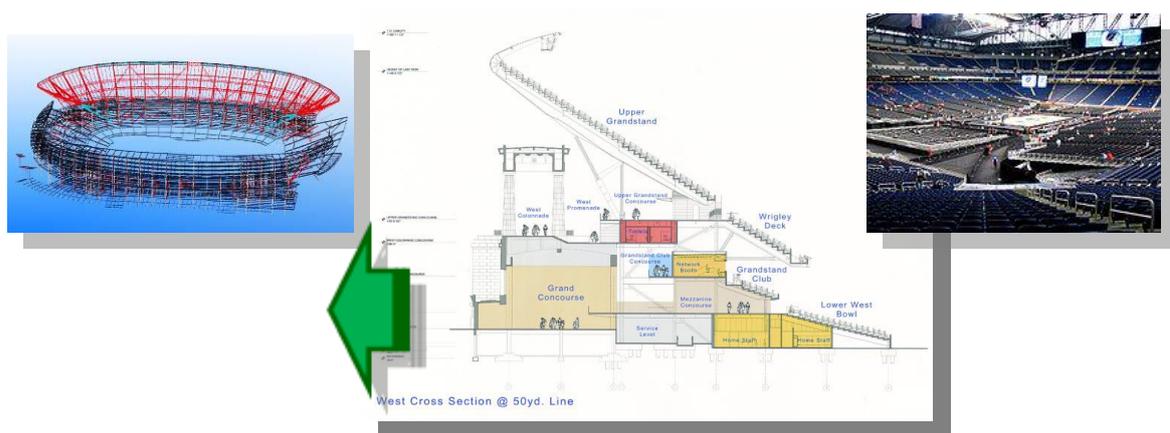


Fig.14 The fiberglass tensioned membrane to cover 95 % of the seats in stadium

According to the integration between history and evolution, Soldier field is preserving the past and protecting the future through some strategies to achieve sustainability (reducing water and energy consumption, reusing and recycling materials, participating and encouraging fans to reduce, reuse and recycle their environmental footprint, improving the Site accesses. So that soldier field consider as an architectural masterpiece to achieve LEED Existing Building certification .It was one of the greenest stadium all over the world.

10. FRAMEWORK FOR STADIUMS' RENOVATION TO ACHIEVE SUSTAINABILITY

The previous analysis of the two sustainable stadiums Castelão Arena in Brazil and Soldier field in Chicago reveals that the renovation for existing building can be a successful solution for sustainability issue. That means preserving the past and protecting the future through some strategies. At the level of architectural design, we need to discuss the implications of the renovation for existing stadiums to achieve sustainability. Figure (15) shows a structural diagram for the analyzed framework for renovation stadiums to achieve sustainability in architectural design.

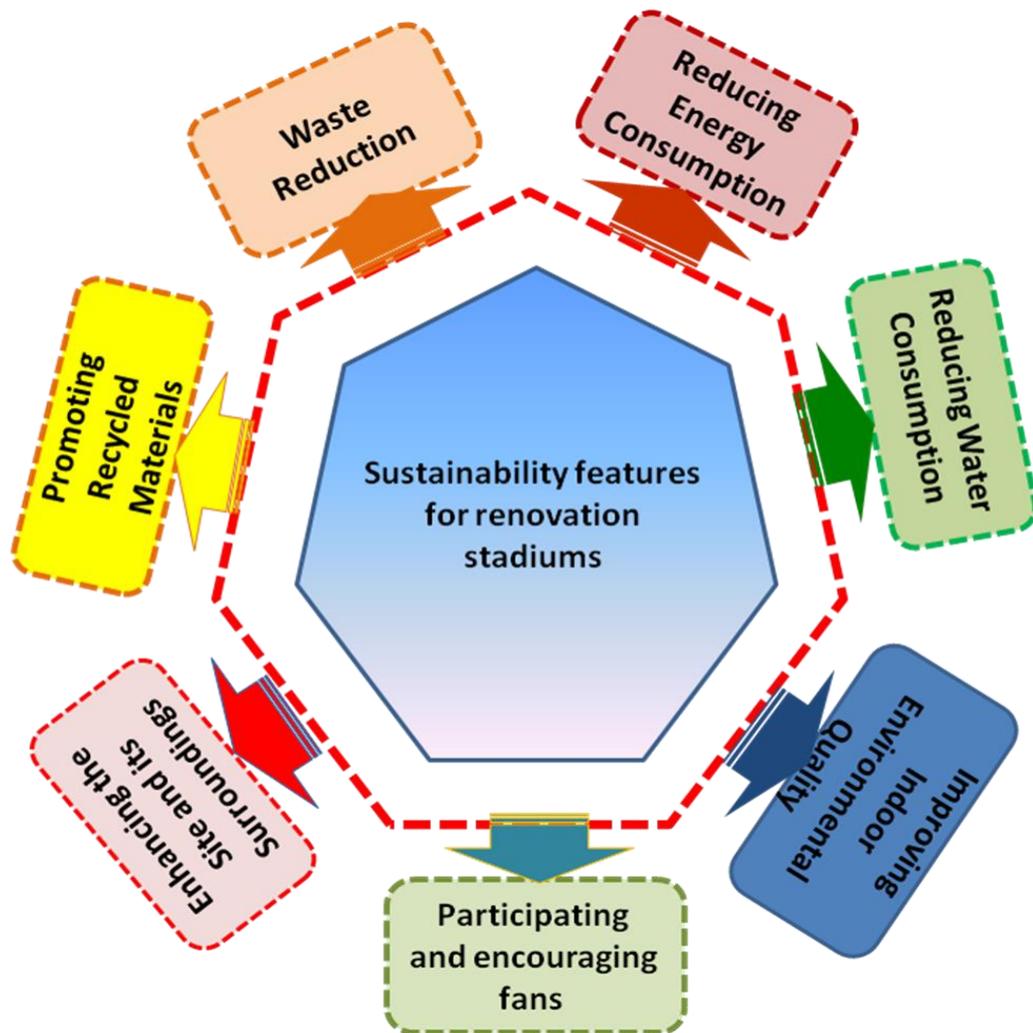


Fig. 15 A framework for the renovation of stadiums to achieve sustainability in architectural design.

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