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## Stadiums as Widespan Structures in Cameroon: Case Study of Ahmadou Ahidjo Stadium and Olembe Paul Biya Stadium

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### Abstract

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Stadiums are widespan structures that represent complex architectural and engineering achievements that blend structural innovation with cultural significance. This research investigates the structural systems and architectural design of two prominent Cameroonian stadiums: the Ahmadou Ahidjo Stadium and the Olembe Paul Biya Stadium. Using a comprehensive methodology that integrates architectural analysis, historical research, and detailed case study assessment, the study examines; the evolution, technological advancements, and contextual challenges of stadium construction in Cameroon. By combining qualitative architectural analysis with structural quantitative evaluations, this study provides a framework for understanding stadium design. Furthermore, this research investigates the structural components of these stadiums, focusing on roof structures, technological innovations, and contextual adaptations. Key findings highlight the importance of balancing innovation, cost-effectiveness, flexibility, and safety in widespan design. The findings contribute to global discourse on stadium architecture, offering insights into how local contexts influence structural design. Finally, Technical guidelines and recommendations are proposed for future stadium construction in Cameroon and in the African region.

**Keywords:** Widespan structures, Structural Systems, Stadium design ,Technological Advancements, Architectural Design, Cameroon.

### 1. Introduction

Stadiums are buildings that shape towns and cities more than almost any other building type in history and simultaneously put a community on the map (Geraint, Sheard and Vickery 2007, 21) . Stadiums are more than venues for sports and entertainment; as they are monumental expressions of architectural innovation and cultural identity. As widespan structures, they exemplify the integration of engineering precision and architectural vision, creating vast unobstructed spaces that accommodate thousands of spectators. In Cameroon, the Ahmadou Ahidjo Stadium and the Olembe Paul Biya Stadium are prominent examples of this architectural typology, that reflects the nation's ambitions and the challenges of constructing such complex structures in a developing context. This paper explores these two stadiums' structural systems, architectural designs, and contextual adaptations, offering a comprehensive analysis of their significance within the broader framework of widespan architecture. By examining their evolution, technological innovations, and the interplay between global design trends and local constraints, this study contributes to the discourse on stadium design in Africa and beyond.

#### 1.1 Background

Wide-span structures as buildings that enclose large areas without intermediate supports, making them ideal for sports arenas and convention halls Santoso (2004) . Stadiums first appeared around 776 BC with the inauguration of the Olympics in Greece (Yaroni 2012). The Roman Colosseum is the first architecturally and structurally designed building that resembles modern-day stadiums. Following the construction of the Colosseum in AD 70, stadium design took off and similar designs were built across many civilizations. Also, during this time, the development of Roman concrete marked a pivotal advancement in history. Unlike the stone and timber used in earlier Greek stadiums, Roman concrete was a durable blend of volcanic ash, lime, and rock that offered exceptional strength and versatility, enabling the construction of expansive arches and vaults that supported large, unobstructed spaces for public assemblies . This innovative material allowed Roman amphitheaters to achieve scale and stability, while accommodating thousands of spectators and setting a foundation for future widespan designs. Following centuries of limited evolution in stadium development, significant advancements emerged in the 19th century. Stadiums have then evolved to meet the changing demands and expectations of society (Jenaway, 2013). This evolution is greatly influenced by technology and has led

to a shift in focus towards spectator experience and revenue generation. Also there is a greater emphasis on viewing areas and amenities for spectators. Modern stadiums incorporate advancements in technology and engineering, resulting in bolder and more unique designs and structures.

In Cameroon, stadiums are very important as symbols of national pride and advancement. More than mere buildings, they embody the nation's rich sporting and football traditions, as well as its ambition to gain international recognition. The Ahmadou Ahidjo Stadium, inaugurated in 1972, and the Olembe Paul Biya Stadium, completed in 2021, are key architectural achievements that blend global design influences with local identity, showcasing Cameroon's distinctive journey in stadium development despite its socio-economic obstacles.

### 1.2 Significance of Stadiums in Cameroon

Football has been means to instill a sense of nationalism and national pride after independence (Pannenberg, 2012). As a nation with a vibrant cultural heritage and a prominent position in African sports, particularly football, Cameroon has strategically utilized stadium architecture to assert its presence on both regional and global stages. Also Pannenberg (2012), discusses that Football is often described as a unifying force in Africa and holds a particular significance in Cameroon, where the sport fosters social cohesion and national pride. The Africa Cup of Nations (AFCON), organized by the Confederation of African Football (CAF) since 1957, is the continent's premier football competition, held biennially to showcase African talent and unity. Cameroon's selection as the host of the 33rd AFCON edition from January 9 to February 6, 2022—the second time since 1972—underscored the country's commitment to leveraging stadium infrastructure to enhance its global image and domestic development (CAF, 2021). The construction of the Ahmadou Ahidjo Stadium marked a pivotal moment in Cameroon's architectural history. As one of the first widespan structures built post-independence, it has showcased the country's capacity to undertake ambitious infrastructure projects. In contrast, the Olembe Paul Biya Stadium, completed in 2021, represents Cameroon's contemporary aspirations and its evolution as a modern African nation. Located in Yaoundé and designed specifically to host AFCON 2022, this 60,000-seat stadium integrates advanced widespan roofing technology, sustainable design elements, and contemporary aesthetics. Its architectural design blends international standards with local identity, incorporating motifs inspired by Cameroon's cultural heritage, such as patterns reflecting traditional artistry. The stadium's state-of-the-art facilities, including energy-efficient systems and advanced spectator amenities, position it as a benchmark for modern stadium architecture in Africa responding to international standards.

### 1.3 Problem Statement

There exists a notable gap in the literature regarding the comprehensive study of widespan structures within the context of Cameroonian stadiums. This lack of knowledge in the literature hinders the ability of Cameroonian architects and engineers to refine their expertise in designing and constructing widespan structures effectively as local architects. The absence of detailed research not only limits local innovation but also restricts the broader understanding of how stadium architecture can be optimized in developing-world contexts. Consequently, this research addresses a critical problem: the need for a thorough investigation into the structural systems, architectural designs, and contextual influences of Cameroonian stadiums. By bridging this gap, the study aims to contribute valuable insights to local practitioners and the global discourse on stadium architecture. The significance of this research extends beyond Cameroon, offering lessons for stadium construction across the African continent and other developing regions.

### 1.4 Objectives and Research Questions

This research aims to comprehensively examine widespan stadium structures in Cameroon through three primary objectives:

1. Analyze the structural and architectural features of Ahmadou Ahidjo and Olembe Paul Biya Stadiums.
2. Evaluate their roof systems, technological innovations, and responses to local challenges.
3. Develop guidelines for designing widespan stadiums in African contexts.

To achieve these objectives, the research addresses the following key questions:

1. What are the essential structural and architectural components of Cameroonian stadium widespan structures, with a concentration on roof systems?
2. How do the structural systems and roof designs of these stadiums reflect local constraints and global standards?
3. What technological advancements enhance the functionality of widespan stadiums in Cameroon?
4. How can contextual adaptations improve safety, sustainability, and cultural relevance?

### 1.6 Structure of the Paper

The article proceeds as follows: a literature review synthesizes global and regional perspectives on stadium design; the methodology outlines the mixed-methods approach; case studies analyze the two stadiums; results and discussion interpret findings; technical guidelines offer actionable recommendations; and the conclusion summarizes contributions and future directions.

## 2. Literature Review

To examine the architectural design, structural engineering, historical evolution, and significance of the Ahmadou Ahidjo Stadium and Olembe Paul Biya Stadium in Cameroon, this study employs a mixed-method research design that integrates qualitative and quantitative approaches.

The methodology ensures a comprehensive understanding of the design, construction, and contextual roles of these structures. This dual approach enables a holistic examination of the stadiums by addressing their technical engineering aspects and their cultural and contextual significance. By combining technical and cultural perspectives to understand how global engineering standards work with Cameroon's local challenges and cultural identity. This approach creates a clear framework for studying stadiums in developing countries, showing how these structures reflect both international design guidelines and trends and local needs, while supporting national pride and sustainable growth.

### 2.1 Data Collection Methods

The research utilizes five key data collection methods to ensure a comprehensive investigation of the Ahmadou Ahidjo and Olembe Paul Biya Stadiums as follows ;

1. **Architectural Analysis:** This method involves a detailed examination of the stadiums' design principles, material selection, and spatial layouts. It explores how aesthetic and functional elements reflect global trends and local adaptations, focusing on aspects such as roof design, spectator amenities, and site integration.
2. **Structural Assessment:** Using computational tools like SAP2000, this method evaluates load distribution, roof design, and structural innovations. It quantifies the performance of widespan systems, such as the cantilever roof of Ahmadou Ahidjo Stadium and the tensile spoke-wheel roof of Olembe Paul Biya Stadium, under various environmental and operational conditions.
3. **Historical Research:** This method reviews archival records, construction documents, and literature to trace the development, renovations, and modifications of the stadiums. It contextualizes their evolution within Cameroon's socio-economic and political history, highlighting shifts in design priorities over time.
4. **Comparative Analysis:** This method compares the structural systems, material choices, and contextual adaptations of the two stadiums. By juxtaposing the conservative engineering of Ahmadou Ahidjo with the innovative design of Olembe Paul Biya, it identifies trends and challenges in Cameroonian stadium architecture.

### 2.2 Analytical Framework

The analysis of the stadiums' structural systems is guided by established classifications from Engel (2007) in *Structure Systems* and Hürol & Baydu (2016) in *The Tectonics of Structural Systems: An Architectural Approach*. These frameworks provide a systematic basis for categorizing and evaluating widespan structural components, such as trusses, space frames, and tensile membranes. Additionally, FIFA and UEFA design standards are applied where relevant to assess the stadiums' compliance with international guidelines for safety, category, functionality, and spectator experience. This dual framework ensures that the analysis is both theoretically grounded and practically aligned with global architectural and engineering standards.

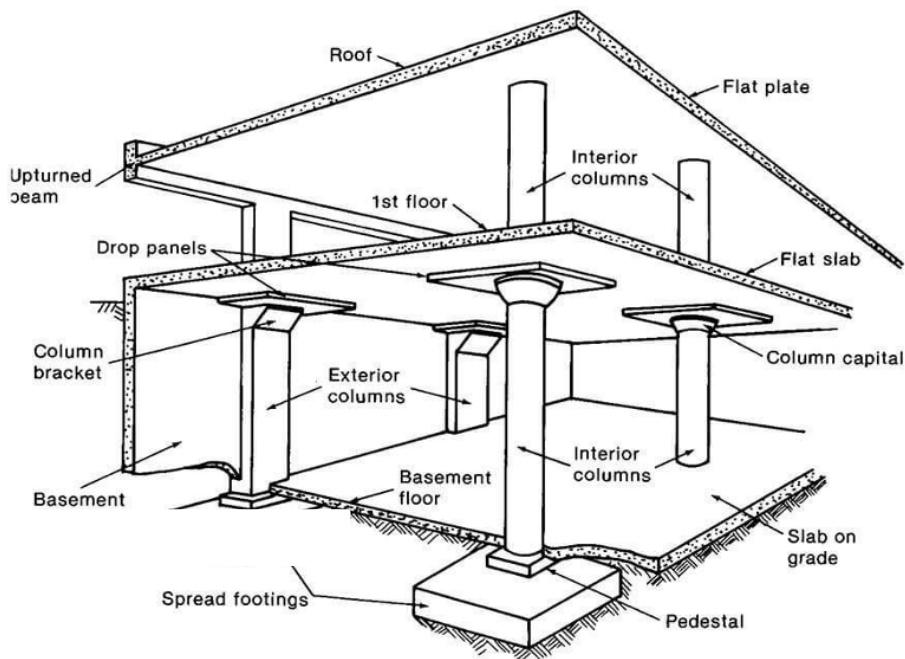
### 2.3 Study Area

The study focuses on Yaoundé, Cameroon, where the Ahmadou Ahidjo Stadium (inaugurated in 1972) and the Olembe Paul Biya Stadium (completed in 2021) are located. These stadiums were selected as contrasting case studies due to their differing construction eras, structural designs, and cultural roles. Ahmadou Ahidjo represents a second-generation stadium with a reinforced concrete cantilever roof, reflecting post-independence pragmatism, while Olembe Paul Biya is a modern Category 4 stadium with a tensile spoke-wheel roof, embodying contemporary global ambitions.

### 2.4 Structural Systems

The successful implementation of widespan structures relies on the integrated performance of several critical components, each fulfilling specific structural functions.

The structural system consists of various components, including vertical force-resisting elements, floor systems, and horizontal force-resisting elements, which together form the three main subsystems. Structural members which vary in characteristics such as material, dimensions, and performance. Elements like foundations, floors, walls, beams, columns, roofs, stairs, and other components work collectively to ensure the building's overall stability and functionality.(Figure 2.1).



**Figure 2.1:** Building Components . Taken From Stadiums as Widespan Structures in Cameroon: Case Study of Ahmadou Ahidjo Stadium and Olembe Paul Biya Stadium [defended master’s thesis] by E.-A. M. Toukam, 2023, Eastern Mediterranean University.

These components are based on their roles and their functions within the system and can be categorized as; Primary load bearing components, secondary load bearing components, connections, support systems and materials (Table 1.1).

**Table 2.1:** Structural Systems Key Components (Developed by Author).

KEY COMPONENTS OF STRUCTURAL SYSTEM	
COMPONENT	ELEMENT
LOAD BEARING COMPONENTS	<ul style="list-style-type: none"> <li>• Walls</li> <li>• Beam</li> <li>• Columns</li> <li>• Foundation</li> <li>• Slabs</li> <li>• Braces</li> <li>• Trusses</li> </ul>
CONNECTION SYSTEMS	<ul style="list-style-type: none"> <li>• Riveted</li> <li>• Bolted</li> <li>• Welded</li> <li>• Pinned</li> </ul>
SUPPORTS	<ul style="list-style-type: none"> <li>• Roller</li> <li>• Pined</li> <li>• Fixed</li> <li>• Simple</li> </ul>

The interaction between these components determines the overall structural behavior and efficiency. Contemporary computational tools enable engineers to model these interactions with increasing sophistication, optimizing each element within the context of the entire structural system.

### 2.5 Structural Systems of Widespan Structures

Structural systems are major subsystems incorporated to resist the loads in and on a building. The prime function of the systems is to transmit safely the loads from the upper portion, or superstructure, of the building to the foundations and the ground (Merritt & Ambrose, 1990). They are the elements of construction that creates a portion of a building's form, either to support the entire structure or other developed assets, such as a bridge or tunnel, or only a part of it. Any form consists of a structure (beams, columns, slabs) and non-structural (doors, partition walls, stairs) elements hence without

no structure there no building. Structural systems can be classified into three categories: low-rise, high-rise, and widespan. Two distinct categories of structural systems exist: traditional and contemporary structures, generating diverse types of spaces, as classified in Table 2.2 . Traditional structural systems include; masonry walls, arches, vaults, and domes. In contrast, contemporary structures includes various types of structures using innovative technologies, categorized as form active, vector active, section active, and surface active.

**Table 2.2 : Classification of Structural Systems (Developed by Author).**

**CONTEMPORARY STRUCTURAL SYSTEMS\***

FORM ACTIVE	VECTOR ACTIVE	SECTION ACTIVE	SURFACE ACTIVE
CABLE	TRUSS 2D + 3D TRUSS	FRAME	SHELL
TENT	SPACE FRAME	SHEAR WALL	FOLDED PLATE
PNEUMATIC	GEODESIC DOME	SLAB	
ARCH			

\*\* Adapted from (ENGEL, 1997)

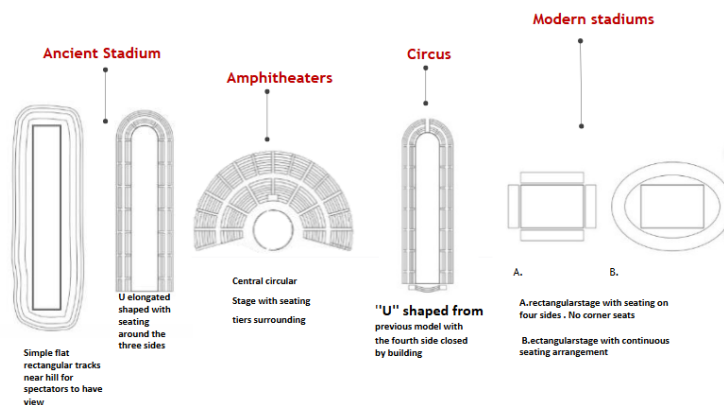
According to Costello (2023), contemporary architecture is widely appreciated and increasingly incorporates sustainable materials, enhancing their value and appeal in a world where sustainability is vital for the future. Modern stadiums consist of this type of structural system that developed with the introduction of concrete and steel as innovative building materials. The use of these materials has greatly shaped the design and construction of today’s stadiums by combining various structural systems.

Therefore, categorizing these new structural system typologies is an essential task for engineers and architects. Such classifications help them make well-informed choices by considering factors like safety, cost, aesthetics, and environmental impact. By evaluating these aspects, professionals can ensure better decision-making in stadium design and construction.

**3 Evolution of Stadium Design**

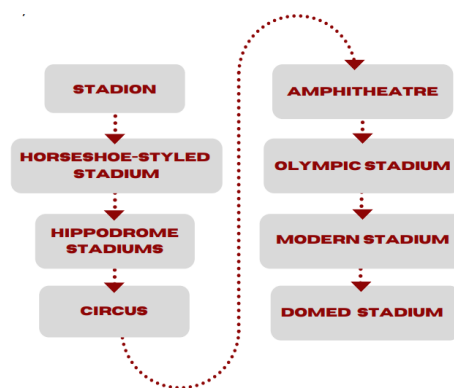
**Historical Progression:**

The development of stadiums shows an impressive evolution of engineering advancements and societal influences. Stadium evolution can be categorized into distinct time periods, though overlaps and regional differences in architectural styles and trends may exist. This categorization offers a broad summary of the major milestones in stadium design throughout history (Figure 3.1).



**Figure 3.1 : The evolution of stadium illustration (Developed by Author).**

According to Yaroni (2012) , stadiums were first developed in ancient Greece and Rome. Both societies stressed the idea of community gathering and public display of strength and talent from ancient Greek stadiums and Roman amphitheaters to contemporary multi-purpose venues, revealing a continuous evolution in structural approaches, spatial organization, cultural significance, user needs, etc. The progression from the first stadium has been through an evolution (Figure 3.2).



**Figure 3.2:** Evolution of Stadiums (Mangaleu Toukam, 2023).

In Ancient Greece, stadiums emerged with the Olympic Games in 776 BC, credited to Heracles pacing 192 meters for a track dubbed the "Stadion". These U-shaped racecourses, like those at Olympia (192 meters) and Delphi (183 meters), used natural hillsides or flat ground, resembling theaters in cities like Thebes (Geraint et al., 2013). Their simple earthwork systems—tiered seating carved into slopes—supported spectators efficiently, laying a foundation for larger designs. What's critical here is their adaptability, leveraging nature to showcase heroic feats with minimal construction. Rome transformed this concept with engineered ambition, leveraging an innovative material: Roman concrete. Amphitheatres, built for gladiatorial combat, and circuses, designed for chariot races, introduced widespan structures like the Colosseum with arches and vault, completed in AD 82 (OCA, 1896). Its elliptical arena, spanning over 150 meters, relied on vaults and arches made possible by Roman concrete—a mixture of volcanic ash, lime, and rock—that offered exceptional strength and durability (Nixdorf, 2008). Unlike Greek reliance on topography, this material allowed constructed tiers to support 50,000 spectators, setting a new standard for scale and stability. The "arena"—Latin for sand—absorbed blood, emphasizing its visceral purpose (Geraint et al., 2013). This structural leap, blending concrete's versatility with precise engineering, balanced form and function, underscoring durability and visibility as timeless priorities.

### 3.1 Types of Stadiums

Stadiums are categorized based on their geometric forms, spatial layouts, specialized purposes, and generational design evolution. These classifications reflect the diverse ways stadiums are designed to enhance spectator experiences, accommodate specific sports or events, and adapt to environmental, economic, and technological contexts.

#### A. Stadiums by Geometric Forms

These are defined by the shape of seating areas and playing fields, influencing spectator experience and event suitability.

1. **Horseshoe Stadium:** U-shaped layout, open at one end, often using natural slopes for tiered seating. It creates an intimate atmosphere with crowd energy focused on the field, ideal for track and field. *Example:* Panathenaic Stadium, Greece. *Use:* Historical venues, athletics.
2. **Oval Stadium:** Symmetrical, oval-shaped seating surrounds the field, primarily for track and field but also soccer or rugby. Viewing angles may be suboptimal in some areas due to the shape. *Example:* Berlin Olympic Stadium, Germany. *Use:* Multi-sport events, athletics.
3. **Rectangular Stadium:** Square or rectangular design, optimized for football with enhanced viewing angles and expandable seating. It accommodates additional facilities, suitable for open or closed configurations. *Example:* Melbourne Rectangular Stadium, Australia. *Use:* Football, multi-sport.
- 4.

#### B. Stadiums by Spatial Layouts

These are categorized by enclosure and exposure to environmental conditions, affecting weather protection and costs.

1. **Open Stadiums:** Lack roofs, leaving fields and stands exposed to weather, which impacts player performance and fan experience. Chosen for outdoor ambiance in favorable climates. *Example:* İzmir Atatürk Stadium, Turkey. *Use:* Cost-effective sports venues.
2. **Closed/Semi-Closed Stadiums:** Feature full or partial roof coverage, often with retractable systems, offering weather protection and lower construction/maintenance costs compared to fully enclosed designs. *Example:* Maracanã Stadium, Brazil. *Use:* Multi-season, high-budget sports.

#### C. Stadiums by Specialized Purposes

These are designed for specific events, sports, or cultural roles, emphasizing innovation and multifunctionality.

1. **Olympic Stadiums:** Built for the Olympic Games, these culturally significant venues feature unique architectural designs and are often preserved as heritage sites. *Examples:* Beijing Stadium, Wembley Stadium. *Use:* Olympics, major international events.
2. **Football Stadiums:** Iconic urban landmarks integrated into commercial districts, with innovative designs tailored to location, climate, and budget. They serve as entertainment complexes. *Examples:* Azadi Stadium, Allianz Juventus Stadium. *Use:* Professional football, urban hubs.

3. **Multipurpose Stadiums:** Designed to host diverse sports and events, incorporating sustainable and innovative solutions to maximize usage and financial viability. *Example:* Stade de France
4. **Specific Purpose Stadiums:** Tailored for individual sports like baseball, soccer, basketball, or hockey, with specialized field and seating configurations to optimize player and fan experiences. *Examples:* Soccer stadiums, hockey arenas. *Use:* Sport-specific events.

### 3.2 Modern Generations

Sheard (2001), notes that contemporary stadiums can be classified into five distinct "generations," with each generation marking the introduction of a new type during the evolutionary process. The idea of "generations" in stadium design captures the progression of design over time, where each generation signifies a major change in design and construction methods.

1. **First-generation modern stadiums 1950s and 1960s:** Prioritized maximum capacity over comfort, featuring concrete terraces with minimal roof coverage and basic amenities. These utilitarian designs emphasized efficiency and economy, shaped by post-war resource limitations and the growing commercialization of spectator sports (Otto & Rasch, 2015). Functionality trumped luxury, reflecting the era's pragmatic needs.
2. **Second-generation stadiums 1970s to early 1980s:** Introduced enhancements in comfort and safety while still focusing on capacity. Ahmadou Ahidjo Stadium, completed in 1972, exemplifies this generation. Its reinforced concrete structure offers formal seating and partial roof coverage but retains relatively basic spectator facilities. The design employs modest cantilevered roof elements for limited weather protection, prioritizing robustness and simplicity over structural innovation (Otto & Rasch, 2015). This approach mirrors the technical capabilities and maintenance considerations prevalent in Cameroon during its early post-independence period.
3. **Third-generation venues, from the late 1980s to 1990s:** Arose in response to high-profile stadium disasters, such as the Hillsborough tragedy. These stadiums emphasized safety through improved circulation, fire protection, and evacuation systems. They also featured more extensive roof coverage and upgraded amenities, often incorporating mixed-use elements to enhance economic viability (Otto & Rasch, 2015). This shift marked a move toward spectator-centric design while maintaining structural integrity.
4. **Fourth-generation stadiums, prevalent in the 2000s and 2010s:** Redefined the stadium as a multi-functional entertainment hub. These facilities boast premium seating, diverse revenue streams—such as retail and hospitality—and advanced media infrastructure. Architecturally distinctive, they serve as urban landmarks and national symbols, reflecting cultural and economic aspirations (Otto & Rasch, 2015). The focus expanded beyond sports to encompass broader entertainment and community roles.
5. **Fifth-generation stadiums:** emerging in recent years, integrate smart technologies, sustainability features, and flexible configurations to maximize utilization. Olembe Paul Biya Stadium embodies traits of both fourth- and fifth-generation designs. Its comprehensive roof coverage, modern spectator amenities, and striking architectural form fulfill national symbolic roles while leveraging contemporary advancements like computational analysis and innovative materials (Otto & Rasch, 2015). Tailored to Cameroonian conditions, it balances global trends with local context, showcasing adaptability and technological sophistication.

Due to this classification the stadiums have been further classified due to their capacities . UEFA's and FIFIA regulations categorize these stadiums into four categories (1, 2, 3, 4) or label them as uncategorized, based on specific qualitative and quantitative requirements related to infrastructure and equipment Figure 3.3.

Category	Minimum capacity	Intention
1	40,000	Very large professional football venue capable of hosting the largest clubs and major international competitions (e.g. FIFA World Cup finals matches)
2	20,000	Large professional football venue capable of hosting large club matches and international competitions
3	10,000	Medium professional football venue capable of hosting club competitions and smaller international competition finals (e.g. youth tournaments)
4	3,000	Small professional football venue capable of hosting smaller club matches and smaller international competition group stages (e.g. youth tournaments)
5	250	Minimum FIFA standard for any football stadium, including development group and community use

Figure 3.3 : Classification of Stadiums According to UEFA Standards.

These requirements encompass aspects like the playing field, access and exits, lighting, safety and security, parking spaces, and spectator areas, detailed in UEFA's regulations (UEFA, 2018). Also UEFA (2018) adds that these regulations do not specify the capacity of stadiums directly, but rather focus on the minimum structural criteria that need

to be fulfilled for a stadium to be classified into a particular category and are also used worldwide for the category classifications.

### 3.3 Roof Systems

The roof plays a major role when it comes to the question of unique design and easy recognition. It is the most important element to create the stadium look (Goepfert and Stein 2009).

Stadium roof systems are critical components of widespan structures, designed to provide shelter, enhance spectator experience, and accommodate large spans without intermediate supports. These systems have evolved significantly, incorporating advanced materials, structural engineering, and technologies like retractable mechanisms.

Early stadium roofs were typically limited to covering main stands, using cantilever structures with modest spans of 10-20 meters. These systems prioritized simplicity and durability over comprehensive coverage or architectural expression. The structural approach relied primarily on concrete frames or simple steel trusses, with limited integration between roof and supporting structure. According to (Nixdorf, 2007), the decision on the roof type is made considering climate and spectators' demands for comfort.

Also The choice of stadium roof can be influenced by environmental requirements, spectator experience, the project construction budget, and the desired aesthetics/image. The inclusion of a roof can also help to retain noise/atmosphere within the stadium bowl, and can protect spectators from the weather to provide a more comfortable viewing environment.

#### 3.3.1 Structural forms for stadiums roof structures

According to Geraint et al., (2013), nine principle structural forms are defined for stadiums roof structures:

- Goal Post structures
- Cantilever structures
- Concrete shell structures
- Compression/Tension Ring
- Tension Structures
- Membrane structures
- Air-supported roof
- Space Frames
- Opening/retractable Roofs

Nixdorf (2008), states that “ *Modern stadia are incorporated with roofing systems in order to provide comfort for spectators and fulfil the requirements and regulations established by different sport federations* ”. The modernization of stadiums began with their roofs and have undergone remarkable evolution; hence the development of these systems demonstrate significantly greater complexity and sophistication, with typical spans exceeding 50 meters and innovative structural systems including compression rings, tension membranes, cable nets, and space frames. These systems create distinctive architectural profiles while providing comprehensive weather protection, controlled daylighting, and acoustic management. The structural integration between roof and supporting elements has become increasingly sophisticated, with forces distributed through complex three-dimensional load paths that optimize material efficiency. In the early days, stadium structures were designed with a 'U' shape, but as time passed, the forms evolved, and this transformation has contributed to the advancement of roof systems (Figure 3.4).

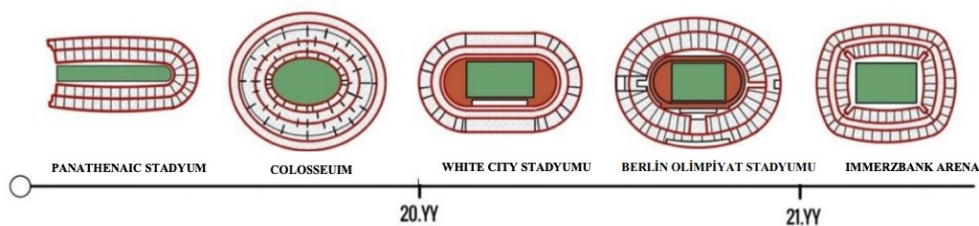


Figure 3.4: Stadium Roof Forms (Gürer & Arslan, 2020).

### 4 Case Study Analysis

The Case analysis explores each stadium's structural systems, roof designs, innovations, and contextual adaptations, alongside the challenges they face. It highlights how architectural and engineering strategies evolved from the early post-independence period to contemporary times, responding to both local conditions and international standards.

#### 4.1 Ahmadou Ahidjo Stadium

1. **Overview:** Built in 1972, renovated 2016, With 42,500 of capacity, it is an open rectangular football stadium. The stadium was named after Ahmadou Ahidjo, the first President of Cameroon It has a rich history of hosting various sporting events and cultural activities .It was the biggest stadium before the construction of the Olembe stadium



Figure xx. Aerial view of Ahmadou Ahidjo Stadium.

2. **Structural System:** reinforced concrete is used as a primary material, valued for its durability, strength, and versatility in widespan construction. Recent trends in Cameroonian stadium design reflect a shift toward modern, functional, and large-scale structures, with Ahmadou Ahidjo relying on concrete frameworks with beam and truss roof systems for partial coverage, enhanced through 2016 renovations to improve structural performance and meet FIFA standards. These rehabilitation and modernization efforts have significantly enhanced structural efficiency, safety, and adaptability to local climatic and budgetary constraints, aligning with global standards while addressing contextual challenges in developing countries.

### STRUCTURE



Figure 4.5: Ahmadou Ahidjo Stadium Original Structure (Mangaleu Toukam, 2023)

### CONSTRUCTION



Figure 4.6: Ahmadou Ahidjo Stadium Current Structure (Mangaleu Toukam, 2023)

3. **Roof Design:** The roof design is simple and utilitarian, providing limited coverage over spectator stands. Comprising concrete beams and trusses, it prioritizes cost-efficiency over extensive weather protection. The partial roof shields key seating areas but leaves much of the stadium exposed to rain and sun, a compromise driven by budget limitations and Cameroon’s tropical climate, where heavy rainfall is common.
4. **Innovations:** The 2016 renovations introduced significant upgrades, including improved seating, enhanced structural stability, and modernized facilities for the Women’s Africa Cup of Nations. These updates preserved the stadium’s core structural character while integrating contemporary safety and accessibility features. The retrofitting process incorporated energy-efficient lighting and improved drainage systems, addressing environmental concerns and operational efficiency.
5. **Contextual Adaptations:** Retrofitted for FIFA standards, addressing budget and climate constraints.
6. **Challenges:** Aging infrastructure, safety concerns, The limited roof span restricts weather protection, impacting spectator comfort during adverse conditions. Safety concerns, such as overcrowding risks and outdated evacuation routes, persist, requiring ongoing maintenance to meet modern standards.

## 4.2 Olembe Paul Biya Stadium

1. **Overview:** Completed 2021, 60,000 capacity, closed/semi-closed multi-purpose stadium Completed in 2021, the Olembe Paul Biya Stadium in Yaoundé is a 60,000-capacity, semi-closed multi-purpose stadium designed for the 2021 AFCON. Named after President Paul Biya, it represents Cameroon’s ambition to host world-class sporting events and is part of an integrated sports complex including a gym, hotel, and shopping mall.
2. **Structural System:** Tensile roof with pre-tensioned cables, compression-tension rings, and PTFE/ETFE membrane.
3. **Roof Design:** Lightweight, large-span, optimized for wind loads and rapid installation.

This stadium typology permits a lightweight and flexible structure composed of A tensile structure solution based on pre-tensioned cables; composed of two internal tension rings (TR= Tension ring, an upper and a lower one) and an external compression truss ring. Known as a spoke wheel roof.

4. **Innovations:** Modular design, integrated sports complex (gym, hotel, mall).
5. **Contextual Adaptations:** Meets CAF/FIFA standards, designed for AFCON 2021, addresses local terrain.
6. **Challenges:** High costs, crowd safety issues , complex roof system.

#### 4.3 Comparative Analysis:

The Ahmadou Ahidjo Stadium and Olembe Paul Biya Stadium, constructed nearly five decades apart shows Cameroon’s architectural and cultural evolution from post-independence pragmatism to global ambition. This comparative analysis Contrast their; structural systems, roof efficiency, technological advancements, and contextual responses. The Ahmadou Ahidjo Stadium reflects a pragmatic or more engineering approach, utilizing reinforced concrete and simple roof systems to meet basic needs within economic constraints. In contrast, the Olembe Paul Biya Stadium embraces advanced tensile structures and modular designs, aligning with international standards and showcasing technological prowess which shows a collaboration and stages. Below is a detailed comparative table that contrasts their structural systems, roof efficiency, technological advancements, contextual responses, and challenges.

	Ahmadou Ahidjo Stadium	Olembe Paul Biya Stadium
<b>Construction Year</b>	1972, renovated 2016	2021
<b>Capacity</b>	42,500	60,000
<b>Structural System</b>	Reinforced concrete framework with beam and truss systems for partial roof coverage.	Tensile roof with pre-tensioned cables, compression-tension rings, and PTFE/ETFE membrane; reinforced concrete for stands.
<b>Roof Design</b>	Simple, cost-effective concrete beam and truss system; limited weather protection.	Lightweight, large-span tensile roof (spoke-wheel system); optimized for wind loads, weather protection, and natural lighting.
<b>Roof Efficiency</b>	Limited coverage; exposed to rain and sun; minimal ventilation.	Extensive coverage; PTFE/ETFE membrane ensures weather resistance and energy efficiency.
<b>Innovations</b>	2016 renovations added modern seating, energy-efficient lighting, and improved drainage.	Modular design, integrated sports complex (gym, hotel, mall), real-time crowd monitoring, and lightweight membrane technology.
<b>Contextual Adaptations</b>	Retrofitted for FIFA standards; uses local materials and labor to address budget and climate constraints.	Meets CAF/FIFA standards; designed for AFCON 2021; addresses local terrain and global expectations with imported materials.
<b>Challenges</b>	Aging infrastructure, limited roof span, safety concerns (overcrowding, outdated evacuation routes).	High construction costs, crowd safety issues (2022 stampede), complex roof maintenance.
<b>Cultural Significance</b>	Symbol of post-independence national pride; functional design reflects economic constraints.	Represents global ambition and modernization; multi-purpose complex enhances community utility.
<b>Cost Considerations</b>	Cost-effective due to local materials and simple design; renovations moderately increased costs.	High costs due to imported materials, advanced engineering, and integrated facilities.
<b>Sustainability</b>	Basic drainage and lighting upgrades; limited focus on energy efficiency.	Energy-efficient membrane roof and lighting; ventilation systems reduce environmental impact.

## 5 Results and Discussion

The analysis of Cameroon's stadium architecture from the post-independence era to the present reveals a dynamic evolution driven by structural systems, roof designs, innovations, and contextual adaptations. This section synthesizes the key findings and discusses their significance, alongside the challenges encountered.

1. **Structural Systems** : transitioned from rudimentary concrete frameworks in the post-independence period to advanced steel and composite structures in contemporary designs. Early stadiums, such as the Ahmadou Ahidjo Stadium (1972), relied on heavy concrete columns and beams, prioritizing durability over flexibility. In contrast, modern projects like the Japoma Stadium (2020) incorporate lightweight steel trusses and modular designs, enabling faster construction and greater adaptability. This shift reflects global architectural trends and Cameroon's increasing access to advanced engineering expertise. However, the reliance on imported materials for modern structures raises concerns about cost and sustainability.
2. **Roof Designs** : Roof designs have evolved significantly, balancing aesthetic ambition with environmental responsiveness. Post-independence stadiums featured minimal roofing, often limited to small cantilevered canopies due to budget constraints. Contemporary stadiums, such as the Olembe Stadium, showcase expansive, tensioned membrane roofs inspired by global precedents like the Allianz Arena. These designs enhance spectator comfort and incorporate rainwater harvesting systems, aligning with local climatic needs. Yet, maintenance of these complex roofs poses a challenge, as specialized skills and funding are often lacking.
3. **Innovations** ; include the integration of sustainable technologies and cultural motifs. For instance, the Japoma Stadium employs solar panels and natural ventilation systems, reducing energy costs. Additionally, facade designs increasingly incorporate patterns inspired by local textiles, reflecting a blend of modernity and cultural identity. These innovations position Cameroon as an emerging hub for architectural experimentation in Africa. However, the adoption of cutting-edge technologies is often hampered by limited local expertise and inconsistent funding.
4. **Contextual Adaptations**; Cameroon's stadiums demonstrate adaptations to the country's socio-economic and environmental contexts. Designs account for high rainfall, humidity, and heat, with features like elevated seating to prevent flooding and perforated facades for airflow. Socially, stadiums serve as multi-purpose venues, hosting cultural and political events, which necessitates flexible layouts. These adaptations highlight a pragmatic approach to architecture but are sometimes undermined by inadequate urban planning, leading to accessibility and infrastructure issues.

Despite these advancements, several challenges persist. High construction costs, driven by imported materials and reliance on foreign contractors, strain national budgets. Maintenance of modern facilities is a recurring issue, with many stadiums falling into disrepair due to insufficient funding and expertise. Additionally, the lack of comprehensive urban integration limits the socio-economic benefits of these projects. Addressing these challenges requires investment in local capacity building, sustainable financing models, and strategic urban planning.

The evolution of Cameroon's stadium architecture mirrors the nation's broader developmental trajectory, from post-independence aspirations to contemporary global ambitions. The shift toward sophisticated structural systems and innovative designs signifies progress, yet it underscores disparities in resource availability and technical capacity. The integration of cultural and environmental considerations is a strength, positioning Cameroon's architecture as contextually relevant. However, overcoming challenges like cost overruns, maintenance, and urban disconnect will be critical to sustaining this architectural momentum. These findings align with trends in other African nations, where ambitious projects often grapple with similar constraints, suggesting opportunities for regional collaboration.

### 5.1 Technical Guidelines and Recommendations (1,500–2,000 words)

These technical guidelines and recommendations provide a roadmap for designing widespan stadiums in Cameroon and Africa that are structurally innovative, safe, sustainable, and contextually relevant. The following guidelines are structured to guide architects, engineers, and policymakers in designing widespan stadiums that are innovative, cost-effective, and contextually appropriate.

1. **Structural Design**: Prioritize lightweight systems (e.g., cable/tension) for large spans, with modular components for cost-efficiency.
2. **Roof Systems**: Incorporate retractable or semi-closed roofs to balance weather protection and costs.
3. **Safety**: Enhance crowd management through wider egress routes and real-time monitoring systems.
4. **Sustainability**: Use recycled materials, solar-integrated roofs, and rainwater harvesting.
5. **Contextual Adaptation**: Design for local climate (e.g., wind, rain), terrain, and cultural significance.
6. **Policy Recommendations**: Encourage public-private partnerships to fund innovative designs and ensure maintenance.

### 5.2 Future Research

Stadium design is influenced by several significant technological trends that expand the possibilities for structural expression, functional performance, and user experience. Also these trends address practical needs while pushing architectural boundaries, making stadiums symbols of progress and community hubs.

One significant trend is the integration of technical infrastructure into roof structures. According to FIFA's *Football Stadiums Guidelines*, the roof serves as a platform for essential systems like lighting, communications, and IT equipment (FIFA, 2023). This requires early design consideration to accommodate structural loads and performance needs while ensuring unobstructed sightlines.

Sustainability is another driving force. Stadium roofs offer opportunities for environmental integration, such as rainwater collection for grey water use and landscape irrigation (FIFA, 2023, Section 2.7). This reduces water demand and aligns with global sustainability goals. Additionally, roofs provide ideal surfaces for solar collectors, generating renewable energy to enhance a stadium's ecological profile. Materials like lightweight polycarbonates or ETFE (ethylene tetrafluoroethylene) are increasingly used in roof designs, offering durability and transparency while supporting solar integration. These systems, evaluated through sun trajectory studies, balance energy production with pitch shading needs, ensuring grass growth and broadcast quality (FIFA, 2023, Section 2.2).

Advancements in materials science further expand possibilities. High-strength composites and tensioned membranes enable expansive, lightweight roofs that span vast distances with minimal supports, as seen in structures like the Allianz Arena. Coupled with digital fabrication techniques—such as 3D printing and robotic assembly—these materials allow for complex geometries and rapid construction, reducing costs and timelines. Parametric design tools enhance this trend, enabling architects to simulate structural behavior, optimize forms, and adapt to site-specific conditions, creating signature expressions that double as urban landmarks.

User experience is elevated through smart technologies. Integrated sensor networks monitor crowd flow, air quality, and structural health in real time, improving safety and comfort. Retractable roofs, powered by automated systems, offer flexibility for weather and event types, while LED lighting and acoustics tailored via computational modeling enhance the atmosphere. These innovations, supported by robust IT infrastructure suspended from the roof, ensure seamless operations and immersive experiences.

## **6. Conclusion**

Stadiums have maintained a consistent design identity across history, from ancient to modern times, evident in their shared shapes, structural components, materials, and construction techniques. The earliest models emerged in Greece during the eighth century BCE and were refined by the Romans through the first four centuries CE. The Colosseum, Rome's iconic amphitheater, is widely regarded as the archetype for modern stadiums, establishing benchmarks for innovative design and construction. It inspired the initial stadium designs of the modern era and shaped the evolution of subsequent structures, contributing to the aesthetic and technical sophistication they exhibit today. This study has explored the architectural and structural evolution of stadium design in Cameroon through a comparative analysis of the Ahmadou Ahidjo Stadium and the Olembe Paul Biya Stadium. By focusing on their widespan structural systems, roof designs, and contextual adaptations, the research illuminates Cameroon's journey from post-independence functionality to contemporary architectural ambition. This conclusion synthesizes the key findings, articulates the academic and practical contributions, acknowledges the study's limitations, and proposes directions for future research, culminating in a reflection on the broader significance of stadiums as cultural and structural landmarks in African contexts.

The structural and architectural analysis of the Ahmadou Ahidjo Stadium (1972, renovated 2016) and the Olembe Paul Biya Stadium (2021) reveals a marked evolution in Cameroon's approach to stadium design, reflecting broader technological, cultural, and socio-economic shifts. The Ahmadou Ahidjo Stadium, a second-generation facility, originally featured a robust concrete framework with minimal roofing, designed to meet basic functional needs during the post-independence era. Its renovation introduced modern steel trusses and an expanded cantilevered roof, aligning it with FIFA standards while retaining its historical significance. In contrast, the Olembe Paul Biya Stadium, a Category 4 facility, embodies contemporary innovation with its lightweight steel lattice structure, tensioned membrane roof, and sustainable features like rainwater harvesting and natural ventilation. These advancements enhance spectator comfort and operational efficiency, positioning the stadium as a symbol of Cameroon's global aspirations.

Both stadiums demonstrate contextual adaptations tailored to Cameroon's environmental and social realities. The Ahmadou Ahidjo Stadium's elevated seating mitigates flooding risks, while its open design facilitates airflow in Yaoundé's humid climate. The Olembe Paul Biya Stadium integrates cultural motifs in its facade, inspired by local textiles, and employs perforated cladding to optimize thermal performance. These adaptations underscore a pragmatic approach to design, balancing global standards with local needs. However, challenges such as high construction costs, reliance on imported materials, and maintenance issues highlight the complexities of implementing ambitious projects in a developing country.

The widespan systems of both stadiums are central to their architectural identity. The Ahmadou Ahidjo Stadium's post-renovation roof relies on a steel truss system, providing greater coverage while maintaining structural integrity. The Olembe Paul Biya Stadium's roof, with its tensioned membrane supported by a radial cable system, exemplifies cutting-edge engineering, enabling a vast, column-free span that enhances sightlines and flexibility. These systems, evaluated against FIFA and UEFA design standards, reflect Cameroon's adoption of global best practices, yet they also expose vulnerabilities, such as the need for specialized maintenance expertise and sustainable financing models. This study advances the understanding of stadium design in developing countries, particularly within the African context. By focusing on widespan structural systems and their evolution, it fills a gap in the literature, which often prioritizes stadiums in developed nations. The comparative analysis of the Ahmadou Ahidjo and Olembe Paul Biya Stadiums provides a nuanced perspective on how post-independence and contemporary architectures coexist, shaped by differing priorities—functionality versus innovation. Drawing on frameworks from Engel (2007) and Hürol & Baydu (2016), the study offers a rigorous classification of structural systems, contributing to the theoretical discourse on tectonics and architectural adaptation in resource-constrained settings. Additionally, the integration of cultural and environmental considerations into the analysis enriches the academic understanding of context-driven design, offering a model for studying other African nations' architectural trajectories.

### Practical Contributions

Practically, this research provides technical guidelines for African stadium construction, emphasizing the importance of balancing innovation with feasibility. The findings highlight the efficacy of lightweight steel and membrane systems for widespan roofs, which reduce material costs and construction timelines while meeting FIFA standards. The study also underscores the value of contextual adaptations, such as climate-responsive designs and multi-purpose functionality, which maximize the socio-economic impact of stadiums. For policymakers and architects, these insights advocate for local capacity building to reduce reliance on foreign expertise and materials, as well as strategic urban planning to ensure stadiums integrate seamlessly with their surroundings. These guidelines are particularly relevant for African countries hosting international events, where stadiums must serve as both functional venues and cultural landmarks.

### Limitations

The study's scope, while focused, introduces several limitations that shape its findings and suggest avenues for future exploration. These are outlined below:

**Focus on Stadiums as Widespan Structures:** The research concentrates on stadiums as widespan structures, with a particular emphasis on roofing systems due to their structural complexity and architectural significance. This focus excludes other elements, such as seating arrangements or circulation systems, which could provide a more holistic understanding of stadium functionality.

1. **Structural System Classification:** The classification of structural systems relies on methodologies from Engel (2007) and Hürol & Baydu (2016). While comprehensive, these frameworks may limit the analysis by excluding alternative categorizations that could reveal additional insights into the structural dynamics of stadiums.
2. **Focus on Contemporary Structural Systems:** The study prioritizes contemporary systems, particularly in the post-renovation Ahmadou Ahidjo Stadium and the Olembe Paul Biya Stadium. This emphasis may overlook historical systems used in earlier phases of the Ahmadou Ahidjo Stadium, limiting the depth of the evolutionary analysis.
3. **Use of FIFA and UEFA Design Standards:** The evaluation is based on FIFA and UEFA standards, which, while globally accepted, may not fully account for local or regional design priorities. Alternative standards could offer a more tailored perspective on Cameroon's stadium architecture.
4. **Selection of Case Studies:** The choice of the Ahmadou Ahidjo and Olembe Paul Biya Stadiums, while justified by their FIFA categorization, historical significance, and structural diversity, restricts the generalizability of findings. Other FIFA-standard stadiums in Cameroon, such as those in Douala or Garoua, may exhibit unique characteristics that could broaden the analysis.
5. **Literature Review Scope:** The literature review draws on key studies (e.g., Gürer & Arslan, 2020; Jenaway, 2013; Miller, 2000; Orhon & Altın, 2014; Sartori & Nienhoff, 2013) but focuses narrowly on structural systems, roofs, and facades. This scope may exclude other architectural dimensions, limiting the study's comprehensiveness.
6. **Geographical Limitation:** The focus on two stadiums in Yaoundé excludes other regions of Cameroon, potentially overlooking regional variations in design and construction practices.
7. **Data Collection Constraints:** The reliance on archival data, site visits, and expert interviews is constrained by incomplete historical records (e.g., for the Ahmadou Ahidjo Stadium's early phases) and limited access to stakeholders for the Olembe Paul Biya Stadium. These gaps may affect the depth of historical and contextual insights.

### 6.1 Future Directions

The limitations of this study pave the way for future research to deepen the understanding of African stadium architecture. Investigating emerging technologies, such as AI-driven design optimization, could enhance the efficiency and sustainability of widespan structures. For instance, AI tools could simulate structural performance under varying environmental conditions, informing cost-effective designs. Additionally, exploring legacy planning for African stadiums—ensuring their long-term use beyond major events—could address maintenance and urban integration challenges. Comparative studies across African nations, incorporating a broader range of stadiums and architectural elements, would further contextualize Cameroon's experience within regional trends. Finally, research into local material innovations and training programs could reduce dependency on imports, fostering self-sufficiency in African construction industries.

Stadiums in Cameroon, as exemplified by the Ahmadou Ahidjo and Olembe Paul Biya Stadiums, are more than architectural feats; they are cultural and structural landmarks that embody community aspirations and national identity. These venues bridge the past and future, blending post-independence resilience with contemporary innovation. By fostering social cohesion through shared experiences—whether sporting, cultural, or political—stadiums serve as catalysts for unity and progress. Their evolution reflects Cameroon's ambition to assert its place on the global stage while honoring its unique context. As Africa continues to urbanize and host international events, stadiums will remain pivotal in shaping sustainable, inclusive, and culturally resonant built environments, driving innovation and community engagement for generations to come.

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### Conflict of Interests

The Author(s) declare(s) that there is no conflict of interest.

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