

SHELL ROOF STRUCTURES IN BUILDING CONSTRUCTION

Analyzing the Strength, Durability and Application of the Shell Roofing System in Building Construction

Ochi Ejimofor¹, Ukaegbe Ugochukwu²

¹Department of Architecture, Faculty of Environmental Studies, Abia State University, Uturu, Nigeria

²Department of Architectural Technology, School of Environmental and Design Technology, Ogbonnaya Onu Polytechnic, Aba, Abia State, Nigeria

Published October 2026

Abstract

The Sheel roofing system, a modern steel-based roofing solution, has emerged as a critical component in contemporary building construction due to its superior mechanical properties, cost-effectiveness, and sustainability. This research paper examines the structural strength, durability characteristics, and practical applications of the Sheel roofing system in building construction. Through a comprehensive analysis of material properties, mechanical performance, and field applications, this study evaluates the system's suitability for diverse construction environments. The findings demonstrate that Sheel roofing systems offer significant advantages over traditional roofing materials, particularly in terms of load-bearing capacity, weather resistance, and long-term durability. The paper concludes with recommendations for optimal application and future research directions.

Keywords: roofing systems; steel roofing; shell roofs; durability; structural performance; building construction

1 Introduction

Roofing systems constitute one of the most critical elements in building construction, providing essential protection against environmental factors while contributing to the structural integrity of the building envelope. Among the various roofing solutions available in the market, the Sheel roofing system has gained substantial attention due to its innovative design and superior performance characteristics. Steel roofing, in general, represents a significant advancement in construction technology, offering enhanced strength-to-weight ratios and improved durability compared to conventional materials such as asphalt shingles, clay tiles, or concrete roofing (Alexander, 2020).

The Sheel roofing system specifically refers to an engineered steel roofing solution that incorporates advanced manufacturing processes and protective coatings to optimize performance in various climatic conditions. This system has been increasingly adopted in both residential and commercial construction projects, driven by growing demands for sustainable, cost-effective, and long-lasting roofing solutions (Kumar & Singh, 2021). Understanding the mechanical properties, durability factors, and application scope of the Sheel roofing system is essential for construction professionals, engineers, and architects to make informed material selection decisions.

2 Background and literature review

2.1 Evolution of steel roofing systems

The development of steel roofing systems has evolved significantly over the past several decades. Traditional steel roofing solutions were primarily limited to industrial applications due to concerns about corrosion resistance and aesthetic limitations. However, advancements in metallurgy, coating technologies, and manufacturing processes have transformed steel roofing into a versatile solution suitable for diverse architectural applications (Martinez, 2019).

Modern steel roofing systems, including the Sheel variant, incorporate multiple layers of protective coatings, including galvanized zinc-iron alloy and polyester or polyvinylidene fluoride (PVDF) finishes, which provide enhanced corrosion resistance and color retention (Chen et al., 2022). These technological improvements have addressed historical limitations and expanded the application spectrum of steel roofing systems.

2.2 Structural performance of steel roofing

Steel roofing systems are characterized by their exceptional tensile strength and load-bearing capacity. The yield strength of modern steel roofing materials typically ranges from 250 to 550 MPa, depending on the grade and thickness of the material (EN 10346; CEN, 2015). This high strength-to-weight ratio enables steel roofing systems to withstand significant mechanical loads, including snow accumulation, wind uplift, and thermal stresses.

The Sheel roofing system specifically employs profiled steel sheets with optimized geometries that enhance structural performance. The profiled design increases the moment of inertia of the cross-section, thereby improving bending resistance without adding substantial weight (Wang & Li, 2020). This engineering approach allows for longer span capabilities and reduced support requirements, resulting in cost savings in the overall roofing structure.

3 Methodology

This research employs a comprehensive analytical approach combining material testing data, literature review, and case study analysis. The methodology encompasses:

- **Material Characterization:** Analysis of steel composition, mechanical properties, and coating specifications based on manufacturer technical data and relevant standards.
- **Performance Evaluation:** Examination of strength parameters including tensile strength, yield strength, and elongation, as well as durability factors such as corrosion resistance, weatherability, and thermal performance.
- **Application Analysis:** Review of case studies and project documentation to assess real-world performance and implementation considerations.

Data sources include peer-reviewed journal articles, technical standards from recognized bodies such as ASTM International and ISO, manufacturer specifications, and industry reports from construction research organizations.

4 Results

4.1 Mechanical strength properties

The Sheel roofing system demonstrates superior mechanical properties compared to traditional roofing materials. The ultimate tensile strength of the steel substrate ranges from 350 to 550 N/mm², while the yield strength typically falls between 250 and 450 N/mm², depending on the specific product grade ([Sheel Industries, 2023](#)). These values exceed the requirements specified in ASTM A792/A792M-20 for coated steel sheet.

The profiled sheet design provides additional structural benefits. The geometric configuration increases the second moment of area, enabling the roofing system to resist higher bending moments. Field tests have shown that Sheel roofing systems can support live loads of up to 2.5 kN/m², significantly exceeding the minimum requirements for most residential and commercial buildings ([Building Research Establishment, 2021](#)).

4.2 Durability performance

Durability is a critical factor in roofing system selection, and the Sheel roofing system excels in this regard. The multi-layer coating system provides excellent corrosion resistance, with salt spray testing demonstrating performance exceeding 2,000 hours without red rust formation (ASTM B117-19; [ASTM International, 2019](#)). The PVDF coating variants offer even superior weatherability, with color retention values exceeding 90% after 20 years of exposure ([Narang et al., 2022](#)).

Thermal performance of the Sheel roofing system has also been extensively evaluated. The reflective properties of the coated steel surface reduce heat absorption, lowering roof surface temperatures by up to 15°C compared to uncoated metal surfaces ([Ghosh & Das, 2021](#)). This characteristic contributes to improved building energy efficiency and reduced cooling loads.

4.3 Long-term performance data

Long-term monitoring studies indicate that properly installed Sheel roofing systems can achieve service lives of 40-50 years under normal environmental conditions ([International Code Council, 2021](#)). The warranty periods offered by manufacturers typically range from 20 to 30 years for coating systems and up to 50 years for structural integrity, reflecting confidence in the product's durability.

5 Discussion

The results of this analysis confirm that the Sheel roofing system offers significant advantages for building construction applications. The combination of high mechanical strength, excellent durability, and favorable thermal properties makes it suitable for diverse climatic conditions and building types.

The structural performance of the Sheel system addresses key requirements in modern construction, particularly the need for lightweight yet robust roofing solutions. The high strength-to-weight ratio reduces the load on supporting structures, potentially allowing for optimization of the overall building framework. This characteristic is particularly valuable in seismic zones where reducing dead load is critical for structural safety ([FEMA, 2020](#)).

From an economic perspective, while the initial cost of Sheel roofing systems may be higher than conventional asphalt shingles, the life-cycle cost analysis demonstrates favorable economics. The

extended service life, minimal maintenance requirements, and energy efficiency benefits contribute to lower total cost of ownership over the building's lifetime (Panchal & Patel, 2022).

However, certain considerations must be addressed for optimal application. Proper installation techniques are essential to ensure watertight performance and longevity. Fastener selection, sealant application, and thermal movement accommodation require attention to detail. Additionally, noise insulation measures may be necessary in certain applications, as metal roofing can transmit rain impact noise without adequate underlayment or insulation.

6 Types of shell roofs

The main types of shell roofs include single-curved shells, double-curved shells, folded plate shells, grid shells, and specialized forms such as umbrella roofs and hyperbolic paraboloids, each defined by their curvature and structural behavior.

6.1 Single-curved shell roofs

These roofs have curvature in one direction only and behave structurally like a combination of arch and beam action. Common forms include:

- Barrel vaults — long cylindrical shells used in hangars, markets, and industrial buildings; they can span large distances efficiently;
- Cylindrical shells — generated by moving a straight line along a curved path; used in sheds, warehouses, and aircraft hangars;
- Conoid shells — formed by moving a straight line along a curved path; used for expressive architectural roofs.

6.2 Double-curved shell roofs

These roofs curve in two perpendicular directions, giving high stiffness and excellent load distribution. Types include:

- Domes — spherical or elliptical shells with positive double curvature; used in stadiums, temples, and planetariums;
- Hyperbolic paraboloids (Hypars) — saddle-shaped shells with negative curvature; can be formed from straight lines, making construction easier; used in stadiums, auditoriums, and canopies;
- Elliptical or toroidal shells — used for specialized architectural or industrial applications.

6.3 Folded plate shell roofs

Folded plates consist of flat slabs joined along fold lines, creating stiffness without continuous curvature. They are used in industrial buildings, gymnasiums and long-span roofs, and provide rigidity through geometric folding rather than curvature.

6.4 Gridshell roofs

Gridshells are lattice shells made of steel, timber, or composite members forming a curved surface. They combine shell action with grid behavior and are used in atriums, museums, and lightweight long-span roofs.

6.5 Umbrella roofs and other special shell forms

Some shell roofs are categorized by their architectural form rather than curvature type:

- Umbrella roofs — shell roofs shaped like inverted or upright umbrellas, often used in public plazas and terminals;
- Folded plate umbrellas or modular shell units — used in repetitive roof systems;
- Free-form shells — irregular curved surfaces enabled by modern computational design.

6.6 Composite shell roof categories (by structural behaviour)

Several sources classify shell roofs by structural action:

- Short shells — where beam action dominates due to short span relative to width;
- Long shells — where arch action dominates along the length;
- Intersection shells — created by intersecting cylindrical or spherical surfaces;
- Shell arches — small arch-like shell elements for short spans.

7 Application of the shell roof

Shell roofs are used in large-span structures such as sports arenas, auditoriums, industrial buildings, and transportation hubs because they provide strong, lightweight, and efficient coverage without internal supports. Shell roofs are thin, curved structural surfaces—often made of reinforced concrete, steel, or modern composites—that carry loads primarily through membrane action (compression and tension) rather than bending. This makes them ideal for covering wide areas with minimal material.

7.1 Major architectural and structural applications

7.1.1 Sports facilities and arenas

Shell roofs are widely used in:

- Stadiums and sports halls where large, unobstructed interior spaces are essential;
- swimming pools and gymnasiums, where humidity-resistant, durable structures are needed.

Their ability to span 50–200+ metres without columns makes them ideal for spectator spaces.

7.1.2 Auditoriums, theatres and concert halls

Shell roofs provide excellent acoustics due to their curved geometry and aesthetic sculptural forms that enhance cultural buildings. Examples include domes, hyperbolic paraboloids and folded plate shells.

7.1.3 Transportation hubs

Shell roofs are common in airport terminals, train and bus stations, and hangars. They allow large circulation areas and high clearances for vehicles and aircraft.

7.1.4 Industrial buildings

Shell roofs are used in warehouses, factories and power plants. Their efficiency and low material use make them cost-effective for large industrial spans.

7.1.5 Religious and civic buildings

Shell roofs create iconic forms in churches, mosques and temples, government buildings and exhibition halls. The expressive geometry supports symbolic and monumental architecture.

7.1.6 Recreational and public spaces

Examples include pavilions, amphitheatres and market halls. Shells provide open, airy spaces with minimal structural intrusion.

7.2 Why shell roofs are used

- Large spans with minimal thickness (often 50–150 mm for concrete shells);
- High structural efficiency due to membrane action;
- Material savings compared to conventional beams and slabs;
- Architectural freedom—curved forms, sweeping surfaces, and expressive shapes;
- Durability, especially in reinforced concrete shells;
- Good acoustic and thermal performance when properly designed.

7.3 Limitations that shape their applications

- Complex formwork for concrete shells increases construction cost;
- Precision required in geometry and reinforcement;
- Specialized engineering expertise needed for analysis and design;
- Difficult to modify once built due to integrated structural behavior.

8 Conclusion

The Sheel roofing system represents a significant advancement in roofing technology, offering superior strength, durability, and application versatility compared to traditional roofing materials. The comprehensive analysis conducted in this study demonstrates that the system meets and exceeds current building code requirements while providing long-term performance benefits.

Key findings include:

- The Sheel roofing system exhibits exceptional mechanical strength with tensile strengths ranging from 350 to 550 N/mm²;
- The advanced coating systems provide outstanding corrosion resistance and weatherability, ensuring service lives of 40-50 years;
- The thermal reflective properties contribute to improved building energy efficiency;
- The system is suitable for diverse applications ranging from residential to industrial construction.

Future research should focus on developing improved coating formulations for enhanced environmental resistance, investigating hybrid system configurations that combine steel roofing with integrated solar or insulation components, and expanding long-term performance monitoring across various climatic regions. As construction industry demands continue to evolve toward sustainability and performance optimization, the Sheel roofing system is well-positioned to meet these challenges.

References

- [1] Alexander J (2020). Modern roofing systems: Technology and application. *Journal of Construction Engineering*, 146(3), 04020045.
- [2] ASTM International (2019). ASTM B117-19: Standard practice for operating salt spray (fog) apparatus. *ASTM International*.
- [3] ASTM International (2020). ASTM A792/A792M-20: Standard specification for steel sheet, 55 percent aluminum-zinc alloy-coated. *ASTM International*.
- [4] Building Research Establishment (BRE) (2021). Roofing systems performance guidelines. *BRE Press*.
- [5] Chen L, Zhang Y, Wang H (2022). Corrosion resistance of advanced coating systems for steel roofing. *Corrosion Science*, 195, 110012.
- [6] European Committee for Standardization (CEN) (2015). EN 10346: Continuously hot-dip metallic coated steel flat products for cold forming – Technical delivery conditions. *CEN*.
- [7] Federal Emergency Management Agency (FEMA) (2020). Seismic design criteria for steel roofing systems. *FEMA*.
- [8] Ghosh S, Das P (2021). Thermal performance of reflective roofing systems in tropical climates. *Energy and Buildings*, 234, 110689.
- [9] International Code Council (ICC) (2021). 2021 International Building Code. *ICC*.
- [10] Kumar R, Singh A (2021). Sustainable roofing solutions for contemporary construction. *Journal of Cleaner Production*, 280, 124456.
- [11] Martinez G (2019). Advances in metal roofing technology. *Construction and Building Materials*, 195, 456–468.
- [12] Narang S, Sharma P, Gupta R (2022). Weatherability assessment of PVDF coated steel roofing. *Surface Engineering*, 38(4), 312–325.
- [13] Panchal H, Patel V (2022). Life-cycle cost analysis of roofing systems. *Journal of Building Engineering*, 45, 103567.
- [14] Sheel Industries (2023). Sheel roofing technical manual: Product specifications and performance data. *Sheel Industries*.
- [15] Wang X, Li J (2020). Structural analysis of profiled steel roofing sheets. *Engineering Structures*, 210, 110234.