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Evolution of roof and its significance in buildings: A Literature study

¹Ar. Nippy Garg and ²Dr. Bhupinder Pal Singh Dhot

¹Research Scholar, GZS, School of Architecture and Planning, Maharaja Ranjit Singh Punjab Technical University, Bathinda, Punjab, India

²Professor, GZS, School of Architecture and Planning, Maharaja Ranjit Singh Punjab Technical University, Bathinda, Punjab, India

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Corresponding Author: Ar. Nippy Garg

Abstract

As an inseparable component of building exterior envelope, the roof serves critical roles in energy conservation, controlling moisture accumulation inside structures, managing heat dynamics and defence for indoor rooms against wind and rain outside. As part of the built environment, the roof has always been more than just a shield. It reflects cultural development and technological progress. The growth of human civilization has long been put on the roof's head even if not as palpably related to it as this saying might suggest. The development of human civilization and the history of roofing are closely related. From the first shelters made of natural materials to today's most sophisticated technology, roof development has played a notable role in architectural history. Roof as an integral component of architectural design, have evolved through time, from basic shelters to intricate technologically advanced structures. In composite climates, characterized by both hot-dry and warm-humid conditions with significant seasonal variations, maintaining thermal comfort in urban residential buildings poses a unique challenge. Among the various building envelope components, the roof plays a pivotal role in mediating heat gain and loss. This paper explores the significance of roofs in achieving thermal comfort in composite climate zones, examining design strategies, material choices, and technological interventions that enhance building performance. Emphasis is placed on passive design principles and their impact on indoor environmental quality, energy efficiency, and occupant well-being.

Keywords: Roof, role, building envelope, buildings, composite climate

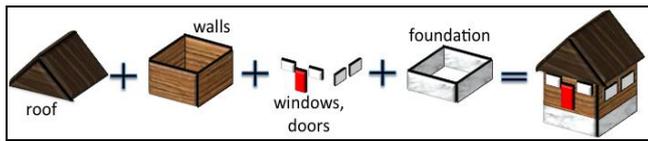
1. Introduction

Humans have always needed buildings in order to perform daily activities as they provide safety from harsh effects of nature and facilitate in performing various tasks." (Ahmed *et al.*, 2016) [3]. Built environment has been integral part of human history and is well known for its role and importance in promoting quality of life besides meeting basic human needs. The habitable quality of apartment buildings in India has lately become a matter of concern. Today, the largest part of construction is qualitatively poor, as the traditional and local knowledge is quickly disappearing and the highly innovative and strongly interesting new sustainable technologies are rarely applied. Most residential buildings respond to the same typology, with thin walls, lack of shading systems, and lack of insulation, especially on the

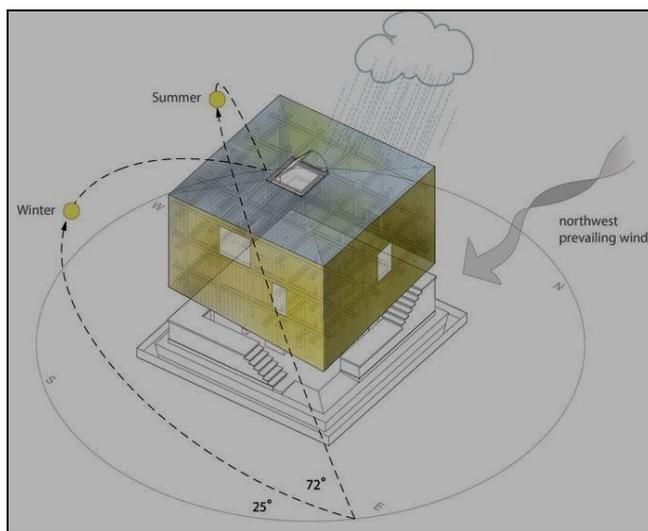
roof.

Buildings act as an interface between the outdoor environment and the indoor environment. Indoor environmental factors are considered to be one of the most important factors affecting occupant assessment of their quality of life in residential building. As per (Pieter De Wilde, 2012) [7] the temperature within the buildings, needs to be maintained within a range that keeps the building occupants safe and comfortable. Thermal environment of the human body is one of the chief factors affecting its wellbeing. It contributes to the comfort of occupants and even affects their health and well-being. The roof has a significant impact on the envelope, especially in residential buildings and other structures with a wide horizontal footprint (Whole Building Design Guide).

1.1 Building comprises of



Due to the sun movement, all the facades of the building don't get heat up at the same time. At different time period, the different facades get heated up. But the roof is a variable that is stable (on the top of the building) and most exposed (experiences heat throughout the day). Therefore maximum amount of heat enters in a building through roof and thus increasing the inner temperature of the building and making the users uncomfortable, which shows that the roof plays a significant role in the building and should be taken care of.



2. Core Functions of the Roof

Roofs have served as more than just a building's functional components throughout history. They contribute significantly to a building's aesthetics, culture, social life, and environmental aspects in addition to shielding occupants from the elements. As a building's top covering, the roof plays a special and complex role in the built environment. A building's comfort, sustainability, and energy efficiency are all directly impacted by its thermal performance.

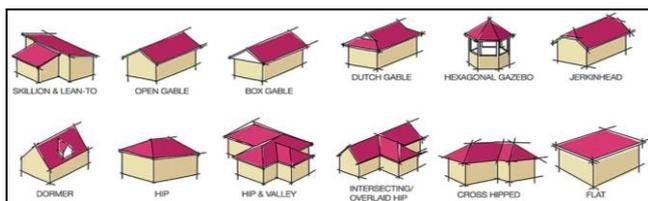


Fig 1: Types of Roofs

Roofs have changed dramatically over time in response to technological, environmental, and aesthetic demands, from ancient shelters to contemporary skyscrapers. Roofs have symbolized social hierarchy, cultural identity, and technological advancement in addition to being a physical barrier. The roof, which was once considered a protective barrier, has evolved in both purpose and design to become

an essential part of modern environmental sustainability in buildings, a cultural identity symbol, and an architectural style determinant.

2.1 The roof has several functional, aesthetic and environmental aspects:

- **Functional considerations:** The main purpose of a building's roof is still to shield the interior from the elements. These days, roof designs continue to place a high priority on insulation, weather protection, and structural integrity. Advances in materials like rubber, metal, and asphalt have made it feasible to develop roofing solutions that are lightweight, durable, and require little upkeep.
- **Aesthetic aspect:** Roofs have a significant impact on residential buildings' visual language. The roof serves as a social status indicator in many societies, and lavish roof designs often reflect wealth and style. This is particularly evident in areas where there is a strong desire for architectural originality and the use of high-end materials or distinctive roof designs may enhance the home's aesthetics.
- **Energy-efficient and environmentally friendly roof designs:** Roofs are becoming more and more important in reducing a building's carbon footprint as environmental sustainability gains popularity.

2.2 Below is an exploration of the various ways in which roofs contribute to the built environment through literature review

2.2.1 Protection and shelter: A roof's primary function is to provide weather protection. The interior of a building is shielded from sunlight, wind, rain, snow, and extremely high or low temperatures by roofs. This protective function ensures the residents' ongoing comfort and safety in addition to shielding the building's materials from environmental damage.

2.2.2 Aesthetic and architectural expression: Roofs not only play a crucial role in the overall design of a building, but they also significantly improve its aesthetic appeal. Throughout history, a variety of architectural styles have used roofs to express cultural values, social status, or technological advancement.

2.2.3 Structural Integrity: The building's overall stability and structural integrity are supported by its roof. They often bear a heavy load from roofing materials, wind, or snow. The roof also contributes to the structural system because it supports the walls and other architectural elements.

2.2.4 Environmental Sustainability: Roofs are becoming a crucial part of environmental sustainability in the modern world. They are not just passive elements; they actively promote energy efficiency, reduce the urban heat island effect, and enhance the ecological quality of cities.

2.2.5 Social and cultural significance: Roofs have cultural and social significance in many communities because they have an impact on how people use, perceive, and view space. In urban areas, the roof is often used for social events, neighbourhood activities, and even farming.

2.2.6 Energy Efficiency and Passive Design: The roof design of a building can have a significant impact on its energy efficiency in modern sustainable architecture. Roofs are at the heart of both passive solar design and energy conservation.

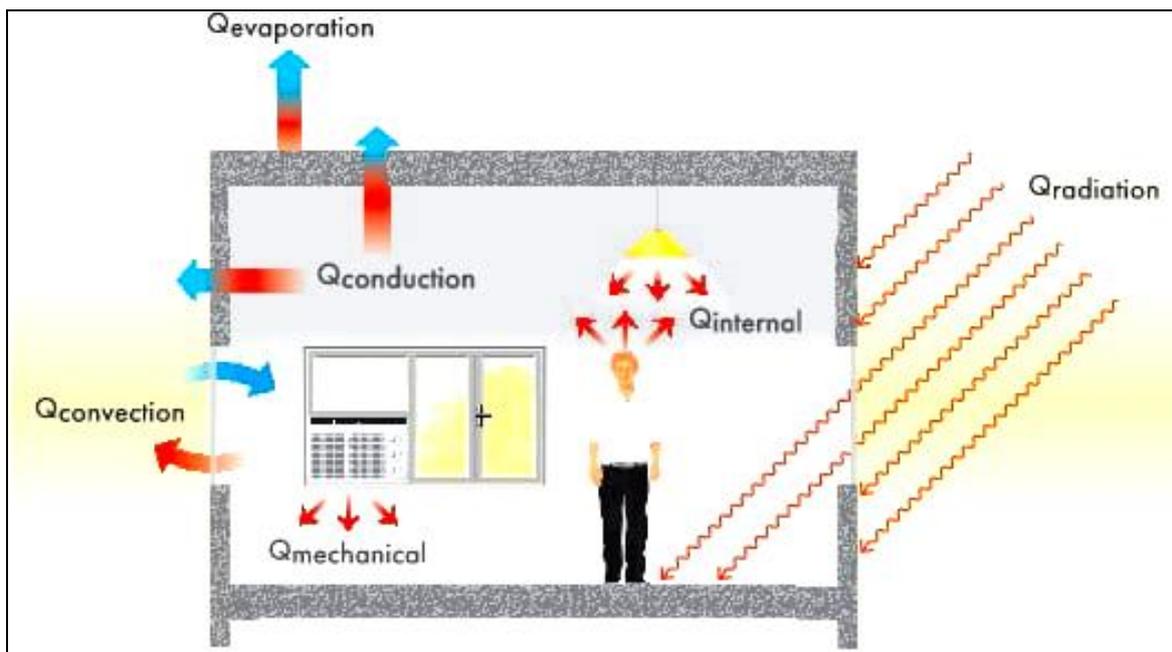
2.2.7 Historical and Technological Evolution: The roof has evolved along with roofing materials, construction techniques and technology in response to changing cultural norms, environmental concerns, and technological demands.

2.2.8 Economic Factors: Energy savings, upkeep, and construction costs are some of the financial aspects that are connected to the roof's functionality. The roofing design and material choice have a direct impact on the initial construction costs and long-term operating costs of a building.

3. The Roof as a Thermal Regulator

Because roofs are among the parts of the envelope most exposed to the elements (direct solar radiation, sky exposure, rainfall, wind, etc.), they have a major impact on thermal performance, comfort, and energy consumption.

3.1 Mechanisms of Roof Thermal Regulation: Heat flow pathways and important physical characteristics must be reviewed in order to comprehend how roofs control thermal performance. Heat transfer is particularly important in buildings for deciding the building fabric, and for designing the passive and active systems necessary to deliver the required thermal conditions for the minimum consumption of resources. The human body must be isolated from the outside world to preserve its heat balance. (As per the Indoor thermal environment and human health: A systematic review.



Radiation	Roofs radiate long-wave infrared and receive short-wave solar radiation. Surface orientation and albedo (solar reflectance) all affect the balance.
Convection	Convective heat losses and gains are influenced by the air above the roof, wind speed, roof shape (flat or sloped), and height.
Conduction	Thermal conductivity, thickness, layering, and insulation all affect how heat moves through roof materials and into the interior.

4. Evolution of roof: From past to present day

The shape, composition, and building methods of roofs have all undergone significant change. Changes in climate

requirements, technological developments, cultural norms, and material availability are all reflected in this evolution.

ERA	Roof Type	Materials	Structural Innovations	Roof Design
Prehistoric	Thatch, earth-covered	Grass, mud, timber	Basic frames	

Ancient	Flat, gabled, domes	Stone, wood, clay tiles	Vaults, early domes	
Medieval	Steep, trussed, domed	Timber, slate, lead	Complex timber trusses	
Renaissance	Mansard, domes	Slate, copper	Geometric dome perfection	
Industrial	Iron, glass roofs	Steel, glass	Wide-span structures	
Modern/ Contemporary	Shells, flat roofs	Concrete, steel	Free-form shapes	
21st century	Green, solar, ETFE, parametric	PV, ETFE, composites	Smart, sustainable systems, climate responsive	

4.1 Prehistoric and Early Roofs

In the earliest human dwellings, roofs were simple and made of readily available materials (reeds, branches, leaves, and animal hides). "The first roofs were probably rudimentary structures made from branches, leaves, grass, and animal hides," according to an info graphic about roofing history. Because water drainage and insulation were so important, these early shelters often had a sloped covering.

4.2 Ancient roofs: Transition to permanent settlement

Permanent roofing systems came into existence during the Neolithic period, when agriculture and settled communities were introduced. Homes and temples in places like Mesopotamia and Egypt used thatch, reeds, sun-dried mud bricks, and wooden beams for their roofs. For instance, flat roofs became popular in arid areas where drainage was less of a problem and rainfall was scarce. Basic materials and methods were used, emphasizing practicality and durability

over thermal insulation and energy efficiency (Heath, 1965) [9].

4.3 Medieval Roofs: Innovations and Styles

Roofing technology significantly improved by the middle age. The pitched roof was primarily used in Europe in response to the need for improved protection from bad weather, especially rain and snow. Gable roofs were common on buildings all over Europe because of their steep slopes, which allow snow to easily slide off. During the Gothic period, roofing started to symbolize religious and cultural significance in addition to its practical use, leading to the introduction of intricate roof designs. In this context, roofs were utilized both for utilitarian purposes and to demonstrate wealth and religious zeal (Fletcher, 1963) [5]. Thatched roofs (Pevsner, 1963) [1] were replaced by more durable materials such as slate and tiles (Douglas, 1985) [2]. During this time period, castles and cathedrals had intricate roof designs, including ribbed and vaulted ceilings. Bigger windows and more eye-catching rooflines were made possible by the elaborate roof patterns of the 12th-century Gothic architectural style, which included flying buttresses, ribbed vaults, and pointed arches (Kostof, 1995) [10].

4.4 Renaissance and Baroque Periods: Decorative and Artistic Roof

The aesthetic and practical aspects of buildings especially the roofs became increasingly significant during the Renaissance. Domed and barrel roofs, which were more common in civic and religious buildings, integrated classical features like proportion and symmetry into roof designs. Terracotta tiles were widely used throughout the Mediterranean, and the decorations were frequently added to the roofs of palaces and churches. Roofs became more and more symbolic during the Baroque period. The grandeur of the time was portrayed by dramatic skylights, massive flowing curves, and decoration. For domes and other unique architectural elements, lead and copper roofing became popular. These cutting-edge roofing techniques were used by baroque architects like Gian Lorenzo Bernini and Francesco Borromini to amplify the dramatic impact of their buildings (Harris, 2001) [12].

4.5 Industrial Revolution and Modern Roofing: Technological Advancements

The Industrial Revolution, started in the late 18th century, significantly altered roofing design. Large, open areas with expansive roofs were made possible by the use of new building materials like steel and glass. Steel and iron were used in place of traditional wooden beams to enable greater roof spans. More expansive and practical roof designs were made possible by the introduction of the truss system and the widespread use of reinforced concrete, especially for public and industrial buildings. Architects were able to construct roofs that can cover greater area with the help of iron trusses and steel beams without making use of the support of internal columns. As a result, large public buildings, train stations, factories, and other contemporary structures were built (Baker, 1996) [4]. Architects such as Le Corbusier and Mies van der Rohe welcomed flat roofs because they believed that the green roofs are practical surfaces for green spaces and mechanical systems. Concrete

roofs have grown in popularity for both residential and commercial buildings due to their versatility, fire resistance and longevity. In the middle of the 20th century, modernist architecture rose to prominence, which placed an emphasis on clean lines and simplicity. Steel or reinforced concrete roofs that were flat or low-slope were commonly utilized (Frampton, 2007) [8].

4.6 Contemporary Roof Designs: Sustainability and Innovation

Energy efficiency and sustainability are now the main concerns of roofing technology. These days, the emphasis is on developing energy-efficient, ecologically friendly roofs with minimal impact. An increase in the use of green roofs (which are made up of a layer of soil and vegetation) in urban areas can be seen. These roofs lessen storm water runoff, provide insulation, and enhance air quality (Getter & Rowe, 2006) [6]. Adding solar panels to roofs is a big part of modern roofs, which shows how the world is moving toward renewable energy. People think that combining photovoltaic technology with roofing systems can help people become energy independent and lower their carbon footprints. New discoveries in materials science have also made it easier to make roofing materials like cool roofs, which reflect more sunlight and soak up less heat. This saves energy and makes the urban heat island less of a problem (Santamouris, 2014) [11]. By using prefabricated roofing systems like modular panels and interlocking tiles has made the building process faster and cheaper. Also, architects and builders are trying out new roof materials and shapes, like roofs that fit in perfectly with their surroundings and roofs that let natural light into rooms (Duerk, 2007) [13]. Modern roofing technologies also include prefabrication and modular systems that make building easier, cut down on waste, and save money. Because of the focus on using less energy and new materials, roofs will likely play a bigger role in helping architecture reach its sustainability goals.

5. Findings

From the earliest animal hides and thatch shelters to the modern, highly developed roofs, roofing has served as both an architectural statement and a practical necessity. Roofs are more than just a covering; they are social spaces, energy systems, architectural features, and environmental mediators.

5.1 The Future/ 21st century Roofs: should be climate responsive, insulated and smart

Future roofs should act like active environmental systems that generate energy, control water, adjust to the climate, and sustain life instead of being passive coverings. It is anticipated that roofs will continue to develop in the future with a stronger focus on environmental performance, functionality, and adaptability. Innovations in roofing materials, like smart roofs that can automatically adjust insulation or adapt to weather conditions, photovoltaic roofing and self-healing membranes, are probably going to become more widespread. The use of roofs as multipurpose areas will grow as urbanization continues. Roofs can be used for social gathering places, community gardens, or the production of renewable energy in addition to offering shelter. Roofs will probably play a bigger role in urban

planning strategies meant to increase resilience to extreme weather conditions as awareness of climate change continues to grow.

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6. Conclusion

Roofs are more than just a covering; they are social spaces, energy systems, architectural features, and environmental mediators. From simple shelter to architectural expression, environmental sustainability, and climate resilience, the roof is an essential and vital component of the built environment.

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