Human Nature Journal of Social Sciences
Vol.6, No.4 (December, 2025), Pp.71-79
ISSN(online): 2788-5240, ISSN(print): 2788-5232
DOI: https://doi.org/10.71016/hnjss/18pyfv05

Original Article **https://hnpublisher.com**

A Study of Eco-Friendly Sustainable Architecture of Pakistan: Designs and Materials

Samina Nasim[1]

[1]Principal/Professor, College of Art & Design, University of the Punjab Lahore, Pakistan
Correspondence: samina.nasim@gmail.com[1]

ABSTRACT

Aim of the Study: This study aims to investigate the strategic planning of South Asian architectural design and materials to resist extreme weather of the region. It will be examined that what kinds of architectural plan, designs and materials were employed historically and are still used in modern construction. The primary aim of this research is to identify sustainable and eco-friendly architecture of the region.

Methodology: The research is based on qualitative research methods. It is a descriptive and observational study, utilising case studies of historical and contemporary architecture of Pakistan. The architectural styles, plans, designs, and building materials employed in the construction of buildings in the South Asian region from 712 A.D. to 2020 A.D., will be focused.

Findings: The architecture of the South Asian region features open plans, innovative designs, and sustainable materials, tailored to the geological, geographical, and climatic factors of the area. Pakistan's contemporary architecture is characterised by sustainability and eco-friendliness.

Conclusion: It is concluded that harmony and synchronisation are maintained between native materials and traditional techniques in order to produce a successful depiction of innovative architecture in the area. The continuation of traditional designs with local construction material and the fusion of new technologies show the creativity of the architects and artisans with advancement. The architects and designers preferably followed the trends, which are suitable for the extreme weather of the region and introduced eco-friendly designs with sustainable construction of contemporary buildings.

Keywords: Diversity, Sustainability, Architectural Materials, Elements, Eco-friendly Architecture, Environment Protection.

Article History

Received:
September 11, 2025

Revised:
October 23, 2025

Accepted:
October 26, 2025

Online:
November 02, 2025

1. INTRODUCTION

The South Asian architectural history is extensive and has witnessed the rise and fall of the empires. Every period has a different style and set of values that reflect the interests of the rulers of the time. Strategic planning that satisfies the demands of the local, geological, climatic and geographical factors is evident in building plans created specifically after the arrival of Islam. It continued to preserve the region's cultural. With arrival of Muhammad bin Qasim’s troops to South Asia in the early eighth century

A.D., the Arab construction style was introduced through the construction of mosque architecture in the region. The construction was simple and directly influenced by Arab design following open-plan. It was suitable for the region's hot climate.

The open-plan design with porticos, courtyard, fountain, arches, perforated latticework, *jalli, v*ertical support for the ceiling of the sanctuary in the form of ails and bays were followed with local building materials. These elements in built form considered as essential parts of the regional construction style add values and speaks about the interest of the rulers of the time. Early Mosques' architectural features were influenced by Hindu, Arab, Persian, and Greek design. The fusion of cultural, social, and economical factors have strong impact on the development of the style. The monument's longevity and durability were ensured by the material selection, and South Asian land is abundant in materials like stone, bricks, wood and marble, all of which were widely utilized in the early built buildings of Subcontinent.

2. RESEARCH METHODOLOGY

It is qualitative research based on descriptive and observational approach, utilising case studies of historical and contemporary architecture of Pakistan. Architectural styles, plans, designs and building materials used for the exhaustion of the buildings of South Asian region its durability and sustainability will be explored and analyzed. The study will be divided into three phases. The first phase will cover about the knowledge of historical architecture of South Asia from 712 A.D. to 1526 A.D. In the second phase the architectural characteristics of the region from 1526 to 1947, and in third phase the architectural trend from 1947 to 2020 will be covered. The strategic planning of modern construction design and cultural preservation, green concrete, natural light, thermal comfort, fenestration, insulation and strategic future planning will be covered. All phases will present the study of design, use of eco-friendly sustainable building materials and evolution of architectural styles in the region.

It is a tour of regional architectural development that encounters many phases of the region's evolving course of construction style and design. It is evident that in context to climate effects and the construction of sustainable eco-friendly sustainable architecture in Pakistan need to be studied because such kind of scholarly research has still not been conducted. The research's objective is to present, how South Asian climatic conditions continue to preserve the legacy of architectural traditions through conventional design trends.

2.1 Data Collection

The data from different libraries, websites social media and articles will be collected to get knowledge of those historical buildings which are not approachable and out of reach to visit. The historical monuments present in Lahore and contemporary buildings of Lahore, Islamabad, Sialkot and Faisalabad will be visited in person to collect the research data. Libraries, social media, websites and published articles will be gathered as secondary sources for the study and for primary sources. In-person site visits, photographs, and interviews with architects and artisans will be part of the primary data.

2.2 Study Objectives

1. To study the historical development of the architecture of Pakistan.
2. To study the evolution of sustainable, eco-friendly architectural designs and durable construction materials.

2.3 Limitations

1. The historical buildings which are not possible to visit, for their information books and websites will be used to get knowledge about the relevant study.
2. The study is limited to focus on those buildings which played a vital part in the identity of the style and developed visible significance for the evolution and development of the regional trends through designs and materials between the time period from 8th century to 21st century A.D.

3. FINDINGS/ HISTORIOGRAPHY

Phase I

South Asians' mastery of architecture was demonstrated by the usage of granary constructions, town planning, magnificent baths, wells, and brick buildings of Indus Valley civilization, which thrived in the territory of Harappa and Mohenjodaro. Sun-dried bricks, often combined with mud and straw, were used to construct the buildings. The Indus valley civilization had a major influence on regional architectural development. Burnt bricks, clay and stone were the major building materials used in the region from 1300 B.C. to eighth century A.D. During Islamic period initially simple construction was adopted. Stone was employed for large constructions starting in the twelfth century. Bricks, wood, a variety of marble grey and red sandstones were used to construct solid constructions with a colossal appearance.

Several mosques were built in both small and big localities over the first five centuries (7ll to 1191 A.D.). The discovery by Pakistani archaeologists of the structural remnants of three significant mosques in Banbhor, Al-mansura, and Udigram (Swat) has significantly simplified our comprehension of the early Muslim history of Sindh. The first town in Dahir, the seaside city of Debal, was taken by the Arab general Muhammad bin Qasim in 711 A.D. He also constructed a mosque there.

Early mosques, such as those in Bhambor and Al-mansoora, were progressively converted into more long-lasting and solid structures utilizing solid materials like stone at first, followed by organic ones like hardwood. The exposed layout of the Banbhore mosque is akin to the traditional pattern of regional mosque construction, which was influenced by the Arabs' use of an open plan with the arrival of troops following Muhammad bin Qasim. During the excavation, the wooden pillars with stone bases supporting the ceiling of the prayer hall became visible. (Khan 1991). The sanctuary opened to the courtyard and was surrounded on three sides by cloisters and passages divided into small apartments (Khan 1991). The ablution tank in the middle the courtyard was its primary feature, the floor was paved with square bricks. The main constuction material was stone, wood and burnt bricks.

Quwwat-ul-Islam Mosque, Dehli built in 1191 A. D. was built by Qutb-ud-Din Aibak, according to the requirement and need of the time. Local materials help to shape the structure with open plan building style. The open plan with open spaces was directly influenced by Arab style mosque constructions. But Hindu influences were evident because of the use on Hindus temples' building material for the mosque construction. The main entrance to the mosque's interior was located on its eastern wall. The roofs of the sanctuary and cloisters, which were supported up by Hindu pillars, were covered with conical shallow domes with lanterns using the corbelling technique. In order to accommodate the climate of the area, the mosque of Quwat-ul-Islam at Delhi, 1192 A.D. was built airy according to the open plan. In the beginning sand stone, burnt bricks were used but during Khilji period marble was extensively used and considered as major construction material. The trends were continued to design the buildings with combination of sand stone, bricks and white marble. Later on, the buildings built in Sultanate period were designed by following solid foundations and massive structures.

Phase-II

The buildings designed in Mughals' period, the architects followed the trends of grandeur structure with rich green spaces in surroundings solid foundations and complexed geometry. In result monumental structure with durable materials were raised which become identity of the region. The triple-domed building and the form of the *punj mukhi* mosque with open plan construction was presenting unique regional style (figure 1,2). The construction style was typical of the Subcontinent. gave new identity to the region which has never been practiced in the other areas globally. Its open spaces, courtyards, and ventilation which are essential in the warm and humid climate of the subcontinent.

Figure 1: Badshahi Mosque Lahore (1671), has triple domed construction of the sanctuary become identity of South Asian region.

Figure 2: Masjid Wazir Khan built during Mughals period between 1634 to 1641. Has quality of *Punj Mukhi* Mosque.

Presence of open spaces were not only limited to mosque architecture, Pakistani traditional *kothis* and *havelis* were also built with vast and open spaces. Pakistani architecture is often built with porticos and courtyards to create a comfortable space and shield against intense hot weather. Homes often incorporate design elements like balconies, courtyards and large windows to allow for natural ventilation and cooling. Historically, native materials including brick, stone, and wood have been used to build residential structures of Pakistan. Due to their distinct identities and styles, these buildings are prestigious and notable because of their own style and identity. Elements like open plans, verandas, fountains and water tanks in the middle of the courtyard to remove weather-related extremes were designed. The Mughal era added richness and diversity. Sand stone, lime, wood, and marble were major building material of this era. A variety of decorative methods, like stucco, relief work, tile work, mosaic, wood, and marble carving, were used to embellish the surfaces. Buildings surfaces were adorned with Islamic calligraphy and inscriptions. The structures were decorated with elaborated carvings, often with geometric and floral patterns.

The buildings built during the colonial era have particular characteristics. Kipling preserved the regional character while drawing inspiration from the area's rich cultural past, integrating European architectural components with Indo-Saracenic patterns, motives, and creative methods. He also helped to introduce a new type of architectural composition. Colonial architects Bhai Ram Singh, Ganga Ram and Lockwood Kipling created strong design compositions and expertly built structures that tell the story of the time by combining European and indigenous features. They handled it well since they were knowledgeable and skilled in their field. To highlight the rich past, the architects modified Sultanate, Mughal, Hindu, Islamic, and Gothic architectural embellishments, inspirations, and thoughts.

Colonial terracotta *jalli*, lattice work, multi-foiled arches, brackets, veranda openings, *chatri*, *jhoraka*, and projecting balconies all of which were used to withstand the region's harsh weather was directly influenced by the Mughal era. windows in a brick clerestory facing *Jharoka*. Colonial latticework with a variety of stone, terracotta, and marble geometric design patterns was influenced by Mughal *jalli* work. Its long history started in the pre-Mughal era, when it also enhanced the architectural aesthetics of buildings built during the British Raj. Later, a variety of patterns made of various materials were used to decorate modern buildings.

3.1 Traditional Construction Materials of South Asian buildings

Bricks have long been a mainstay of construction throughout South Asia. They were often sun-dried or baked in a kiln using clay, sand, and water. Stone was frequently used in South Asian architecture,

particularly for imposing constructions like mosques and temples. Stones including sandstone, granite, marble, and limestone were used as major construction materials. Wood was frequently used in South Asian building construction, particularly for roofing, windows, and doors. Teak, Deodar and Sal are some of the wood varieties that are utilized. The main component of the Subcontinent's vernacular building was mud, which was mixed with straw to create a durable, eco-friendly material. Thatch made from palm leaves, reeds and dried grass is still widely used as a roofing material in rural areas. Concrete, timber, granite, and limestone are favoured for brick, stone, and marble construction in urban areas.

Climate change is having an effect on South Asian buildings, particularly with regard to extreme weather and heat stress. South Asia's rich cultural heritage provides opportunities for the preservation and promotion of traditional building materials and techniques. Natural resources like mud, wood, bricks, and thatch were essential for early constructions. Weather, extreme temperatures, humidity, and climate change reduce durability. Regular maintenance extends its lifespan. Inadequate construction and design techniques reduce durability.

Phase-III

Since the beginning of the universe, evolution and changes in lifestyle and technology have been inevitable which continue ages to ages. Art and architecture of the civilizations show their lifestyle and culture which help to know about the development of the nation. Similarly architectural records of South Asian region evident about the rich culture of the region. In contemporary period Pakistani architecture is successfully maintaining cultural legacy with continuity of traditional trends and identity of the region. Many contemporary buildings are built with the combination of traditional elements, new methods, technologies and architectural decorative techniques. A range of architectural styles are presented in the design composition of modern buildings of Pakistan. Eco-friendly sustainable architecture is being constructed in this era of climate change by fusing cutting-edge methods and technical approaches with conventional building patterns.

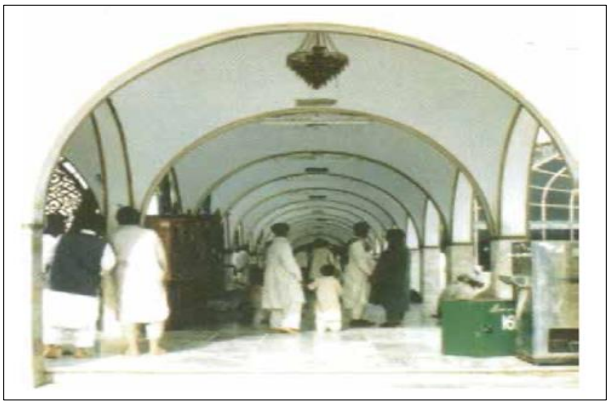

Figure 3 Vaults of the Ali Hajwery, Data Darbar Mosque

Figure 4 Interior of the vaults of the Ali Hajwery Data Darbar Mosque

Strategic future planning, water ponds, insulation, green concrete, fenestration, natural light, thermal comfort, and ecologically sustainable construction techniques are observed in modern contemporary construction of Pakistan, who are maintaining traditions with addition of new technologies and adopting innovative designs with foreign influences. A number of modern buildings, such as the open-plan of Faisal Mosque (1986) and the mosque in Behria Town, Lahore (2014), are designed to preserve the region's cultural heritage. The vaults of the Ali Hajevery Data Darbar Mosque, Lahore rebuilt in 1997 is constructed with modern and contemporary materials (figure 3,4). Similarly, classic elements like central, open spaces encircled by rooms and patios are also included into the design of residential buildings.

Traditional building material burnt bricks are continued and abruptly used for modern contemporary constructions of Pakistan.

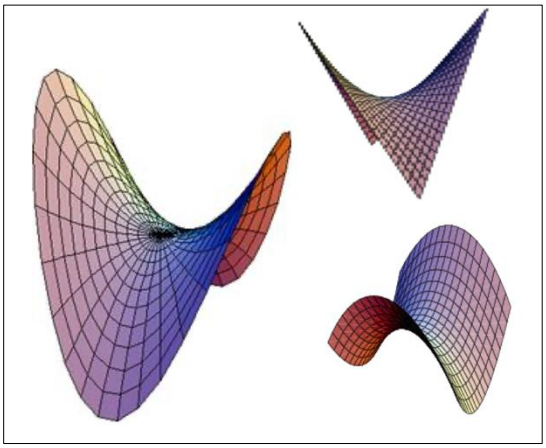

Figure 5: Exterior of the Faisal Mosque (Drawing by Author)

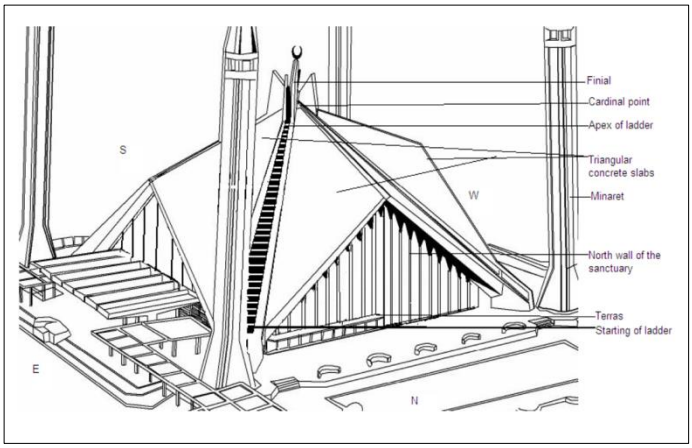

Figure 6: Hyperbolic paraboloid roof structure, that combines hyperbola and parabola.

Source: http://mathworld.wolfram.com/Hyperbolicparaboloid.htm

One of the more complex examples of the use of advanced technology with new materials is design of the sanctuary of Faisal Mosque Islamabad (figure 5). Its hyperbolic paraboloid construction with gable point is unique in country and advanced materials are used for its durability to bear the intensity of extreme weather like heat or cool and weight bearing strategy (figure 6). The primary function of this concrete shell structure is to cover a huge area without requiring any vertical supports for ceiling. Architect Giorgio Baroni first employed the hyperbolic paraboloid systems in 1938. (vtechworks.lib.vt.edu) The hyperbola and the parabola are the two shapes utilised in this long span design. The load is applied to the hyperbola's and parabola's connecting and intersecting edges. Short portions of the design can be used in building, therefore using the entire shape is not required. In a similar vein, the Faisal Mosque's roof solely uses the load-shifting or saddle quality idea. For aesthetic reasons, the soft curved lines of the hyperbola and parabola are transformed into sharp contours having straight lines in accordance with the mosque design specifications. At each point where the triangular roof slabs contact, weight is transferred from the walls to the girders, hinged beams, and cross beams. The current shell construction approach can be used to create both straight and curved lines.

In Malaysia, the Masjid Negara Kuala Lumpur was constructed in 1957, before the Faisal Mosque. The Kinali Island Mosque in Istanbul was constructed between 1964 and 1965, along with other buildings. After the Faisal Mosque was finished, the Azad Jamu Kashmir University Mosque was constructed in Islamabad in 2000. Despite being built using hyperbolic paraboloid architecture, none of them resemble the roof design of the Faisal Mosque. This cosmopolitan style has been embraced by architects worldwide.

The only thing that makes the architecture of the Faisal Mosque similar to a clearstory is the ventilation system. The Faisal Mosque only has light-related glass affixed to its roof. Cross ventilation is provided by doors, and there are tiny bird apertures. either ladder-like structure has two sturdy girders that are ten inches thick on either side. They are affixed to the minarets' subterranean base. Two feet one inch above the earth and six feet ten inches square make up each foundation (Nasim 2008). The translucent glass allows natural light to enter the sanctuary and visually reflects the shimmering rays of the sun. Through these glass areas, artificial light from the sanctuary reflects outdoors throughout the day and at night, creating a very distinct "skeletonal" image.

3.2 Modern Eco-Friendly Sustainable Materials

The building materials sector in South Asia welcomes innovation, particularly in the fields of sustainable materials, disaster-resilient construction, and energy-efficient design. The developmental course of Pakistani architecture has been influenced by the country's diverse climate zones, which range from the mild, temperate northern parts to the scorching, arid deserts of Sindh and Balochistan. Pakistani architecture has changed over time to reflect the country's regional and cultural variety as well as the traditions of its citizens. Pakistan's rapid urbanization and progress are reflected in the country's architecture, which has embraced modern and contemporary characteristics.

Steel, concrete, and cement are the primary materials for modern structures using the new technologies. Steel is used in high-rise structures to produce new concepts and designs in response to demand for modern, technologically advanced structures. However, the use of glass in the design of windows, doors, and facades gained prominence. In contemporary mosque of Ali Hajvery Data Darbar and residential buildings of Lahore, coloured glass is fitted with the help of advanced technology and new materials to give unique stylized appearance. Another material that is often used to construct roofs, cladding, windows, and door frames is aluminum. Sustainable materials are being sought in order to satisfy modern demands and make living more comfortable. Modern materials like concrete, glass, steel, and aluminum present both potential and difficulties. Things become less durable as they weather naturally. Settlement of the soil cause degradation. When sustainable materials are employed, the environmental impact is reduced. High-tech, inventive designs and materials boost durability. Regular maintenance increases lifespan. Educating builders and homeowners increases durability.

Recyclable resources like glass and plastic are being utilized to cut waste and advance sustainability. Compared to regular concrete, low-carbon concrete is more sustainable, has a lower carbon footprint, and has less negative environmental effects. It is advantageous and in line with the demands of the new millennium to use solar panels and renewable energy. Modern buildings are using innovative technologies like polyurethane and insulated panels based on polyisocyanurate to reduce energy consumption and promote sustainability. Cork is a sustainable material that is utilized in South Asian buildings for both flooring and insulation.

Energy-efficient and recyclable materials are becoming more and more common. As an environmentally friendly sustainable material bamboo is at the top of the list. For example, bamboo is a highly renewable resource with no carbon impact. Additionally, it is durable, reusable, and recyclable. Low-carbon concrete is made with supplementary cementitious materials, which reduce greenhouse gas emissions. It is also sturdy and long-lasting. Sustainable wood, certified by organisations like the Forest Stewardship Council, promotes moral forestry practices and reduces deforestation. Green roofing materials that reduce energy use, absorb carbon dioxide, and promote biodiversity include sedum and other plant species (Mihalakakou and Souliotis, 2025).

Modern architecture protects against the catastrophic effects of global warming by utilising architectural concepts, designs, features, and materials. robust and the construction of buildings during the colonial era using wood and iron-fired bricks Lahore's rich past has made it more important over time. Historic buildings reveal the splendour of a rich traditional monuments and tell the stories of the era. In an attempt to preserve cultural heritage, the British, like in other Subcontinental regions, blended foreign architectural features in built form, specifically for the facades of the monument constructed in Lahore. Innovative hybrid style was produced by combining eastern architectural design with western and South Asian architectural decorative techniques, local materials and design motives. These structures make a powerful statement by presenting various ideas, inspirations, varied perspectives, and cultural fusions. They also had a considerable impact on the development of new architectural styles.

4. CONCLUSION

Over the ages, South Asian architecture has witnessed the rise and fall of civilisations and each era uses its architectural language to convey its history. The ruler's and the populace's tastes are evident. The developmental course is apparent in its design. Each dynasty created something novel and inventive while maintaining traditional designs and continuation of local materials, demonstrating an eco-friendly attitude towards architectural language. It conveys the strengths and characteristics of the region as well as the laws in effect. In the beginning, open spaces were incorporated into the design of mosques, tombs, forts, and residential areas. Keeping in view extreme hot weather of the region open spaces and green areas surrounding the buildings were the basic need of the plan. But in modern contemporary constructions with the continuity of traditions new materials were used to maintain the intensity of the weather.

Maintenance of harmony and synchronisation between native materials, traditional techniques, and western influences in order to produce a successful depiction of innovative architecture in the area was preferred by the architects of the time. Combination of simplified designs and innovative forms, architectural features enabled modern architects preserve the region's legacy which served strong basis for post-contemporary architecture in Pakistan. It is concluded that the South Asian region has plenty of natural resources for use as building materials. In modern times the use of local building martials were continued with combination of advanced technologies and eco-friendly sustainable materials such as wind-resistant roofing, heat-resistant coatings. The utilization of climate-responsive products for the climate change projections with strategic planning. Reusing materials and encouraging recycling is promoted in order to maintain the existing buildings. Green infrastructure and climate-responsive transit systems are encouraged. technology, advanced materials, and architectural design strategies for climate-resilient buildings are encouraged.

Acknowledgements

None.

Conflict of Interest

Author declared NO conflict of interest.

Funding Source

The author received NO funding to conduct this study.

ORCID iDs

Samina Nasim [1] https://orcid.org/0009-0003-3475-3027

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