Construction of Grand Mosque, Academic and Social Complex at Allahabad, Kandyaro, Sindh, Pakistan

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Abstract

In this case study, the construction of the Grand Mosque, an academic and social complex at Allahabad, Kandiaro, Sindh, Pakistan, was explored. The main objective of the study was to represent the integration of smart and sustainable construction practices, primarily focusing on the usage of traditional craftsmanship and local materials. The design of the mosque gained insight from esteemed Islamic architectural sites. The mosque's design draws inspiration from renowned Islamic architectural sites, combining traditional design elements with contemporary methods to maintain both cultural and functional relevance. Handmade Kashi tiles used in the construction of the mosque are an essential element, reflecting the cultural legacy of Sindhi Kashgari art and enhancing the building's aesthetic and spiritual atmosphere. The raised domes of the mosque are considered climate-responsive design features, promoting natural airflow and passive cooling. Higher maintenance costs for Kashi tiles and limited passive cooling during severe weather conditions were the challenges associated with the mosque. In addition to this, employing modern construction practices with skilled labor indicates that the project maintains its authenticity while benefiting from state-of-the-art engineering approaches. The current case study revealed the significance of preserving cultural heritage while incorporating modern efficiency, which made a mosque that served as both a cultural landmark and a sustainable building. This case study provided key insights such as the design of the mosque, the construction process, and the sustainability of modern approaches in the times ahead.

Keywords—Grand Mosque, Smart and Sustainable practices, Islamic architecture, Kashi tiles

1 Introduction

In recent decades, Islamic religious architecture has evolved due to shifts in culture, advancements in technology, and artistic innovation. Mosques, representing spiritual sanctity and community identity, have also been shaped by contemporary architectural trends [1,2]. Starting in the 7th century, it incorporated elements from Byzantine, Persian, and Roman styles, blending them into unique forms that emphasized functionality, aesthetics, and religious symbolism [3]. The early period of Islamic architecture is marked by idiosyncratic features, e.g., minarets, large domes, courtyards, arches, and intricate decorations [4]. These features served aesthetic purposes and reflected the religious and cultural significance of the structures [5]. Over the years, these elements were tailored to suit regional contexts, such as the Middle East, North Africa, Central Asia, and the Indian subcontinent, where local architectural traditions were integrated [3]. The subcontinent, such as Indo-Pakistan, perceived a notable fusion of Islamic architecture with native architectural design, with Mughal styles, represented by iconic structures such as the Taj Mahal and grand mosques. The fusion of architectural elements showcases the artistic and cultural exchanges that marked the period, where Mughal emperors integrated various influences into their monumental designs [6]. The fusion of Persian, Turkish, and Indian architectural styles, along with local craftsmanship like Kashi tile work and carved stone, demonstrates the ongoing balance of innovation and tradition in Islamic architecture [3].

The Holy Quran references the first mosque built by Prophet Adam and the reconstruction of the Kaaba by Prophet Ibrahim and his son Ismail. Prophet Muhammad (PBUH) also played a role in mosque

ISSN: 2523-0379 (Online), ISSN: 1605-8607 (Print)
DOI: https://doi.org/10.52584/QRJ.2202.03
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construction, participating by carrying bricks and emphasizing the reward for building mosques in pursuit of Allah's blessings (Bukhari, 1984, Vol. 1, Book 8, Hadith 450). Architectural monuments like Mohenjo-Daro and Taxila in Pakistan provide key insights into early architectural practices in the Indus Valley, with their sophisticated urban planning and engineering techniques later influencing Islamic architecture [7]. These sites, with their fusion of Greco-Buddhist and Persian influences, laid the groundwork for the architectural evolution seen in Islamic structures [8].

The study of Islamic architecture is enriched through the design and construction of the Grand Mosque Allahabad in Kandiyaro, Sindh, Pakistan, as shown in Figure 01 (a). This contemporary project features 101 domes of varying sizes and draws inspiration from both Islamic architectural heritage and local cultural elements (Figure 01 b). The mosque's design exemplifies the fusion of traditional styles with modern innovations, reflecting the ongoing evolution of Islamic architecture. This research explores key theoretical issues in Islamic architecture, including design, construction, and the balance between innovation and tradition. The study also emphasizes the importance of financial transparency, community involvement, and accountability in the construction process. The Grand Mosque Allahabad project not only contributes to the body of knowledge on Islamic architecture but also aims to create a significant cultural heritage site for future generations, reflecting the architectural traditions of Sindh.

1.1 Historical Evaluation of Islamic Architecture

Mosque architecture evolved significantly over time, with each period and region contributing to distinct design principles. The earliest mosque established by the Prophet Muhammad (PBUH) and his companions was a modest structure, consisting of a simple prayer hall with a shaded area. Over time, it was expanded to include arcades, laying the groundwork for adaptable and varied architectural forms [9]. During the Umayyad era, mosques began to serve more defined religious functions, while in the Abbasid period, they developed into integrated mosque-palace complexes [10]. In regions like Morocco and Andalusia, mosque architecture followed the hypostyle layout, reflecting Syrian influences, whereas Yemeni mosques blended in design features from pre-Islamic temple traditions. Anatolian and Kurdish mosques, shaped by Iranian and Arab architectural legacies, prominently featured pillared interiors with arches and vaulted ceilings [9]. In Egypt, mosque architecture became increasingly ornate under the Fatimid, Ayyubid, and Mamluk dynasties, characterized by the use of keel-shaped arches and distinctive minaret styles [11,12].

Iranian mosques incorporated domes and iwans, influenced by pre-Islamic styles, while Ottoman mosques evolved into domed–square structures to integrate large spaces with minimal vertical support [13]. Key architectural elements, both basic and additional, define mosque design. The basic elements include the main hall, sahn (courtyard), mihrab (niche), and minbar (pulpit), while additional elements like minarets, domes, ablution facilities, riwaqs (arcades), and maqsurahs (enclosures) serve both functional and symbolic roles. These features, such as the main hall's rectangular shape aligned to the Qibla, the sahn's cooling function, and the symbolic significance of domes and minarets, contribute to a mosque's architectural identity [14,15]. Regional variations shaped mosque types, with six primary styles emerging: the hypostyle (Arabic), Persian, Ottoman, Indian, and Chinese types. The hypostyle mosque, common in Arabia, includes a courtyard and prayer hall, often with domes and minarets [15]. Persian mosques are characterized by iwans, bulbous domes, and ornate decoration [14], while Ottoman mosques feature centralized domes and slender minarets influenced by Byzantine architecture [15]. Indian mosques typically have triple domes and spacious courtyards, while Chinese mosques, like the Great Mosque of Xi'an, incorporate timber structures and traditional Chinese roof forms. These regional differences reflect diverse cultural and climatic influences shaping mosque design [14].

1.2 Sustainable Construction Practices

Sustainable construction plays a crucial role in reducing environmental impacts by improving energy efficiency, conserving resources, and minimizing harm [16]. Practices such as high-performance insulation and low-VOC paints lower energy consumption and promote healthier environments [17][18][19]. The integration of smart technologies, like the Internet of Things (IoT) and building automation systems, allows for real-time monitoring of energy use, air quality, and environmental conditions, enhancing the performance of sustainable designs [20].

In mosque design, sustainable construction and smart practices are reshaping traditional features such as building mass, interior space, and daylighting [21]. These innovations combine environmental efficiency with spiritual values, reflecting a balance of tradition and technological advancement. Contemporary mosque design increasingly integrates sustainable

(a) Original View (1989 – 2004)

(b) Isometric view of the Mosque

(c) Aerial view of the mosque

Fig. 1: Various views of the grand mosque

methods and smart systems to ensure both sustainability and spiritual connection [22].

The use of green building materials plays a crucial role in advancing sustainable construction by significantly reducing the environmental impact of building processes and enhancing the overall sustainability of structures. These materials are defined by their eco-friendly properties, including energy efficiency, resource conservation, and minimal environmental harm [23]. The significance of sustainable construction cannot be overstated, as it plays a crucial role in minimizing the environmental impact of both building and operation, supporting broader sustainability goals [24]. By adopting sustainable construction practices, architects and builders can reduce resource depletion, lower energy consumption, and mitigate pollution, all while promoting occupant health and ecosystem well-being. Sustainable construction methods, such as high-performance insulation, enhance energy efficiency by reducing heating and cooling demands, leading to long-term energy savings [25]. Additionally, practices like using low-VOC paints improve indoor air quality, contributing to healthier living environments [26]. The integration of green building materials with smart construction practices is a key trend shaping the future of sustainable construction [27]. Technologies like the Internet of Things (IoT) and building automation systems enable real-time monitoring and management of building performance. Smart sensors and IoT devices track parameters such as energy consumption, indoor air quality, and environmental conditions, providing crucial data for optimizing building operations [28]. By combining these technologies with sustainable materials, building efficiency and sustainability are significantly enhanced. For example, energy-efficient windows and insulation materials can be integrated with automated systems to adjust heating, cooling, and lighting based on occupancy and environmental factors [23].

Architecture reflects human cultural values and ideas, and mosque architecture specifically embodies the principles of Islam, such as modesty, sustainability, and humane design [23]. While traditional Islamic mosque design has maintained certain features

across eras—emphasizing function and spiritual significance—modern technologies, innovative construction methods, and new materials have influenced contemporary mosque architecture. These advancements are particularly evident in aspects like building mass, unobstructed interior space, and daylighting, which are the main focus of this research. Modern mosque design increasingly integrates sustainability, efficiency, and spiritual connection, reflecting a blend of tradition and innovation [29, 30].

1.3 Sustainable Mosque design in various regions

Several mosques worldwide have adopted sustainable design practices to reduce energy consumption and improve environmental performance. For example, the Cyberjaya Mosque in Malaysia utilizes modern materials and a layout suited to the hot-humid climate, promoting natural ventilation to reduce cooling loads [31]. In Dubai, the Khalifa Al Tajer Mosque integrates advanced technologies such as automated sensors for thermal and lighting control, while its zoning system allocates smaller spaces for regular prayers and larger areas for bigger gatherings, optimizing energy use [32]. A new mosque in Cambridge, England, is being built with eco-design principles in mind to promote sustainability [33]. Similarly, Indonesia's national mosque has completed an eco-friendly retrofit, reducing its carbon footprint and becoming the first place of worship globally to receive the final Excellence in Design for Greater Efficiencies (EDGE) certification [34]. In addition to these examples, several countries have implemented policies to promote environmentally sustainable mosque design. Morocco plans to retrofit 600 mosques with solar heating, daylighting, and photovoltaic cells, aiming to reduce energy use by 40% [35]. Indonesia is working toward establishing 1,000 eco-mosques, while Jordan and Qatar are focusing on solar power and environmentally friendly design solutions for their mosques [36][37][38]. These international efforts provide valuable context for exploring similar sustainable practices in mosque design. Recent studies have also examined the impact of modern architectural trends and technologies on mosque design, focusing on how contemporary developments aim to preserve the spiritual essence and cultural identity of mosques. AL-Ammar and AL-Atabey [1], as well as Toorabally et al. [2], explored the influence of modern technologies on mosque design, while Niknam et al. [39] studied how contemporary architecture affects Islamic motifs. Ra'ouf et al. [40] suggested that modern mosque design is shaped by functional, aesthetic, and symbolic factors, contrasting with traditional influences. Researchers such as Al Tal [41], Ho-teit [14], and Mahdavinejad [42] have also investigated the role of modern architectural theories in mosque designs, emphasizing the need to balance modern trends with traditional elements to preserve mosques' spiritual and cultural significance.

Further research has focused on the evolution of mosque architecture, particularly regarding modernization, symbolism, and technological advancements. Hamzehnejad et al. [43] identified authenticity criteria for modern mosques in the Islamic world, while Awad [44] and Mahmoud et al. [45] examined mosque design trends in northern UAE cities and globally. Al-Bukhari et al. [46] noted that modern mosques reflect technological progress, societal needs, and economic status, while maintaining cultural and spiritual identity. Studies by Alkhaled [47], Alhefnawy et al. [48], and Toman [49] analyzed mosque architecture in Turkey, Italy, and Riyadh, respectively, while Asfour [15] examined the shift from historical to contemporary mosque styles, emphasizing the tension between modernism and symbolism. Additionally, several studies have explored mosque architecture in the Kurdistan Region of Iraq, with Ali et al. [50] classifying mosques, including two historic mosques in Sulaymaniyah, based on key mosque prototypes.

2 Design and architecture of the Grand Mosque Allahabad

2.0.1 Design of Grand Mosque

The Grand Mosque Allahabad in Kandiyaro, Sindh, draws inspiration from some of the most renowned traditional Islamic architectural sites, including Masjid Nabvi in Madina, Saudi Arabia; Imam Ali Raza Mosque in Mashhad, Iran; Sultan Ahmed Mosque in Istanbul, Turkey; Shah Jahan Mosque in Thatta, Sindh, Pakistan; and Khudabad Mosque in Dadu, Sindh, Pakistan [51]. These mosques, known for their grandeur and timeless beauty, have greatly influenced the design of the Grand Mosque, which strives to balance traditional aesthetics with modern construction techniques [52]. The mosque is designed to uphold the cultural legacy of Sindh, specifically by preserving the Kashi heritage of the Indus civilization. The intricate hand-painted tile work (Sindhi Kashi) adds a level of craftsmanship that ties the structure to the region's rich artistic traditions, ensuring that the mosque resonates with both historical and spiritual significance [53,54]. The use of fair-face concrete further blends the modern with the traditional, offering both durability and visual appeal [55]. Beyond its physical grandeur, the design serves as an embodiment of spiritual devotion. The mosque is intended

not only as a place for worship but as a sanctuary for contemplation and prayer, where visitors can feel a profound connection to their faith. It stands as a symbol of enduring devotion to Allah, inviting future generations to visit and partake in its sanctity. The mosque's architecture is also characterized by the use of sustainable design principles, such as raised domes on brackets to facilitate natural airflow, helping the building remain cool during the hot summer months. This feature enhances the building's environmental performance while maintaining its aesthetic beauty [56].

2.1 Prescribed Construction Procedure

This case study examined the Allahabad Mosque, situated in Kandiyaro, approximately 415 km from Karachi, along the main National Highway. The mosque is situated in Allahabad, a town in the Noushero Feroze District of Sindh Province, Pakistan. The district is bordered by Khairpur District to the north, Sanghar District to the east, Shaheed Benazirabad District to the south, and Larkana District to the west. Allahabad, the specific location of the Grand Mosque, is a small but historically significant town within the district. The approximate geographical coordinates of the Grand Mosque, Allahabad are as Latitude: 26° 50' 32.57" N, and Longitude: 68° 07' 22.73" E. The location is shown on a map of Pakistan (Figure 2a).

The mosque is at the finishing stage, focusing on Kashi works, while other civil works in the mosque have been completed. The mosque was constructed on an area of 65000 Sq. ft. and surrounded by landscaping. The total area of the mosque is approximately 10 acres (48400 Sq. Yds.). It has 101 domes of different sizes, ranging from 12 ft. to 64 ft. in diameter at different heights. The height of the main dome is 115 ft., with a 64 ft. diameter from its collar or base as shown in Figure 2 (b). The mosque encompassed its identification through minarets having a height of 120 ft. from ground level. The Allahabad Mosque has a main hall with an area of 24,000 square feet. This hall holds the capacity of about 8,000 to 10,000 persons to perform Salat collectively. Furthermore, this hall is also connected with four corridors having a width of 15.5 ft. Multiple arches are also planned in the area to validate the beauty of the mosque. A simplified picture capturing the entire area and domes is presented in Figure 2 (c).

2.2 Architectural details of Allahabad Mosque

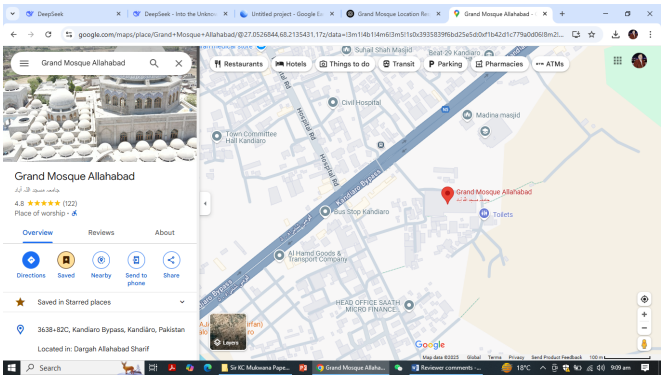
To generalize the considerations of design, some inspirations were drawn from mosques like Shah Jahan Mosque, Thatta, Sindh, and Khudabad Mosque, near Dadu, Sindh. Sultan Ahmad Mosque, Istanbul, Turkey, and Hazrat Imam Ali Raza Shrine and Mosque, Mashhad, Iran, were also visited and studied in detail to incorporate elements of Islamic heritage and artistic works as shown in Figure 3 (a) [57].

The outstanding characteristics of the Mosque are the running corridors and the provision of 101 domes symbolizing attributes of Allah, which leaves the structure without any flat roofs [58]. These elements not only enhance the aesthetic appeal but also serve functional and spiritual purposes within the mosque's design. The absence of flat roofs in favor of domes reflects a deep-rooted tradition in Islamic architecture, emphasizing purity and simplicity. Likewise, the technique of raised domes on brackets is an innovation in Islamic architecture, which enhances the overall echo within the mosque and turns the entire edifice environmentally friendly to cater for hot summers, as the heated air finds its way out [56].

As per the initial conceptual plan, the entire structure was constructed around the existing hall. However, after the completion of 101 domes in 2012, it emerged that:

- The concrete used violated the building codes.
- The outer fabric of the structure defied symmetry, rather, interfering with harmony.
- The main dome was shorter than the dome constructed on the verandah.

In view of these observations, the structure was reconsidered in line with the visited mosques. Other significant design parameters of the mosque include the use of fair-faced concrete, steel fabrication, improved formwork, formation of setbacks in concrete, and application of hand-painted Kashi tiles. The use of fair-faced concrete, steel fabrication, improved formwork, setbacks, and hand-painted Kashi tiles not only fulfills functional requirements but also enriches the aesthetic and spiritual experience of the worshipers, consistent with previous studies [59, 60]. These parameters should be part of the framework for similar types of constructions as shown in Figure 3 (b). To briefly describe the methodology, it is required to characterize the local conditions of the construction subject to the building materials and customized design of the mosque. Such as the use of fair finish concrete, idealizing more appropriate admixtures. Determination of the preferred material was the major accountability of the research due to the availability or scarcity of building materials. Hence, it required critical analysis followed by engineering knowledge. Moreover, the study also entails knowledge about the special skills



(a) Location on map

(b) Standard Layout

(c) Provision of Domes

Fig. 2: Location on map, Standard Layout, and Provision of Domes

in fabrication as needed to create setbacks for such indigenous structure adorned by Kashi tiles. Above all, the preferences in constructions are accumulated with numerous parameters, including local knowledge, customs, weather conditions, culture, etc. As a result, the variations are used to characterize larger cultural areas. In fact, Muslim cities could not maintain a local school of architecture for long to formulate individual traditions Figure 3 (c) [61]. In continuation of the susceptibility of construction materials, the project is being executed considering the accurate balance between the design and operational aspects. Further architectural planning details can be observed in Figure 3 (d).

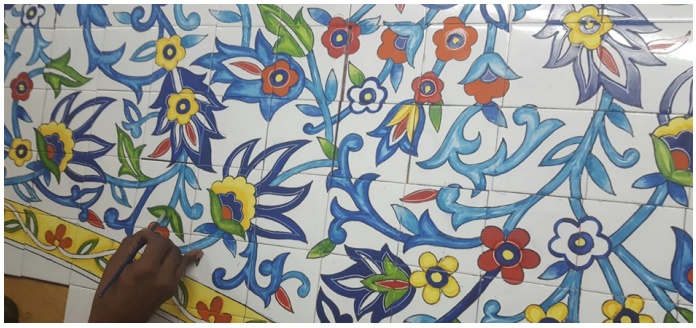
2.3 Implications of Islamic Architecture

It is a common perspective to draw inspiration from Islamic architecture within the Indo-Pak subcontinent for the construction of mosques, shrines, gardens, and fortresses [62]. The specific construction style is often biased towards the Mughal period, similar to the perspectives predominant in the Ottoman Empire in Turkey and the Safavid dynasty in Iran. These structures have left undeniable marks on history. Similarly, the monuments of Lahore, Delhi, and Agra may be considered exemplary models against the backdrop of the 16th and 17th centuries. It is evident that Indo-Islamic architecture has matured into a blend of indigenous and Western Islamic traditions [63]. Under normal circumstances, exposure to such architectural styles can be attained through modifications in construction norms. Similar modifications have been introduced in the grand mosques of Makkah and Medina, Saudi Arabia. Other sources of inspiration include the Sultan Ahmed Mosque (also known as the Blue Mosque) in Istanbul, Turkey. Similarly, the Mughal kings produced marvelous Islamic structures that enriched the environment of the Indus Valley civilization [64], including the Thatta Mosque, Badshahi Mosque, and Wazir Khan Mosque. Later adaptations can be seen in the Khudabad Mosque near Sehwan. The outcome of this research project represents a model of Islamic architecture, as depicted in Figure 04.

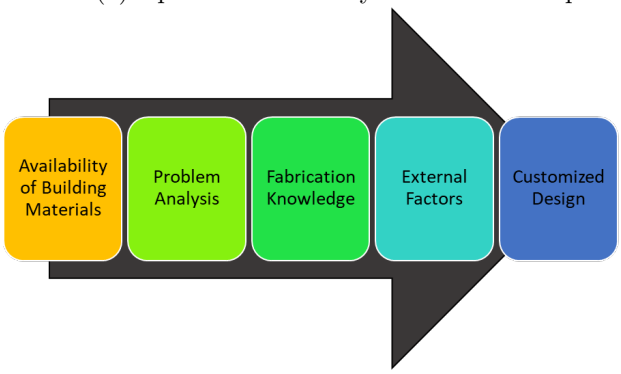
2.4 Influential Monuments

The next phase of the methodology involved influencing the project by drawing on the evolution of existing architecture, which often reflects the challenges posed by previous masterpieces. To achieve this, several locations were visited not only to gain engineering knowl-

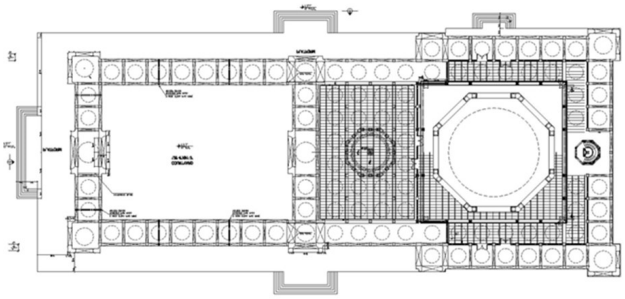
(a) Opted Guidelines by Khudabad Mosque



(b) Hand Painted tile Work



(c) Material Applicability



(d) Layout Plan of Mosque with details of 101 Domes

Fig. 3: Opted Guidelines by Khudabad Mosque, Hand Painted tile Work, Material Applicability, and Layout Plan of Mosque with details of 101 Domes

Fig. 4: Courtyard of Allahabad Mosque

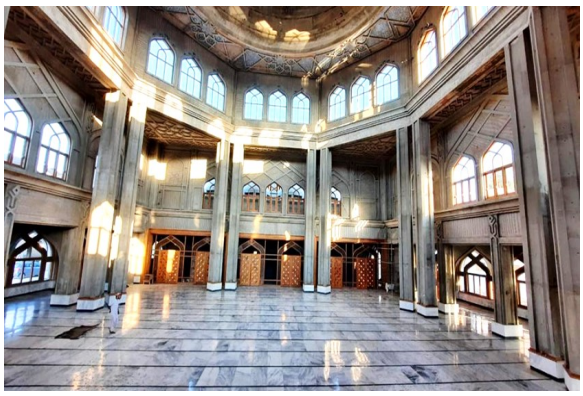


Fig. 5: Mosque Aesthetic

edge but also to provide a model for the construction of the mosque. This phase was organized according to the blue mosque, Turkey, Hazrat Imam Ali Raza Islamic Complex, Iran, Shah Jahan mosque, Pakistan, Khudabad mosque, Pakistan, and Suleman mosque, Turkey, respectively. As influenced by the masterpieces during the construction of the mosque, the existing structure can also be visualized through Figure 05.

3 Design Pattern Strategies

Additional architectural innovations are deliberated to develop a model, ensuring a series of emerging designs and patterns for subsequent research stages. This synchronization with intellectual impetus often originates from imperial patrons, aiming to surpass admired older monuments. The implementation establishes the credibility of professionals, including Architects and Engineers, in demanding novelistic works [65]. This research study characterizes the roles of Architects and Engineers from a broader perspective, focusing

on determining classical structural design and subsidized criteria for tile design patterns. All features are proportioned for effective production and construction techniques, as prescribed by the construction management strategy. The flow chart is represented in Figure 6 (a), while the actual setup is depicted in Figure 6 (b).

3.1 Integration with Fair Finish Concrete

This phenomenon emerged in the late 19th century and has evolved into a modern construction technology that eliminates the need for plaster and finishing. Engineers now use steel fabrication and continuous concrete pouring to achieve a permanent finish that requires minimal maintenance. This high-demand concrete is a popular choice for modern architecture and various building structures due to its versatility in styling and reshaping [66]. The use of fair-faced concrete, as seen in the Allahabad Mosque, is a groundbreaking approach that has never been used on such a large scale in mosque construction worldwide. To achieve this, careful investigation and planning were necessary to design setbacks on the surface where hand-painted tiles would be fixed. Steel frames were prepared in advance according to the specifications of each setback, ensuring accurate shapes. The fair finish concrete method is showcased in Figure 7 (a) and (b) [67].

4 Revival of Sindhi Kashgari Heritage

The application of hand-painted Kashi tiles is a traditional element that adds cultural significance and artistic value to the mosque's design. These tiles often feature intricate patterns and vibrant colors, reflecting the rich heritage of Islamic art while also serving as a means of enhancing the spiritual atmosphere within the mosque [60]. To preserve the ancient art of Kashighari from the Indus Valley civilization, the Allahabad Mosque exclusively uses Sindhi Kashi or handpainted tiles. Only floral patterns have been chosen over geometric designs, which require intricate details to transfer onto the Kashi tiles. Historically, Kashi work has been practiced for the last 5000 years in Sindh, and cities near the Indus River, such as Mohenjo-Daro and Harappa, bear witness to this legacy [68]. This mosque is a masterpiece that promotes the Kashi heritage of the Indus civilization, constructed using fair-finish concrete. The incorporation of handmade Kashi tiles throughout the structure showcases novel design and architectural beauty, contributing to Islamic architecture. This approach is illustrated in Figure 08. Moreover, this mosque is a testament to devotion to Almighty Allah, seeking blessings for generations. It transforms visitors who offer prayers, connecting them with this magnificent heritage [69].

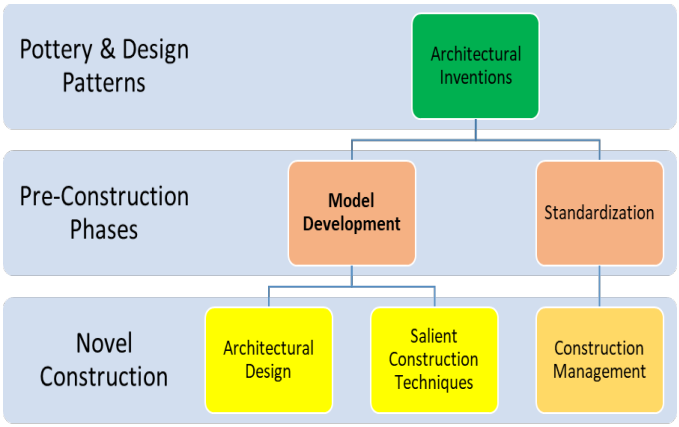
4.1 Application of Handmade Kashi Tiles in the Structure

The notable feature of this structure is the extensive use of handmade Kashi tiles throughout the mosque, applied directly to the setbacks and arranged to showcase Islamic heritage [70]. The whirl design pattern on the tiles creates symmetry and harmony in the building's structure, as seen in Figure 9 (a). Additionally, Kashi tiles adorn the arches and domes, represented in Figure 9 (b). The use of Kashi tiles symbolizes the oldest civilization in Sindh, with the most decorative work associated with handmade tiles that have been practiced for centuries [71]. This is highlighted in Figure 9 (c). In Sindh province, geometric forms and foliage are commonly used, with literature showing contextual similarities to medieval work in Persia. Two classes of tile work exist: one with patterns traced over tiles regardless of shape, and another with tiles shaped like flowers, buds, and stems. This is known as hard-backed red terracotta in Sindh and Multan.

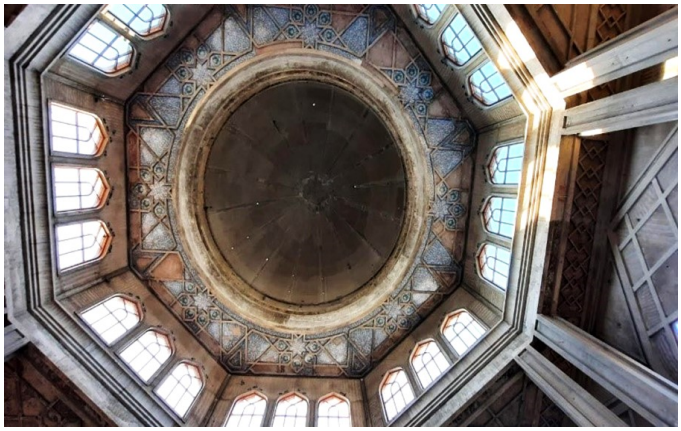
The architects of the Allahabad Mosque took the initiative to secure Sindhi tradition by promoting the use of porcelain tiles and channeling calligraphy works to emphasize uniqueness [72]. This is justified through research on Kashi art backgrounds in Punjab, Multan, India, Dabgir Mosque, Makli Necropolis, and Shah Jahan Mosque [70]. The decorative art has evolved towards more florid actions, reflecting simplicity in Sindh and resembling the late Kalhora and Talpur periods, which mark the golden age of Sindh's unique design [73]. This design is presented in Figure 9 (d).

5 Discussion

The Grand Mosque of Allahabad distinguishes itself with its focus on sustainable construction through the use of local materials like handmade Kashi tiles (Section 3.1). This approach contrasts with mosques that rely on industrial materials, reducing environmental impact by minimizing transportation. The mosque also integrates natural climate-responsive strategies, such as wide courtyards and verandahs, promoting passive cooling (Section 1.1). This reduces reliance on energy-intensive systems compared to other mosques that prioritize air conditioning and mechanical cooling. The mosque integrates traditional craftsmanship with modern construction techniques as discussed in Section 2.2, employing skilled local labor alongside modern engineering tools. The



(a) Construction Strategy



(b) Artistic Work

Fig. 6: Construction Strategy and Artistic Work of Mosque

(a) Identifying Fair Face Concrete

(b) Typical detail of 99 domes of Allahabad Mosque in Fair Face Concrete

Fig. 7: Identification and Typical detail of 99 domes of Allahabad Mosque in Fair Face Concrete

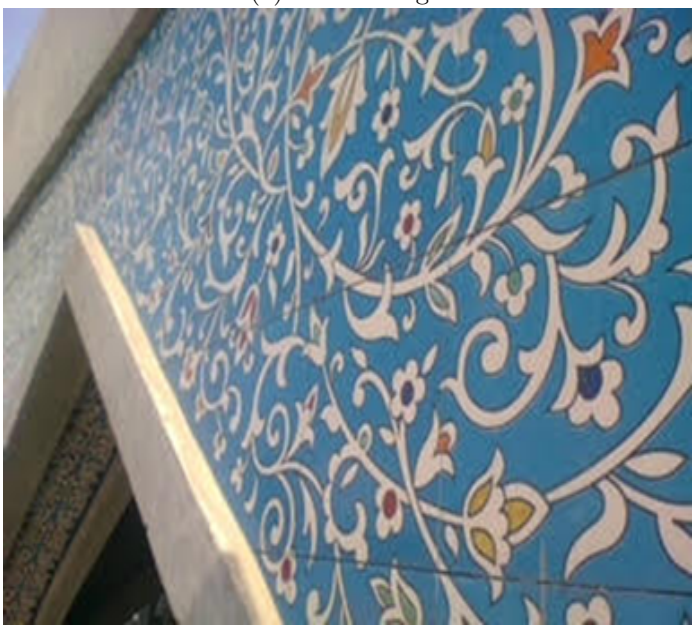
Fig. 8: Handmade Kashi Tiles

use of this approach suggests that the structure retains its authenticity while benefiting from modern quality control, in contradiction to mosques that rely exclusively on modern technologies. The design combines traditional Islamic architecture with regional heritage as elaborated in Section 2.4. In contrast to several other mosques that followed conventional designs, the Grand Mosque integrates Sindhi Kashgari heritage, reflecting cultural continuity while meeting modern functional needs (Section 3). This approach establishes a distinctive sense of place, offering a unique connection to the regional context.

Regardless of these strengths, the mosque encounters several challenges, such as the durability and maintenance of handmade Kashi tiles (Section 3.1). These challenges need more upkeep over time, leading to higher operational costs. Further, though passive cooling is effective, it may face challenges during severe weather conditions, possibly requiring supplementary systems that could impact the mosque's sustainability

(a) Kashi Design

(b) Proposed Kashi Work on Building Arches



(c) Organized Work of Kashi Tiles

(d) Decorative Art of Kashi

Fig. 9: Fig. 09: (a) Kashi Design, proposed, work, organized work, and on Building Elements, and (d) Decorative Art

goals. The unification of traditional building materials and construction techniques could also lead to higher construction costs and timelines, posing scalability challenges for future projects. On the other hand, the Grand Mosque of Allahabad serves as an innovative example of blending sustainability, heritage, and modern construction techniques. Confronting these challenges will further enhance the energy efficiency and longevity of the mosque.

In summary, the Grand Mosque of Allahabad is believed to provide a model that balances cultural heritage with sustainability and modern construction practices. However, there are several challenges, such as material durability, environmental resilience, and scalability, which need attention. Future projects can learn from this mosque by improving areas like energy resilience and maintenance strategies.

6 Conclusion

The main objective of the study was to represent the integration of smart and sustainable construction practices, primarily focusing on the usage of traditional craftsmanship and local materials. The construction of the Grand Mosque situated in Allahabad is considered a significant project that highlighted the revival of Sindhi Kashgari heritage. This study provided a comprehensive understanding of Islamic architecture and its ramifications. Hand-made Kashi tiles used in the construction of the mosque are an essential element, reflecting the cultural legacy of Sindhi Kashgari art and enhancing the building's aesthetic and spiritual atmosphere. The project of the construction of the Grand Mosque not only signifies the cultural heritage but also promotes the social and academic development of the community. Employing fair-finish concrete together with traditional design elements was an incredible achievement, exhibiting the potential for innovation in construction techniques. The modern design pattern strategies and influential monuments demonstrated the project's pledge to conserve cultural legacy while embracing modernity, which served as both a cultural landmark and a sustainable building. The construction of the Grand Mosque is a momentous project that positively resuscitates Sindhi Kashgari's heritage while incorporating modern construction techniques. This case study is believed to be very useful for academia as well as researchers, as the project serves as a model for future developments that aim to preserve cultural legacy while promoting social, academic, and economic growth.

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