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SUSTAINABILITY IN HISTORICAL ISLAMIC ARCHITECTURE: LESSONS FROM SHEIKH LOTFOLLAH MOSQUE'S CONSTRUCTION TECHNIQUES

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ABSTRACT

This research examines the construction techniques and principles of sustainability in the architecture of Sheikh Lotfollah Mosque, one of the most prominent examples of Islamic architecture. The main goal is to identify the sustainability elements of this mosque, emphasizing the use of local materials and traditional methods so that it can be presented as a model for contemporary architecture. The research deals with environmental challenges and the need to design sustainable buildings in today's world, which is faced with a decrease in natural resources and an increase in demand. In this regard, the research questions are: 1- What construction and architectural techniques have been used in the Sheikh Lotfollah Mosque that have contributed to its stability and durability over time? 2- How can the sustainability techniques in the architecture of Sheikh Lotfollah Mosque be used as a model for the design of contemporary buildings? The method of this research is considered interpretative-historical. Its content has been prepared and adjusted using descriptive-analytical and library-documentary studies as well as field studies. The findings show that the Sheikh Lotfollah Mosque has achieved stability and durability by using architectural techniques in accordance with climatic conditions. The conclusion emphasizes that the principles of Islamic architecture, especially the use of local materials and environmentally friendly methods, can inspire contemporary architecture. The implications of this research include providing practical models for today's architects who seek to design sustainable and environmentally friendly buildings. The key contribution of this research is in reviving traditional techniques and matching them with new technologies. The novelty and originality of this research is that, for the first time, it has carefully examined Sheikh Lotfollah Mosque from the perspective of sustainability and links these concepts to contemporary architecture, which can be influential in the design of future buildings.

Keywords:
Sheikh Lotfollah Mosque; Islamic Architecture; Construction Techniques; Principles of Sustainability; Contemporary Buildings

1. INTRODUCTION

The main subject of this research is the investigation of construction techniques and sustainability principles in the architecture of Sheikh Lotfollah Mosque, one of the masterpieces of Islamic architecture in Iran. This mosque, which was built in the Safavid period, is not only noted for its beauty and architectural splendor but also because of the use of local materials and construction methods that are compatible with climatic conditions. It is considered an outstanding example of sustainable architecture [1][2]. The importance of this matter is more

apparent in today's world, where we are facing environmental challenges and the need to design sustainable buildings.

The analysis of Sheikh Lotfollah Mosque can help to understand the principles of sustainability in Islamic architecture and provide solutions to revive these principles in contemporary architecture. In an era when architects seek to combine new technologies with traditional methods [3], this research can act as a bridge between the past and present and provide valuable models for future designs. Therefore, the detailed investigation and analysis of this mosque not only helps to preserve the cultural heritage but also helps to develop sustainable architecture.

Any type of research and scientific research should refer to the history and background of that subject so that one can start researching with sufficient knowledge of the gaps and unmet needs. In this regard, in this article, several researches that have been studied in recent years are briefly brought up, and the results are stated in Table 1.

Tabel 1. Research Background

Research Reference	Year of publication	Results
[4]	2023	The study's findings suggest that the Sheikh Lotfollah Mosque's transformational principles are attributable to the index of spatial geometry, which is triggered by rotation, direction change, and translational movement of structural and physical elements, external walls, and connecting internal spaces.
[5]	2023	Four pillars of calm, movement, connection, and union are specified for perception in Safavid mosques, according to Mulla Sadra's spiritual process at the perceptive levels. The audience's perspective may improve at each level following the stability stage for several reasons. In the movement pillar, through necessary movement; in the connecting column, through light and transparency; and, lastly, in the unity pillar, through the connection of the space and the observer. The observer's ability to perceive more clearly is facilitated by these factors, first at the sensory level and subsequently at the imagined and rational levels.
[6]	2022	The research's conclusions demonstrate that, with a value of (1.000), the shaping of large and small spaces as altars, ponds, shrines, mosque courtyards, and domes has the largest factor contribution, while the least significant factor contribution is associated with architectural materials (0.523). The way that the spaces were arranged in the mosques during the Safavid era, particularly in the mosques of Sheikh Lotfollah and Imam, produced a rich and unexpected combination as well as serene and lovely spatial impressions.
[7]	2022	The results indicate that this inscription's text is a hadith, referred to as the Hadith of Jabir. This study further demonstrates that 'Ali-Reza 'Abbasi, a well-known and accomplished calligrapher from the Shah Abbas I era, was the person who wrote this inscription.
[8]	2021	The analysis's findings indicate that as mosques' surfaces increase, so does the amount of heat absorption exposed to radiation and in the shadow area. Therefore, domes with rising surfaces and high heights that create shade are appropriate for hot, dry climates, while domes with rising surfaces and high contact surfaces that receive radiation are ideal for cold, dry climates.
[9]	2020	The findings highlight the salient features of Sheikh Lotfollah mosques' sense of place, including the entrance, hallways, walls, ceiling, mihrab, and dome; light and substance enable the triangular union of physical elements to transition from appearance to conscience. Thus, at the greatest level, a deep internal dialectical link between Sheikh Lotfollah and its observer establishes a sense of location.
[10]	2018	The results of the research show that in the inscriptions of the minarets, a combination of the main conclusions of the current article's studies are presented to create a framework that can aid in the construction of other mosques and structures with comparable areas.
[11]	2017	The study's findings confirm that the primary causes of the damage were rising moisture levels brought on by nearby sewage and water line leaks. Thus, among the needs for the restoration project are pipe repair, grouting of the foundation, and area organization.
[12]	2016	The findings indicate that the mosque entrance corridors in Isfahan are curved and rotated, maybe to facilitate the prayerful vision of a bright, spiritual space beyond the dim, narrow passageway leading to the prayer hall.
[13]	2015	The findings indicate that, just during Nowruz, the number of visitors to the Sheikh Lotfollah Mosque exceeded its actual daily bearable capacity, whereas, during other months of the year, it was significantly less than its actual monthly tolerable capacity. As a result, the policies required to run this building during times of prosperity and recession are essential to avoid permanent harm to this historic structure.

By examining the documents, articles, and research conducted in the field of Sheikh Lotfollah Mosque, scattered Contents are found, but in the field of Sustainability in Historical Islamic Architecture: Lessons from Sheikh Lotfollah Mosque's Construction Techniques, there is nothing special. This is the reason for the importance and necessity of the present research.

By focusing on Sheikh Lotfollah Mosque and analyzing its construction techniques from the perspective of sustainability, this research presents significant innovations in the field of Islamic architecture studies. Many previous researches have focused on the aesthetic and artistic aspects of Islamic architecture, but this research, with a new approach, investigates the construction techniques and principles of sustainability in the architecture of this mosque and seeks to extract lessons for contemporary architecture. What distinguishes this research from other studies is the detailed and systematic analysis of traditional construction techniques and materials used in this mosque, which have played a significant role in its durability and sustainability.

Another innovative aspect of this research is the connection between the traditional techniques of Islamic architecture and the modern principles of sustainability. This study shows how old knowledge and experiences can be used to solve contemporary problems. In a situation where contemporary architecture is facing environmental challenges, this research can inspire and provide new solutions for designing sustainable buildings. On the other hand, this research pays special attention to the place of local materials and methods compatible with the climate, which can be considered as a new approach in the design of sustainable and environmentally friendly architecture.

Finally, this research can create a platform for the revival of Islamic architectural techniques and their integration with new technologies. By providing a detailed and practical analysis of the construction techniques of Sheikh Lotfollah Mosque, this research can help expand the knowledge and insight of contemporary architects and provide efficient models for the design of future buildings. This combination of tradition and innovation, especially in the field of sustainable architecture, can be an important step towards preserving cultural heritage and responding to today's environmental needs.

In today's world, architecture is facing major challenges such as climate change, depletion of natural resources, and increasing demand for sustainable buildings [14]-[16]. In the meantime, architects and designers are looking for solutions that not only meet functional and aesthetic needs but are also compatible with the environment. However, many modern design and construction solutions are still not sustainable enough and often consume natural resources in an unsustainable way [17][18]. In this context, traditional Islamic architecture and especially the construction techniques of Sheikh Lotfollah Mosque as one of the masterpieces of Iranian-Islamic architecture, can be an important and inspiring model for contemporary sustainable architecture.

With more than four hundred years old, Sheikh Lotfollah Mosque is still known as one of the prominent buildings of Islamic architecture, which has not only achieved visual beauty and splendor by using local materials and advanced construction techniques for its time, It has also shown high resistance and durability over time [19]-[21]. It shows that the architects of this period have used principles in design and construction that have contributed to the stability of the building according to the environmental and climatic conditions. Hence, the careful examination of these principles and techniques can meet the needs of contemporary architecture and lead to the development of new and more sustainable approaches in construction. This research seeks to answer questions about how to use traditional knowledge to solve today's architectural challenges by analyzing Sheikh Lotfollah Mosque. Now, this research seeks to answer the following questions:

- What construction and architectural techniques have been used in the Sheikh Lotfollah Mosque that have contributed to its stability and durability over time?
- How can the sustainability techniques in the architecture of Sheikh Lotfollah Mosque be used as a model for the design of contemporary buildings?

The main purpose of this research is to investigate the construction techniques of Sheikh Lotfollah Mosque as one of the prominent examples of Islamic architecture with an emphasis on sustainability. This research tries to identify the key elements and principles that have contributed to the stability and durability of this building by in-depth analysis of the architectural details and construction techniques of this mosque. Among the sub-objectives of the research is to investigate the use of local materials, design methods based on climatic conditions and traditional construction methods that have been used in this mosque. This research also aims to extract models for contemporary architects through the analysis of the architectural techniques of Sheikh Lotfollah Mosque, which they can use in designing sustainable buildings that are suitable for environmental and cultural conditions. Finally, this research seeks to provide solutions for reviving traditional methods and combining them with modern technologies in architecture to lead to the development of more sustainable and environmentally friendly buildings.

2. METHODS

This research investigates the sustainability elements of Islamic architecture, especially the Sheikh Lotfollah Mosque, using a qualitative approach of interpretive-historical type. Its purpose is to analyze the structural techniques and stability principles of this Safavid period building and their application in contemporary architecture. The data is collected through library sources and field studies and analyzed by descriptive-analytical method to identify historical sustainability techniques and use them in the design of contemporary sustainable and efficient resource architectures. Accordingly, the research methodology involved several steps, which will be outlined in sequence:

A. RESEARCH DESIGN

The research follows a qualitative interpretive-historical approach, focusing on understanding the sustainability elements of Islamic architecture, specifically the Sheikh Lotfollah Mosque. For this purpose, this approach was chosen to explore the construction techniques and sustainability principles of Sheikh Lotfollah Mosque, an architectural masterpiece from the Safavid period, and to analyze how these techniques can inform contemporary sustainable architecture. The descriptive-analytical method combines historical document analysis with field studies. The qualitative nature of this research aims to explore sustainability through a deep contextual understanding rather than statistical or experimental investigation. The rationale for choosing this design is its suitability for examining historical architecture, where interpretative analysis and insights drawn from historical sources and direct observation are key to uncovering sustainable practices.

B. DATA COLLECTION

The data for this research were collected using a combination of library-documentary sources and field studies. Documentary materials such as books, scholarly articles, and architectural manuscripts were examined to gain insights into the historical context and technical aspects of the mosque's construction. The fieldwork component involved photographic documentation of the mosque's structural and architectural features. The photos taken during the field studies (in 2024 by the authors) played a crucial role in capturing the intricate details of the mosque's construction techniques, which were further analyzed for sustainability elements. The use of multiple data sources ensured the reliability of the findings and provided a comprehensive understanding of the mosque's architectural and environmental strategies.

C. DATA ANALYSIS

Data were analyzed using descriptive-analytical techniques. The architectural elements of Sheikh Lotfollah Mosque were closely examined to identify the materials, construction methods, and environmental strategies used in its design. Special attention was paid to elements such as natural lighting, ventilation, and the use of local materials, which contribute to the building's sustainability. The data were analyzed through both qualitative content analysis of the documentary sources and visual analysis of the field photographs. The analysis focused on identifying sustainability techniques and determining how these historical methods can be adapted to contemporary architectural practices, especially in designing environmentally friendly and resource-efficient buildings.

This methodical approach allowed the researchers to derive practical models for sustainable architecture based on the traditional techniques used in Sheikh Lotfollah Mosque and to propose innovative applications for contemporary architecture. Now, the overall information about the structure of the research stages is given succinctly and clearly, as seen in Figure 1.

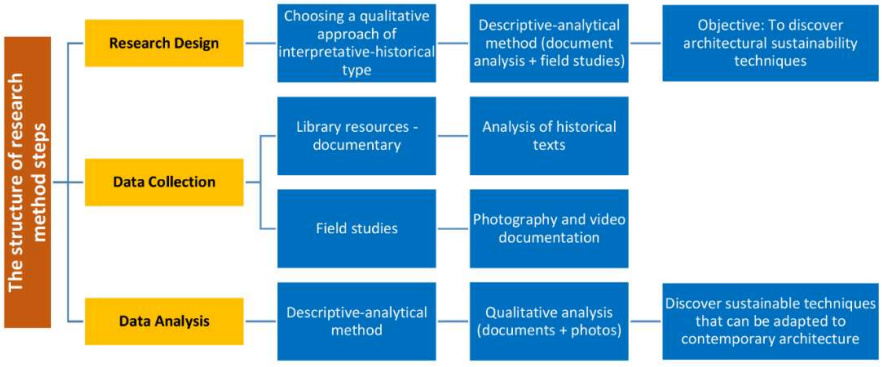

Figure 1. This structure shows the main stages of research as a sequential and goal-oriented process.

3. RESULT AND DISCUSSION

A. RESULT

Sheikh Lotfollah Mosque is one of the prominent works of Islamic architecture and a clear example of Iranian architectural art located in Isfahan city (Figure 2) [22]. This mosque, which was built in the Safavid period by the order of Shah Abbas I, has been considered one of the world's architectural masterpieces for more than four hundred years since its construction [23]. What makes this mosque different from other mosques is not only its external beauty and artistic decorations but also the construction and architectural techniques used in it, which have made this building resist natural and human destructive factors and is still functioning well today [24]. Also, the prominent features of this mosque, including natural ventilation systems, optimal use of natural light, and the combination of local materials, show the depth of knowledge and understanding of the architects of that period about the principles of sustainability in architecture. In this research, an attempt is made to answer the research questions by carefully examining the features and architectural techniques used in the construction of Sheikh Lotfollah Mosque, which have contributed to the stability and durability of this building over time.

Figure 2. A look at Sheikh Lotfollah Mosque

A. 1. CONSTRUCTION AND ARCHITECTURAL TECHNIQUES EFFECTIVE IN THE STABILITY AND DURABILITY OF SHEIKH LOTFOLLAH MOSQUE

A. 1. 1. USE OF QUALITY RAW MATERIALS

One of the main factors of the stability of Sheikh Lotfollah Mosque is the use of quality and sustainable raw materials in its construction. The materials used in the construction of this mosque, such as bricks, stones, tiles, and mortar, were selected from the best and highest quality materials available at that time. The bricks used in the walls and roofs are of a type that has high resistance to pressure and temperature changes. Also, the stones used in the foundations of the mosque have been selected from stones resistant to wear and erosion, which has greatly contributed to the durability of the building. Table 2 examines the innovations and benefits of using quality raw materials, such as brick, stone, and mortar, in the construction of the mosque and expresses its effects on the stability and durability of the building.

Table 2. The use of quality raw materials in the construction of Sheikh Lotfollah Mosque.

Feature	Innovation	Benefits	Impact on stability and durability	Figure
Resistant bricks and stones	Using bricks and stones with high resistance to pressure and temperature	Increasing the resistance of walls and foundations	Reducing destruction and erosion of walls and foundations	
Special mortars	Using mortars with a special composition and high-strength	Increase the adhesion and strength of the structure	Preventing the separation of different building components over time	

A. 1. 2. INTELLIGENT DESIGN OF THE BUILDING

The architectural design of Sheikh Lotfollah Mosque is in such a way that in addition to its beauty, it is also technically very intelligent. One of the distinctive features of this design is the presence of large and cylindrical arches that distribute the weight of the roof evenly on the foundations of the mosque. This technique minimizes the pressure on the building and thus increases the stability of the building over time. Table 3 deals with the innovations and advantages of the building's intelligent design, including arches and weight distribution, and its effects on the stability of the mosque structure.

Table 3. Intelligent design of the building in Sheikh Lotfollah Mosque.

Feature	Innovation	Benefits	Impact on stability and durability	Figure
Large and cylindrical arches	Designing the arches so that the weight of the roof is evenly distributed	Reducing pressure on walls and foundations	Increasing the resistance of the structure against lateral pressures and building collapse	
Weight distribution in building	Uniform distribution of weight between bases and columns	Reducing stress concentration in one point	Preventing local destruction and increasing the lifespan of the building	

A. 1. 3. NATURAL VENTILATION SYSTEM

Another important technique used in the construction of the Sheikh Lotfollah Mosque is the use of a natural ventilation system. In this mosque, instead of using artificial ventilation systems, natural methods have been used to cool the interior. This technique includes the use of large and open arches, the correct placement of doors and windows, and the creation of natural airflow inside the mosque. This system keeps the interior of the mosque cool in summer and warm in winter, which in turn helps the durability of the building. Table 4 examines the innovations and benefits of using the natural ventilation system in the mosque and its effects on the durability and comfort of the interior of the mosque.

Table 4. The natural ventilation system in Sheikh Lotfollah mosque.

Feature	Innovation	Benefits	Impact on stability and durability	Figure
Natural airflow	The design of the building in such a way that the airflow is established in it naturally	Lowering the internal temperature in summers	Reducing the negative effects of temperature changes on the building and materials used	
Placement of doors and windows	Using the strategic location of doors and windows for better ventilation	Increase internal airflow	Preventing the accumulation of moisture and increasing the durability of internal materials	

A. 1. 4. USE OF TILING AND ARTISTIC DECORATIONS

One of the prominent features of the Sheikh Lotfollah Mosque is the beautiful and artistic tiles used on the walls and ceilings. These tiles are not only artistically valuable but also act as a protective layer for the walls. The tiles used in this mosque are waterproof and resistant to temperature changes, which makes the walls of the mosque resistant to harmful weather factors, such as rain, snow, and direct sunlight. Also, special

techniques are used in the installation of these tiles that prevent them from cracking and separating. Table 5 examines the innovations related to the use of tiling and artistic decorations in the mosque and shows how these decorations contributed to the preservation and sustainability of the building.

Table 5. The use of tiling and artistic decorations in Sheikh Lotfollah Mosque.

Feature	Innovation	Benefits	Impact on stability and durability	Figure
Waterproof and resistant tiles	Using tiles with waterproof properties and resistant to temperature changes	Protection of walls against atmospheric factors	Reducing the destruction of walls and increasing the lifespan of decorations	
Tile installation techniques	Using special methods to prevent tiles from cracking and separating	Increasing the strength of decorations	Maintaining the beauty and integrity of decorations over time	

A. 1. 5. USE OF NATURAL LIGHT

The design of Sheikh Lotfollah Mosque is such that it uses natural light in the best possible way. In this mosque, large windows and their correct placement in the walls are used so that sunlight enters the interior in a uniform and gentle manner. This technique not only contributes to the natural lighting and beauty of the interior but also prevents excessive heating in summer and helps the durability of the building. Table 6 examines the innovations and benefits of using natural light in the design of the mosque and its effects on the stability and durability of the interior space of the mosque.

Table 6. Utilization of natural light in the design of Sheikh Lotfollah mosque.

Feature	Innovation	Benefits	Impact on stability and durability	Figure
Natural lighting	Designing windows so that sunlight enters gently and evenly	Reducing the need for artificial lighting	Reducing the negative effects of intense heat and light on interior materials	
The strategic location of the windows	Using the correct position for better use of sunlight	Improving natural indoor lighting	Maintaining optimal conditions for indoor space	

A. 1. 6. BASIC DESIGN OF BASES AND COLUMNS

The foundations and columns of the Sheikh Lotfollah Mosque are designed and built in such a way that they can withstand the weight of the roof and side pressures well. These columns are made of resistant stones and use special techniques that prevent them from moving and changing their shape over time. Also, the foundations of the mosque are designed in such a way that the weight of the building is evenly distributed on the ground, which makes the building resistant to earthquakes and other natural destructive factors. Table 7 deals with the innovations related to the design and construction of mosque foundations and columns and their effects on the stability and durability of the building structure.

Table 7. The basic design of foundations and columns in Sheikh Lotfollah Mosque.

Feature	Innovation	Benefits	Impact on stability and durability	Figure
Resistant stone pillars	The use of resistant stones and the special design of the columns	Bearing the weight of the roof and side pressures	Preventing the displacement and deformation of the columns and increasing the stability of the building	
Uniform foundation design	The design of the foundations in such a way that the weight of the building is evenly distributed	Reduced pressure focused on specific points.	Increasing the building's resistance against earthquakes and natural forces	

A. 1. 7. DETAILED MAPPING AND ENGINEERING

One of the important factors in the stability of Sheikh Lotfollah Mosque is the precise mapping and engineering used in its construction. Architects and engineers who have played a role in the construction of this mosque have carefully investigated and made detailed calculations so that it can be built in the best possible way. This accuracy in mapping and engineering has made the building very resistant and stable in terms of structure. Table 8 examines the importance of accurate mapping and engineering in the construction of the mosque and its effects on the durability and stability of the building.

Table 8. The role of accurate mapping and engineering in the construction of Sheikh Lotfollah Mosque.

Feature	Innovation	Benefits	Impact on stability and durability
Accurate mapping	Using accurate mapping techniques and engineering calculations	Increasing accuracy in construction and design	Increasing structural stability and preventing structural errors
Using modern technologies	Utilizing the advanced technologies of the time for precise design	Reducing the possibility of engineering errors	Increasing the durability and stability of the building against destructive factors

A. 1. 8. STRATEGIC LOCATION OF THE MOSQUE

The geographical location and strategic placement of Sheikh Lotfollah Mosque also played an important role in its stability. This mosque was built in one of the high and safe places of Isfahan city, which has been protected from natural hazards such as floods and soil erosion. Also, the placement of this mosque among the surrounding gardens has made the building protected from strong winds, which has also greatly contributed to its durability. Table 9 deals with the innovations and benefits of placing the mosque in a suitable geographical location and its effects on the protection and sustainability of the building.

Table 9. The strategic location of Sheikh Lotfollah Mosque.

Feature	Innovation	Benefits	Impact on stability and durability
Good geographical location	Building a mosque in a high and safe place	Reducing natural hazards such as floods	Building protection against soil erosion and flood
Enclosed in gardens	The location of the mosque among the surrounding gardens	Protection against strong winds	Reducing destruction caused by atmospheric factors

A. 1. 9. CONTINUOUS MAINTENANCE AND RESTORATION

Another factor that contributed to the stability of Sheikh Lotfollah Mosque is its continuous maintenance and restoration throughout history. Over the years, this mosque has been carefully examined and restored by experts and restoration specialists so that any damage and damage can be repaired in time. These measures have greatly contributed to the preservation and stability of this building over time. Table 10 examines the role

of continuous maintenance and restoration in maintaining the optimal state of the mosque and its effects on the durability and stability of this historical building.

Table 10. Continuous maintenance and restoration of Sheikh Lotfollah mosque.

Feature	Innovation	Benefits	Impact on stability and durability
Continuous renovation	Carrying out periodical repairs by specialists	Maintaining the optimal condition of the building	Preventing the destruction and long-term erosion of the building
Using traditional restoration techniques	Using traditional restoration methods and original materials	Preservation of the originality and beauty of the building	Increasing the lifespan and stability of restored structures

A. 1. 10. USING SYMMETRY AND HARMONY IN DESIGN

The symmetry and harmony used in the design of the Sheikh Lotfollah Mosque are not only important in terms of aesthetics but also contribute to the structural stability of the building. Symmetry in the distribution of weight and pressure makes the building more resistant to external forces such as wind and earthquakes. Also, harmony has greatly contributed to the durability and stability of the building in the design and combination of materials used in construction. Table 11 deals with the innovations and benefits of using symmetry and harmony in mosque design and its effects on the stability and durability of the building.

Table 11. The use of symmetry and harmony in the design of Sheikh Lotfollah Mosque.

Feature	Innovation	Benefits	Impact on stability and durability
Symmetry in design	Creating symmetry in different components of the building	Uniform distribution of pressure and stresses	Increasing resistance to natural forces such as earthquakes
Harmony in the composition of materials	The use of harmony in the composition of the materials used	Increase the integrity of the structure.	Reducing the risk of destruction and uneven erosion in the building

A. 2. THE APPLICATION OF ARCHITECTURAL SUSTAINABILITY TECHNIQUES OF SHEIKH LOTFOLLAH MOSQUE IN THE DESIGN OF CONTEMPORARY BUILDINGS

A. 2. 1. SUSTAINABILITY TECHNIQUES IN SHEIKH LOTFOLLAH MOSQUE ARCHITECTURE

Sustainability in architecture means designing and building structures that are compatible with the environment and have the least negative impact on it [25, 26]. This concept includes the optimal use of natural resources, reducing energy consumption, and creating healthy and livable environments for humans [27, 28]. In recent years, with increasing public awareness of climate change and the need to reduce the negative effects of human activities on the environment, sustainability in architecture has become one of the most important topics in this field [29, 30].

Sheikh Lotfollah Mosque, one of the prominent examples of sustainable architecture in the Safavid era, has always been studied and analyzed. With its intelligent design, this mosque shows how the architects of that period were able to achieve sustainability in architecture by using simple but efficient techniques. Among the techniques used in this mosque, we can mention the use of natural light for lighting, natural ventilation for temperature control, and the selection of native and local materials for construction. These techniques not only help to reduce energy consumption but also increase the durability and longevity of the building. In this regard, the plan of Sheikh Lotfollah Mosque has been presented with a comprehensive analysis, in which natural ventilation and natural lighting, especially the location of windows, have been determined graphically and using Photoshop software (Figure 3).

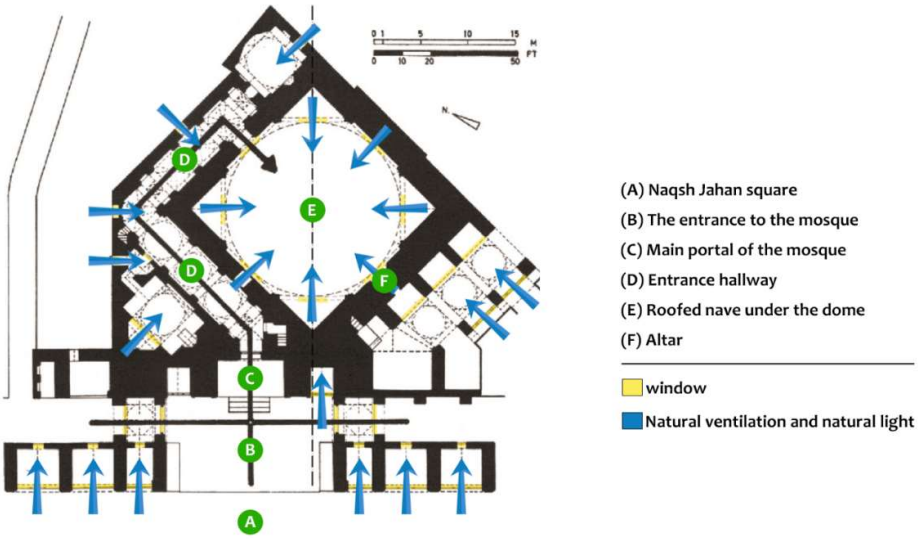

Figure 3. Comprehensive analysis of Sheikh Lotfollah mosque plan

a. USE OF NATURAL LIGHT

One of the most prominent features of Sheikh Lotfollah Mosque is the intelligent use of natural light. The interior design of the mosque is such that sunlight does not enter the interior directly, and this makes the interior always bright, without the need for artificial light sources. It helps to reduce energy consumption and, at the same time, makes the indoor space more pleasant for worshippers. Table 12 examines the features, benefits, challenges, and potentials of using natural light in contemporary buildings inspired by the design of Sheikh Lotfollah Mosque.

Table 12. The use of natural light in the architecture of Sheikh Lotfollah Mosque.

Feature	Description	Benefits	Challenges	The potential of use in contemporary buildings	Figure
Type of lighting	The interior design is such that natural light enters the space indirectly.	Reducing energy consumption, improving the quality of interior space	The need for careful design to prevent overheating	Using smart glass and large windows for better use of natural light	
Orientation of the building	Proper orientation of the building about the path of the sun.	Increasing the efficiency of sunlight	Restrictions on the choice of building location	Using simulation software to optimize orientation in design stages	
Windows and openings	Using windows and small openings at high altitudes.	Controlling light intensity and reducing the need for artificial light	Limitations in the application of this technique in different climates	Using controlled windows for better light and heat management	

b. NATURAL VENTILATION

Sheikh Lotfollah Mosque keeps the indoor temperature at a favorable level by using natural ventilation techniques. The dome-shaped roof of the mosque with a high height and the use of small windows in the upper part provide the possibility of natural ventilation and air circulation. This design is such that in the summer, hot air quickly leaves the inside of the mosque, and cooler air enters inside. In winter, due to the high height of the roof, heat is maintained in the lower part of the mosque, and the interior remains warm and pleasant. Table 13 is dedicated to the analysis of natural ventilation techniques used in Sheikh Lotfollah Mosque and the feasibility of using these techniques in contemporary buildings.

Table 13. Natural ventilation in the architecture of Sheikh Lotfollah Mosque.

Feature	Description	Benefits	Challenges	The potential of use in contemporary buildings	Figure
Dome roof	Using dome roofs with high height for better ventilation.	Control the temperature naturally, reducing the need for artificial ventilation.	Need a lot of space to build large domes	The use of two-shell roofs and natural ventilation in contemporary designs	
Air inlet and outlet	Placing windows and openings in strategic points for air circulation.	Improving indoor air quality, reducing energy consumption	The need for accurate design in harmony with the climate	Using combined ventilation systems to optimize airflow in buildings	
Internal temperature adjustment	Internal temperature control according to the climate and different seasons.	Improving occupant comfort, reducing heating and cooling costs	It may require design changes in some climates	Use of high thermal mass materials and patio designs to aid ventilation and indoor temperature	

c. USE OF LOCAL MATERIALS

Another sustainable technique used in the construction of the Sheikh Lotfollah Mosque is the use of indigenous and local materials. The use of local bricks and beautiful tiles has not only increased the durability and stability of the building but also reduced the construction costs and, at the same time, is more compatible with the environment. This technique not only helps to conserve natural resources but also reduces maintenance and repair costs. Table 14 examines the use of local and indigenous materials in the Sheikh Lotfollah Mosque, the advantages, challenges and similar solutions in the design of contemporary buildings.

Table 14. The use of local materials in the architecture of Sheikh Lotfollah Mosque.

Feature	Description	Benefits	Challenges	The potential of use in contemporary buildings	Figure
Use of bricks	Using local bricks to build walls and structures.	Reducing transportation costs, compatibility with the environment	Limited access to high-quality resources	Development of modern and recycled brick-making techniques using local resources	
Native tiling	Using local tiles for interior and exterior decoration.	Increase durability and preserve beauty and local art.	The need for periodic maintenance and repairs	Using modern and resistant tiles inspired by traditional designs in contemporary buildings	
Natural materials	Using natural materials such as plaster and lime for interior coverings.	Increasing durability, reducing environmental impact	The need for special processes to improve quality and resistance	Using native and renewable materials with modern technologies in new buildings	

A. 2. 2. FEASIBILITY OF USING THE TECHNIQUES OF SHEIKH LOTFOLLAH MOSQUE IN THE DESIGN OF CONTEMPORARY BUILDINGS

Table 15 is dedicated to the general analysis of the feasibility of using different sustainability techniques in Sheikh Lotfollah Mosque for the design and construction of contemporary buildings.

Table 15. Feasibility of using the techniques of Sheikh Lotfollah mosque in the design of contemporary buildings.

Feature	Description	Benefits	Challenges	The potential of use in contemporary buildings
Use of natural light	Using indirect lighting techniques and smart glasses.	Reducing energy consumption, improving quality of life	High initial costs for implementing smart glasses	Designing buildings according to proper orientation and using advanced technologies
Natural ventilation systems	Using natural ventilation systems to control temperature and air flow.	Reducing energy consumption, increasing the comfort of residents	The need for accurate design and coordination with the climate	Using combined ventilation systems to increase energy efficiency in buildings
Use of local materials	Using local and native materials for construction.	Reducing costs, increasing compatibility with the environment	Limitations in access to high-quality materials	Using renewable and recycled materials with modern technologies

Considering the sustainability techniques used in the Sheikh Lotfollah Mosque, the question arises: how can these techniques be used in the design of contemporary buildings? In response to this question, several basic aspects can be mentioned:

a. USING NATURAL LIGHT IN CONTEMPORARY BUILDINGS

In contemporary buildings, the use of natural light can help reduce energy consumption. With the appropriate design of windows and the use of new technologies such as smart glass, sunlight can be used more efficiently. This not only helps to reduce energy costs but also improves the interior of buildings and provides a more pleasant environment for residents.

b. NATURAL VENTILATION AND TEMPERATURE CONTROL

By using natural ventilation techniques, it is possible to control the internal temperature naturally in contemporary buildings. Using dome roofs or opening windows in strategic points of the building can help air circulation and reduce the need for artificial heating and cooling systems. These techniques can be very useful, especially in tropical and subtropical regions.

c. USE OF LOCAL AND INDIGENOUS MATERIALS

In the design of contemporary buildings, the use of local and indigenous materials not only helps to reduce construction costs but also leads to the stability and durability of the buildings. In addition, the use of local materials reduces transportation and thus reduces greenhouse gas emissions. This issue can be considered as one of the basic principles in the design of sustainable buildings.

A. 2. 3. CHALLENGES AND OBSTACLES

Table 16 is dedicated to the examination of challenges and obstacles that may be encountered in the implementation of sustainability techniques, such as those used in Sheikh Lotfollah Mosque, in contemporary architecture.

Table 16. Challenges and obstacles of using sustainability techniques in contemporary architecture.

Challenge	Description	Effects	Suggested solutions	Successful examples
Climate change	Geographical differences and climatic changes may reduce the effectiveness of some techniques.	Reducing the productivity of traditional techniques in different climates	Adapting techniques to local conditions and using mixed methods	Modern buildings with green roofs and natural ventilation systems in different areas
Economic constraints	High initial costs for implementing	Decreased adoption of sustainable techniques		

	sustainable techniques may prevent widespread use.		Using cost-effective solutions and financial support	Sustainable architecture projects with government and private sector support
Lack of knowledge and awareness	Lack of general and specialized knowledge about sustainability techniques.	Lack of optimal use of sustainability techniques	Holding workshops and specialized training courses	Educational programs in schools and universities and professional training

Although the use of sustainable techniques in the architecture of Sheikh Lotfollah Mosque as a model for designing contemporary buildings can be very effective, this approach also faces challenges and obstacles. Among these challenges, the following can be mentioned:

a. CLIMATIC CHANGES AND GEOGRAPHICAL DIFFERENCES

One of the main challenges in using the architectural techniques of the past is climatic changes and geographical differences. For example, the natural ventilation techniques used in the Sheikh Lotfollah Mosque may not be as efficient in areas with different climates. For this reason, contemporary architects should choose and apply appropriate techniques according to the specific conditions of each region.

b. ECONOMIC CONSTRAINTS

The use of sustainability techniques may increase initial construction costs. Although, in the long run, these techniques can help reduce energy and maintenance costs, the initial costs may not be acceptable for many projects. Therefore, architects and designers should look for solutions that are both economically viable and adhere to the principles of sustainability.

c. NEED FOR EDUCATION AND AWARENESS

Another obstacle to using sustainable techniques is the lack of awareness and knowledge about these techniques. To optimally utilize these techniques, there is a need to educate and raise awareness among architects, designers, and even clients. This issue can be addressed through educational programs and specialized workshops in the field of sustainable architecture.

B. DISCUSSION

B. 1. THEORY OF SUSTAINABILITY IN SHEIKH LOTFOLLAH MOSQUE

The theory of sustainability in Sheikh Lotfollah Mosque has been integrated into its design and construction. Since the mosque was designed for the private use of the king and courtiers [31], its smaller size and greater focus on specific functions are notable compared to other public mosques. The sustainability principles applied in this building include several aspects:

- Utilization of local materials: The main materials used in the construction of this mosque include bricks and mosaic tiles, which are sustainably sourced from local sources [32]. This use of local materials has not only reduced costs and energy consumption but also ensured harmony with the region's climate and environment.
- Design for the use of natural light: one of the distinctive features of the Sheikh Lotfollah Mosque is the design of the dome and its openings, which bring natural light into the interior in the best way [33]. This design helps to reduce the need for artificial light and takes advantage of the sustainable principles of using natural resources.
- Natural ventilation: The mosque has guaranteed natural ventilation with proper design of corridors and intelligent placement of openings under the dome [34]. This design helps to reduce the need for mechanical ventilation and energy use in the space.
- Harmony with the climate of Isfahan city: the design and construction of Sheikh Lotfollah Mosque is in harmony with the hot and dry climate of Isfahan [8]. Thick walls and tiles act as thermal insulators and help control the temperature inside the building.

B. 2. THE CONSTRUCTION OF SHEIKH LOTFOLLAH MOSQUE AND ITS CHANGES OVER TIME

The Mosque of Sheikh Lotfollah, which was built during the reign of Shah Abbas I Safavid between 1602 and 1619 [35], is one of the most important examples of Islamic architecture, where the elements of sustainability are well evident in its design [36]. This mosque is one of the most important works of Islamic

architecture and part of the large complex of Naqsh Jahan Square in Isfahan and is known as one of the architectural masterpieces of the Islamic world. The main architect of the mosque, Professor Mohammad Reza Esfahani, was one of the most prominent architects of his time.

Due to its private and limited use, this mosque has remained away from major changes throughout history [37]. Its main structure has remained without any major changes, but several restorations have been done over the years to preserve the beauty and integrity of this building [38]. The most important restorations took place during the first Pahlavi period [39], and recent efforts to preserve the tiling and structure of the mosque are still ongoing.

Due to the fact that the mosque was specially built for the use of courtiers and did not require extensive public services, no structural changes or developments were made to it. It has helped to preserve the historical and architectural authenticity of this valuable building.

B. 3. CONSTRUCTION AND ARCHITECTURAL TECHNIQUES EFFECTIVE IN THE STABILITY AND DURABILITY OF SHEIKH LOTFOLLAH MOSQUE

The research conducted regarding the construction and architectural techniques used in the Sheikh Lotfollah Mosque has been more comprehensive and detailed than the previous studies. While many previous researchers have paid attention to the artistic beauty and architectural decorations of this mosque [6][38][40]-[42], the current research has tried to examine the factors of stability and durability of this building from a different perspective.

Previous studies, such as Iranian cultural heritage research [43], have mainly focused on the artistic and architectural aspects of Iranian mosques, including the Sheikh Lotfollah Mosque. However, these studies focused more on aesthetic and symbolic analysis and examined the role of decorative elements in the transmission of mystical and religious concepts. For example, the studies conducted by Orak et al. [44] analyzed the role of tiling and calligraphy in the Sheikh Lotfollah Mosque. They introduced these elements as outstanding artistic features but paid less attention to the technical dimensions and structural stability of this mosque.

However, due to the importance of sustainability in architecture, the current research has decided to analyze and investigate the construction and architectural techniques that have contributed to the durability of this building over time. This research has shown that the use of quality raw materials, intelligent design of the building, natural ventilation system, and the use of tiling resistant to climate change are among the factors that have not been addressed so far. Unlike the previous research [45], this research has more comprehensively addressed the impact of these techniques on the stability of the mosque and emphasized their role in increasing the life of the building.

One of the main innovations of this research is focusing on the analysis of the natural ventilation system used in the Sheikh Lotfollah Mosque, which has been neglected in previous studies [46]. While previous research mainly focused on the aesthetics of interior spaces and the role of lighting [47], this research has shown that the careful and intelligent design of arches and air currents not only adds to the beauty of the building but also plays an important role in controlling temperature and humidity. Interior space as a result of the preservation of the mosque's materials and durability. In addition, the present research has analyzed the use of natural light in the design of Sheikh Lotfollah Mosque. While previous studies have been limited to examining light as an aesthetic element [48], this research has shown that the intelligent use of natural light has helped to reduce the need for continuous maintenance and maintain suitable environmental conditions for many years. This new perspective can be used as a model for sustainable design in modern architecture.

Finally, the current research has taken a step beyond the previous studies with a more comprehensive and detailed analysis of the engineering and mapping methods used in the construction of Sheikh Lotfollah Mosque. While the previous research [49] has focused more on the general analysis of the architecture of this mosque, this research has shown that the accuracy of engineers and architects in mapping and using quality raw materials is considered one of the key factors in the stability and durability of this building. Therefore, by presenting a new and more comprehensive perspective compared to previous studies, the present research has been able to achieve a better understanding of the factors that have contributed to the stability and durability of Sheikh Lotfollah Mosque. This research, with a more detailed examination of construction and architectural techniques, has not only helped to understand this historical work better but can also be used as a model for the design and construction of sustainable buildings in the current era.

B. 4. THE APPLICATION OF ARCHITECTURAL SUSTAINABILITY TECHNIQUES OF SHEIKH LOTFOLLAH MOSQUE IN THE DESIGN OF CONTEMPORARY BUILDINGS

In the present study, the sustainability techniques used in the architecture of Sheikh Lotfollah Mosque were investigated as models for the design of contemporary buildings. This research aims to provide practical suggestions based on sustainability principles for architects and designers of today's buildings by reviewing and analyzing the architectural features of this mosque. However, this research, beyond the previous studies [50]-[55], has also addressed practical and applicable aspects in the contemporary world.

Previous studies have extensively investigated the architecture of Sheikh Lotfollah Mosque from historical, cultural, and aesthetic aspects [37]. For example, studies such as [56] have been conducted. They have paid more attention to the artistic and aesthetic aspects of this mosque and less to the sustainability aspects and its architectural techniques as modern models. Still, These studies have especially focused on symbolism and cultural communication and have tried to examine the mosque as an artistic masterpiece. Although these researches have contributed to a deeper understanding of the cultural and historical importance of this building, they have neglected the detailed analysis of sustainable techniques and their practical application in contemporary architecture.

On the other hand, some other research has dealt with the technical aspects of Sheikh Lotfollah mosque's architecture. For example, research such as work [57] has investigated the construction and engineering techniques of this mosque and has focused on the methods of construction and use of materials. But even though these studies have made references to sustainability techniques, they have mostly been carried out in specialized fields of engineering and without addressing the contemporary applications of these techniques in today's world.

In the current research, an attempt has been made to fill these gaps, and by focusing on the sustainability techniques used in the Sheikh Lotfollah Mosque, the practical application of these techniques in the design of contemporary buildings has been investigated. In this regard, not only the techniques of natural lighting, natural ventilation, and the use of local materials have been analyzed as principles of sustainability, but also efforts have been made to reinterpret these techniques in a modern and practical way for the design of today's buildings according to contemporary needs. For example, unlike previous researches that mostly describe the characteristics of mosque architecture [58], this research has entered a new field by providing practical solutions and suggestions for using natural lighting techniques in contemporary buildings. Among these suggestions, we can mention the use of smart glasses to control light and heat in indoor spaces, which not only reduces energy consumption but also helps to improve the quality of life of residents. In addition, in the field of natural ventilation, this research has tried to adapt these techniques to modern needs by more closely examining the techniques used in Sheikh Lotfollah Mosque. For example, in contemporary designs, the use of opening windows and domed ceilings have been proposed as solutions for natural ventilation that can lead to a reduction in dependence on artificial heating and cooling systems.

Another innovation of this research is to pay attention to the economic and practical aspects of using local and indigenous materials. Contrary to previous studies that mostly focused on the artistic and historical aspects of the use of these materials [59], this research investigated the economic and environmental benefits of using native materials in the design of contemporary buildings. It not only helps to reduce construction costs but also reduces greenhouse gas emissions and increases environmental sustainability.

In general, this research seeks to present a new approach to sustainable architecture by examining the sustainability techniques used in the architecture of Sheikh Lotfollah Mosque and proposing practical solutions for the use of these techniques in the design of contemporary buildings. Focusing on contemporary needs and utilizing new technologies, this approach strives to use the rich architectural heritage of the past as a source of inspiration and guidance in creating a more sustainable future. The current research shows how to use the knowledge and techniques of past architecture and adapt them to the needs and challenges of contemporary architecture.

4. CONCLUSION

This research has successfully achieved its goals of identifying and analyzing construction techniques and principles of sustainability in the architecture of Sheikh Lotfollah Mosque. The results show that this mosque is a unique example of sustainability in Islamic architecture by using local materials and methods compatible with climatic conditions. The findings of this research add to the existing knowledge in the field of Islamic and sustainable architecture because it shows how traditional principles can be used to respond to contemporary environmental challenges.

According to the investigations, it can be concluded that Sheikh Lotfollah Mosque, as one of the masterpieces of Islamic and Iranian architecture, has unique features that have contributed to its stability and durability over time. The use of quality raw materials, intelligent design and precise engineering, ventilation and natural lighting systems, artistic tiling, and continuous maintenance are all factors that have made this mosque remain in good condition after centuries. These techniques and principles used in the construction of the Sheikh Lotfollah Mosque are not only considered as a model for the construction of sustainable buildings in Islamic architecture. Still, they can also inspire architects and engineers in the design and construction of modern buildings. Finally, the stability and durability of Sheikh Lotfollah Mosque show the commitment to using engineering and architectural methods, which emphasize the place and importance of Iranian art and culture in the world and has turned this building into one of the most important cultural and architectural heritages of the world. The use of natural light, natural ventilation, and local materials are among the prominent techniques used in the construction of this mosque. These techniques have not only helped to reduce energy consumption and increase the durability of the building but have also led to the creation of a pleasant and relaxing atmosphere for worshipers. In the design of contemporary buildings, the techniques used in Sheikh Lotfollah Mosque can be used as an inspiring model. Using natural light, natural ventilation, and local materials can help create more sustainable and environmentally friendly buildings. However, architects and designers should look for suitable and practical solutions to exploit these techniques according to the specific conditions of each region and economic limitations. For this purpose, to achieve sustainable architecture in the contemporary era, there is a need to educate and increase awareness about sustainable techniques. This can be achieved through training programs and specialized workshops and help increase the quality and sustainability of buildings. In this way, the rich architectural heritage of the past can be used as a source of inspiration and guidance towards creating a more sustainable future.

The importance of these findings is that they can be used as a model for contemporary architects in designing sustainable and environmentally friendly buildings. This research shows that traditional architectural techniques if properly reviewed and integrated with modern technologies, can help develop sustainable and efficient solutions in contemporary architecture. The applications of this research are wide and can be used in various fields such as urban design, restoration of historical buildings, and architectural education.

However, the present research also faced some limitations, including the limitation in accessing complete and accurate historical sources and technical limitations in the accurate reconstruction of some traditional techniques. For future research, it is suggested that more investigations be done in the field of matching traditional techniques with modern technologies, as well as comparative studies with other Islamic monuments, to generalize the results to other architectural structures. This path can help to develop a more sustainable architecture in line with climatic conditions.

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