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Retrofitting Mechanisms of Valuable Heritage Buildings: Al-Kifl Shrine as a Case Study

Suhaib Abbas Ali*, Kadhim Faris Dhumad

Department of Architectural Engineering, Faculty of Engineering, University of Baghdad, Baghdad 10071, Iraq

Corresponding Author Email: sahaib.ali2014p@coeng.uobaghdad.edu.iq

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ABSTRACT

Historic buildings that represent the cultural heritage of countries face many problems due to natural and unnatural deterioration factors, and their conservation requires multi-level interventions. Scientific and technological progress has enhanced the sustainability of these buildings by providing modern techniques and materials used in all stages of conservation, starting from documentation and architectural survey, determining the causes of damage, and ending with choosing the appropriate technique and material for implementation by international conservation principles. The research problem is the lack of local studies that address retrofitting mechanisms and the role of modern techniques in preserving historical buildings in Iraq. The research aims to identify appropriate techniques, considering specialized technical conditions such as safety, structural compatibility and efficiency to preserve buildings from deterioration. The research focuses on studying the shrine of Al-Kifl in Babylon Governorate as a model. The study introduces the application of a proposed retrofitting mechanisms using modern materials and techniques to strengthen and support the shrine within the comprehensive conservation processes. The study concluded that the mechanisms of retrofitting to preserve heritage buildings used in the study are effective, do not damage details, preserve the authenticity of the building, and predict future damage.

1. INTRODUCTION

The research concerns the concepts related to restoration and conservation, as well as its theories and methods. It focuses on preserving historical buildings, knowing the associated concepts, and determining the methods and degrees of intervention to reach an ideal conservation work that achieves the continuity of the architectural and structural value of the historic building.

Some of the historic buildings are exposed to ineffective restoration work in previous restorations, such as the lack of accurate documentation of the structural and decorative condition of buildings. This has made assessing the quality of these works more difficult and may contradict the recommendations of the Venice Charter, paragraph 16 [1]. Also, ineffective restoration sometimes included the removal or covering of many original inscriptions and decorations in a manner that contravenes international conservation principles [2].

There is a need to adopt modern technologies within sustainable retrofit mechanisms. These mechanisms include advanced technologies, documentation, cleaning, and reinforcement techniques, without compromising the building's historical appearance, while preserving the authenticity of the historic building [3, 4].

2. METHODOLOGY

2.1 Theoretical framework

This research aims to clarify the concept of retrofitting historic buildings, focusing on the role of modern technologies in preserving and rehabilitating these buildings. The flow chart illustrated in Figure 1 represents the retrofitting processes of historical buildings. Three main topics in the process can be explained as follows:

(1) Heritage Building Analysis: Understanding the nature of heritage buildings, their classification, the causes of their deterioration, and determining the required intervention levels, using previous literature and documentation and inspection techniques that continue before, during, and after restoration work.

(2) Retrofitting mechanisms and modern techniques: Reviewing the different restoration methods with a focus on modern techniques in: Documentation and Accurate Diagnosis:

- Visual Documentation such as (3D Laser Scanning, Photogrammetry technique).
- Invisible Documentation such as fiber optic microscope, colorimeter, ground radar, ultrasound, infrared.

(3) Implementation of retrofitting mechanisms:

- Structural reinforcement, such as (Reinforcement: micro-pillars, injection, steel bars, carbon fibers).
- Cleaning and treatment, such as Physical, chemical, biological, and special techniques.
- Application of compatible materials.

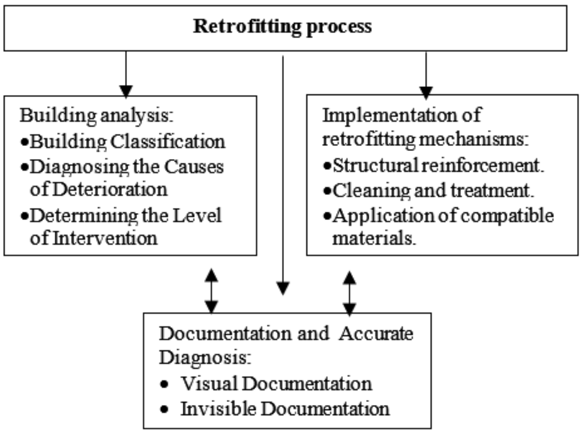


Figure 1. Flow chart of retrofitting process in heritage buildings

2.2 Practical study

Case Study (Al-Kifl Shrine): Practical application of the concepts and techniques mentioned on Al-Kifl Shrine and evaluation of the proposed retrofit mechanisms, including:

- Apply survey and documentation techniques, examination and diagnosis, reinforcement and strengthening, cleaning and treatment, and insulation.
- Considering international laws, analyzing the results and proposing future solutions to protect the shrine.

The research studies the mechanisms of retrofitting historical buildings theoretically and practically, focusing on modern technologies. It presents the Kifl Shrine as a case study for applying these technologies and evaluating their effectiveness.

3. RETROFITTING OF HERITAGE BUILDINGS

3.1 The concept of retrofitting

Retrofitting is the installation of new or modified parts or equipment in an existing object or its adaptation for a new purpose [5, 6]. In heritage building conservation, retrofitting is a conscious intervention that balances preserving original values with meeting modern needs using modern technologies [7]. It aims to improve the structural performance of the building using modern technologies. It may include updating the function of the building to adapt it to a modern function without conflicting with its historical and architectural values. The retrofitting process relies on the integration of modern technologies in various stages: surveying and documentation (photography, 3D scanning), inspection and diagnosis), reinforcement and consolidation works, cleaning and treatment (physical, chemical, biological), and insulation works [8]. Retrofitting contributes to preserving the authenticity of the building using compatible materials and techniques [7].

3.2 Retrofitting and conservation

Retrofitting represents an advanced level of conservation, going beyond maintenance and restoration to include targeted intervention to improve the condition and function of the building, and requires a comprehensive strategy that takes into account the building’s location, value, condition, and proposed function, to preserve and enhance the building’s value [9].

Conservation interventions are limited and reversible, meaning that any future restoration or repair can be removed or replaced. International conventions refer to the concept of reversibility. The Venice Charter of 1964 states in paragraph (12): "All additions intended to replace missing parts must be recognizable from the original and must be designed and implemented in such a way that they can be removed without damaging the original structure of the building" [10].

The Burra Charter of 1979 also emphasized the principle of reversibility in paragraph (15.2): "New changes or additions must be capable of being removed or retracted without affecting the original materials or causing damage to the original elements" [11].

The ICOMOS Charter guidelines stated: "Interventions in historic structures must be as reversible as possible and must be carried out in a manner that does not damage the original historic fabric" [12].

The aim is to maintain the continuity of the building over time through appropriate use and modifications [13].

Several levels of conservation are determined according to the nature of the level of intervention required to preserve the historic building, noting that any conservation work can include a wide range of these levels and concepts and according to the problems that the building is exposed to. Each conservation method has its own limits and proportions of intervention, and interventions can be carried out using modern or traditional materials and techniques. They can be:

Retrofitting, regeneration, maintenance, restoration, reshaping, rehabilitation, transfer of the monument, reconstruction, reproduction, adaptation and reuse [14]. Table 1 shows the levels of conservation.

Table 1. The levels of conservation

Level	Type of Intervention	Definition
1	Maintenance	Routine upkeep to preserve current condition and prevent deterioration
2	Reuse	Reassigning a new function to a building without significant alterations
3	Adaptation	Minor modifications to accommodate new use while retaining key features
4	Retrofitting	Structural or functional improvements without altering visual character
5	Rehabilitation	Functional and structural upgrades to meet current standards while preserving value
6	Reshaping	Altering some elements to accommodate new needs, potentially changing appearance
7	Regeneration	Revitalization of the building and surrounding urban context
8	Restoration	Returning a building to its original condition using documented evidence
9	Reconstruction	Rebuilding lost or damaged parts based on historical documentation
10	Reproduction	Creating a full-scale replica of a structure for educational or display purposes
11	Transfer of the Monument	Relocating the entire structure to protect it from threats

4. DETERIORATION FACTORS OF HISTORIC BUILDINGS

Damage factors cause problems and deterioration of historic buildings and are divided into two main factors: Natural factors: (climatic, geological, biological, forces of nature) and non-natural factors: (human, urban, technological, cultural, political, economic, and structural defects). These factors cause multiple effects on the historical building, such as organic damage to building materials, cracks, deviation of architectural elements, separation of walls, subsidence of soil, and demolition of some buildings. Technology plays a role in monitoring and identifying these defects to choose the appropriate intervention for conservation [8].

The factors can be divided into natural and unnatural. The study proposes a summarized table for factors of damage and corresponding causes according to various related literature as shown in Table 2 [15-17].

Table 2. Factors, causes and manifestations of damage

Factors	Cause	Manifestations of Damage
Natural environment (climatic, geological, biological, forces of nature)	Climatic factors (rain, temperature, humidity, wind, seismic)	• The appearance of cracks resulting from thermal expansion and contraction • Moisture stains, plaster flaking, and plaster damage • Corrosion of construction materials, such as disintegration and damage to stone • Building collapse
	Biological factors (plant and fungal growth, insects, rodents)	• It breaks down the stone as it grows, allowing water to enter the cracks and accelerating the deterioration of the stone • Erosion of the stone surface
	Animals	• Chemical hazards, such as animal waste
Unnatural	Inaccurate restoration and additions	• Leads to cracks and loss of original elements, such as engravings and decorations
	Negligence and lack of regular maintenance	• Rapid deterioration of components due to lack of maintenance
	Bombing and deliberate sabotage	• Partial or total destruction
	Nearby construction and development activities	• Cracks and structural deformation caused by vibration or excavation near the building

5. MODERN TECHNIQUES

The study focused on retrofitting mechanisms through modern technologies, starting with virtual and non-virtual scanning and documentation techniques and moving on to reinforcement and cleaning techniques, as follows:

5.1 Technologies for virtual scanning and documentation processes

The use of the digital revolution can contribute to documenting historical buildings better than traditional methods in the architectural documentation processes of historical buildings, whether separate buildings or in groups, and studying their potential in the process of exchanging experiences between the various parties interested in the conservation process, which enables them to make sound decisions in this field [18].

For example, laser scanning can be used to obtain the shape and texture of existing landmarks, while three-dimensional modelling can be used to restore damaged or incomplete cultural heritage assets. The process includes 3D digitization, digital data processing and storage, archiving and management, representation, and reproduction [19]. Each device has its own use depending on the available space, required accuracy, and output method.

The benefits of these techniques include the accurate identification of the locations and causes of damage, which helps in choosing the most appropriate methods of treatment and intervention and reducing unnecessary interventions by:

- Providing accurate information about the condition of the building.
- Avoiding interventions that may harm it.
- Providing basic information for restoration and reinforcement operations, which helps in identifying the appropriate materials and techniques for restoration and reinforcement.
- Using inspection techniques periodically to monitor the condition of the building after restoration and detect any new signs of damage [20].

They can be classified into:

- Visual Documentation, Measurement and Exploration.
- Invisible Documentation, Measurement and Exploration are as follows.

5.1.1 Visual documentation, measurement and exploration

With the development of science and technology, many exploratory and documentation programs and devices have emerged that document the visual parts of these devices such as [20-23]:

- Photo Metric. Camera.
- Photogrammetry technique.
- Total Station.
- Close-range photogrammetry.
- 3D Laser Scanning.
- Building Information Modeling (BIM).
- Virtual Reality (VR).
- Geographic Information Systems (GIS).
- Use of Drones.
- Augmented Reality (AR).
- Smartphone applications for heritage documentation.
- Portable LIDAR technology.

Figure 2 demonstrates Laser Scanning and photogrammetry as most techniques used in visual documentation of heritage buildings.


Laser Scanning [24]


Photogrammetry [25]

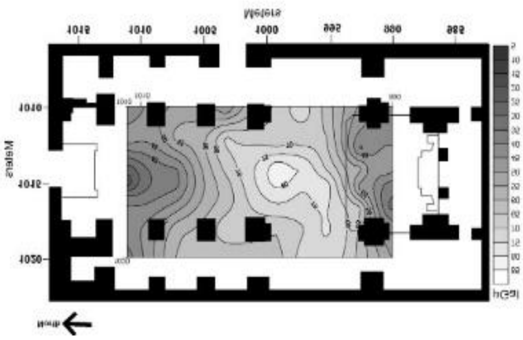
Figure 2. Most techniques used in visual documentation of heritage buildings

5.1.2 Invisible documentation, measurement and exploration

Many exploratory and documentary programs and devices have emerged that document and explore the invisible parts of the historical building's parts and elements such as [26-29]:

- Fibre optics microscopy
- Colorimetry
- Ultrasonic
- Endoscopy
- Micro-Drilling
- Infrared Thermography
- Ground-Penetrating
- Micro Gravimetric
- Acoustic Emissions (AE) Technology

Figure 3 shows two techniques mostly used in invisible documentation of heritage buildings.


Inside don church (Valencia, Spain) [29]

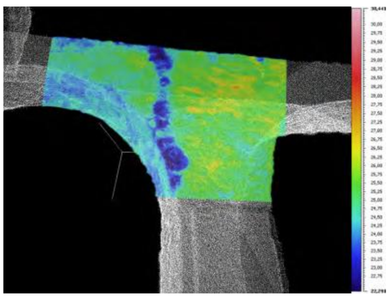

Detecting water leakage by IR [30]

Figure 3. Two techniques mostly used in invisible documentation of heritage buildings

5.2 Cleaning techniques in retrofitting

Historic building cleaning is an essential step in the retrofitting process, following the survey and documentation processes, and aims to remove dirt and harmful materials accumulated on the building surfaces while preserving the integrity of the original materials. Choosing the appropriate cleaning method requires an understanding of the nature of the dirt and materials that make up the building [31]. Cleaning techniques used in historic buildings are classified into three main categories:

(1) Physical techniques: They depend on mechanical force to remove dirt and include:

- Water cleaning: Pressurized water (water jet) or spray is used, and the water can be hot or cold. This method is effective in cleaning limestone and marble, low cost, and easy to control. However, it may not be suitable for silicon stones or deteriorated buildings [32].
- Steam cleaning: Steam is used to remove dirt, sulfate scale, and some types of paint, and is useful for stone surfaces [33]. Figure 4 shows a portable steam cleaner used to clean decorative marble pieces.

Figure 4. A portable steam cleaner used to clean decorative marble pieces [29]

- Mechanical cleaning: involves scraping and chiseling using hand tools or pneumatic machines. This method is used to remove fragile contamination and paint, but may not be suitable for polished surfaces [33].
- Micro-blasting: Uses a fine abrasive material (such as marble powder) with water and compressed air to remove dirt [34].

(2) Chemical techniques: These rely on chemical reactions to remove dirt, and include the use of acids, alkalis, solvents, detergents, and biocides. These techniques require extreme caution in use, and neutralization or rinsing with water after application. Figure 5 introduces cleaning technique using ammonium carbonate in a fibre and paper poultice. Examples of materials used include acidic detergents (such as hydrofluoric acid), alkalis (such as caustic soda), alkaline gels, and enzymes [35, 36].

Figure 5. Cleaning of cement plaster façade details using ammonium carbonate in a fibre and paper poultice [35]

(1) Special techniques including poultices technique, ultrasonic technology, laser cleaning technology, and biological cleaning technology [37, 38]. Figure 6 demonstrates laser cleaning of Greek marble.

Figure 6. Greek marble head after laser cleaning without damage [36]

From the above, there are important considerations for choosing the appropriate technique:

- The cleaning method must be chosen based on the nature of the dirt and the type of materials that make up the building.
- The cleaning methods must be safe for the original materials of the building, and not cause any damage to them.
- It is preferable to start with the least harmful methods and move to more powerful methods when necessary.
- Tests must be conducted on small areas before applying any cleaning method on a large scale.

5.3 Modern techniques for treating the infrastructure

Foundation Reinforcement: Micropiles are used to fix foundations without leaving any trace of their use. Micropiles are driven into the soil to support the foundation to prevent soil degradation and provide a new, permanent foundation for the building and maintain its integrity without disturbing the surrounding soil. Problems with this technique include narrow spaces, service conflicts near exterior walls, exposure of some archaeological features during excavation, and changes in the structural behavior of the monument when exposed to earthquakes [39].

5.4 Modern techniques for structural treatment

They are used for structural reinforcement such as wall reinforcement, arches, bars, minarets, cracks and internal fillings. They include:

5.4.1 Reinforcing the structural frame using an anchors system

It works to improve the structural performance of the building by resisting horizontal loads and resisting cracks that have been treated. It is also used to reconnect walls separated from each other and the ceiling [40].

5.4.2 Pressure wall injections strengthen walls

They add a liquid binding material to the building to fill gaps in the thickness of the walls, especially in the walls (Double Skin Construction with Core), where moisture dissolves the internal mortar of the wall, which leads to cracks and separation between the two walls. They are characterized by their speed of implementation, and their disadvantages include the possibility of swelling in the wall when injected in a large, uncalculated quantity [41].

5.4.3 Structural elements reinforcement techniques using carbon fibers (FRP)

It strengthens structural elements that need to increase their load-bearing capacity without compromising the original material. It is implemented using a group of solid fibers assembled from carbon or glass, which are fixed to the surface to be strengthened by coating them with epoxy materials. It is characterized by ease and speed of implementation, and the fibers are made of a material that does not rust, corrode, or rot and is invisible to the eye [42]. Its disadvantages include its vulnerability to heat and combustion and its sensitivity to ultraviolet rays. This technique cannot be used if there are engravings or decorations on the element to be strengthened [43, 44].

Therefore, using glass fiber-reinforced plastic in heritage buildings must be done according to precise standards that balance achieving structural safety and preserving architectural and historical values. This is confirmed by international conservation charters, such as the Charter of the International Council on Monuments and Sites (ICOMOS, 2003) [12].

5.5 Modern techniques in horizontal insulation works

The rise in the groundwater level in historical areas due to leaks from nearby sewage networks has led to an increase in the percentage of salts and the deterioration of the walls. Therefore, it is necessary to isolate the roofs to stop the sources of salts. There are two methods:

- Chemical insulation: This is done by injecting the walls with silicone materials that prevent water absorption.
- As for facade insulation, the insulating material is sprayed on the facade stones to be insulated after strengthening them.
- Physical insulation: This is summarized in cutting the entire wall at the level required to be insulated using a hydraulic saw and inserting PVC strips specifically for insulation in place of the cuts [40].

6. THE PRACTICAL ASPECT

6.1 Case study selection criteria

In order to demonstrate a sample of retrofitting process of heritage building, Al-Kifl shrine is selected as a case study site. Criteria of selection of Al-Kifl shrine can be summarized in the following:

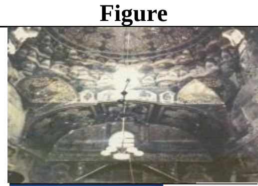
- The site has a significant value in respect to religious and historical vision.
- This site provides a suitable research framework for analyzing the effectiveness of applying modern technologies in documentation, processing, and consolidation, and evaluating their compatibility with international standards, particularly those stipulated in Article 16 of the Venice Charter regarding scientific documentation [1].
- The site is easily accessible.
- Security allowance from the official agency to accomplish the research.
- The study also provides an opportunity to propose strategies that preserve the site's architectural identity without compromising its authenticity, contributing

to addressing the local knowledge gap in the field of retrofitting religious heritage buildings in Iraq.

6.2 Site characteristics of Al-Kifl shrine

Al-Kifl district is located halfway between Hillah and Najaf, about 30 km southwest of Hillah, and is part of Babylon Governorate. Among its most important archaeological and heritage landmarks are the shrine of the Prophet Dhu Al-Kifl and the conical dome of the shrine. The study area is the shrine room and the dome of the stalactites. The shrine building and its dome are characterized by unique elements and details dating back to various historical periods, as shown in Table 3 [45].

Table 3. Architectural element, type and historical period of the shrine room and the double conical Dom

Architectural Element	Type	Historical Period	Figure
The contracts	Tri-sector	The Ilkhanate	
The domes	Conical	Seljuk	
Inscriptions and decorations	Geometric	Old	
Muqarnas	Botanical	The Ilkhanate	

6.3 Proposed solutions through retrofit mechanisms

The research suggested a mechanism for retrofitting using modern techniques in surveying, documentation, cleaning, and reinforcement and adding new services (that have the ability to reflect), such as lighting and air conditioning. These techniques and additions do not harm the originality of the building and its value. Based on field observations and technical reports, the impact of deterioration factors on the Al-Kifl shrine. Various factors affect architectural and structural elements and can be summarized as follows:

(1) Natural Factors

Environmental and climatic conditions have contributed to the deterioration of the Al-Kifl shrine. The most prominent manifestations of this deterioration include: erosion and cracking of the foundations due to rising groundwater levels and salts, and damage to the original floors due to humidity and soil disintegration. Humidity has also caused cracks and swelling in the walls, separation of stone cladding, and fading of plant motifs. Hairline cracks have appeared in the arches, muqarnas, and double dome due to earthquakes, and the external surfaces have deteriorated due to erosion and a lack of drainage systems.

(2) Unnatural Factors

Human interventions and neglect have exacerbated the deterioration of the Al-Kifl shrine, including the stability of the foundations has been affected by demolition, expansion, and neglect, and the replacement of the historical floors with modern mosaic tiles, which are incompatible with the building's authenticity. Non-specialized restoration work also caused the covering and removal of some original inscriptions and decorations, the accumulation of carbon resulting from burning candles, and the distortion of the walls with random electrical installations.

In addition, incorrect maintenance led to the loss of the outer layer and the deterioration of the outer cover. Furthermore, the use of incompatible materials, such as the distortion of the exterior portico with modern marble, resulted in the loss of parts of the building's historical identity, as shown in Figure 7.

Based on what was studied in the research on deterioration factors, in addition to what the research addressed on modern modification mechanisms through modern techniques and materials, the basic steps required after monitoring deterioration factors are:

(1) Conducting surveying work using modern surveying and architectural documentation techniques: using (Total station and Lider scanning techniques), as this technology is available and specialists are present.

(2) Conducting monitoring work for hidden damage in the foundations, walls and dome using ultrasonic techniques to detect damage to materials (wood, decorative ceramics) to determine the location of the damage, and infrared technology (Detector IR) for walls, arches and ceilings to determine the extent of the damage to choose the most appropriate technique for treatment. And using ground-penetrating radar technology to detect defects, cracks or any changes in the foundations and soil.

(3) Carrying out cleaning work using modern cleaning techniques and according to the parts as in Table 4.

Figure 7. Natural and unnatural deterioration factors (neglect, humidity, and the effect of candles)

Table 4. Cleaning methods using modern cleaning techniques or each part

The Element				Cleaning Technology	Notes
Interior elements	The walls 	The part without inscriptions	Physical cleaning	Micro-Blasting	Helps eliminate harmful chemicals
				Water Mists	It does not require much labour. It is used for large areas
				Steam Jet cleaning with DOFF Cleaning sys	Used for curved surfaces and not for use on weak or coloured stones
				Ice jet cleaning	Preferred for iron surfaces
				Justice Cleaning System	It removes colours in the stone and is not recommended for use on coloured surfaces
		The part containing the inscriptions and mirrors		Mechanical cleaning to remove dust, mud and greasy substances using a soft brush and in more solid colour areas Chemical cleaning technique (compress cleaning) Laser cleaning technology for small areas and is not used for mirrors	Cleaning process in which water is an element poses a risk to the decorative element
	Vaults 	Contracts engraved with plant motifs		Chemical cleaning technique (compress cleaning) Mechanical cleaning to remove dust and grease using a soft brush and in harder coloured areas	Cleaning process in which water is an element poses a risk to the decorative element 
	The Dome	Engraved with floral motifs		Chemical cleaning technique (compress cleaning) Mechanical cleaning to remove dust and grease using a soft brush and in harder coloured areas	
	Stalactites	Engraved with floral motifs		Ultrasonic Cleaning is used to clean small and delicate items	
	The floor	Cleaning is not recommended because the existing flooring is an intrusive element (tile). It should be removed and replaced with units that match the historic building			
	Wooden elements			Chemical cleaning of decorated and non-decorated items, organic solvents or compresses method	
External elements	The outer shell			Water Mists Steam cleaning	
	Double conical dome			Mechanical cleaning to remove dust and grease using a soft brush and in harder coloured areas Steam cleaning	
Hidden items	Foundations				Hidden elements that cannot be cleaned but are strengthened and protected from deterioration

(4) Strengthening: The process of restoring the bonding and cohesion of the stone material by linking the healthy parts to the damaged parts of the stone and improving the stone's ability to resist various environmental factors. This is done by:

- Injection method: Injection is done through the cracks and gaps in the stone blocks.
- Using iron clamps: Used in some stones that have large cracks and are fixed with one of the epoxy plastics.
- Freezing: Using ultraviolet rays and works to strengthen the bonds between the deteriorated stone grains.
- Strengthening the stone using plastics (thermo-setting synthetic plastic) and treating fine cracks.
- Silicones: They are characterized by being water-repellent materials, which is a very important feature because water is a major factor in the damage of archaeological elements.

- Adhesives and pastes: Their advantages are to close large openings that exceed 10 cm to improve the mechanical properties of the area surrounding the cracks.

(5) Protection: After the strengthening process, a system is applied to protect the materials from the effects of weather factors or human factors by using surface membranes with (Micro Crystalline Wax).

(6) Structural restoration: Table 5 demonstrates various restoration works proposed for the Al Kefil shrine. This task should be assigned to specialized companies, workers and technicians specialized in this field.

Table 5. Structural restoration works

Soil Treatment	Foundation Restoration	Restoration of Walls, Domes and Vaults	Wall and Ceiling Insulation
Soil injection	Piles and strip foundations	Replace damaged items with new ones.	Natural insulation
Reducing groundwater levels	Micro piling	Wall injection Carbon fibre for wall reinforcement Cintec system for bonding two layers of wall	Physical isolation Chemical insulation Mechanical insulation

6.4 Precision conservation works

The decorative elements and drawings were damaged and decayed, and some of the inscriptions fell. After the initial documentation work, continuous documentation of the decorations and inscriptions during the cleaning stages, and structural reinforcement of the main elements of the building. The restoration operations of the inscriptions explained in Figure 8 can be stated as follows:

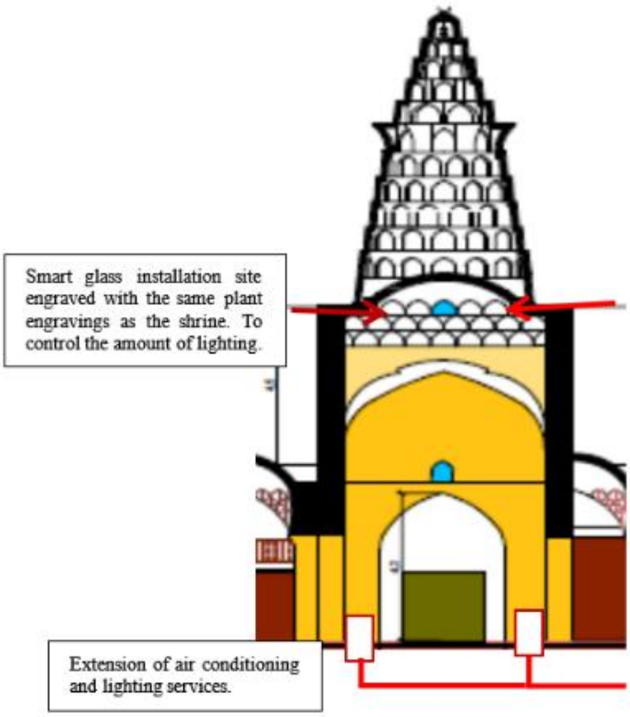


Figure 8. Proposal to add smart services (ventilation and lighting)
Source: Researchers

- Documentation work using 3D imaging and copying techniques with laser beams (3D scanner) as they are more accurate and do not lead to the deterioration of engravings or drawings.
- Completing the plant drawings with the same colors as the damaged drawings and redrawing the missing parts of the mural drawings using 3D printer techniques.
- It is necessary to achieve balance and distinction between the modern and old parts of the drawing. This is what the conservation laws call for.
- Refining the openings in the shrine room, and making a cover with an Islamic inscription (screen) that is open and its openings are at an angle to prevent water from entering when it rains, and removing the electrical outlets that are currently present, to get rid of the vibrations resulting from the fans.

Lifting and removing electrical wires completely because they distort the building and walls. And compensating for sustainable lighting using fiber optic technologies.

- Installing air conditioning systems and creating ground air ducts to maintain the temperature of the building from the inside.
- From the outside: Adding decorative lighting that focuses on the conical dome using modern lighting technologies such as the LED system, which has a long operating life and rationalizes electricity consumption.

7. CONCLUSION AND RECOMMENDATION

7.1 Conclusions

- The mechanisms of retrofitting to preserve heritage buildings used in the study are effective, do not damage details, preserve the authenticity of the building, and predict future damage.
- The retrofitting works are capable of being removed and replaced, and the replaced materials must be distinctive and compatible with their original counterparts.
- In addition to the continuous monitoring and documentation techniques that monitor visible and invisible variables, both tangible and intangible.
- The cleaning techniques are non-destructive. Rather, they enhance the value of the element and extend its life.
- The retrofitting mechanisms, techniques, and materials used are not visible or tangible and do not affect the authenticity of the building and make it resistant to natural and unnatural variables and influences such as earthquake resistance.

7.2 Recommendations

Mechanisms of retrofitting through modern technologies are an effective tool when restoring heritage buildings, provided that they meet several conditions, the most important of which are:

- Testing them and proving their suitability for use before starting work.
- Achieving the principle of reversibility (removability and replacement) and (technology that can be reversed in the future).
- Integration with the old heritage building.
- Contrast and clarity from the heritage building.
- Implementation by specialized companies.
- Equipping the building with sensors and continuous monitoring devices linked to computers and reference systems, with a decision being made to address the problems detected by the devices. This is done after removing all the distorted wires from the shrine building from the inside, as well as the lights and exhaust fans.

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