Case Study

Evaluation of Historic Buildings Reparation in Tripoli, Libya

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Abstract: Historic buildings are regarded as a national heritage for their countries and therefore worthy of conservation. In an attempt to conserve them, various forms of intervention have been made over time. These interventions often lead to a problem when performed without adherence to architectural conservation principles. This paper aims to examine the compliance of reparations of historic buildings in Tripoli, Libya to architectural conservation principles and to discuss the main reasons that led to contradictions to these principles. The research demonstrated that about 40% of the observed works comply with architectural conservation principles. The main reasons that led to the contradictions are lack of knowledge and lack of proper repair materials in the local market in addition to security and safety. The findings have practical significance and provide lessons learned from successful and nonsuccessful experiences that should be passed into future repair works to avoid a repetition of mistakes. **DOI: 10.1061/(ASCE)AE.1943-5568.0000427**.

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Introduction

Historic buildings (HBs) are old buildings that have architectural, historical, environmental, and socioeconomic values. They are regarded as a national heritage for their countries and should, therefore, be conserved. In an attempt to repair such treasures, various forms of intervention have been made over time. These interventions often lead to a problem when done without adherence to architectural conservation principles. This paper explores the nature of Libyan historic buildings' reparation to evaluate the extent of compliance with architectural conservation principles. Also, it sheds light on the main reasons that lead to a contradiction to these principles.

The Levels of Intervention and Conservation Principles

The intervention in HBs means any action that has a physical effect on the fabric of buildings (BS7913; BSI 1998) to extend their life. According to Feilden (2004), the intervention could be one or a combination of the following actions: prevention of deterioration, preservation of the existing state, consolidation of the fabric (causing something to make it stronger), restoration (returning HB to a known earlier state), rehabilitation, or reconstruction.

For guiding the intervention in HBs, the principles of architectural conservation should be considered. The Burra Charter advocates a cautious approach to change, in that we should "do as much as necessary to care for the place and to make it useable, but otherwise change it as little as possible so that its cultural significance is retained" (ICOMOS 1999). In addition, several authors (Brereton 1991; Dann et al. 1999; Dann and Wood 2004; Feilden 2004; English Heritage 2004; Hume 2007) have emphasized that any intervention must be the minimum necessary and historic evidence must not be damaged, falsified, or removed. Furthermore, like-for-like repairs are preferred and repairs should be sensitive and reversible (Dann et al. 1999; Dann and Wood 2004; Hume 2007).

Moreover, the use of traditional (original) techniques and materials for conserving HBs is a priority, whereas appropriate modern (alternative) techniques and materials can be used when the original cannot be used (ICOMOS 1999; Sweetser 2002). For instance, ICOMOS (1999, p. 3) stated that:

> Traditional techniques and materials are preferred for the conservation of significant fabric. In some circumstances, modern techniques and materials which offer substantial conservation benefits may be appropriate.

Furthermore, Brereton (1991) and Lazarus (2007) call for the adoption of proven techniques, either traditional or innovative. For instance, Lazarus (2007, p. 327) stated that:

> Both conventional and innovative conservation techniques should be considered. The latter may provide more cost-effective means of protecting buildings than those that are more familiar, and they may be able to solve problems that in previous centuries did not have a sympathetic solution. However, where they are not yet fully proven it is unlikely that they will be immediately adopted for historic buildings, but worth developing further with that intention in mind.

Regarding affected materials in HBs, Dann et al. (1999) called for the repair of these materials (even if in a deteriorated condition) rather than their removal or replacement because they contribute to a building's character. However, where replacement is necessary, the new material should be compatible with historic material (Dann and Wood 2004; Hume 2007). In addition, Brereton (1991), and Dann and Wood (2004) suggest the need for truth in the use of materials in terms of the new work being distinct from the old, with no attempt to disguise or artificially age the work.

Moreover, Lazarus (2007) emphasizes that the repair materials that are used in HBs should be suitably sourced and integrated with existing materials, whereas new materials should be recognized and kept under review.

In brief, the main architectural conservation principles which provide guidelines for dealing with HBs as discussed could be included in five principles:

- minimal intervention,
- like-for-like repairs (materials and methods),
- repairs should be reversible,
- repairs should be sensitive, and
- truth to materials, in terms of distinguishing old and new materials.

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Methodology

The research presents a case study investigation into the nature of repair work on a sample of HBs in the city of Tripoli, Libya. The compliance of reparations to architectural conservation principles is examined. In addition, the main reasons that lead to a contradiction to these principles are discussed. The method of data collection is observations that included six historic buildings in the city of Tripoli, Libya that have been repaired recently or under repair during the period of field research. The findings are analyzed qualitatively and quantitatively.

The Findings and Discussions

Six historic buildings in the city of Tripoli, Libya were observed: al-Mushat mosque, the arts and crafts school, the Islamic museum, the former British consulate, the former bank of Rome, and the former French consulate. These buildings were built between the 15th and 19th centuries. The construction materials used in these buildings were mainly limestone for walls bonded with a lime mixture, wood and lime mixtures for roofs, in addition to redbrick for domes. The walls were plastered with a lime mixture. The reparations in these six HBs are categorized into four sections: consolidating HBs and treating cracks, dealing with dampness, replacing and restoring the original features of facades, and providing services and security.

Consolidating HBs and Treating Cracks

In al-Mushat mosque, the cracked walls were supported during the repair work (Fig. 1), this process is essential to avoid more damage or risk of failure. According to British standard BS7913 (BSI 1998), the priority should be given to the "work which should be put in hand without delay for health and safety reasons, to prevent imminent damage or to arrest rapid deterioration." Supporting the cracked walls is at the top rank of the priority of work in HBs and complies with the "Repairs should be sensitive" principle.

Furthermore, for diagnosing the situation of cracks in the walls of al-Mushat mosque and Islamic museum, a process of checking the expansion of cracks (Figs. 2 and 3) is used. Expansion of a crack indicates that there is a foundation or a wall problem, whereas the stability of the crack indicates that the situation is unharmed. Diagnosing HBs' condition is an essential work for conserving them, as Brereton (1991, p. 7) stated: "It is essential to identify causes before specifying remedies and in pursuit of this there is a need for a careful and accurate diagnosis including, where appropriate, monitoring of the structure." This complies with the "repairing should be sensitive" principle.

Moreover, for supporting the foundations of the arts and crafts school there is exaggerated use of reinforced concrete (Fig. 4). This practice contradicts conservation principles in terms of "minimal intervention," although reinforced concrete is a suitable material for supporting foundations due to its strength and flexibility. There is a level of uncertainty about the amount of reinforced concrete required to support foundations to keep the building safe. Furthermore, there is harmful use of reinforced concrete for treating cracks in the former British consulate (Fig. 5). Instead of grouting the cracks with a proper material such as lime pozzolan mortar (Torgal et al. 2012), some stones were removed and replaced by reinforced concrete. This contradicts conservation principles in terms of "minimal intervention" and "repairs should be sensitive" and "repairs should be reversible." In such a case, the

Fig. 1. Al-Mushat mosque, consolidation of cracked walls during refurbishment work.

Fig. 2. Al-Mushat mosque, monitoring cracks on a wall.

Fig. 3. The Islamic museum, checking the expansion of cracks.

Fig. 4. The arts and crafts school, exaggerated use of concrete.

Fig. 5. The former British consulate, exaggerated and inappropriate use of reinforced concrete.

main reason that led to contradiction to conservation principles is lack of knowledge regarding treating cracks.

In the former British consulate, in an attempt to consolidate arches, wrong metallic ties were used to support the arches horizontally. This caused cracks in the capitals of columns (Fig. 6). This contradicts the "repair should be sensitive" principle. The main reason that led to the contradiction in this case is a lack of knowledge regarding proper metallic ties for supporting arches. However, in the Islamic museum, prestressed metallic ties were used to prevent horizontal forces in arches (Fig. 7). This process complies with the "repair should be sensitive" principle.

Dealing with Dampness

In al-Mushat mosque, for treating dampness in walls and ceilings, the reparation depended on removing all internal and external plaster layers (Fig. 8). This is also what occurred in the previous refurbishment works in the former British consulate and the former bank of Rome. In addition to harming and reducing the value of HBs' fabric, it caused an increase in the cost of repairing work. More harm might be incurred because of uncovered external walls and domes during the rainy season (before replastering).

Fig. 6. The former British consulate, inappropriate metallic ties were used to support arches.

Fig. 7. The Islamic museum, prestressed metallic ties were used to support arches.

Fig. 8. Al-Mushat mosque, repair work depended on removing all plastering layers.

Fig. 9. The former French consulate, removing old plaster layers of the affected areas.

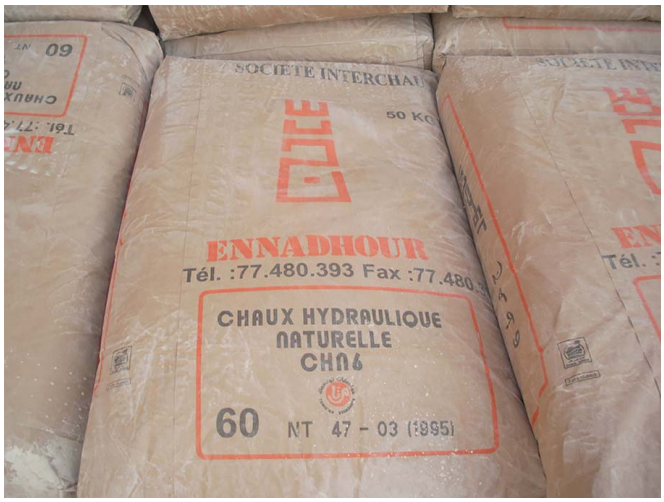

Fig. 12. Al-Mushat mosque, imported materials (hydro carbonate lime) for plastering.

Fig. 10. The former British consulate, dampness in walls.

Fig. 13. Al-Mushat mosque, testing hydro carbonate lime mixture.

Fig. 11. The former bank of Rome, high dampness in walls.

Fig. 14. The Islamic museum, special repair materials were imported for repairing works.

Fig. 15. The former bank of Rome, the main facade was restored according to an old photograph.

Fig. 16. The Islamic museum, repairing metallic-works.

Fig. 17. The former French consulate, using the same materials for restoring the original wooden-works.

Fig. 18. The former French consulate, distinguishing old and new ceramic tiles.

Fig. 19. The former French consulate, electric wires were lined randomly in walls.

Fig. 20. The Islamic museum, underground water supply, sewage, and air-conditioning systems were established adjacent to the museum.

This contradicts conservation principles in terms of "minimal intervention" and "repairs should be sensitive." Repetition of the same mistake in different sites indicates that there is a lack of knowledge. However, identifying and repairing the specific affected areas in the former French consulate (Fig. 9) are economic, easily measured, and comply with "minimal intervention," "repairs should be sensitive," and "truth to materials" principles.

Furthermore, for treating dampness in the former British consulate (Fig. 10), and the former bank of Rome in Tripoli (Fig. 11),

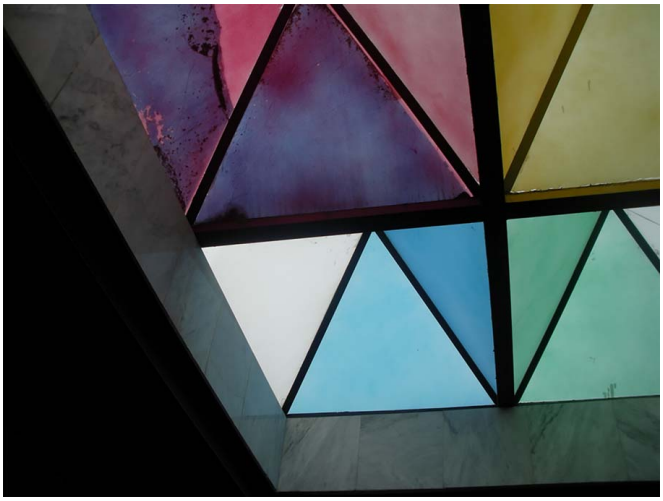

Fig. 21. The former bank of Rome, a modern material was used to cover the internal courtyard.

ordinary cement mortar was used for replastering the walls and ceilings. This caused continuity of the same problem of dampness and serious damage to the HBs' fabric because condensation built up within a stone. In historic buildings, the free movement of water vapor through the fabric of a building in both directions is essential (Edinburgh 2016). This can be achieved when porous materials such as lime components are used for plastering. Moreover, plastering the walls with ordinary cement mortar gives a new appearance to historic buildings. In other terms, HBs appear as new buildings. The use of inappropriate materials results in damage to the cultural value of historic buildings (Myers 1984). Owing to the damage and giving a new appearance to historic buildings, using ordinary cement mortar for plastering HBs' walls and ceilings contradicts "minimal intervention," "like for like repairing," "repairs should be reversible," "repair should be sensitive," and "truth to materials" principles. Unavailability of proper materials in the local market (lime components are not available often in the Libyan local market) and lack of knowledge (repetition of the same mistake in different sites) are the reasons that led to the contradiction of conservation principles. However, in al-Mushat mosque and the Islamic museum, hydro carbonate lime components were imported and used for replastering (Figs. 12–14). This complies with "like for like repair" principle.

Replacing and Restoring the Original Features of Facades

The missing cantilevered wooden window in the main facade of the former bank of Rome (Fig. 15) was restored according to the original features that are taken from old photographs. These photos and their dates detail the historic antecedents of the HBs that give insight on the alterations and degradations that occurred in them over time. This helps in conducting

Table 1. Percentage of the compliance of work done with conservation principles

The work done in the historic buildings	Architectural conservation principles				
	Like-for-like repair	Truth to materials	Sensitive repair	Reversible repair	Minimal intervention
Al-Mushat mosque: supporting the cracked walls during the repair work	—	—	√	—	—
Al-Mushat mosque and Islamic museum: checking the expansion of cracks in walls	—	—	√√	—	—
Arts and crafts school: an exaggerated use of reinforced concrete for supporting the foundations	—	—	—	—	X
British consulate: harmful use of reinforced concrete for treating cracks in the walls	—	—	X	X	X
British consulate: wrong metallic ties used for supporting the arches	—	—	X	—	—
Islamic museum: prestressed metallic ties used to prevent horizontal forces in the arches	—	—	√	—	—
Al-Mushat mosque, former British consulate and former bank of Rome: removing all plaster layers	—	—	X XX	—	X XX
French consulate: repairing the specific affected areas	—	√	√	—	√
British consulate, and former bank of Rome: using ordinary cement mortar for re-plastering	X X	X X	X X	X X	X X
Al-Mushat mosque and Islamic museum: lime components used for re-plastering	√√	—	—	—	—
Bank of Rome: main facade restored according to old photos	√	—	—	—	—
Islamic museum: repairing rather than replacing original wooden- and metallic-works	—	—	√	—	√
French consulate: old windows replaced with new windows made of the same materials and method	√	—	—	—	X
French consulate: old damaged ceramic tiles replaced with new ones having same design and materials and distinguishing old and new ceramic works.	√	√	—	—	—
French consulate: electric wires lined randomly in walls	—	—	X	—	X
Islamic museum: underground hidden facilities established adjacent to HB to provide sewage, water, and air-conditioning systems	—	—	√	—	—
Bank of Rome: internal courtyard covered with modern demountable materials	X	—	—	√	—
The percentage of the compliance of work done with architectural conservation principles	(5/8) 62.5%	(2/4) 50%	(7/15) 46.66%	(1/4) 25%	(2/11) 18.18%
			Average: (17/42) 40.47%		

Note: √: Compliance, X: Contradiction … (more than one √ or X means more than one building).

restoration processes correctly and contributes to achieving the "Like-for-like repairs" principle.

Furthermore, in the Islamic museum, affected original woodenworks and metallic-works were repaired (Fig. 16). Repairing rather than replacing, contributes to achieving "minimal intervention" and "repair should be sensitive" principles. In the former French consulate, due to uncertainty of the durability of the old wooden windows (a safety reason), the original windows were replaced with new windows (Fig. 17). This contradicts the "minimal intervention" principle. However, the new windows were made of the same materials and methods. This complies with the "Like-for-like repairs" principle.

Furthermore, in the former French consulate, damaged ceramic tiles on the walls of the inner courtyard were replaced with new ones using the same size, materials, texture, and colors. In addition, the old and the new wall ceramic works were distinguished from one another (Fig. 18). This complies with "like-for-like repairs" and "truth to materials" principles.

Provision of Services and Security

In the former French consulate, electric wires were lined randomly in the walls distorting the appearance and negatively impacting the strength of the walls (Fig. 19). This contradicts "minimal intervention" and "repairs should be sensitive" principles. The reason that led to the contradictions might be attributed to a lack of knowledge. However, in the Islamic museum (Fig. 20), underground facilities were established adjacent to the historic building to provide sewage, water, and air-conditioning systems. The concept was to make these services hidden and ensure that they do not have negative impacts on the building in compliance with the "repairs should be sensitive" principle.

Furthermore, the internal courtyard of the former bank of Rome (Fig. 21) is covered with modern demountable materials. This attributed to the new function of this building, which is a branch of al-Umma bank (Libyan bank). Although modern materials are inappropriate for HBs, a security reason forced the contradiction to the "like for like repair" principle. However, using materials that can be dismantled and removed from their setting complies with HBs conservation principles in terms of "Repairs should be reversible."

Statistical Results Analysis

Forty-two observations were taken from six historic buildings in the city of Tripoli, Libya. The results demonstrated that around 40% (17/42) of the observed works comply with architectural conservation principles (Table 1). Like-for-like repairs and truth to materials principles achieved 62.50% and 50% of compliance, respectively. Whereas repairs should be sensitive, repairs should be reversible and minimal intervention principles achieved 46.66%, 25% and 18.18% of compliance, respectively. The results demonstrated a low percentage of compliance with architectural conservation principles in observed HBs.

Conclusions

The set of observations in several historic buildings in the city of Tripoli demonstrated that the percentage of compliance with architectural conservation principles is about 40%. The main reasons that led to the contradictions are lack of knowledge regarding proper repairing materials and methods, unavailability of proper repair materials in the local market, and safety and security reasons. The findings have practical significance and provide lessons learned from successful and nonsuccessful experiences that should be passed into future repair works to avoid repetition of mistakes.

Data Availability Statement

All data, models, and code generated or used during the study appear in the published article.

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