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APPRAISING MATERIALS AND THEIR REMEDIAL MEASURES FOR THE PRESERVATION OF HERITAGE ASSEMBLIES

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Abstract

Heritage assemblies are the most resistant and sacred symbols of early civilizations. These include temples, forts, pilgrimage centres, etc., and act as an important part of a nation's economy by promoting tourism. They make a significant contribution to the overall development, therefore it is essential to preserve them. Each assembly has a distinct design, architectural characteristic, material behaviour and possesses a discrete preservation issue that necessitates innovative solutions. The worse stagnation of an assembly takes place due to various factors like environmental loads, aging, material deterioration, inadequacy in traditional construction techniques, and urban development. This is a prodigious loss to a nation as these assemblies are not only a major source of livelihood but are one of the prime sources for retaining the socio-cultural and economic values along with their safeguard. There is a rising demand for the preservation of cultural values and heritage assemblies. Therefore it is imperative to swot the right contemporary material equally compatible with the ancient engineered technology of the heritage assemblies for their preservation. This paper will help to endorse and know the get-at-able materials that can embrace the preservation of the ancient assemblies against deterioration and damage tolerance. Archaeology, Architecture, and Aesthetics (AAA) can be attributed as the prime objective of the paper which extends and throws light on meaningful testimonies of ancient engineering with an effective and advanced knowledge of traditional technology and material behaviour.

Keywords: *Preservation, Ancient construction, Historic materials, Deterioration, Environmental loads, advanced engineering techniques.*

INTRODUCTION

The term 'heritage' is often applied to an assembly that requires preservation because of its historical architectural, cultural, and aesthetic value. 'Heritage materials' are referred to valued objects, historic assemblies, and traditions (Carter and Grimwade 1997). 'Temples' often called as house of gods, irrespective of any culture, caste, and tradition are important and abundant architectural examples to comprehend cultural heritage (Silva 2015). Saving these assemblies and temples from hazardous failure and material deterioration is a very responsible job. Preservation is highly recommended for ancient monuments screening signals of decay, intend to further utilization. But at the same time, the architectural characteristics and aesthetics should not be modified or altered to retain their religious and cultural significance (Nasser 2003). To achieve this the heritage material and traditional engineering techniques should be carefully adopted for a systematic approach with an awareness of application techniques. As the preservation of these assemblies takes place due to distinct grounds the application of materials and construction techniques to be used for minor modifications should be carefully implemented (Douglas 2006). This not only balances good management and efficient economic sense but preserves the nation's legacy and inherently sustainable practices. Further, there is a need to specify the standards for the treatment of heritage assemblies with a distinct approach for consolidation, reproduction, reconstruction, preservation, deterioration perversion, rehabilitation and restoration Table 1.

Table 1 Overview of historic treatment using a seven stage standard approach

	Standard approach	Historic treatment
I	Consolidation	The process of making something stronger refers to the stabilization of weakened areas
II	Reproduction	The process of reproducing the exact geometry and details of a damaged assembly by new construction
III	Reconstruction	Reconstructs disappeared or non-surviving sections of an assembly

IV	Preservation	Accents on maintenance, repair of existing features and materials
V	Deterioration perversion	Addresses unique problems in preserving heritage and its identity in an effective manner
VI	Rehabilitation	Rehabilitation improves the socio-economic, cultural-historic, and or technological values of cultural heritage assemblies**.**
VII	Restoration	Renovation of various original forms, materials, aesthetics, etc, to their former position undeniably to let disappear.

Source: Heritage conservation – Rehabilitation of architectural and urban heritage by: K F H Mood 2019 Doi:10.5772/intechopen.86670.

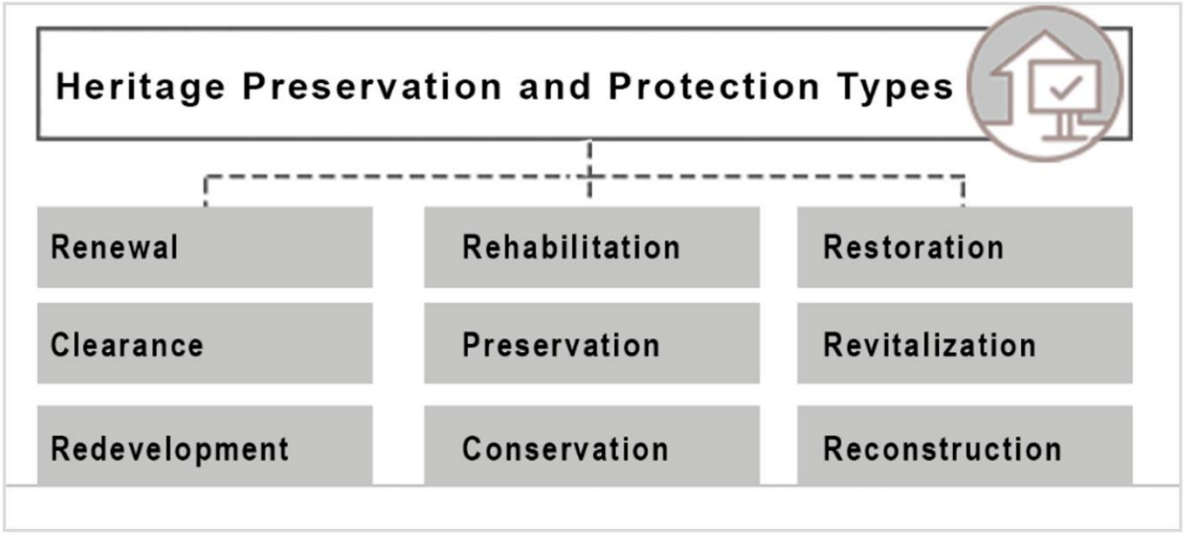
Need for preservation

Does our past worthy a future?

Preservation leads to a greater significance for an assembly and its neighbouring properties. It includes advanced technology, efficient skills, and calculations. The intrinsic purpose of preservation is the innovation for saving the hazardous failure of assemblies Table 2. Preserving heritage assemblies is vital in understanding a countries' national heritage making it an environmentally responsible practice (Sandbhor and Botre 2013). An immediate advantage of heritage assembly is that it is already existing: therefore no energy is required to place a new assembly or to demolish it (Evans 2002) Figure 1. They have their way to sustain their pilgrim values, socio-cultural values, and continuity of historic area as monument zone. The deterioration of such assemblies and sites is due to natural and man-made hazards. It is imperative to preserve the heritage assemblies by:

1. Investigation of the structure after a hazardous event (diagnosis)
2. Material assessment of the structure (the phenomenon of decay)
3. Appropriate application for a longer life span and
4. Upgradation of codes and practices by the competent authorities (Evans 2002)

Table 2 Understanding the heritage protection methods and preservation strategies



Source: Heritage and conservation strategies, understanding the justification and implications, Gdrc.org

Before implementing the preservation act, appropriate investigation and assessment of the physical, chemical, and mechanical characteristics must be determined. Depending upon this information the material selection must shed light on the traditional techniques used in the original architectural form during the preservation stage (Gutschow 2011) .

Figure 1 Preserving heritage assemblies a) Left: Brick assembly Qutub Minar Delhi. b) Right: Stone assembly Temple of Parthenon, Greece. *Source: Maps of India.com*

Historic Preservation Act in a Broad-Spectrum

The archaeological sites, historic districts, temples: the dwelling of deities, and other places of worship are unique fundamental concepts as identified in the National Historic Preservation Act (NHPA, 1966) (Kanefield 1996). The classification of heritage assemblies and sites are graded as Grade I, II, and Grade III as per their sequence of significance. Development approval

for the exterior façade and height regulation should be approved by the heritage management committee to preserve the ancient assembly and beauty of the historic area (Mishra 2019).

Grading

The grading criteria of the historic assemblies are done based on religious and historic significance, associational and architectural significance associated with each structure to analyze its deterioration. The heritage assembly status is furnished with appraisals, photographs, visuals, audios, and hyperlinks of the GIS systems (Hunter 2005). The heritage Grade –I include assemblies and sites having national historic significance symbolizing architectural design, style, technology, and material usage. Heritage Grade II includes assemblies and sites having regional or local historic significance with appraisals of past and present use Table 3. Heritage Grade III includes assemblies and sites having significance for an urban scape that evoke archaeology, architecture, and aesthetics (*AAA*).

Table 3 UNESCO, World Heritage Committee Grading criteria

Year of implementation	Cultural Criteria Grades I, II	Natural Criteria Grades III
2002	(i), (ii), (iii), (iv), (v), (vi)	(i), (ii), (iii), (iv),
2005 (revised)	(i), (ii), (iii), (iv)	(viii), (ix), (vii), (x)

Selection Criteria: See Annexure I, Source: http://whc.unesco.org/en/criteria/

METHODS

The increasing risks of damage require a methodology for the management of heritage assemblies and sites. It is further evaluated using sufficient data of vulnerable assemblies graded on various categories. This leads to categorizing preliminary data which are falling under the vulnerable or endangered category followed by data deficient or least concerned for appropriate evaluations Figure 2.

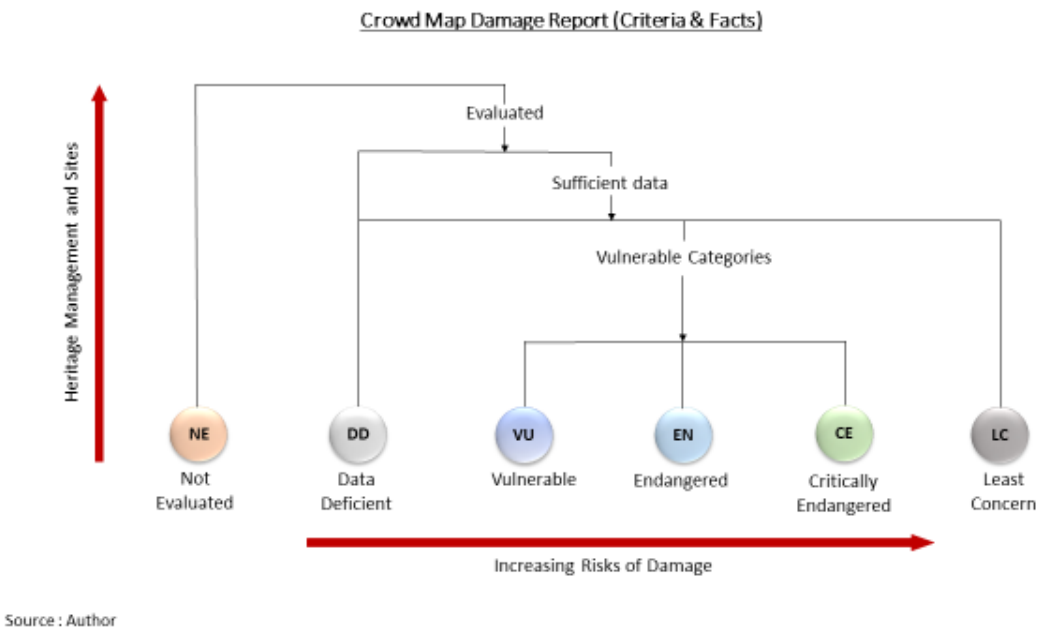


Figure 2 Methodology showing increased risks of damage

Classification of Preservation Methods

There are few systemizations in the preservation field especially for non-load-bearing elements of heritage assemblies to prevent them from deteriorating (Lopez-Perez 2013). Due to structural defects and various other conditions, the preservation activities are different for different surroundings and assemblies. Injection of cracks, fractures, porous plugs along with the contamination of materials in the destroyed historic zones must be appraised. To assign a preservation activity the methodological techniques explained in Table 1 must be understood.

Figure 3 Material evaluation and remedial measures. *Source: WHC, ICOMOS*.

Following are some special materials, methods, and techniques that can be used for the preservation of heritage assemblies, damaged structural fragments, and protective coatings using appropriate repair remedies (Carter and Grimwade 1997),(Lakhani and Sharma 2018) Figure 3.

A. Preservation treatments by materials
B. Cleaning and Biocide treatments
C. Repair: Reinstitution of damaged fragments
D. Rebuilding: Renewal of completely damaged fragments
E. Strengthening: Adoption and addition of structural fragments
F. Mortar repair and Consolidating treatments
G. Patching Materials and protective coatings
H. Reinforcement materials
I. Grouting Materials

The International Council of Monuments and Sites (ICOMOS) principles for the management of preservation worked on data, methods, and deterioration of cultural heritage materials under damage scenarios (Araoz 2011). Hence selection of heritage materials must be constantly

evolved however, ignoring or underestimating the aesthetic and technical characteristics of the materials used can lead to negative results of preservation.

THE HERITAGE MATERIALS

Heritage assemblies impart and endorse respect for history and different societies that lived in different eras. They provide a sense of identity and continuity for future generations (Kurin 2004).

At present, the contemporary practices in the field of preservation of cultural heritage assemblies contribute significant attention to study, material properties. Heritage materials occupy a prominent position as natural stone, bricks, mortar, wood, ceramic, gypsum, sand, and lime. The above remark throws light to focus the complex and dynamic aspects of architectural research which need to be studied, that a historic structure is not only a physical form rather its functions depend on the interrelationship to the local order making it relevant in disaster practices Figure 3. However, the important link between the heritage assemblies, their location, and interrelationship with the local order is essentially found missing and the main problem is due to the existing condition during the preservation stage Figure 4.

Causes of Deterioration

With age and exposure to environmental loads (like wind, hail, UV rays, earthquakes, etc) the resistance of a building material decreases (Sharma 1994). To name a few are

1. Water, Ultraviolet component and Thermal movement
2. Biodegradation, Chemical attack, Mechanical disruption
3. Disaster (earthquake, flood, landslide)
4. Human Vandalism

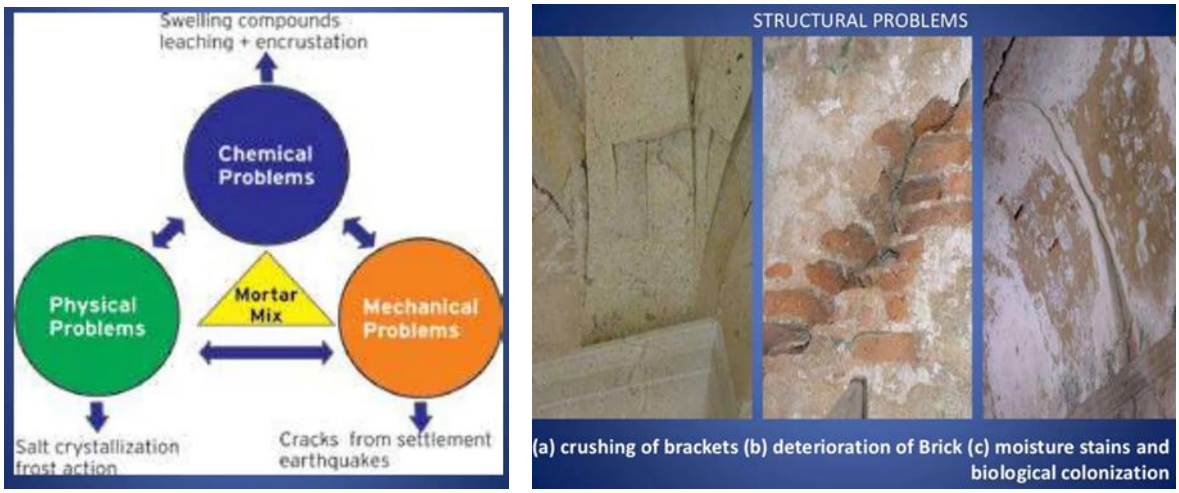


Figure 4 Left: Investigation of problems before preservation. Right: Assessment of structural problems for appropriate methodology. *Source: (Lakhani and Sharma 2018)*

REMEDIAL MEASURES (REPAIR MATERIALS)

Plenty of materials and techniques are available in the industry to preserve the heritage assemblies. The repair techniques should be positioned with strict schedules followed by periodic maintenance as per the requirements. Each technique and material has a different composition and methods, hence it is advisable to check the compatibility of modern and ancient materials before the application.

Wood Preservatives

To protect the heritage assemblies the structural and non-structural wooden components need wood preservative treatments against fungi and insect attacks. The main objective of wood preservation is to increase the life span and thereby reduce deforestation (Barnes and Murphy 1995). Following are a few wood preservatives:

- ✓ **Boron:** Boron the fifth element in the periodic table, is transparent, with no odor, and effective against fungi and most insect attacks with low toxicity Figure 5. It is used to impregnate wood and prevents leaching in case of unprotected soil or environmental conditions (Obanda, Shupe, and Barnes 2008).

Figure 5 Borate-based wood preservatives *Source: USDA Forest Service, a guide for material selection.*

✓ **Vapor-boron:** Vapor-boron is a cost-effective efficient treatment with environmental sustainability to comprehend the mechanical performance of treated material during preservation Equation 1. It uses borate ester and trimethyl as an extremely potent chemical agent for wood. The chemical equation reacts with the moisture present in wood or wood composites results in the precipitation of boric acid forming a by-product called methanol (Vinden, Torgovnikov, and Sethy 2017). The chemical reaction is

$$B(OCH_3)_3 + 3H_2O \longrightarrow H_3BO_3 + 3CH_3OH$$

Equation 1 Chemical reaction of boron with moisture present in wood *Source: (Reinprecht 2016)*

✓ **Copper azoles:** It has a greenish-brown color and little or no odor. It protects wood from decay and insect attack corrosion of metal fasteners relative to untreated wood Figure 6.

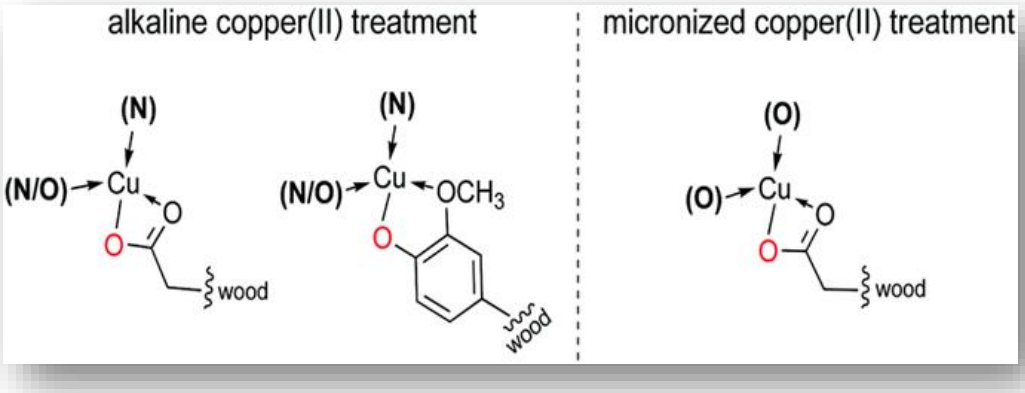


Figure 6 Wood treatment methods *Source: (Reinprecht 2016) (Xue, Ruddick, and Kennepohl 2016)*

Resins

Synthetic and epoxy resins are extensively used during preservation treatments, especially for stone consolidation and protection. This is because they are less prone to physical, chemical, mechanical, and biological deterioration. Hence, the demand for preservative material is swiftly rising due to its excellent chemical resistance, mechanical strength, and effortlessness working (Selwitz 1992). For heritage assemblies, resins are used as a very good grouting material for injection in wood, brick, concrete, and metal as an adhesive coating for high performance when compared to cement grouting Figure 7.

Figure 7 Image showing repair remedial practices over heritage assemblies *Source: Photographs clicked by authors during the site survey, Nepal.*

Glass Fiber Reinforced Polymer (GFRP)

GFRP composite material is a comparatively low-cost composite material as paralleled to carbon and other fiber composites. The original size, shape, and weight of the member remain unaltered (unlike any other jacketing method) therefore Figure 8; this method is particularly useful for strengthening historic and artistic masonry assemblies. GFRP provides minimum

disturbance to the existing structure (Williams 1997). The strengthening work can be performed with the normal functioning of the structure.

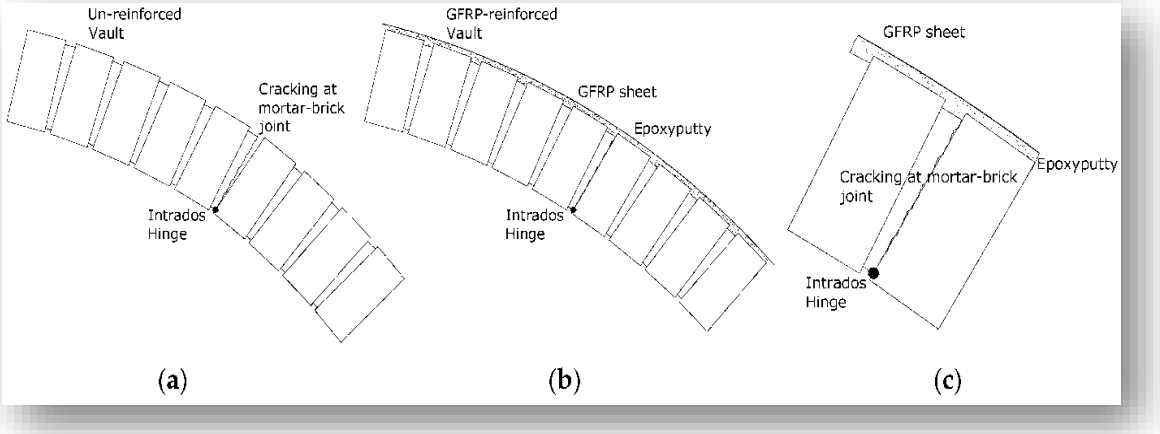


Figure 8 GFRP application on brick and stone masonry joints

Waterproof Agents

Acrylic polymers: They are transparent, resistant to color stability and weathering due to hydrolysis, and do not absorb UV light which degrades the structure. Figure 9 elaborates waterproofing techniques.

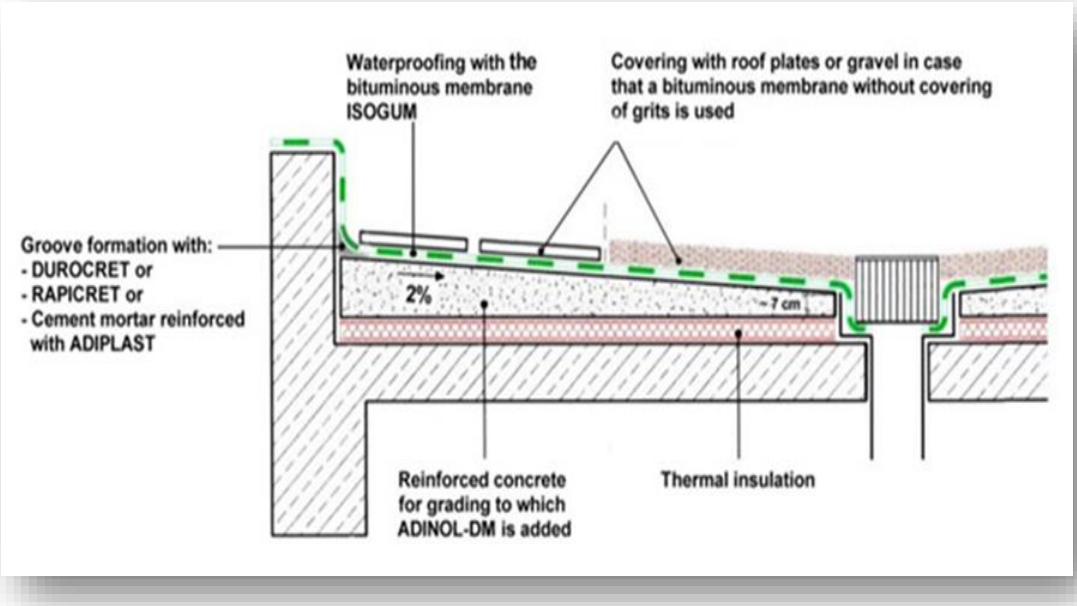


Figure 9 Waterproofing and groove formation application of mortar

Source: https://www.isomat.eu/solution/waterproofing-of-inverted-roofs-en

Styrene-Butadiene Rubber: SBR resists moisture and water penetration into the mortar. It is resistant to fire, toxic gases and acts as an anticorrosive for steel sections. It is harmless to humans and resistant to bacteria and fungus. It is used for extraordinary performance as a coating for floor grouting from 3% to 25% for specialized applications when used as adhesive systems in stone, concrete, wood, brick, metal, and many other materials (Ohama and Ramachandran 1996) Figure 10. Has good mechanical strength, chemical resistance, and is easy to apply. For the monuments, it is a very good grouting material than cement grouts, as it gives good strength to the structural members' Figure 11.

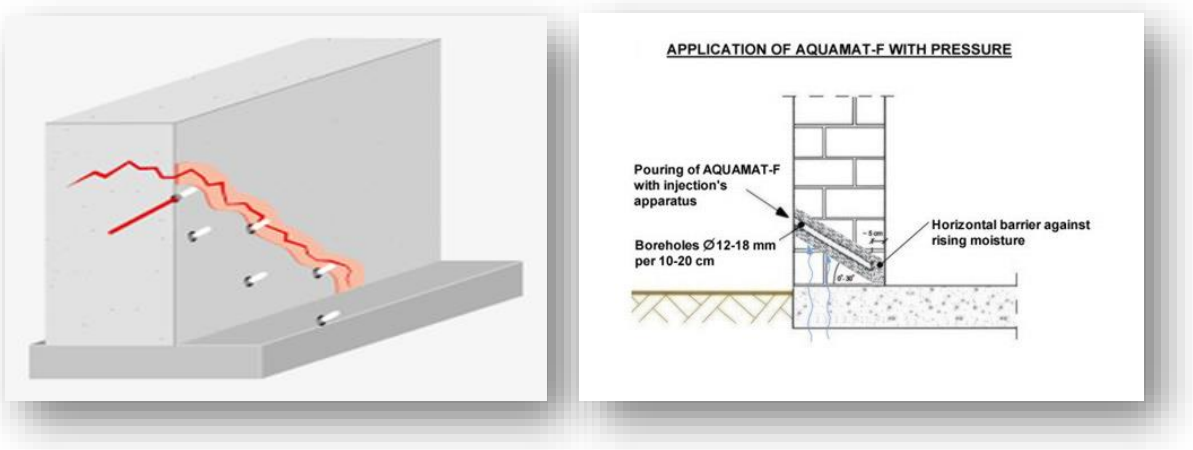


Figure 10 Grouting and injecting techniques *Source: ISOMAT Solution*

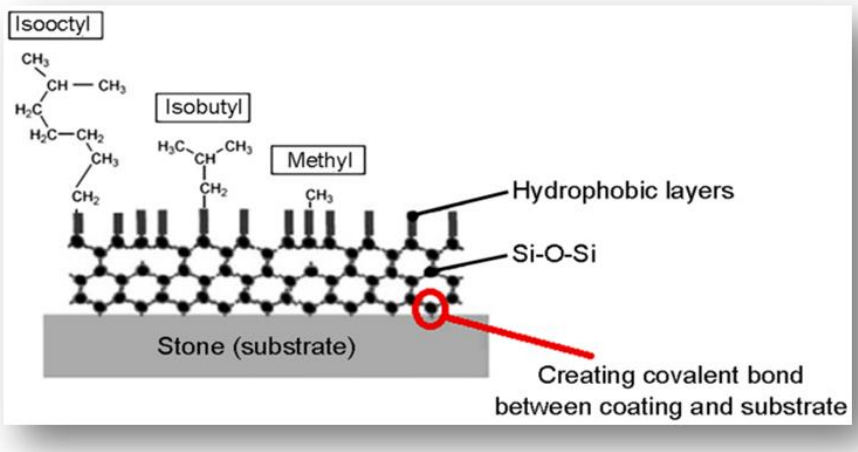


Figure 11 Methodology for stone preservation forming hydrophobic layers *Source: (Zucchelli et al. 2021)*

FINDINGS AND DISCUSSIONS

As the preservation methods for any heritage assembly are complex in nature with invisible difficulties. The cost of the site, construction, and materials are also much higher as compared to conventional techniques due to the challenges involved in it. The use of original material must be encouraged, but due to the non-availability of heritage materials; elevates a major problem of material procurement having similar specifications in texture, strength, color, and quality aspects. It is also observed during preliminary surveys, map preparations, and archaeological GIS reports, require detailed team investigation, inspections, and appraisals as an important step in preservation works of heritage assemblies. Data collection which includes detailed documentation and description is equally challenging due to lack of permissions. Hence Non-destructive survey methods (NDS) can be used for depicting the core strength of wall masonry as an appropriate solution (Moropoulou et al. 2013). The filling of horizontal and longitudinal cracks by synthetic and epoxy resins for structural components such as beams and columns, not only strengthens but also avoids their replacement Figure 10. This proves economical and helps in saving the original material. It is always recommended to practice periodical maintenance to ensure efficient working in the future.

CONCLUSIONS

The deteriorated historic features of any heritage assembly or structure should be repaired rather than replaced. For this replacement of missing features must be carefully documented, along with the application of distinctive materials, finishes, and traditional construction techniques to preserve the Archaeology, Architecture, and Aesthetics (*AAA*) as the prime objective for preservation methods. New additions should not become the essential form of the heritage assembly. A false sense of historic conjectural features that never existed must be discouraged. Additionally, the selection criteria amidst *traditional* and *state-of-the-art (contemporary*) techniques should be taken up for each case with a different contextual

approach. Keeping in mind the least invasive heritage values and their compatibility as removal or alteration of any heritage material having distinct architectural features leads to effect the overall socio-cultural and economic aspect threaded through the so-called term *Tourism* (Committee and others 2003). Heritage assemblies are a gift by our ancestors for ages. The integrity of the original assembly is destroyed to meet the current demands of urbanization. Such endeavours need tremendous education, pieces of training, and pragmatic potentials in the area of preservation with an architectural, engineering, management, and social approach is the need of the hour.

The involvement of more practitioners and technical professionals is required. The potential of heritage assemblies' significance needs to be realized by integrating and contextualizing the scope and work of preservation, not only as a self-contained ancient science, as a technological endeavour of the historic fabric but also as a socio-economic practice. The paper concludes with the recommendation for protecting heritage assemblies that as new techniques and theories continue to evolve, the urban development and historic scenario, the heritage professionals, conservationists, and architects must acknowledge to integrate the historic fabric with manageable change, rather than refute the aforementioned inevitability.

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Disclosure statement

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