International Journal of Advances Engineering and Civil Research (2024)4,(2) 26– 37

ISSN : 2974-4385 (Print) ; 2974-4393 (Online)
International Journal of Advances Engineering and Civil Research
Available online at : https://ijaecr.journals.ekb.eg/

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Rehabilitation of historic structures using modern techniques

Keywords
rehabilitation; historical buildings, modern techniques, Materials, Conservation, Restoration, Principles .

ABSTRACT

When repairing and restoring historical buildings, the challenge is to preserve their value. It is essential to use materials that closely match the originals in both composition and application methods. This paper aims to synthesize current techniques and methods for selecting building materials in the rehabilitation of historical structures. A bibliographic study was conducted to examine the causes and types of degradation, the evolution of construction and building materials over time, and the current methods for analyzing their characteristics and compatibility with the original materials. The theoretical analysis revealed that historical buildings can degrade due to natural causes (chemical, physical, biological, and mechanical) or traumatic events (fires, earthquakes, and wars), leading to a reduction in structural strength and stability and a loss of historical value due to the deterioration of architectural details.

Introduction:

Throughout history, construction methods and materials have continually evolved. Initially, less processed materials, closer to their natural state, were used. Today, complex composites are produced and utilized, offering multiple properties and benefits. However, in the repair and restoration of historical buildings, preserving their value presents a challenge. It is crucial to use materials similar to the original ones in both composition and application methods to maintain the authenticity and value of architectural details. Theoretical analysis has shown that the degradation of historical buildings can occur due to natural causes (chemical, physical, biological, and mechanical) or traumatic events (fires, earthquakes, and wars), leading to reduced structural strength and stability and the loss of historical value due to the deterioration of architectural details. Multi-hazard studies, like the URBASRISK Project (2012), have been conducted in heritage areas to identify and classify the cultural values of historical buildings for mapping and analysis. Using field data, satellite, street, and aerial images, a database of building attributes was created (Georgescu et al., 2015). Scientific literature (Wang, 2008; Chua et al., 2001) also highlights that, despite thorough initial assessments, hidden structural elements or material layers often emerge during renovation or restoration, potentially altering the phases, costs, and duration of the

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project. Thus, a comprehensive diagnosis is necessary, extending beyond a superficial assessment of the visible overall condition.

Research Objectives:

This research aims to study innovative and modern methods and materials used in the rehabilitation of historical buildings to preserve their longevity, history, heritage, and civilization. Here are some specific objectives:

- Assess and evaluate the effectiveness of modern techniques and materials used in the rehabilitation of historic structures.
- Identify methods to ensure that modern rehabilitation techniques preserve the historical and architectural authenticity of the structures.
- Investigate the compatibility of modern materials with original construction materials to prevent any adverse reactions or degradation.
- Analyze the impact of modern rehabilitation techniques on the structural integrity and stability of historic buildings.
- Study the long-term durability and sustainability of modern rehabilitation methods in preserving historic structures.
- Ensure that modern rehabilitation methods comply with local, national, and international regulations and standards for the preservation of historical sites.
- Explore innovative solutions and emerging technologies that can enhance the rehabilitation process while maintaining historical value.

I. Some Considerations when Rehabilitation and Restoration of Historical Buildings:

1- Structure Types: Includes buildings (like castles, cathedrals, museums), bridges (constructed from concrete, metal, wood), cobblestone roads, frescoes/paintings (such as statues and monasteries), etc.

2- Degradation Levels: Ranges from superficial to partial to total degradation.

3- Degradation Causes: Covers general causes (natural or traumatic) and specific causes for localized degradation.

4- Materials Used in Construction: Consists of rocks (andesite, granite, limestone, marble, etc.), wood (beech, oak, etc.), and binder materials (lime, cement, mortar, iron nails).

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5- Material Analysis Methods: Techniques for analyzing materials in the rehabilitation of historical buildings.

6- Material Identification and Selection: Emphasizes identifying and selecting materials for renovation/restoration that are compatible with the originals.

7- Preservation Implementation: Establishing methods to maintain the unique characteristics of all types of historical buildings for future generations.

II. About the Materials used in Historical Structures:

The main materials used in constructing historical buildings were stone, wood, and lime. Stones, either used in their natural state or carved, were sourced locally for wall construction. A mix of lime and sand was used as the binder between the stones. When lime (calcium oxide) was placed between the stones and water added, it formed quenched lime (calcium hydroxide), a white paste that hardened and bonded the stones. Roofs were made from hardwoods, with roofing covers of tiles (burned clay), wooden shingles, or chipped sandstone.

Before industrialization, degradation was primarily due to natural events (earthquakes, floods, etc.) or traumatic events (wars). The development of factories and increased air pollution caused new degradation issues for the building materials of historical monuments. Marble, limestone, sandstone, and mortars, containing significant amounts of calcite, were particularly susceptible to acidic air pollution. Their oxidic composition and porosity were affected by chemical reactions with pollutants. Henley (1967) (Sabbioni, 2003) showed that calcium carbonate could be nearly entirely replaced by gypsum or hard black carbon deposits due to pollution. Calcareous materials also face issues from biological colonization, mechanical degradation, limestone exfoliation, black crust formation, surface dirt, and salt efflorescence.

Methodology:

I. Principles of Conservation, Rehabilitation and Engineering Activities on Historic Buildings:

A) In December 2017, the IIWC in Delhi developed and adopted the "Principles for The Conservation of Wooden Built Heritage" document as an update to ICOMOS's "Principles for the Preservation of Historic Wooden Structures" from 1999. The update initiative commenced in Guadalajara, Mexico (2012), Himeji, Japan (2013), and Falun, Sweden (2016), drawing on foundational texts like the Venice Charter (1964), Amsterdam Declaration (1975), Burr Charter (1979), Narra Document on

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Authenticity (1994), and ICOMOS and UNESCO doctrines. This document aims to establish universally applicable principles and practices for preserving wooden built heritage and its cultural significance. **The Following Principles have been Formulated :**

- Acknowledging the global cultural importance of wooden structures across history.
- recognizing the diverse construction techniques, wood types, and quality used over time.
- Appreciating the craftsmanship inherent in wooden heritage and its transmission across generations.
- Adapting conservation strategies to evolving cultural values and criteria for authenticity.
- Respecting local traditions and diverse approaches to conservation.
- Utilizing chronological and seismic resilience data inherent in wooden structures.
- Addressing vulnerabilities to environmental factors, biological threats, and human activities.
- Promoting community involvement in sustainable preservation and societal benefits.

These principles provide guidance for rigorous conservation and engineering practices to effectively address the unique challenges posed by historic wooden buildings, outlining specific actions tailored to their distinctive characteristics and preservation complexities.

B) According to the ICOMOS document, the primary objective of conservation is to preserve the authenticity of historic buildings, which encompasses their architectural layout, functional design, structural system (load-bearing system), materials used, technical solutions (including connections), and the overall integrity that reflects their historical and cultural significance. This approach considers the evolution of the building over time while aiming to retain all defining features that contribute to its character. **These features, include:**

- The entirety of the structural system
- Non-structural elements like facades, partitions, and staircases
- Surface appearance and distinctive characteristics
- Ornamental woodworking details
- Traditional construction methods and techniques
- Structural materials, including their quality and unique attributes

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Examples that adhere to these principles are often UNESCO World Heritage sites, such as the Church of Peace in Jawor, Lower Silesia province, built in the latter half of the 17th century, and the Gothic Church of the Assumption of the Blessed Virgin Mary in Hoczów, Lesser Poland province, constructed towards the end of the 14th century.

II. Modern Techniques in Rehabilitation Historic Structures and Buildings:

Modern techniques in the rehabilitation of historic structures and buildings have evolved significantly, blending traditional conservation principles with innovative approaches to ensure the preservation of cultural heritage while accommodating contemporary needs and sustainability goals.

1) Non-Destructive Testing and Monitoring:

One of the key advancements in rehabilitation is the use of non-destructive testing (NDT) techniques. These methods, such as ground-penetrating radar, infrared thermography, and laser scanning, allow for detailed analysis of structural conditions without causing damage to the historic fabric. NDT helps in identifying hidden defects, assessing material properties, and monitoring structural stability over time, crucial for making informed conservation decisions.

2) Structural Strengthening and Retrofitting:

To enhance the structural integrity of historic buildings without compromising their authenticity, engineers employ advanced techniques like fiber-reinforced polymers (FRP) and carbon fiber wraps. These materials provide additional strength to masonry, timber, or stone structures, improving seismic resistance and durability while preserving the original appearance.

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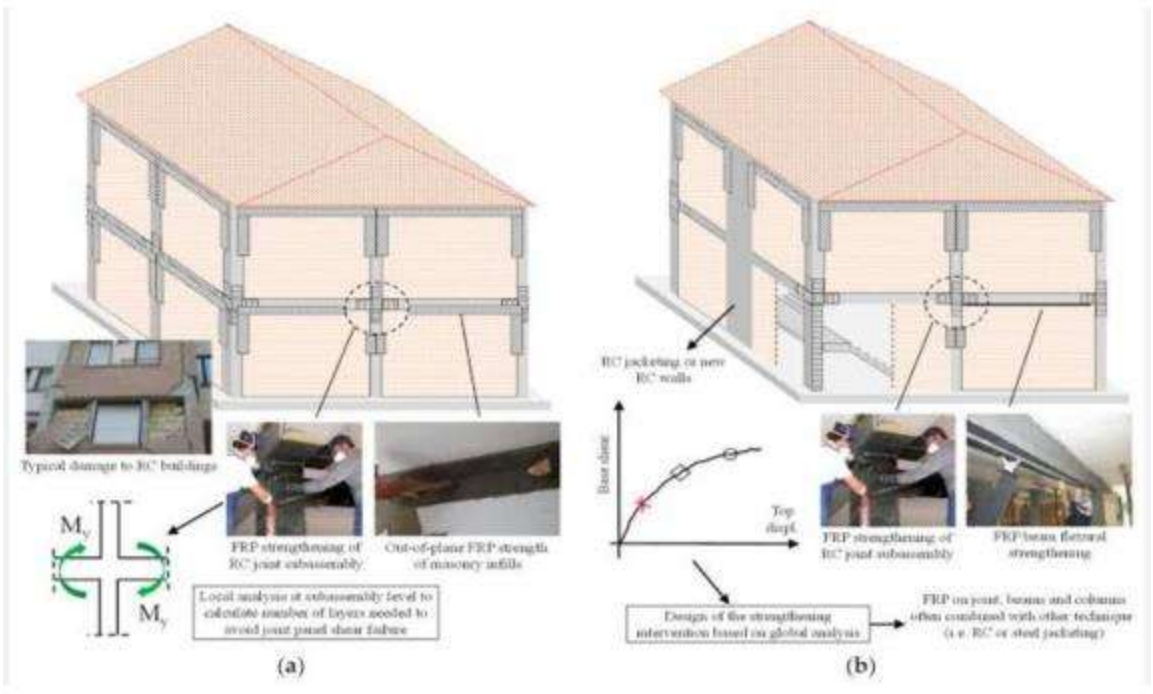

Figure 1 : Polymer Del Vecchio, C.; Di Ludovico,2009

3) Adaptive Reuse and Functional Adaptation:

Adapting historic buildings for contemporary uses while respecting their historical character is a prominent rehabilitation strategy. This approach involves carefully planning interior modifications to accommodate new functions such as residential, commercial, or cultural purposes. Techniques include flexible space planning, integrating modern amenities while preserving original features, and ensuring accessibility compliance.

4) Conservation Materials and Techniques:

Advances in conservation materials such as lime mortars, breathable coatings, and conservation-grade timber treatments ensure compatibility with historic building materials. Techniques like micro-sandblasting, laser cleaning, and poultice cleaning are used for gentle removal of pollutants and biological growths, preserving surface finishes .

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Figure 2 : Lime mortars " The building Lime Forum 2010"

5) Energy Efficiency Upgrades:

Retrofitting historic buildings to meet modern energy efficiency standards is another important aspect of rehabilitation. Techniques include installing high-performance insulation materials, energy-efficient windows and doors, and integrating renewable energy systems like solar panels. These upgrades reduce energy consumption, enhance occupant comfort, and contribute to the sustainable use of historic structures.

Overall, modern rehabilitation techniques aim to strike a balance between preserving the historical authenticity and enhancing the functional viability and sustainability of historic structures. By integrating cutting-edge technologies with traditional craftsmanship and conservation ethics, these approaches ensure that our architectural heritage continues to enrich future generations.

Results of Study:

The absence of historical continuity in architecture and construction across modern Poland, largely due to frequent wars resulting in the loss of many valuable wooden structures, combined with partitioning and shifting borders post-World War II, has led to a scarcity of wooden architectural monuments throughout the country. This lack of continuity poses significant challenges when applying comparative methods during diagnostic and conservation studies, particularly in engineering, architectural, and construction tasks such as reinforcement, protection, repair, adaptation, and reconstruction. Such methods often cannot be directly related to analogous solutions found in existing buildings, with successful implementations being rare and mostly confined to open-air museums.

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A potential solution to this issue lies in referencing early documentation, typically found in textbooks, albums, drawings, and lithographs. Interest in Polish wooden architecture notably grew at the turn of the 19th and 20th centuries, recognizing these buildings as integral to national cultural heritage and necessitating special documentation and preservation efforts. During this period and the interwar years, publications including textbooks, guidebooks, and catalogs emerged, detailing traditional building techniques and presenting historical, contemporary, and modern construction methods, forms, and solutions.

The contributions of Professor Jan Sas Zubrzycki and ethnographer-historian Zygmunt Gloger were particularly significant in this regard, providing invaluable knowledge about historical wooden buildings and their unique architectural and construction techniques. This knowledge is crucial for making informed decisions regarding the preservation, restoration, rehabilitation, or reconstruction of historic wooden buildings, ensuring their historical continuity, integrity, and authenticity.

The distinctive architectural and structural solutions found in historic Polish wooden buildings necessitate a tailored approach to conservation, engineering, architecture, and construction activities. These solutions often reflect local traditions, carpentry craftsmanship, aesthetic trends, and ornamental traditions, serving as expressions of the builder's vision, skills, and technological capabilities.

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Figure 3: Example of wooden building in an open air Museum " sustainability .pdf"

Figure 4 : Façade Walls in a garden side "sustainability 2023.pdf"

It is crucial to consider the specific characteristics and associated challenges of historic buildings during diagnosis, which informs conservation and rehabilitation measures, as well as the overall revitalization process. Ongoing evaluation studies aim to refine this approach for better adaptation to the unique needs of wooden historic buildings.

Depending on the depth and interdisciplinary scope of diagnostic studies conducted, the assessment of revitalization potential can vary significantly. At a broad level, this assessment aids in preliminary decisions regarding the initiation of revitalization efforts. It evaluates numerous aspects, including the technical and structural condition of the building, as well as broader interdisciplinary factors aligned with principles of sustainable development.

This assessment method can resemble a SWOT analysis, providing insights such as:

- Strengths: Positive attributes of the revitalized building, including its technical condition, advantageous location, and historical or cultural significance.
- Weaknesses: Challenges and deficiencies of the building, such as poor structural condition or inadequate installations essential to the load-bearing structure (e.g., damaged ceilings, foundations).

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- Opportunities: Potential avenues for effective revitalization, such as adaptive reuse possibilities, benefits for the local community, economic advantages, and social benefits.
- Risks: Potential drawbacks associated with the revitalization process, including risks related to changing utility functions or challenges anticipated during rehabilitation efforts.

This structured analysis helps stakeholders comprehensively evaluate the feasibility and potential outcomes of revitalization projects, guiding decisions and strategies to ensure the successful preservation and sustainable use of historic wooden buildings.

Recommendations:

Develop a conservation plan that outlines specific objectives, methods, and timelines. Engage multidisciplinary experts including architects, engineers, conservators, and historians to ensure comprehensive planning,

Prioritize the preservation of authenticity by retaining original materials, techniques, and design elements wherever possible. Use reversible conservation methods to avoid irreversible alterations.

Conduct thorough structural assessments using non-destructive testing methods to evaluate the integrity of timber elements. Implement necessary maintenance to prevent deterioration and ensure structural stability

Establish a long-term monitoring and maintenance plan to track the building's condition post-revitalization. Regular inspections and proactive maintenance are crucial to sustain its longevity and cultural value.

Document the revitalization process comprehensively, including successes, challenges, and lessons learned. Share this knowledge through publications, conferences, and workshops to benefit future conservation projects

Conclusion :

In conclusion, the conservation, rehabilitation, and revitalization of historic wooden buildings demand a balanced approach that respects their cultural significance while adapting to contemporary needs. These structures, often bearing witness to centuries of craftsmanship and cultural evolution, require meticulous planning, interdisciplinary expertise, and community involvement to ensure their preservation for future generations.

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Key principles include the preservation of authenticity through careful documentation and reversible conservation methods. Structural integrity assessments using advanced technologies are crucial for informed decision-making, coupled with proactive maintenance to mitigate deterioration risks. Adaptive reuse strategies allow these buildings to serve modern functions while retaining their historical character, contributing to sustainable development goals.

Furthermore, continuous monitoring and education efforts are essential for the long-term sustainability of revitalization projects. By documenting successes and challenges and sharing knowledge widely, we can improve practices and preserve the unique heritage embodied in historic wooden buildings.

Ultimately, through careful planning, respectful conservation practices, and community involvement, we can safeguard these cultural treasures, celebrating their legacy and ensuring they continue to enrich our shared cultural landscape.

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