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HISTORICAL TIMBER AS A SUSTAINABLE MATERIAL STUDIES ABOUT ISLAMIC ARCHITECTURE IN EGYPT

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ABSTRACT

Wood is an old – modern material, It was and still used in a widely range in a various purposes as construction, decoration and remains the most popular material all over the world, The research provides an overview of the role of timber as an important heritage element which forms the main characters and distinguishes features of many historical buildings in Islamic architecture and used widely in many applications, it had been played a great role in construction and structure of buildings, besides that it had been used in a beautiful purpose in different places whether indoors or outdoors use . The research presents the case studies of historical timber in different types of building in Islamic architecture which constructed from more than 1400 years ago, although the historical timber in old buildings exposed to many disasters and faced quite numbers of problems as a result of natural phenomena, man-made, humidity, and termites but it still stands proudly as a great sustain materials.The research shows how he use of timber in historical buildings as sources of inspiration and living evidence of ways of sustainable building practices the types of deterioration which appeared clearly an effect on the statue of historical timber, for that the research introduces some recommendations in the light of ICOMOS international charter " Principles for the Preservation of Historic Timber Structures 1999" that Emphasizes the necessity of taking a serious steps and clear strategy to save our heritage elements.

KEYWORDS:
Historical, Timber, Sustainable, Islamic Architecture, Egypt

INTRODUCTION

Timber has been used as a primary source of building material for ages in the construction of a building. and the Wood Committee's Principles affirms that timber structures from all periods are important as part of the cultural heritage of the world. It is considering the oldest material used by humans for construction after stone despite its complex chemical nature, wood has excellent properties which lend themselves to human use over the centuries. The uses of timber in Egyptian buildings back to the ancient Egyptian Dynasties since (3500 B.C), but it may not have been widely used, that's due to the lack of timber in Egypt most of them are imported from abroad [1]. At the beginning of Islamic architecture when wood trade and import became prosperous in Egypt, the timber is considered a vital part of architectural buildings, especially in construction works as ceilings, stairs, columns, domes, built-in cupboards, etc.

It exposed to decay and degrade rapidly compared to stone, brick or other major historic building materials, as a result of moisture, fungi, insect attack or fire. Wood is actively affected by relative humidity, which causes it to expand and contract. Moreover, wood may be deformed by warping [2].

In Egypt, there are more than half of Islamic monuments all over the world especially in Islamic Cairo which distinguished by the existence of a rich architectural heritage which was built during the various Islamic reigns in Egypt. The Islamic Cairo was listed in the UNESCO World Heritage list in 1979. It is suffered from many factors of deterioration which effect on historical elements and due to loss of its values. Earthquakes considered one of the most dangerous agents which causes the collapsing and deterioration of monuments. Since 1906, a group of earthquakes was recorded in Egypt about 67 earthquakes with a magnitude of 4-5 Richter scale, 11 earthquakes with a magnitude of 5-6 Richter scale [3]. The recent one that rumbled the Islamic Cairo on October 1992 with a magnitude of 5.9 to 6.2 Richter caused a great damage for more than 170 historical buildings [4]. In general, The Statistics indicate that the city of Cairo exposed to three main strokes of

earthquakes every century "earthquake every 33 years" [5]. In spite of all these disasters, which faced historical buildings in Egypt but we are still steadfastly during the times. That is returned to uses sustainable materials and techniques in buildings. In the past few decades, the interest to restore and preserve of these historical buildings has grown extensively, but many problems and mistakes are still showing up and need to urgent solution.

TIMBER COMPOSITION AND PHYSICAL CHARACTERS

Wood is consisting of 3 main components that Cellulose (40– 50%), Lining (15–30%) Hemicelluloses (15 –25%) the most factors effect on Timber are water relative and humidity (RH) [6]. The shape of timber changes due to variations in moisture content. There is a converse relation between temperature and RH to the size of timber and its quality where changes the dimensional (expansion and shrinkage) [7] according to surrounding RH and amount of water into cells as figure 1.

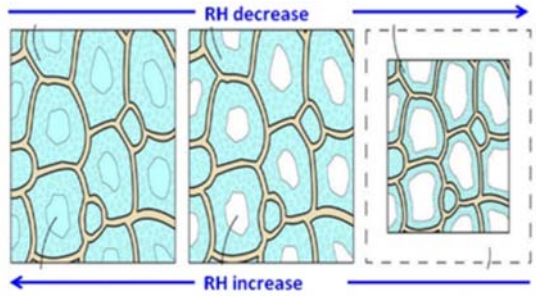

Figure 1. Show the proportion of water in wood cells when RH change [7]

Moisture represents one of the most important factors which damage wood and causes many problems as distortion Design of timber structures and Durability with MC < 20%, where change 1% of MC led to Shrinkage in different directions (spruce & pine) of wood about 0.01% change in longitudinal direction, 0.1% change in radial direction and 0.2% change in tangential direction [8]. There are many causes to raise the percentage of MC such as rain, condensation on walls, or groundwater from wet foundations. It may also result from a vapor source (persistent high relative humidity) [9]. Wood responds to moisture by swelling and shrinking with increases and decreases in ambient RH. But wood is anisotropic, meaning that moisture-related dimensional changes vary in its three principal axes—longitudinal (parallel to the grain), radial, and tangential. The most pronounced moisture response is in the tangential direction, where wood may swell up to eighty times in longitudinal direction, While In the radial direction, wood swells about half as much as it does tangentially [10].

In a hot and arid atmosphere in most Arabian countries. Timber had suffered from many problems, The layout of Egypt helped to use timber where located in the north-eastern part of Africa, its latitudinal position between 22o and 32o N place. It firmly in the sub-tropical dry belt (with average rainfall of 432.1 mm and RH = 62.5% to 74%), Solid wood (timber) has been utilized as structural elements in historical buildings for previous physical reasons besides its sociology side where comfortable for people to live.

The research studying the old timber in historical buildings which have been exposed to outdoor factors for long periods as changes of temperature and moisture as figure 2. The structure of ancient timber is much more complex and diverse than new timber. Fibers are shaped something like tracheid, but are much shorter(1mm) and tend to be round in cross-section and connected end to end, which due to change and difference in its diameters where the ends decrease in size and diameter became less than middle as figure 3 in addition to Erosion of smooth-planed surfaces of various wood species [11].

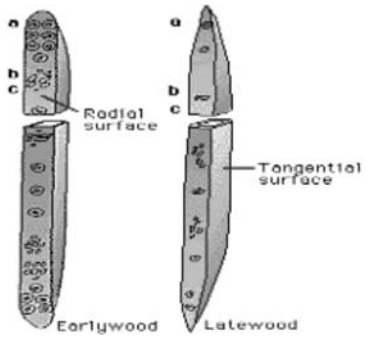

Figure 2. The shape of new timber and ancient one [7]

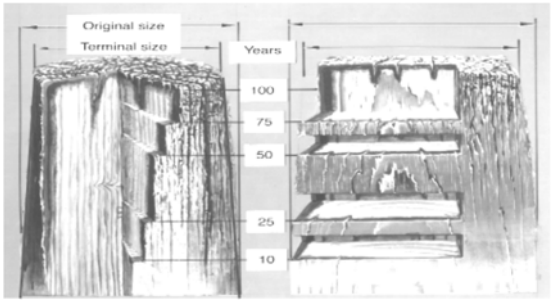

Figure 3. The effect of weathering process on round and square timbers, interior wood below surface is relatively unchanged [10]

SUSTAINABLE TIMBER IN ISLAMIC BUILDING:

The uses of timber across centuries is reflecting the sustain thinking of architects and craftsmen through several civilization and Islamic era. The status of wood as a sustainable construction material has been reflected upon with regards to different features such as environmental friendliness, durability, waste disposal, recycling and has a lighter carbon footprint than other construction materials [12]. The environmental sustainability recognizes that human activity over time and the health of the environment are interdependent and that environmental health has necessary social, political and economic determinants. Probably the most significant environmental benefit of timber is renewability and biodegradability [13]. Wood is also the only structural building material with third-party certification systems in place to verify that products have come from a sustainably managed resource. It has low manufacturing process energy

and benign air emissions. It is an excellent insulator against hot or cold weather. The old timber buildings remain a model for minimum energy consumption in buildings. It is stiffening and strong properties of structure architectural that bearing pressure loads and distributed it, the construction simpler and safer than steel or concrete construction. A comparison with steel and concrete shows that radiate pine structural timber, for example, has the strength for weight ratio 20 percent higher than structural steel and four to five times better than unreinforced concrete in compression [14].

In old buildings, there was an ecology of materials, a natural dependence between the building materials to create a balance of strength, movements due to changes in humidity and temperature. In many cases, when we add new materials, the balance that once existed between traditional materials is distorted or destroyed. The previous studies found that the traditional timber house had far less impact on the environment in almost every aspect than the modern, fully-insulated timber-frame house. For example, the global warming potential of the timber-frame house, expressed in CO_2 equivalents, was more than double that of the ancient Buildings and –Timber houses. The building materials used in old-houses are mainly naturally sustainable materials and used in their natural form and therefore create a minimum of waste. The negative side of the traditional timber buildings was that the total energy consumption was twenty percent higher compared to the fully insulated modern buildings.

The measured energy consumption for heat and electricity is 37 MWh/year and the area heated to 10 °C or more, Atemp, is 235 m2. The key figure for energy consumption is 157 kWh/m2 and per year. This is considered low for an old building in this category, according to the comparative key figure given, statistic interval 170–208 kWh/m2 and per year, when calculating the energy performance of the building [15] at Boverket's web site. Timber stores as much as 250 Kg/m3 of carbon dioxide (CO_2) and releases only 15Kg/m3 into the atmosphere. In contrast, Steel, Concrete and Aluminum store no carbon dioxide while they release 5320 Kg/m3, 120Kg/m3 and 22000 Kg/m3. respectively into the atmosphere.

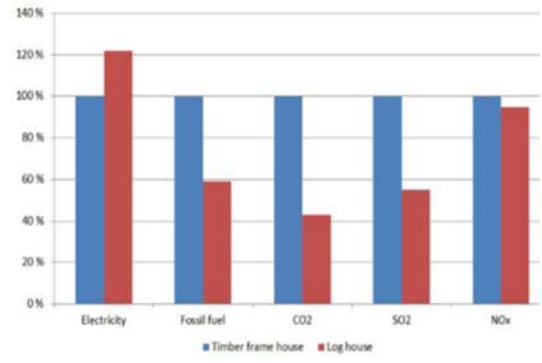

Figure 4. shows a normalized consumption and emissions for the timber frame and the log house. (After Fossdal and Edvardsen (1995).

In addition to its environmental benefits, wood's natural beauty and warmth have a positive effect on building occupants. In two studies conducted at FP Innovations and the University of British Columbia, for example, the use of visual wood was shown to lower sympathetic nervous system (SNS) activation, which is responsible for physiological stress responses in humans [16]. As a result, an increasing number of architects are incorporating wood in their designs as a way to achieve goals such as improved productivity and performance in schools and offices, and better patient outcomes in hospitals [17].

WOOD ELEMENTS IN ISLAMIC ARCHITECTURE

There were two main groups of wood in Islamic architecture in Egypt: local wood and imported wood. Most of the wood were imported from abroad [1] as Sudan, Indian, Ethiopia and Arab Gulf countries. It was used for furniture, coffins, boats, etc., because the local species were weak able to bends and curves with the use of big panels and affected on the great differences between the temperature in the orbital climate to cut into small pieces and assembled it "fillings consolidated" in the furniture industry which based on a combination of pieces of wood with different geometric shapes and avoids the phenomenon of large wooden arched pieces.

Local wood as buckthorn- Sycamore- Acacia- Cypress [18]. The most important types of a local wood called (Azizi) which characterized by the good bearing of natural factors such as rainwater. It was used in stairs and various construction elements of outdoor applications besides its ancient appearance, also used Sycamore principally for lumber, veneer, railroad, fence posts, and fuel which not affected on water, the lumber is used for furniture, pallets, flooring and some decorative panels. Therefore, they used Acacia which characterized by strength, solidity tends to redness as the shape of beech when exposed to atmosphere peppered dark veins and discoloration and basically used in construction works. Beside Oak the main characterized of it heartwood is rated as very resistant to decay fungi and difficult to treat with preservatives. It was used in the big form of flooring, timbers, boat and ship construction, and decorative veneers [19].

It was used as a wide range in Islamic architecture building as mosques, houses, markets, and schools, etc., principally, crafts and builders are interested in an appropriate level of performance. The type and level of performance vary for the applications of timber in a building. It is important that a builder understands what performance is required for each material to be used in the structure. Solid wood (timber) has been utilized as floors, beams, ligaments, cantilevers, etc, and various purpose in Islamic buildings it has also taken the tendons which linked wooden ceiling without any vibration or deflection, but even they admired with this material by exaggerated in drilled with Plant inscriptions, Quranic verses, and calligraphy and decorated it with golden water whether indoor or outdoor applications.

CEILING & ROOFS

Timber had played a major role in covering the roofs in most Islamic buildings where transferred the loads and distribute it to the shoulders, then on horizontal stone walls to foundations in the ground in safely way in old and Traditional technique still used in some houses in villages in Egypt where implemented as a sequence steps as follow:

The main Timber stacked in the short direction of the room to be performed by the ceiling with distance far between each other 50 cm and install these timber in building and entered into the wall then arrange small wooden branches (secondary beams) in the direction perpendicular of main Timber, and stacked next to each other so as not to leave any spaces between them, and it is diameters about 3-5 cm as figure 5 a-b, then coated with layer of clay and covering layer to prevent water for reach the timber then decorated and drilled inside the ceiling.

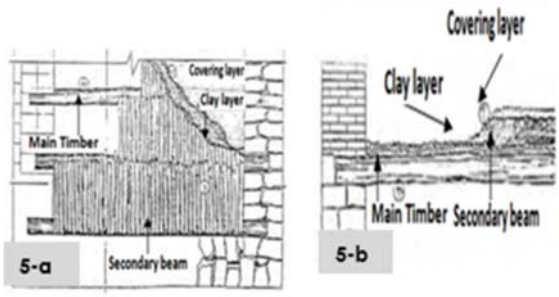

Figure 5-a. Plan of Traditional ceiling in Islamic buildings
Figure 5-b. Section in Traditional ceiling

LIGAMENTS.

Timber can be used also as a ligament element between columns, It was a Horizontal wooden tie beam in both direction above column capitals connecting outside stone walls with internal structure [20] also it has a great benefits to hang the lamps and small chandler on it where provide the lights in different places in the mosque as figure 6 show these ligaments inside Amr Ibn El-Ash mosque in Cairo 642 AD the first mosque in Africa.

Figure 6. Historical photo of Amr Ibn El-Ash mosque in Cairo

THRESHOLDS.

Threshold is a straight structural element used to cover the holes whether doors and windows of stone buildings, it was made of a straight piece of wood to get a flat surface and set according to the type and display the hole and cover the timber with a layer as figure 7.

Figure 7. Timber thresholds to cover the holes, "Doors and Windows"
Source: resarcher 2012.

CANTILEVER.

A cantilevered timber had appeared in Islamic architecture as a part of the form and structure of buildings. Its support wooden corbel as figure 8. It is extending outward away from a wall of the building. Cantilevered design as a beam that holds up the balcony is secured only at one end, meaning the other end that extends outward from the structure is unsupported, this design is safe for use and aesthetically pleasing and comfortable as figure 9.

Figure 8. Wooden Corbel in Al-Razaz house1480 A.

Figure 9. Part of the main facade of the Labib Jabr house in 18 century monument No. 497

STAIRS.

The architects and craftsman used Timber in stairs whether the indoor and outdoor building in Islamic architecture as a beam in a Traditional technique hasn't still used now, it also used in balustrades and handrails as figure 10.

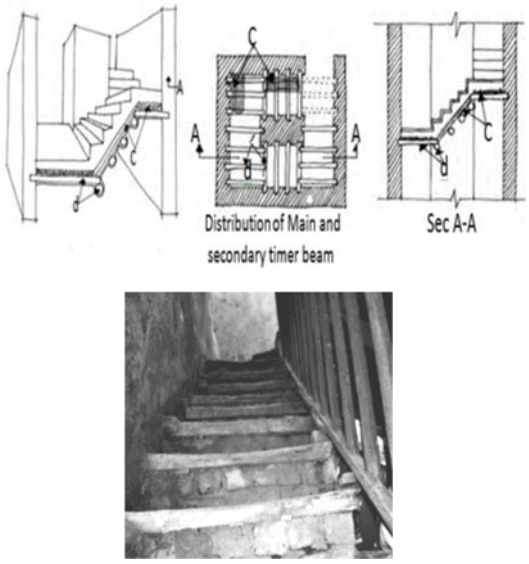

Figure 10. Timber as a beam, handrails and noise of stairs in one of old houses in Egypt
Source: Researcher 2013

THE PROBLEMS AND CAUSES OF DETERIORATION

The deterioration in timber moves from the outside towards the inside; in wood, decay and deterioration caused by fungi and insects may start from within and move outwards. These characteristics necessitate various interventions in historic timber structures to preserve them, which are different from those which are used in structures constructed of more permanent materials. In the second half from last century, the historical buildings in Islamic architecture in Egypt faced Many challenges and disasters which had due to many agents of deterioration that effect on many Historical elements mostly timber and its susceptible to damage and loss its value as following figure 11:

1. Natural disasters: the bad impact of October 1992 earthquake that rumbled Islamic Cairo and damaging 170 historic buildings [4] and increasing its degradation which caused offsets of the construction elements of horizontal and vertical link and deeply affecting in increasing the cracks and crevices and inclination of some timber roofs.
2. Heavy and dense Traffic in ancient historical Cairo and the effect of car exhaust and pollutant agents on the wooden elements on facades.
3. Climate changing and Thermal movement, Incorrect temperature "Direct and undirected Solar Radiation".
4. Saturation of walls with humidity and salt as a result from increasing the underground water level around the Archeological site in Islamic Cairo.
5. Neglecting and leaving the timber elements in the historical building for a long period without restoration and maintenance process.
6. Weak of infrastructure system in the surrounded urban of the historical building and poor sewage water system.
7. Incorrect relative humidity and Moisture movement includes: Rainwater, Services areas (Bathrooms & kitchens).
8. Bad Human Interventions "Material Bad use &Modifications" and incorrect rehabilitation (wrong use).
9. Attack by Pests, white ants and termites.
10. Lack of Protective methods in heritage sites to preserve historical timber and Lack of Specialized Storage Facilities to save wooden elements.

Figure 11. Forms of deterioration

CASES STUDY

We have many successful case studies to intervene and treat the historical timber in ancient houses as: Al-Razaz house, El-Hwarry house, Al-Sehamya house and many others. Bayt Al-razaz is one of the oldest Islamic houses in Bab Al-wazir street in Islamic Cairo, its back to Mamlouk era in 1480 Ad. listed in Egyptian Ministry of Antiquities as Monument No. 235, it is consisting of 178 rooms on four levels [21] most roofs of it were suffered from many signs of deterioration. The Project records the trend of deterioration that appeared on ancient timber in historical houses in Egypt as a result of previous agents which causes many signs of deterioration on the state of timber [22] as figure 12 (a, b,c,d) :

- Buckling, decomposition and decay of wooden parts.
- Crashing and loss of wooden parts.

- Cracks and separation of most architectural blocks of walls and wooden roofs.
- Deflection of the main beam.
- Sweeping wooden panels and beams.
- Blistering of the color layer.
- Discoloration and loss of color Layer

Fig (12 a, b, c, d) The deterioration signs of timber in Al-Razaz house
Source : American Research Center in Egypt (ARCE)

THE RESTORATION PROJECT INCLUDED

The restoration project of the historic house has been achieved through the cooperation of American Research Center in Egypt and the Supreme Council off Antiquities. The Executive group examined all parts of the building and found that groundwater and rainwater are the main reasons affecting the house that led to the deterioration of most wooden elements and historical timber in house. Basically, the timber is restored back to its original condition by removing decayed section and replacement is made by using new timber. Each of the conservation for timber buildings are differed in which the selection of techniques depended on the cost, the selected approaches, total building condition and deteriorations and the availability of resources, the team of work had solved most problems which faced them in a successful way as sequences steps as figure 13 :

- Preparing all data of the monument which includes the archaeological and architectural analysis and registering the monument and all the architectural and decorative details.
- Registering and monitoring all the problems around the monument whether networks of roads, sanitation, electricity, and etc.
- Surveying monitoring and documentation the current situation of all historical elements of timber.
- Examine all roofs and record the signs of deterioration of each.
- Classified the degree of deterioration "sever - moderate- fit" cases to groups.
- Determine the standard of the intervention of each.
- Consolidation the old timber then removes the inside and decorated layer to repair and restoration
- The main beams of exterior layers and insert the new timber instead of damaged ones.
- Strengthening the ceilings by using modern wood "Baratim" added to the old wood and became solid.
- Replace all decay timber with others with taking into consideration distinguish between old and new ones to save the historical evidence as Venice charter 1964.
- Implementation of the insulation layers to preserve timber from rainwater and to ensure ceilings dryness, and prevent water leakage inside ceilings then put the final finishing layer.
- Reinstall the interior layer again and Decorated or recolor it by similar colors.

Figure 13. Sequences of restoration project in Al-Razaz house
Source: American Research Center in Egypt (ARCE)

APPROACH AND STRATEGY.

The research introduces some guidelines and recommendations through record many cases of historical buildings and trends of deterioration which appeared in ancient timber, and in the light of international charters such as the Venice Charter 1964, the Nara Document on Authenticity 1995 for the Principles of the Preservation of Historic Timber Structures, adopted by the ICOMOS International Wood Committee [23]. All previous approaches for preserving the historic buildings go back to the earliest days of modern preservation theory. As early 1839 argued that minimal intervention is the best. The argument was developed further by John Ruskin and the British Society for the Protection of Ancient Monuments in the latter part of the nineteenth century 'Do as little as possible and as unnoticeably as possible' neatly sums up the overruling norm in the preservation philosophy of the late twentieth century. With this modest approach, the material authenticity of the historic buildings as it has been left to us by history is retained. The approach of preservation includes three Phases that deal with the sense of timber as a very sensitive, sustainable and livable material. Secondly conservation process and standards of intervention, thirdly an educational and awareness guideline as:

PHASE I:

Timber play a vital role in express the spirit of building, so when mention historical timber you should make a deep relation with cultural value and preservation of identifying and authenticity of heritage

sites, so all treatment and intervention process should be installed with great respect for historical and aesthetic significance to this ancient timber. From the perspective of sustainable development, it is interesting to observe that old building may be more environmentally friendly than modern ones. Faced with growing pollution and global environmental problems, the new building industry aims to create sustainable solutions for the future. In this respect, a great deal of attention has so far been focused on energy saving. However, this is not sufficient, and a comprehensive life-cycle analysis will give a better understanding of the total environmental consequences of a building project. Life-cycle analysis quantifies energy and material usage, air and liquid emissions as well as the solid waste generated at each stage of a product's lifecycle.

Thus, the life-cycle analysis provides an analysis and assessment of the environmental effects of a building's materials, components and assemblies throughout the entire life of the building. The life-cycle analysis examines the full range of impacts over all the phases of a product's life, instead of focusing on any specific stage [24]. Sustainability can only be obtained if the solutions chosen are simultaneously ecologically viable, economically feasible, and socially desirable as figure 14. If the balance among these criteria is not reasonable, it is likely that the desired outcome will not be sustainable because of failure in one or more of the three areas.

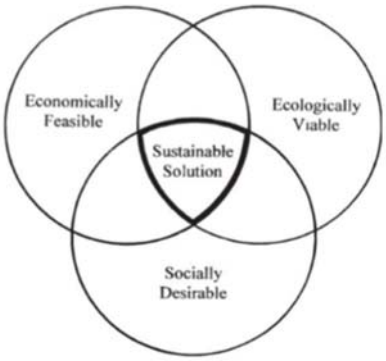

Figure 14. Sustaining desired ecosystem conditions requires that management goals and actions fall within the intersection of three spheres: that they be simultaneously ecologically viable (environmentally sound), economically feasible (affordable) and socially desirable (politically acceptable). After Salwasser et al., 1990.

As a result, an increasing number of architects are incorporating wood in their designs to achieve goals such as improved productivity and performance in schools and offices, and better patient outcomes in hospitals

PHASE II:

- Conservation of Historic Timber Structures considered an ecological approach (2) through treat with the building as a unit and seeking to preserve the load-bearing qualities and reveal its cultural heritage values and begin to follow traditional means in conservation and treatment of historical timber, where not impede future conservation work or access to necessary documentary evidence.
- Monitoring and maintenance consider a very important step for the conservation of timber structure Based on prior study and assessment.
- Minimum intervention in a structure is the best policy, and that preventive conservation should always have first priority. So, any conservation process for historical wood buildings we should follow an up – down approach to change all deteriorated elements "roofs, ceiling, floors, etc.".
- Replacement timber can be used where necessary to replace decayed members with taking into consideration the Performance requirements which will lead to properties that are important for inclusion in the specification. Generally, for timber, this can be accomplished by selecting an appropriate grade, species, and treatment for the timber.
- Accept the use of contemporary materials, such as polymeric materials, and techniques such as structural steel reinforcement in preservation or repair work. The principles advise when a part of a member is replaced, traditional woodwork joints should be used to splice the new part to the existing part, if this is appropriate and compatible with structural requirements "The Wood Committee's Principles, like Article 10".
- We can use the same type of wood in restoration and replacement works as in the original construction. As each species has its own specific physical properties, using the same kind means that the replacement parts will behave in the same way as the original material.
- The preservation and repair of timber structures using traditional methods will first, preserve the integrity of the historic buildings and second, revive the ecological thinking that characterized the societies which produced them. The deal with timber is almost needed a seasonal maintenance as a result from bad weather which may have accelerated the rapid deterioration.
- Ensure from Isolation the wooden roofs in historic houses, by installing an insulating a tight layer to prevent water leakage and consider the slope degree of roof surface to avoid the accumulation of water.
- After restoration timber needs to be coated with a non-slip finish or grooved to provide a slip-resistant surface periodically.
- Compare the results of different treatment options in every stage to choose the best which fit on historical timber in heritage site in Egypt.

- Limiting the use of toxic substances to preserve wood from decay and for repair, such as epoxies, which we do not recommend and avoid Chemical preservatives only when necessary, controlled and monitored, and with great care for the safety of historical timber and environment.
- Estimate the impact of environmental factors (Temperature, RH, light, pollutants, etc.) in timber restoration project and the effect of each on it.

PHASE III:

- Prompt the public awareness and knowledge culture about the importance of timber structure and it is a role in construction and built heritage.
- Cooperation between different relevant authorities to preserve and maintain the elements in historical buildings as architects, chemists, engineers of material properties to reach the best material for the treatment of wood and maintain their appearance without accrue any damage.
- Updated the legal regulations to correspond with new approaches and new experience from recent earthquakes protect traditional technique of built by using timber without destroying their authenticity as a part of cultural heritage.
- Education and Training are necessary as a means of transferring knowledge of timber conservation and Study the international charters before any intervention process.
- Increase the skills about timber treatment and maintenance through holding a periodically training to all relevant professionals who work in this field as architects, conservators, engineers, draftspersons, and site managers.
- Craftsmanship and appropriate technologies should be used in traditional woodworking when splicing new elements to old ones, they should be distinguishable from old as Venice charter1964.

CONCLUSION

Timber was used across eras in various purpose and it was achieved many principles of sustainability through function performance and social, environmental, and structural factors and etc. Historic timber structures considered one of the sources of inspiration and living evidence of ways of sustainable building practices although timber as buildings or structure materials deteriorated faster than others, and required more frequent repair work. But stil, l people prefer this material over the ages.

The Preservation process of existing historical buildings using traditional technique could contribute towards a sustainable future where could well be adapted to the repair of the same structures, as well as to contemporary building practice.

With growing concerns over climate change and the environmental impact of buildings, it stands to reason that green building concepts will be increasing, so all approaches will towards to sustainable design and green construction materials that identify the lowest impact alternatives with the environmental, and the wood will be a best sustainable choice for a growing range of applications.

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