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WOOD STRUCTURES REPAIR

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ABSTRACT

Wood is one of the oldest and most reliable building materials that have been in use for various types of constructions since ancient times. Wooden products and constructions have to be regularly maintained with the aim to increase their lifetime. When they became damaged, through inspection of their state is important, the diagnosis of the cause, type, degree and range of their damage. There are various reasons for the destruction of wooden structures. These are the following: microbiological damages, environmental factors (heat, light, condensation, chemical attack, etc.), inappropriate alterations and repairs, mechanical damage, fire and flood. The most used materials for repair of wooden structures are: wood, iron, steel, concrete, epoxy resins and fibber reinforced polymers. The degrees of intervention on structures range from simple maintenance to deep rehabilitation, with two broad categories of work repair (to simply restore the load-bearing capacity of the building elements that have been compromised by cracks, loss of section and material degradation) and strengthening (to increase the load-bearing capacity as a counter to general decay or due to change in building use).
There are several methods of repairing wooden structures such as: removal and replacement, addition of elements, sealing/filling, repair of cracks, and prothesis. Repair of wood may include splicing repair of degraded or lost segments, the use of inserted or external fasteners, aside from prosthetic repair, injection and consolidation with synthetic resin. Where there is a significant reduction in their sections, structures could be augmented with added members, with replacement only considered as a last resort. Timber members that are otherwise intact but displaced due to impact or movement may be dismantled and reassembled to restore structural connectivity and load paths.
This paper focuses on the materials and methods used to repair wooden structures, also are reflected with concrete figurative cases, some solutions of issues by applying various improving materials in wooden constructions.

Keywords: wood; structures; repair; materials; methods.

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INTRODUCTION

Wood is among the oldest of all building materials. As a natural material, wood is unique, innovative, easy to handle, sustainable, environmental friendly and can be readily recycled. Nowadays, wood has a broad range of uses. Most furniture is made of wood. There are enormous uses of wood: in construction of framework, for decoration (flooring, wall panels, ceiling panels, furniture), for external applications (cladding, decking, pergolas, landscaping, fencing), in making pulp and paper, in making wood-based compositions, etc.

1. WOOD AS A BUILDING MATERIAL

Wood has a large potential for use as a structural and building material. Wood is one of the oldest and most reliable building materials that have been in use for various types of constructions since ancient times. Wood is most commonly used natural building and construction material. There are different types of wood used in building constructions works. Each wood types has its own individual properties and strengths, therefore careful selection of appropriate wood type for a particular application is necessary. Wood is a material that is used for a variety of structural forms such as beams, columns, trusses, walls, flooring, framework and large timber panels, girders, etc. There are a number of inherent characteristics that make timber an ideal construction material. Some of the important properties that help in the section of good quality wood are as follows: color, soundness, texture, grains, density, hardness, warping, toughness, abrasion, strength, module of elasticity, permeability, durability, defects. Wood can easily be shaped and connected using nails, screws, bolts and dowels or adhesively bonded together.

Wood applications has several advantages over the other buildings materials like: it is easily available, available at low cost, exhibit good strength and durability, light weight as compare to concrete and brick, almost all types of timber materials have unique aesthetic appeal, usually better than other building materials, most of the timber engineered wood products create structures that are strong, visually appealing and unique.

2. REASONS FOR DESTRUCTION OF WOOD STRUCTURES

There are various reasons for the destruction of wooden structures. These are the following:

- Microbiological damages- Microbiological damages are caused by microorganism such as fungi and bacteria. The different kinds of fungus damages are caused by different taxonomic groups or species of fungi. Decay, stain, mold and most soft rot are caused by fungi. There are five kinds of microbiological damage: decay or rot, soft rot, stain (largely known as "sap stain" or "blue stain") and bacterial degradation.
- Environmental factors (heat, light, condensation, chemical attack, etc.) - The chemical bonds that hold the constituent of wood together begin to break down as temperatures increase past 100^{o} C. Above 200^{o} C hemicellulose and cellulose begin to break down producing fire and tars.
  Wood exposed to sunlight change color. The ultraviolet component of the sunlight breaks down the lignin in the upper 0.05-0.5 mm of the wood, leaving a loose matrix of partially modified cellulose fibers. This leads to the silvery appearance on the wooden surfaces. Under damp conditions, molds which feed on the breakdown products can cause a similar slow erosion of the surface. The combined effects of light, wind, water and freeze and thaw produce stresses which result in small surface cracks.
  In the most building the air-moisture loading is unusually high because there are drainage faults or some other source of excess moisture. In that case the roof of the wood structure will make a cold surface so that the internal relative humidity sometimes increases to dew point. This leads to decay of the wooden structure.In contact with moist wood, building elements made out of water-sensitive metals may begin to corrode. This does not just harm the metals, it can also

cause chemical reactions in the wood that will eventually weaken the surrounding wood. This will lead to break up the wooden structure.

- Inappropriate alterations and repairs - Structural timbers fulfill a role that can be seriously compromised by interventions that are seen as improvements by building occupants, but take no account of the building construction. These can cause cracking or displacement and even the collapse of wood structure.
  Typically, such interventions that can cause significant weakness and must be avoided are the following: [1]

- cutting deep pipe in joints and floor beams,
- cutting tie beams and braces to insert doorways between attics,
- the removal of structural components to insert staircases,
- converting two rooms into one, without appropriate structural consideration,
- trapping water, for example, by applying external mortar repairs to timber frames.

- Mechanical damage - Process such as impact or perhaps overloading may cause mechanical damage, when the wood will splinter. Another form of mechanical damage has been caused by wear over time and is sometimes found on door thresholds, stair trends or floorboards. Surface become depressed and the wood may be differentially eroded, leaving ridges.
- Fire and flood - Wood might ignite as cellulose in the wood-cell walls breaks down, producing tars and flammable volatile compounds and gases. There is no fixed ignition temperature, because this depends on parameters such as the dissipation of flammable volatiles, the density of the timber and its chemistry, and the duration of exposure to devoted temperatures. A typical ignition temperature is around 350 ^{o} C.
  Floods are also one of the factors that lead to the destruction of wooden structures because long-term exposure of wooden structures to water, leads to decay of wood.

3. WOOD CONSTRUCTIONS REPAIR

Structures refer to the load-bearing elements of a building, such as columns, beams, floor slabs, load-bearing walls, roof trusses and foundations. Secondary structural elements may include corbels, struts, lintels, etc. In combination, these elements form a structural system to carry the weight of the building itself or ‘dead load’, and ‘live load’ – the users, fixtures, furniture and so on occupying the building – as well as environmental stresses such as wind load. Structures are generally designed according to the specific building types, catering for the maximum load associated with the particular building use – such as residence, office, warehouse, car park and so on. [2]
Wooden products and constructions have to be regularly maintained with the aim to increase their lifetime. They can be highly durable when properly treated, detailed and built. They can easily be reshaped or altered, and if damaged they can be repaired. However, when they became damaged, through inspection of their state is important, that is, the diagnosis of the cause, type, degree and range of their damage.
The degrees of intervention on structures range from simple maintenance to deep rehabilitation, with two broad categories of work: [2]

- Repair – to simply restore the load-bearing capacity of the building elements that have been compromised by cracks, loss of section and material degradation,
- Strengthening – to increase the load-bearing capacity as a counter to general decay or due to change in building use.

Generally, the repair of degraded building material is achieved through restoring the geometry of structural elements. When the loss of a section is not very significant, it will be sufficient to adopt protective measures of the existing materials without having to restore the geometry. When restoring the geometry, materials identical to the original ones should be used. Should new materials be used, their compatibility with the original material in terms of strength, modulus, dimensional stability and vapor permeability should be looked into to avoid incompatibility issues. Repair of wood may include

splicing repair of degraded or lost segments, the use of inserted or external fasteners, aside from prosthetic repair, injection and consolidation with synthetic resin. Where there is a significant reduction in their sections, structures could be augmented with added members, with replacement only considered as a last resort. Timber members that are otherwise intact but displaced due to impact or movement may be dismantled and reassembled to restore structural connectivity and load paths.

4. MATERIALS FOR WOOD CONSTRUCTIONS REPAIR

The choice of the appropriate material for wood structures repair is often a hard and complex decision. There are several factors that provide successful choice such as knowledge on each repair material, its long term performances and compatibility with the original materials, environmental conditions, type of desired intervention, etc. The most used materials for repair of wooden structures are: wood, iron, steel, concrete, epoxy resins and fibber reinforced polymers.

- Wood - The most commonly used material for repairing wooden structures is wood.The use of wood in repair techniques has the advantage of avoiding material incompatibilities and degradation due to different physical behavior of materials to environmental actions. (gif.1)
- Steel – Metals are used in timber structures, either as original material or in conservation interventions. The physical and mechanical properties of metals are used to overcome inefficiencies of timber elements or to easily achieve connections between them. One of those metals is steel, whose ideal mechanical behavior makes it especially suitable for interventions and repair. But of great impact on its use is the impact on environmental factors. The possible condensation on the interfaces of steel and timber elements takes to the degradation of the surrounding wood and at the same time undermining the effectiveness of connections. Therefore the best solution to avoid corrosion problem is to use stainless steel. Another problem associated with steel is the rapid loss of its mechanical properties under the action of high temperatures. This can be of great danger once steel is often used in key structural roles, such as connections and import improvements of bearing capacity. If these weaknesses of steel are correctly prevented, than stainless steel is a very effective material for repair of wood structures. (fig.2)
- Concrete – Interventions using concrete are restricted only to the cast of concrete slabs over timber floors. By assuring a proper connection between concrete and wood beams is created a composite system which takes the best characteristics from both materials (concrete and wood). The concrete slab is stressed to compression while the timber beams work in tension. This system has a way of stiffening timber floors to in-plane actions, allowing the distribution of loads along the masonry bearing walls. (fig. 3)

Fig. 1. Repair wood structures with wood elements

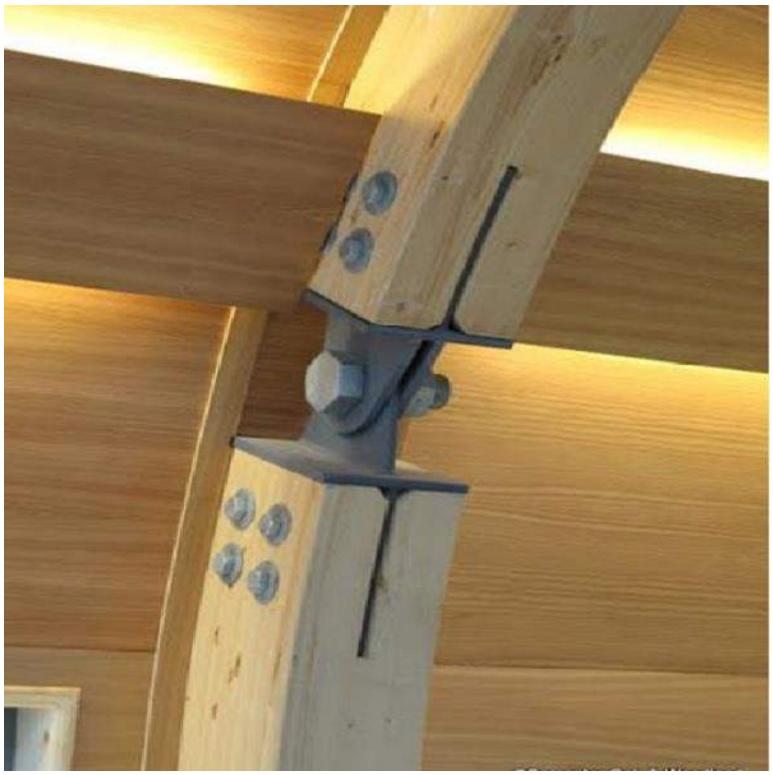

Fig. 2. Repair wood structures with steel

Fig. 3. Repair wood structures with concrete

- Fiber reinforced polymers - Fibre reinforced polymers are composite, heterogeneous and anisotropic materials with a prevalent linear behaviour until failure. An FRP-reinforcement consists of connecting parts (stripes, plates or rods of high strength fibres embedded in a polymer matrix) and a bonding agent (glue, mortar or casting compound) . Fibre-reinforced composite materials offer several advantages that make them very attractive when used for timber repair and strengthening. They are easily applicable and offer extremely versatile design options being suitable for strengthening of timber elements under bending, connections between different elements or between original elements and prosthesis, local bridging where defects are present, confine local rupture or prevent crackopening. The most common fibres used in composites are glass, carbon and aramid. (fig. 4)
  Each type of fibres of these composites has a different characteristics. Each can be optimal for a specific use and situation :
  - Carbon fibres are less sensitive to environmental conditions and creep phenomena;
  - Aramid fibres are more resistant to impulsive loads;
  - Glass fibres have a constitutive model that easily adapts to timber strains. They have a low elastic modulus and high ultimate strain, therefore reducing the risk of debounding which can cause a premature collapse.

Fig. 4 Typical installation of FRP in a wood roof system

- Epoxy resins - Epoxy resins are suitable adhesives for timber strengthening purposes. In 1934, Paul Schlitz was the first researcher to manufacture epoxy resins successfully. Epoxy resin is a chemical compound that is made from the reaction of a chemical called epoxy and hardeners such as polyamide. Adhesion mechanisms primary consist of interlocking of the adhesive with the surface of the support with formation of chemical bonds between polymer and support. Epoxy resin-bonded repair systems have been used successfully both for the upgrading of structural timber and for the repair of timbers which have been degraded by fungal decay, insect attack or mechanical / structural failure. They have also proved successful in cosmetic repairs. The use of epoxy adhesives provides versatility and easiness of connection between different materials, greater stiffness, uniform distribution of loads and uniform stress distribution. Resins are recognized for their excellent adhesive properties, the ease usage, their high mechanical strength and their resistance to chemical attack. In addition, they are waterproof and do not rot. Large structural timbers can be repaired and strengthened using epoxy resin and allows replacing rotting timber with low disturbance. (fig. 5)

Fig. 5. Repair wood structures with epoxy resins

5. METHODS FOR WOOD STRUCTURES REPAIR

There are several methods of repairing wooden structures. Some of them are the following:

- Removal and replacement - If possible, efforts should be made to preserve the original parts and members of the timber structure. This is especially important for wooden buildings that are of historical and cultural significance. Repair should be preferred to replacement, whenever it is possible. Replacement is only advisable in exceptional cases when conservation by other means is demonstrated to be impossible or harmful. When the damage to some parts of the structure is huge and they can't be repaired, then the only option is to replace them with new parts. In the method of replacement, it should be use the same species of wood with similar natural characteristics and with the same or better grading than the replaced member, in order to avoid incompatibilities between new and historical parts. However, new members or parts should be visually distinguishable from the existing ones, as long as it doesn't affect the aesthetical value of the structure. Also, It is recommended for new member or parts to be discreetly marked, by carving, by burnt marks or by other methods, so that they can be identified later.
- Addition of elements – Adding elements can be a solution especially in the case of structures that need to be reinforced due to higher loads coming from the new use. In this way, the wooden structure can get its desired load capacity by adding new elements instead of strengthening its members.Examples of this method can be the addition of floor beams in parallel with the original, as well as the introduction of a new support element, supports or cables in the roof structure.

- Sealing / filling - Sealing is a method of introducing new wood that binds to the original wood element with epoxy adhesive and reinforcing bars or simply by filling the gaps with epoxy resin.
- Repair of cracks - Cracks can be repaired using a wide variety of techniques, from traditional to modern, using different materials. The type of crack is decisive on the selection of the technique. Some traditional approaches are the application of empalmes, bolts and straps. Empalmes can be used for the repair of transversal cracks. They consist on the addition of new timber elements on one or both sides of a beam, connecting the new and the original materials with bolts or nails. Longitudinal cracks can be repaired with bolts or straps. The technique consists on tying and stitching the crack with perpendicular bolts that completely cross the section or straps that tighten and close the cracks. Epoxy resins with low viscosity can be injected on cracks conferring to the section a mechanical behavior identical to the sane situation. The introduction of reinforcement bars of stainless steel or FRPs bonded with epoxy can as well be an appropriate solution for both longitudinal and transversal cracks. In those cases when the damage is not localized but disperse throughout the beam the reinforcement can be distributed along the beam, being obtained in this way a composite beam.
- Prosthesis - Prosthesis is a concept used for interventions in which a part of a single member is cut out and substituted by an element that substitutes its function. This method can use any technique of connecting the wooden structure and the new added part. These interventions are performed on the extremities of elements, close to the supports of floor beams and roof frames. The removed parts may be replaced by timber, stainless steel or epoxy resin.

CONCLUSION

Wood is one of the oldest and most reliable building materials that have been in use for various types of constructions since ancient times. There are a number of inherent characteristics that make timber an ideal construction material. Wood applications has several advantages over the other buildings materials like: it is easily available, available at low cost, exhibit good strength and durability, light weight as compare to concrete and brick, almost all types of timber materials have unique aesthetic appeal, usually better than other building materials, most of the timber engineered wood products create structures that are strong, visually appealing and unique. Wooden products and constructions have to be regularly maintained with the aim to increase their lifetime. They can be highly durable when properly treated, detailed and built. However, when they became damaged, through inspection of their state is important, that is, the diagnosis of the cause, type, degree and range of their damage. The choice of the appropriate material for wood structures repair is often a hard and complex decision. There are several factors that provide successful choice such as knowledge on each repair material, its long term performances and compatibility with the original materials, environmental conditions, type of desired intervention, etc. There are several methods of repairing wooden structures. Repair of wood may include splicing repair of degraded or lost segments, the use of inserted or external fasteners, aside from prosthetic repair, injection and consolidation with synthetic resin. Where there is a significant reduction in their sections, structures could be augmented with added members, with replacement only considered as a last resort. Timber members that are otherwise intact but displaced due to impact or movement may be dismantled and reassembled to restore structural connectivity and load paths.

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