Traditional methods of timber protection against bio-deterioration

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ABSTRACT: Timber, as a construction material, has played an important role in the history of architecture and construction since its very beginning. Naturally, the concerns about its durability and resistance are equally old and have been registered throughout history on building treaties and writings that can date back as far as the Old Testament. Being a natural material, bio-deterioration is one of wood's main weaknesses. Early attempts to deal with this issue included the resource to simple techniques as charring, immersion on saltwater and painting with natural oils and tar. On the 19th century the timber preservation industry was born and new methods and chemical preservatives were introduced. Presently most of those methods are known to be harmful to the environment and over the past decades the banned substances list has progressively increased urging the timber preservation industry to research for new sustainable methods. The study presented in this paper consists of a survey of traditional preservation products and technics and was conducted based on a historical bibliographical research. The results obtained were compiled into a database. This study, revealing a great deal about past construction methods, provides a valuable insight to the conservation of antique wood elements and allows understanding the timber elements condition when inspecting and rehabilitating old buildings. This insight can also be useful to the ongoing research on sustainable timber protection as the principles behind past methods can be the base to develop new improved solutions.

1 INTRODUCTION

Wood as a natural material is not immune to deterioration, however, this process relies on the exposure to a specific environment for a sufficiently long period of time. The length of this period varies significantly with timber species, environmental conditions, the degree and the type of exposure.

The agents of deterioration are living organisms, generally insects, fungi and marine wood borers, which use wood as a source of food, shelter. The survival of these organisms depends on the existence of specific requirements such as moisture, temperature and oxygen.

In a first approach to timber preservation methods, deterioration can be avoided if the surrounding conditions are unsuitable for the development of these organisms. For example, in extremely dry environments, with low temperatures, or environments saturated with water, wood may become immune to the attack of these organisms and in this way kept preserved for hundreds of years (Wilkinson, 1979). Numerous archaeological findings are an example of this condition, for instance the wooden coffins found in the tombs of Egyptian Pharaohs which remained dry during 4000 years showed no signs of degradation by fungi or insects (Connell, 1991), or the English ship Marie Rose which sank in 1545 and that was preserved for 4 centuries in the deep sea bed (Connell, 1991).

However the presence these conditions, adverse to deterioration organisms, is not compatible with most situations in which timber is used in construction, and in a practical sense timber

preservation refers to the improvement of wood's natural durability by treatment with chemicals that are toxic to insects, fungi and marine borers (Wilkinson, 1979).

2 THE HISTORY OF TIMBER PRESERVATION

The use of wood as a building material has accompanied the history of architecture since the beginning and, naturally, the concern about its durability also has an equally ancient history.

The most famous example confirming this longevity is in the Old Testament. The specificity on the description of the timber preservation method in God's speech when He advises Noah to build an ark reveals the importance of this issue at the time it was written.

> *[13] So God said to Noah, "I am going to put an end to all people, for the earth is filled with violence because of them. I am surely going to destroy both them and the earth.*
> *[14] So make yourself an ark of cypress wood; make rooms in it and coat it with pitch inside and out.* Old Testament - Genesis (6, 13-14)

2.1 *The classical antiquity and the architectural treatises*

Several historical records describe the use of wood preservation methods in classical antiquity. In the 5th century BC the Greek geographer Herodotus describes the use of alum as flame retardant and the use of oil's extracts, bitumen, and resins for the preservation of organic materials (Unger, et al., 2001). Other records from this period indicate that the Greeks treated timber structures with oils injected through pre-drilled holes in order to achieve greater penetration of the preservative, and that to keep the timber pillars dry these were laid over stone foundations (Wilkinson, 1979). In AD77, Plinius Secundus reports in *Naturalis Historia* the discovery that in the temple of Ephesus the wooden statue of Diana would have been impregnated with nard oil through several holes drilled in its base (Unger, et al., 2001). Later excavations have revealed the use of charring at the timber pillars used in this temple (Wilkinson, 1979).

In the 4th century BC Alexander the Great decreed that the pillars and other pieces of timber used in bridges should be treated against decay with oil. Also in *Naturalis Historia*, Plinius Secundus reports that wood treated with cedar oil would be resistant to rot and insect attack .

In the 4th century Palladius, author of the treatise of agriculture *Opus Agriculturae*, describes the use of seawater as wood preserver (Unger, et al., 2001).

Therefore, the first attempts to increase the natural durability of timber involved preservation methods such as charring, storage in salt water, and brushing with oil, tar and pitch (Unger, et al., 2001). These preservation methods are based on two principles, the introduction of toxic/repellant elements to the agents of deterioration, and the control of moisture content in wood through the application of products that reduce its absorption capacity.

Through Vitruvius writings, we know that the knowledge about timber preservation was not limited to these two principles. In his treatise *De Architectura*, 1st century BC, Vitruvius dedicates the last two chapters of the second book to the durability of timber used in construction.

Besides describing preserving treatments such as charring, the use of cedar oil and residues from olive oil production, Vitruvius gives special emphasis to the natural durability of wood. He lists and describes different species of trees, their characteristics and the suitability of each one for the use in construction by relating the four elements present in each specie (air, water, earth and fire) with its role in construction (Maciel, 2006), what you would call nowadays "Protection by design".

However, to Vitruvius, timber's natural durability does not only depend on the characteristics of its species as it is influenced by the climate that the tree is exposed during its growth, and the season and method used for felling. According to Vitruvius is recommended that felling should be done in autumn when the tree recovers its natural robustness. In spring, the tree resources are directed to the blooming foliage and fruit. Vitruvius also recommends that the tree cutting should be phased. A first cut to the core will allow the sap to drain out with the tree still standing. When dry and without moisture the tree will be in best condition for use and ready to be cut down (Maciel, 2006).

In *De Architectura*, Vitruvius registers the knowledge and techniques of a distant time, however, this treatise became an unquestionable reference in timber preservation history which influence lasts until the present day. Throughout several centuries Vitruvius writings on timber use and preservation were the base of most architectural treaties as no significative evolutions in treatments and methods were registered until the Renaissance period.

In 1485 Leon Battista Alberti in his treatise *De Re Aedificatoria* compiles various methods of timber preservation by ancient authors as Theophrastus, Vitruvius, Cato and Hesiod. Alberti describes the different views of each author on the felling season, the influence of the moon phase and the techniques and recipes to increase the natural durability of wood.

From Alberti's described techniques stand out: the use of cow dung to rub the newly harvested wood in order to protect it from heat and winds thus avoiding its tendency to split, Theophrastu's suggestion that wood buried in the soil would become denser, Cato treated timber with olive mill wastewater to immunize it against moth and wood borers, and Pliny reported that the Egyptian Labyrinth was built with wood boiled in olive oil (Krüger, 2011).

Alberti also mentions the possibility of certain woods , through various processes , become compact and strengthened against damage from the elements, for instance citrus timber dried in seawater and gains a compact uncorrupted hardness or chestnut wood which is purified by sea water, and that any wood that is buried in moist place while still green lasts forever (Krüger, 2011) .

In 1570 Andrea Palladio also addresses the topic in *I quattro libri dell'architettu*ra. The second chapter of the first book is dedicated to the use of timber in construction, however Palladio does not add new information to the knowledge already registered by Vitruvius and Alberti.

2.2 *The introduction of new chemical substances*

In the 15th century, the rise and development of large mercantile shipping fleets and the importance they had in the economy of several European countries, elevated the demand for more effective preservers as the damage caused by dry rot fungi and marine wood borers had disastrous economic consequences. It is reported that in 1590 over 100 ships of the Spanish Armada were destroyed, not by enemy vessels but by *Teredo navalis* or shipworm (Wilkinson, 1979). This situation led to the search and introduction of new chemicals in wood protection.

The first scientific study is conducted by the German chemist Johann Glauber, who in 1657 developed a process in which timber was carbonized in a fire, coated with tar, and then immersed in pyro ligneous acid, a product of wood distillation (Wilkinson, 1979).

In 1705 the chemist W. Homeberg presented at the Academy of Sciences in Paris a report on the use in southern France of mercury (II) chloride in wood floor boarding for protection against insects. At this time the use of mercury (II) chloride as a timber preservative is not a novelty. Leonardo da Vinci protected the panels from their paintings with a mixture of mercury (II) chloride and arsenic trioxide , and other historical records report that this mixture was used in the 17th century by the Franciscan Monks of San Domingo to control termite infestations (Unger, et al., 2001). Homeberg was also responsible for the discovery of boric acid, which is still today one of the main substances used in timber preservation, at the time labelled Sal Sedativum Hombergi (Unger, et al., 2001). Later, in 1718, the first commercial prepared wood preservative was patented in Sweden, the Holtz-Balsam which was a wood balm based on copper or iron sulfate (Unger, et al., 2001).

Despite the advances in techniques and methods of preservation the new substances introduced, being soluble in water, were susceptible to leaching when applied in moist environments or in contact with water, this associated with their high cost made their application at a large scale impracticable, thus not resolving the need for an effective timber protection solution.

In a report published in 1817 the civil engineer William Chapman estimated that the average life of a ship in the British Royal Navy to be only seven to ten years, which made it extremely difficult to maintain the six to eight thousand ships fleet in reserve in case of another war (Wilkinson, 1979).

2.3 *Industrial timber preservation*

In the 19th century, the innovations introduced by the Industrial Revolution paved the way for the birth of a wood preservation industry. On one hand the expansion of railways and telecom-

munications lines increased the demand on treated wood for railway sleepers and poles, on the other hand the large access to a mineral coal supply, and the invention of the steam engine provided the necessary technical solutions for the timber preservation at a large scale. These events made the first half of the 19th century the period of greatest innovation in the history of wood preservation.

In 1836, Dr. Franz Moll patented a byproduct of the distillation of coal as wood preservative, creosote (Wilkinson, 1979). This preservative is not water soluble and therefore not likely to leach when applied in moist environments, it has a good fungicide and insecticide effect, and due to the abundance of coal during the industrial revolution it was, by comparison with other preservatives, a cheap and affordable product. However, the difficulty of its application made its success depend on the evolution of application techniques which happened a few years later.

With the invention of the steam engine the necessary technology was developed to build metal vessels capable of withstanding high pressures. Taking advantage of this circumstance, in 1831, Frenchman Jean Robert Bréant patented a method for applying preservatives under pressure in a closed metal chamber. In a first stage vacuum is applied to remove the air inside the wood cells and later the preservative liquid is injected under pressure. However this equipment was not adaptable to industrial use, Bréant resolved the problem from a scientifically point of view but did not create a practical solution (Wilkinson, 1979).

John Bethell's patent for pressure treatment with creosote marked the beginning of the industrial timber preservation in 1838 (Nunes, 2007). Designated by Bethell or full-cell, the process consisted of applying an initial vacuum, a pressure preservative injection and a final vacuum stage. After the treatment wood cells are filled with preservative (Wilkinson, 1979). After Bethel's invention of the creosote timber preservation industry grew rapidly.

Despite the success the high consumption of creosote, considered excessive by some users, prevented further growth of the industry. In the early 20th century a more economic method was developed, the empty-cell process, invented in 1902 by Wasserman and implemented by Max Rueping. Four years later Cuthbert Lowry is responsible for the introduction of another similar process. In both cases there isn't an initial vacuum and when pressure I released at the end of the treatment, creosote is forced out of the cells, leaving only the cell walls coated.

The Bethell process continues today to be the most widely used for the application of preservative treatments in depth, however the application of creosote is still made by the empty-cell process as it is optimized for this product (Nunes, 2007).

In parallel three other industrial processes were also developed in the first half of the 19th century and although they were not as successful as the Bethel, Rueping and Lowry processes, they are an important reference in the history of wood preservation.

In 1832 John H. Kyan after 20 years of experiences marks the beginning of modern wood treatments with the patent for a wood treating process by immersion in mercury (II) chloride (Unger, et al., 2001). This process, called Kyanising, was used on a small scale for the treatment of railway sleepers in southern Germany (Wilkinson, 1979). As the preservative used is corrosive to metals, immersion was done in masonry pits. Later Kyan attempted to improve the efficiency of his process by applying pressure to the timber in closed wooden tanks, but this method had little success.

Few years later, in 1838, Sir William Burnett developed a preservation process by steeping timber in zinc chloride and 9 years later the process evolved to injection in an large pressure cylinder. This process, now called Burnettising, was widely accepted by the railway authorities, in the United States and in Europe, mainly because of the low cost of zinc chloride (Wilkinson, 1979).

Also in 1838 Dr. Boucherie patented a sap-displacement process utilizing a solution of copper sulfate as the preservative, this method became known as the Boucherie process. By this method the recently felled trunks are injected through one end with the preservative treatment which forces out the existing sap through the other end (Heaton, et al., 1993). Although it has a slow application and only the sapwood is treated this process was particularly used to treat large poles. Through the years this method was abandoned and replaced by pressure impregnation processes (Nunes, 2007).

Creosote remained as the only recognized wood preservative until the thirties decade in the 20th century when its first two major competitors were introduced: the pentachlorophenol (PCP) and products based on copper, chromium and arsenic (CCA). Some years later the treatments with boron dip-diffusion were introduced (Nunes, 2007).

3 TIMBER PRESERVATION IN PORTUGAL

The history of timber preservation in Portugal is based on the same needs and solutions described in the previous chapters, except for some specific local design circumstances, the break with the global timber preservation history is only chronological.

3.1 *Naval construction*

Given the importance of the Portuguese Discoveries, and its consequent scientific and economic development, in the history of Portugal, it is not surprising that the earliest reference found for wood preservation relates to Vasco da Gama, who to protect his fleet against *Teredo* sp. had the timber used in the construction of ships charred (Unger, et al., 2001).

In the 16th century João Baptista Lavanha publishes the *Livro Primeiro de Architectura Naval*, a shipbuilding manual. The influence of Vitruvius is clear, Lavanha writes about the importance of the felling season, the choice of species, drying and preservation of woods between felling and its use by conservation in salt water or buried in moist sand. In the 5th Chapter, Lavanha includes tar and bitumen in the list of materials to be used in shipbuilding (Lavanha, séc. XVI).

3.2 *The "A Construção Moderna" magazine*

The difficulty in obtaining references on timber preservation methods in Portugal between the 16th and 20th centuries may be indicative of the lack of importance or knowledge on the subject in the national context at the time.

In the found reference sources there is a clear separation between the timber industry and carpentry /joinery, being that timber preservation is almost exclusively linked to the first one.

A Construção Moderna was, as indicated on the cover of the first issue, "a biweekly illustrated magazine under the direction of a group of builders, with the collaboration of technical expertise". The publication lasted 20 years, between 1900 and 1919, adopting the name *A Construção Moderna e as Artes do Metal* in the period between 1911 and 1914. The articles in this magazine depict the state of the art of the Portuguese construction industry in the early 20th century. This picture covers both theoretical knowledge through the analysis of state of the art articles, as well as what was practiced on site through the analysis of published building specifications.

On the accessed issues, covering a large part of all publications over the 20 years of existence, a wide number of references was found on timber durability and preservation, which in a first analysis demonstrates the importance of this subject matter at this time in Portugal. These references, which range from specification documents, state of the art articles and small occasional recipes, cover a large spectrum of preservation processes, from traditional methods to the new industrial and modern methods whose introduction in Portugal is contemporary with this publication.

In 1902 the article *Conservação da Madeira*, published between issues 48 and 69, begins by explaining the special importance of wood preservation methods at the time.

> "If throughout times wood preservation has had a justified special attention, today it is a capital problem, as its consumption has increased extraordinarily not only due to the development of commercial exportations, but also due to the expansion of the rail, telephone and telegraph networks, which consume every year millions of steres of timber, and still the mining and paper industries cause the destruction of several hectares of forest. (...) Some foreign international publications have reported processes that are not yet in practice among us therefore we believe to be interesting gathering here the know information about the main ones" (Anon., 1902).

As proposed, the article presents various modern methods of wood preservation, namely the Bethel, Blythe, Boucherie, Rutgers processes and the Nodon & Bretonneau process in which antiseptic solution based of borax, soda ash and resin is incorporated into the wood, by replacing the sap (Anon., 1902).

In 1909, in the article *Conservação das Madeiras* is described a method for timber preservation with creosote, according to the author "the efficiency of this process and its superiority to all others which have been tested so far is proved with the result of numerous experiments that have been made with great precision and care." (Anon., 1909-1910) The author justifies this claim by quoting two studies, one conducted by the Royal Academy of Amsterdam and another held in Plymouth where multiple treatments were tested in different species of submerged wood. Both studies concluded that creosote would be the most effective treatment.

In 1911 H. de Matos publishes an article entitled *Conservação das Madeiras*, where he lists methods and techniques to preserve timber.

The first methods described are related to the post-felling period. It is referred the importance of the bark removal and to deposit timber in well ventilated areas where it is protected from the intense heat and humidity. According to Matos one of the most active causes of deterioration is the sap that remains in the vessels after the tree felling. Before the introduction of modern processes the effects of the residual sap could be neutralize through solidification by drying the sap naturally or in a kiln, or though leaching the sap by immersion in running water or in steam kiln. Matos notes that hard and softwoods are conserved almost indefinitely in fresh and sea water and buried in mud or wet sand, but timber immersed in salt water become hard, difficult to work with, and unsuitable for use in common constructions.

In the second part of the article, the author describes four types of substances employed for timber conservation. The tar, applied hot and mixed with coal tar, pitch and fat. The oil coatings, which he considers the best wood preservatives, when used in a liquid state so that it penetrates well into the timber. The varnishes that can be applied directly on wood or other painted finishes, which main advantage is the ability to protect wood from ambient humidity variations and wood borers. And the use of mineral solutions, where Matos describes Boucherie Legé and Fleury processes, and the use of copper sulfate as the "substance that appears to give best results" in a solution of 1 kg of copper sulfate to 100 liters of water.

Matos also mentions two other processes that are not included in the previous items. The lead plate wrapping of structural elements encased in walls. And the wood preservation with lime, in which wooden planks are stacked inside a tank and then covered with quicklime which is gradually watered. According to the author the timber acquires great consistency, hardness and never rots (Matos, 1911).

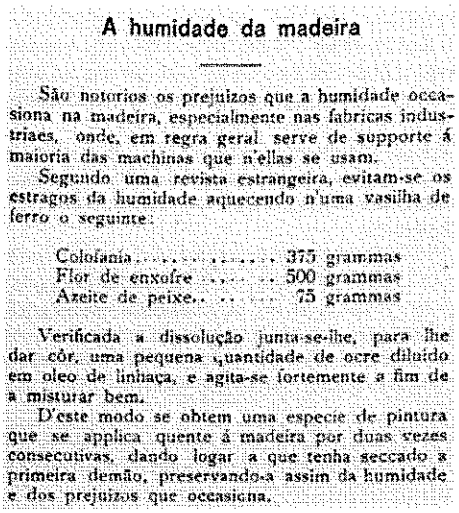
In 1914 in an article entitled *As Madeiras,* the chapter *Meios Preventivos Para Conservar a Madeira Posta na Obra* reports a set of techniques and processes for wood preservation, however the author adverts that even though several methods have been invented to extend timbers natural durability, so far none has been able to comply. The various methods described include the application of plaster over timber conserves it by absorbing moisture and keeping it dry, though the plaster should not completely cover the timber piece. Lime can have the same moist absorbing effect however its causticity can degrade the timber surface. Charring for protection against moisture and wood borers, the tar made with a mixture of coal tar pitch or asphalt and lime which is applied hot and then covered with a layer of heated fine sand, the oil from coal, considered a good preserver as it contains carbolic acid, and the oil paints and varnishes.

For timber used in moist environments, the author recommends soaking the timber in lime, coating with petroleum or with liquid bitumen, to the same effect can be obtained in softwoods using molten fat.

It is also referred the immersion a hot saturated solution of borax as a process used in Germany , and the use of wood vinegar to preserve timber exposed to the weather in England.

Finally, the author describes the modern and industrial processes for wood preservatives giving special emphasis to the application of copper sulfate with the Boucherie, Sege and Fleury methods. With less detail it is also referred the use of creosote with the Bethel process, the Freret process of kiln drying with smoke, the immersion in a hot solutions of sulfuric acid and alum, and barium chloride by Paine process, and the use of zinc chloride by the Brunnett process.

During the twenty years of publication, timber preservation is also covered in small specific articles and notes containing recipes and solutions that stand out for the peculiarity of the ingredients used, for instance the use of a mixture of sublimed sulfur and fish oil to protect wood from moisture (Fig.1), or the immersion of timber logs in a solution of boiling water and sugar (Fig.2).



A humidade da madeira

São notorios os prejuizos que a humidade occasiona na madeira, especialmente nas fabricas industriaes, onde, em regra geral serve de supporte á maioria das machinas que n'ellas se usam.

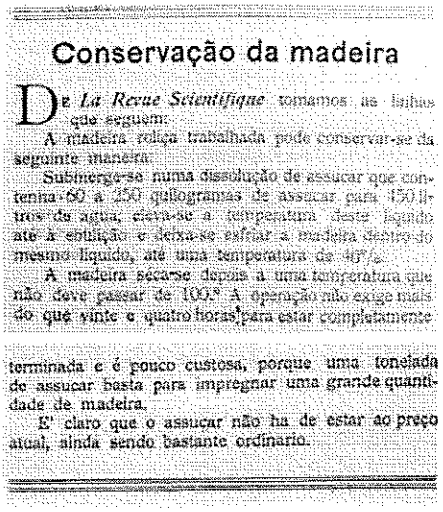
Segundo uma revista estrangeira, evitam-se os estragos da humidade aquecendo n'uma vasilha de ferro o seguinte:

Colofania	375 grammas
Flor de enxofre	500 grammas
Azeite de peixe	75 grammas

Verificada a dissolução junta-se-lhe, para lhe dar côr, uma pequena quantidade de ocre diluido em oleo de linhaça, e agita-se fortemente a fim de a misturar bem.

D'este modo se obtem uma especie de pintura que se applica quente á madeira por duas vezes consecutivas, dando logar a que tenha seccado a primeira demão, preservando-a assim da humidade e dos prejuizos que occasiona.

Figure 1. (Anon., 1909-1910).



Conservação da madeira

De *La Revue Scientifique* tomamos as linhas que seguem:

A madeira roliça trabalhada pode conservar-se da seguinte maneira:

Submerge-se numa dissolução de assucar que contenha 60 a 250 quilogrammas de assucar para 150 litros de agua, eleva-se a temperatura deste liquido até á ebulição e deixa-se esfriar a madeira dentro do mesmo liquido, até uma temperatura de 40°/o.

A madeira secca-se depois a uma temperatura que não deve passar de 100.° A operação não exige mais do que vinte e quatro horas para estar completamente terminada e é pouco custosa, porque uma tonelada de assucar basta para impregnar uma grande quantidade de madeira.

E' claro que o assucar não ha de estar ao preço atual, ainda sendo bastante ordinario.

Figure 2. (Anon., 1916).

3.3 *Construction manuals in the 20th century*

In the first half of the 20th century two authors stand out for the quality and detail of their manuals. João Emilio Santos Segurado, Industrial Engineer and author of several books published in the Biblioteca de Instrução Professional, among which *Trabalhos de Carpintaria Civil* and *Materiais de Construção*, and F. Pereira da Costa author of the *Enciclopédia Prática da Construção Civil* which is a set of fascicles published between 1930 and 1936.

Several chapters of the *Enciclopédia Prática da Construção Civil* are dedicated to carpentry but only on the first fascicle on timber roof structures we find a reference to timber preservation.

> "The painting of trusses with oil paint it is advisable for the conservation of timber, especially as these elements are attacked by solar heat and insects. The application of preservative coatings against insects in roof timber elements should not be overlooked" (Costa, 1955).

In *Trabalhos de Carpintaria Civil* the, also unique, reference is made to the preservation of structural elements and use of oil paint. In this case the prescription of the author specifically refers to the protection of timber beams encased in masonry walls, where it the moisture content is likely to increase and consequently the development of rot fungi. "To protect timber from rotting , the tips encased in the wall should be painted with oil paint , red lead paint for example, tar or coating it with plaster, or encasing it with a zinc sheet or cork boards" (Segurado, 1936).

The preservation of timber beams in contact with masonry walls is a recurring concern, several references to this situation where found. In 1900 the specifications for the house of Mr. Miguel Henrique dos Santos, in Rua Rosa Araújo , published in *A Construção Moderna*, the architect Ventura Terra prescribes that all parts of timer structural elements beams which are in contact with masonry walls shall be suitably painted with minium paint before its set in place (Ventura Terra, 1900). The *Regulamento Geral de Edificações Urbanas*, published in 1951, in the Artº 39 states that when using timber without adequate pre-treatment, the tips of the beams of the introduced masonry walls should be protected with an appropriate coating or lining to prevent its decay (R.G.E.U, 1951).

In *Materiais de Construção*, João Segurado approaches the timber preservation subject with more depth, addressing various preservation methods, both ancient and modern.

In the 18th chapter, *Conservação da Madeira*, Segurado recommends the exact same processes for post felled timber as H. Matos described in his article *A Conservação da Madeira* published in *A Construção Moderna* in 1911.

Segurado organizes the timber preservation processes into three groups : the application of coatings, the injection of antiseptic substances, and charring . "Coating and charring preserve timber from moisture and insect attack ; antiseptic substances form along with the sap an insoluble compound that fills the wood pours, hardens it , cause the sap fermentation to disappear and prevent wood borers" (Segurado, 1936).

As the main coatings applied in timber preservation the author refers to tar, paints and varnishes. For timber injection he describes the Boucherie process, the Blythe and Bethel processes with creosote, the injection of zinc chloride by the Burnett, Wellhouse and Rutgers processes, and the use of mercury (II) chloride by the Kyan process.

The author gives particular focus to the Boucherie process and describes in detail the evolution of the process from the first applications with the tree still standing (Fig.3) until adaptation for the treatment of poles and sleepers for railways (Fig.4). As the injected preservatives with this process the author refers creosote, copper sulfate, zinc chloride and mercuric chloride. According to Segurado the months of September to December are indicated as the preferred season for felling and treatment with the Boucherie process, as during this season the sap is more fluid making the injection time shorter (Segurado, 1936).

Segurado also describes other preservation methods, carbonization and vulcanization. The first is defined as a process used since ancient times that is still applied in pieces of wood that are buried,

> "this operation (carbonization) makes the timber surface more compact and less permeable, it impregnates the wood with self-distilled products for its conservation and it causes the organized ferments that may exist on its surface to disappear" (Segurado, 1936).

The author lists as examples of methods of carbonization application with a gas torch by the Lapparent method in 1862 and the industrial method for charring masts and beams developed by Hughon.

Figure 3. Tree injection (Segurado, 1936).

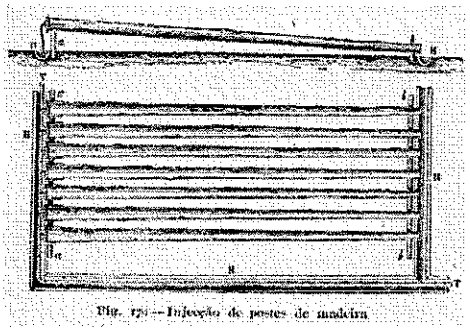


Figure 4. Timber pole injection (Segurado, 1936).

The vulcanization, according to Segurado, consists on exposing the timber to heat. For this process is described the Haskin method:

> "The timber is placed in a long cylinder surrounded by a series of tubes in which circulates water vapor, the heat drives out the moisture contained in the timber. (...) Then the cylinder is filled with hot air under the pressure of 10 to 15 kilograms per square centimeter (...) The theory on which this process is based storage is that the heat coagulates the albumen contained in the timber, and the sap distillation turns it into several conservative wood compounds such as creosote, carbolic acid, etc. . , that in this way are prevented from exiting the timber due to the pressure to which it is subject."

However, Segurado states that this process will not likely find enthusiast as it has an inconsistent performance, producing contradictory results from time to time.

3.4 *Industrial timber preservation in Portugal*

Industrial wood preservation in Portugal began in the early 20th century with the treatment of railway sleepers and telecommunication lines poles at the Marinha Grande and Figueira da Foz plants. Initially these treatments were performed with solutions of copper sulphate through the Boucherie and Bethel processes. Later, the Portuguese Railways changed the sleeper's treatment to creosote through the Rueping process (Romão, et al., 1985).

In 1952 the plant at Figueira da Foz started treating poles with multi-salt mixtures. Consequently the application of preservatives by vacuum / impregnation was extended to the preservation of timber for general use in construction. The interest in this type of treatment caused a gradual increase and installation of other factories around the country. Later the development of the double vacuum method with organic solvent preservatives allowed the application of preservatives in sawmills and furniture factories.

In the report *Wood Preservation in Portugal* , from 1985 , the authors indicate the existence of 14 industrial wood preserving companies spread over 17 production units and accounting for a total of 26 cylinders installed . According to the authors the majority of the activity of this industry is dedicated to treating railway sleepers, and timber poles for agriculture. The preservation of timber for construction is not common, and most of the timber is applied untreated, or treated with preservatives through brushing or spraying (Romão, et al., 1985).

The article *A Industria de preservação em Portugal*, published in 2009, updates the data from the previous report. The author states that there are 13 companies producing treated wood, distributed in 16 plants, where predominantly pine timber is pressure treated. *Pinus pinaster* is treated in 15 plants and *Pinus sylvestris* in 5 plants and the remaining treated species are *Pinus, caribea, Picea abies* and *Pinus elliotii* (Esteves, 2009).

4 CONCLUSION

The timber durability issue was solved during the last centuries using preservatives which are hazardous to the environment and public health. At the end of the 20th century, the awakening of a global ecological awareness and the spread of sustainability principles raised environmental issues that challenged the timber preservation industry and the substances it used for timber treating. The life cycle analysis concept altered the way we evaluate the impact of preservatives and treatments. Over the past few years list of hazardous and prohibited substances have been compiled and legislated.

This new standpoint, and consequent restrictions forced the wood preserving industry to research and develop alternatives to replace the hazardous substances with natural products or products that present less danger to man and the environment and also develop non-conventional methods of timber of protection, such as the use of physical barriers against borers, biological control with insect pheromones or timber modification so as to make it less desirable/available for wood-destroying organisms (Nunes, 2007).

New products sold in the market remind us of some old wood preservation methods. For instance, linseed and cedar oils can be found in contemporary commercial preservative formulations and the principles of wood charring is the base to the development of thermally modified wood.

At this stage on the search for alternatives it is important to look at the past and evaluate the relevance and validity of traditional preservation methods that may bring contributions to the formulation of new solutions. The technological accomplishment that will allow finding a balance between environmental protection and the preservation of wood will have a crucial role in the future of construction.

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