# Durability - Preservative treatment

STEP lecture A15
L.M.R. Nunes,
P.P. de Sousa
Laboratório Nacional de
Engenharia Civil (LNEC)

## Objectives

To explain the need for preservative treatment and to introduce the different types of treatment. To outline the specification of a preservative treatment for timber and wood-based panels.

## Prerequisite

A4 Wood as a building material

## Summary

Fungi and insects are the two main biological agents responsible for timber degradation in service. Therefore, their life cycles and types of action are summarized. The concept of natural durability is explained and the factors influencing this timber property are outlined. Different wood species have different natural durability, thus the concept of durability classes emerges and is explained.

Preservative treatments can be used to avoid timber degradation and the types of preservatives and methods of treatment are described. The specification of a preservative treatment for timber and wood-based panels is outlined. Future perspectives in timber preservation are also discussed.

## Introduction

Under ideal conditions timber can be in use for centuries without significant biological deterioration. However, if conditions are not ideal, many widely used species need a preservative treatment to be protected from the biological agencies responsible for timber degradation, mainly fungi and insects.

Preservative treatments are chemical treatments where specially formulated products containing biocides (fungicides and/or insecticides) are incorporated into the timber in order to upgrade its durability against the biological attacks. These preservative treatments are normally applied to the timber before use; however they can also be applied to timber in service.

Timber preservation is indeed a major issue. For example, this was demonstrated by the results of a survey carried out in 1980 involving more than two hundred Swiss architects (Sell et al., 1982), where, in opposition to the high rating of timber when compared with other building materials in terms of aesthetics, durability was clearly the major shortcoming of this material. It is obvious that it is very difficult to increase the use of structural timber without taking care that the durability of the material is assured during its intended life.

When a designer proposes a timber structure, a doubt occurs frequently on whether he should specify for a preservative treatment for the timber and, if so, what type of treatment and preservative should he request. The answers to these questions are not always simple, as a certain number of inter-related factors should be taken into account. EC5 states these factors in a general way and also states that "the environmental conditions shall be estimated at the design stage to assess their significance in relation to durability and to enable adequate provisions to be made for protection of the products". Moreover, with respect to the resistance to biological organisms, it requests that "timber and wood-based materials shall either have adequate natural durability in accordance with EN 350-2 for the particular hazard class (defined in EN 335-1 to 3), or be given a preservative treatment selected in accordance with EN 351-1 and EN 460".

In this lecture a background summary of durability and preservation of timber is given. The information will be linked to the package of European Standards (EN Standards) about this subject, already published by the European Committee for Standardization (CEN) or in final phase of elaboration by the Technical Committee CEN/TC 38 - "Durability of wood and wood-based products". These documents will apply in Europe in the near future and will help designers to answer the questions formulated above.

## Biological agencies of timber degradation

The two main biological agencies responsible for timber degradation are fungi and insects although in specific situations, timber can also be attacked by marine borers. Some notes about these agencies are given below.

### *Fungi*

Taking into account the effect of their action, two types of fungi can be distinguished: wood-destroying fungi and wood-disfiguring fungi. The attack of the latter have normally no significant effect on the mechanical resistance of timber as they only depreciate the aesthetic appearance of the material, without destruction of the cell wall. However, extensive degradation of decorative coatings can occur due to the action of these fungi that include mould and blue stain fungi.

On the other hand, wood-destroying fungi affect the mechanical resistance of timber and are of greater interest within the scope of this lecture. These fungi attack timber by means of an enzymatic action that results in rot and they include the Basidiomycete wood-rotting fungi responsible for brown or white rot - so called due to the colouration given to the timber attacked - and the soft rot fungi, which are grouped together on the basis of their ability to form cavities in the wood cell wall, that leads to a surface softening of the timber and eventually to rot in depth. For the growth of wood-rotting fungi a moisture content higher than 20% is needed.

### *Insects*

Insects attack timber by opening tunnels which sometimes are packed with bore dust. The two main types of insects causing the deterioration of timber are beetles (*Coleoptera*) and termites (*Isoptera*).

Beetles are insects with a larvae cycle. The flying insects lay their eggs in cracks, splits, rough surfaces of timber or wood pores and, the resulting larvae penetrate the timber by boring tunnels as they develop. This is the destructive stage of the life cycle; the adult insect will complete it after metamorphosis and the opening of the exit hole, which will probably be the only visible sign of the attack on the timber surface. There are several species of wood-boring beetles throughout Europe; the most common are the House Longhorn beetle (*Hylotrupes bajulus*), the Common Furniture beetle (*Anobium punctatum*), the Death Watch beetle (*Xestobium rufovillosum*) and the Powder Post beetle (*Lyctus brunneus*). Although only attacking softwood, the House Longhorn beetle is by far the most damaging and it can cause failure in structural timber, particularly when the sapwood content is high. Normally, beetles attack dry timber but they can tolerate higher values of moisture content.

Termites are social insects that build their nests in contact with the ground and forage over a distance for their food, building tunnels between their nests and the source of timber, which should have moisture content conditions similar to those referred to for wood-destroying fungi (greater than 20%). This description applies only to the most important species found in Europe, the subterranean termites, namely Reticulitermes lucifugus and Reticulitermes santonensis.

*Marine borers*
In European marine waters the most common borers are the shipworm (Teredo spp.) and the gribble (Limnoria spp.). The shipworm is a bivalve mollusc with larvae that settle on timber where they lodge by boring an extensive network of holes. The gribble is a small shrimp-like crustacean that bores into the timber surface, where it lives, making numerous side burrows and causing erosion on marine timber structures.

*Presence of biological agencies in Europe*
The biological agencies referred to previously are not present all over Europe. In fact, a survey carried out by CEN/TC 38 in the different CEN Members (no data from Iceland and Luxembourg) shows that there is a generalized risk of fungi attack in all countries (with an insignificant risk of attack by some species in Austria and Italy) but the risk of attack by insects varies significantly from country to country - linked to the average air temperature - as it is reflected in Table 1, resulting from that survey.

| Countries / Insects | A,B NL, UK | CH | D | DK | E | F | GR | I | IR | N | P | S | SF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| House Longhorn beetle | R | R | R | I/L | R | R | R | R | O | L | R | L | O |
| Common Furniture beetle | R | R | R | I | R | R | R | R | R | R | R | R | R |
| Death Watch beetle | R | I | R | I | I | R | I | I | R | I/O | O | I | I |
| Powder Post beetle | R | R | R | O | R | R | R | R | R | O | R | I | O |
| Termites | O | O | I | O | R | L | I | L | O | O | R | O | O |

R - Risk; I - Insignificant risk; O - No risk; L - Locally present in the country

*Table 1 National declarations concerning the risk of attack by insects.*

## Timber properties related to preservation

*Natural durability*
Natural durability of timber, understood as the ability to resist the attack of a biological agency without any preservative treatment, varies significantly from timber species to timber species and, within the same species, it is greater in the heartwood than in the sapwood.

In order to assess the natural durability of a timber species, a series of tests can be performed, and the results obtained usually lead to the attribution of a certain durability class to the different timber species. EN 350-1 "Durability of wood and wood-based products. Natural durability of solid wood - Part 1: Guide to the principles of testing and classification of the natural durability of wood" establishes those tests (field tests and/or laboratory tests) and the criteria for the evaluation of the results, and defines a certain number of durability classes regarding the resistance to the attack of fungi, beetles, termites and marine borers.

However, natural durability tests have been performed for a long time on different timber species all over the world. The information resulting from those tests was gathered in EN 350-2 "Durability of wood and wood-based products. Natural durability of solid wood - Part 2: Guide to natural durability and treatability of selected wood species of importance in Europe", where, whenever possible, the durability classes defined in EN 350-1 are assigned to around 100 timber species, including softwoods and hardwoods. The use of this information should be made, however with care, taking into account the criteria set in EN 350-2. For instance, the natural durability class assigned for resistance to fungal attack, refers only to the heartwood, as sapwood is considered not durable for all timber species (note that sapwood content in hardwoods is lower than in softwoods).

*Treatability*

The effectiveness of a preservative treatment depends mainly on the amount of preservative that is absorbed by the timber and the depth to which it penetrates, although factors like distribution of preservative may also play an important role in the effectiveness. The ease of timber impregnation is naturally related to the type of product used and to the method of treatment adopted but it depends mainly on the degree of permeability and the moisture content of the timber. EN 350-2 also includes, for the timber species listed, an indication of the corresponding treatability, based on a four classes system (treatability classes). From this information, it becomes clear that sapwood is much easier to impregnate than heartwood; in the end, it is quite possible that the durability of the sapwood of a certain timber species subjected to a proper preservative treatment becomes higher than the natural durability of the heartwood of that same species.

## Timber preservatives

Timber preservatives are chemical products intended to increase timber's resistance to the attack of biological agencies. They have usually been classified into three major types: tar oil preservatives, organic solvent preservatives and water borne preservatives. However, aqueous emulsion systems are also now well established in timber preservation.

Tar oil preservatives were the first to be used to treat timber industrially and include a set of different products obtained by distillation of coal tar; the most important products of this group are creosote and the anthracene oils. Due to its odour, difficulty to over-painting and general eco-toxicological characteristics, most countries have now restricted the use of this type of preservative to exterior works (e.g. transmission poles, railway sleepers) and immersed timbers.

Organic solvent preservatives are solutions of biocides (fungicides and/or insecticides) on a non-polar organic solvent that can be volatile or non-volatile. Products using a volatile solvent (e.g. white spirit) are the most common and can be described generally as light organic solvent preservatives (LOSP) or paintable preservatives; additives like water repellents and colouring agents may also be included. The key features of these products are the ready penetration on timber even when applied by superficial methods (e.g. brushing, dipping) and the absence of dimensional changes of the timber. These products are widely used in joinery and cladding.

Water borne preservatives are basically constituted by mineral salts dissolved in water. The most common products belong to the group of preservatives known generally as "chromated copper". Amongst this group are chromated copper arsenate (CCA), chromated copper borate (CCB) and chromated copper silicafluoride (CFK).

These products are normally forced deep into timber, using pressure and the treatment requires the drying of the timber after treatment. Other water borne products like disodium octaborate tetrahydrate and sodium fluoride are also used but their application is mainly by diffusion in green timber. Water borne preservative products are probably the most widely used in timber structures. Timber adequately treated with CCA is suitable for internal or external use and in situations where the risk of attack is high. Corrosion of metal devices in contact with CCA treated timber can occur - especially if the moisture content of timber is high - and adequate protection should be provided.

Lastly, it is important to point out that there are several European Standards (EN Standards) already published concerning the test methods for the evaluation of the effectiveness of preservative products. Actually, two EN Standards about preservative products with special interest for this lecture are in preparation: EN 351-1 "Durability of wood and wood-based products, Preservative-treated solid wood - Part 1: Classification of preservative penetration and retention", prEN 599 "Durability of wood and wood-based products. Performance of preventive wood preservatives as determined by biological tests - Part 1: Specification according to hazard classes" and prEN 599-2 "Id. - Part 2: Classification and labelling".

## Methods of preservative treatment

Methods of preservative treatment of timber normally comprise a set of techniques used to force a preservative product to penetrate into the timber in order to get an adequate retention and penetration. There are several methods of treatment with different degrees of effectiveness. The right choice depends on the timber species and the retention and penetration values relevant to the hazard class.

The following methods of timber treatment are widely used: brushing, spraying, dipping, diffusion, double vacuum and vacuum pressure. The first four are non-pressure methods but, in the last two, pressure is needed and the necessary equipment includes a closed cylinder (autoclave). A brief description of these methods is included in Annex A (informative) of prEN 599-1, where the product penetration into the timber (defined according to EN 351-1) normally attained in those treatments is also given. Based on that information, a brief description of pressure methods - probably the most appropriate for timber used in structures - is made. In the vacuum pressure method, timber is introduced into a closed cylinder and subjected to a vacuum to remove air from the cells. The preservative liquid is then introduced and a pressure usually between 0,8 and 1,5 $N/mm^2$ is applied. A final vacuum removes excess liquid from the timber surface before normal atmospheric air pressure is restored and the timber removed. This process, called "Bethell process" or "full-cell process" can be slightly changed on the "Rueping process" or "empty-cell process", in which the initial vacuum is replaced by an air pressure, in order to increase the recovery of preservative during the final vacuum.

The double vacuum method is similar to the vacuum pressure method ("Bethell" process) but the pressure applied is lower (less than 0,2 $N/mm^2$) and the period of final vacuum is bigger.

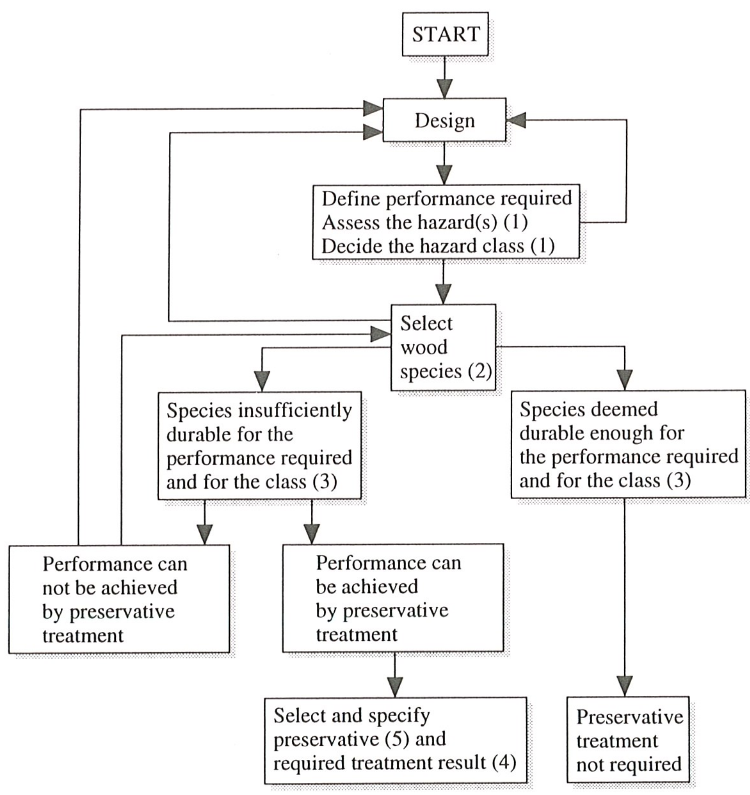
Furthermore, it is important to notice that the vacuum pressure and diffusion methods rely heavily on water borne preservatives and can be used to treat timber even in the pole form. The use of organic solvent preservatives is usually restricted to the double vacuum method and superficial applications. With these treatments the timber should be at the final dimensions and any areas exposed by subsequent cutting or drilling should be further protected.

## Specification of a preservative treatment for timber

Previously in this lecture, a brief background concerning the biological agencies responsible for timber degradation, the timber properties related to preservation and the methods of preservative treatment was given, and relates closely to the standardisation work ongoing in Europe.

This information will be useful now to answer the questions that designers are often facing with, as formulated in the beginning of this lecture. They concern the need of a preservative treatment for timber in a specific situation and the choice of the type of treatment and preservative product to be used. The answers to these questions will be also based on the EN Standards already published or in final phase of elaboration.

In order to deal with this problem, some basic data is still missing. They concern the assessment of the risk of attack by biological agencies of a certain timber piece in a specific situation and from this emerges the concept of hazard classes. EN 335-1 "Durability of wood and wood-based products. Definition of hazard classes of biological attack - Part 1: General" establishes five hazard classes for timber and wood-based products and indicates the biological agencies relevant to each situation. EN 335-2 "Id. Part 2: Application to solid wood" defines those classes for timber and includes, in an informative Annex, a decision-making sequence to help designers to select a suitable timber species for a specific use.




1) See EN 335-1 and figure A.2 of EN 335-2    2) See EN 350-2
3) See EN 460    4) See EN 351-1    5) See prEN 599-1

*Figure 1    General decision-making sequence for selection of timber appropriate to the hazard class of use (from EN 335-2).*

Figure 1 shows this decision sequence adapted from EN 335-2; it should be noted that all standards listed in this figure have already been referred to previously in this lecture, with exception of EN 460 "Durability of wood and wood-based products. Natural durability of solid wood. Guide to the durability requirements for wood to be used in hazard classes" that gives guidance on the selection of a timber species according to its natural durability for use in a particular biological hazard class.

This decision sequence shows that a coherent system of EN Standards is in its final phase of preparation to help designers in making decisions about this subject. The information included in this lecture gives a general overview of this standardisation system but it is obviously not complete; therefore, the only way for a designer to take the right decisions when specifying a preservative treatment for timber is by careful consultation of the appropriate EN Standards that soon will be in force in several countries of Europe and that will be probably adopted later on to a larger extent.

## Specification of a preservative treatment for wood-based panels

Wood-based panels are also extensively used in timber structures, namely, plywood, particleboards, fibreboards and oriented strand boards, and durability of these products should obviously be discussed.

It is important to emphasize that the majority of the information given so far also applies to wood-based panels. The main difference is related to the natural durability of these products, which depends less on the species than in the case of timber; in fact some additional factors like thickness of particles and plies, fibre preparation, binder characteristics and quantity can also contribute to durability. Additionally, the equilibrium moisture content of a wood-based panel in a given environment, usually differs from that attained by timber of the same species from which they are made.

Taking this into account, prEN 335-3 "Durability of wood and wood-based products. Definition of hazard classes of biological attack - Part 3: Application to wood-based panels" defines, similarly to Part 2 for timber, different hazard classes for plywood, particleboards, fibreboards, and cement-bonded particleboards, the latter being considered to have an insignificant risk of attack in all hazard classes. Furthermore, prEN 335-3 includes an informative Annex giving guidance on the suitability of different types of wood-based panels (characterized by appropriate EN Standards relating to the products) for use in the hazard classes. It is important to note that prEN 335-3 applies to non-coated panels, though, in timber structures, this will be the common situation.

The natural durability of wood-based panels can also be increased by a preservative treatment. In this case, the preservative products used are normally organic solvents and the treatment is usually made, or by brushing, or incorporating a preservative product in the binder or in the plies during the fabrication. This latter method assures a greater protection than the first. Some innovative methods of treatment like vapour boron treatment have, in recent years, shown promising features for the treatment of wood-based panels.

## Future perspectives in timber preservation

In recent years, two principal factors have provoked changes in treatment technology and preservative products: the increasing cost of some solvents, and the even more important concern over environmental aspects of timber preservation, including air and water quality standards, and the effect of treated timber on man and on non-targeted organisms.

Most countries now have regulations regarding timber preservatives and many of them do not allow the use of certain active ingredients such as dieldrin. Traditional organic biocides, like creosote, pentachlorophenol or lindane are partially restricted as well as the most commonly used water-borne copper-chrome-arsenic formulations.

Nowadays, several products, either new or rediscovered, are already being introduced into the market and these include: borates and copper naphthenates or organic and organometallic systems like isothiazoles, chlorotalonil, thiazoles and triazoles.

Environmental health and safety requirements point to the use of preservatives that comply with the following characteristics: the preservative should be non-toxic to humans and to the environment or at least be rendered non-toxic when fixed in the timber; the treatment should be carried out when the timber is in its final shape in order to minimize treated timber waste; plant operations should exclude emission of toxicants and there should be no soil, air or waterway contamination; and redundant preservative treated timber should be recycled or disposed of with minimal environmental disruption.

## Reference

Sell J. et al. (1982). Holz im Bauwesen. Report No. 210, Swiss Federal Laboratory for Materials Testing and Research (EMPA), Dübendorf, Switzerland.