# Modified Wood Versus Termite Attacks: What Should Be Improved in Assessment Methodology ?

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## ABSTRACT

Wood can be modified by mechanical, thermal and chemical treatment, whose aim to improve its physical and biological properties such as strength, dimensional stability and resistance to decay. Biological resistance of modified wood meant for outdoor use is assessed mainly to wood degrading fungi, by calculating wood mass losses after fungal attacks. Several studies have demonstrated that resistance to fungi can be highly improved through different wood modification processes, by reducing moisture contents or by limiting absorption of the nutritional components from the medium. But the ability of modified wood to resist xylophageous insects, especially termites, which are a great problem for timber construction in the countries of southern Europe (such as France, Spain, Portugal and Italy) and some of their overseas territories, is often neglected. Many studies have demonstrated that termite resistance of thermally treated wood is low, and that the resistance of chemically treated wood may vary. The differences in the effectiveness of wood modification for biological resistance against fungal decay types or termite species can be easily accounted for by these organisms' exhibit distinct degrading systems and environmental preferences. However, testing methodologies used to assess resistance to termites are deficient in certain other respects. These methodologies are not always relevant, especially when the tests are performed under laboratory conditions, for the reported mortality rates in isolated groups of termites do not reflect the behaviour of a termite colonies in natural field conditions. For this reason, above ground resistance tests or lab tests performed on bigger colonies could provide more reliable results. Another issue is that laboratory results based only on insects' mortality cannot account for the service life expectations, such as the impact of aesthetic damages, maintenance and expected durability of wooden construction parts.

## INTRODUCTION

### *Termite biology and distribution*

Termites are xylophageous insects that are widely distributed in warm climates across the countries of southern Europe (Portugal, Spain, France, Italy, the Balkans: see the map in fig. 1). They occur mainly in natural areas, such as temperate forests, but urban infestations are also very common. In fact, termites have been be found quite far away from their natural environment, for instance in Hamburg, Germany and the Devon, the UK, that is, in two countries whose forests are naturally free from these insects. Urban infestations are mainly due to human activity, particularly in the construction sector, which is susceptible to involve intensive transport of infested soil and wood.

Two kinds of termite, belonging to two distinct genera, occur in Europe: the drywood termite and the subterranean termite. They are very different in terms of their colonial organization and exploitation of food resources. Drywood termites form small colonies in single pieces of wood (*e.g.*, logs, stumps, wine stocks, or wooden window frames when they enter manmade constructions) and keep feeding on them. Their natural area of distribution is mainly restricted to the Mediterranean coasts. Subterranean termites establish huge underground colonies and they dig in the ground looking for pieces of food they can feed on. They constitute the biggest danger for timber constructions in Europe, because they can tunnel over long distances (several hundreds of meters) and are able to get through various construction materials (wooden panels, different kinds of insulating substances such as polystyrene, plastic water pipes, electric sheaths and others) to locate water and cellulose-containing materials they can use as a source of food.

So far six species and one subspecies of subterranean termites have been identified and described in Europe, all belonging to the genus *Reticulitermes* (Clément *et al*. 2001). Of the six, two are believed to have been introduced in France several hundreds years ago. Recent genetic studies (Austin *et al*. 2005) have demonstrated synonymy between the north-American species *R. flavipes* and the French species *R. santonensis*, which is the only species causing damages to constructions in the northern half of France (*e.g*. Paris). Another species, *R. urbis*, is believed to have been introduced in France and Italy more recently and likely from the very south-eastern Europe (the Balkans) or from the Middle-Orient (Uva *et al*. 2004, Luchetti *et al*. 2007).

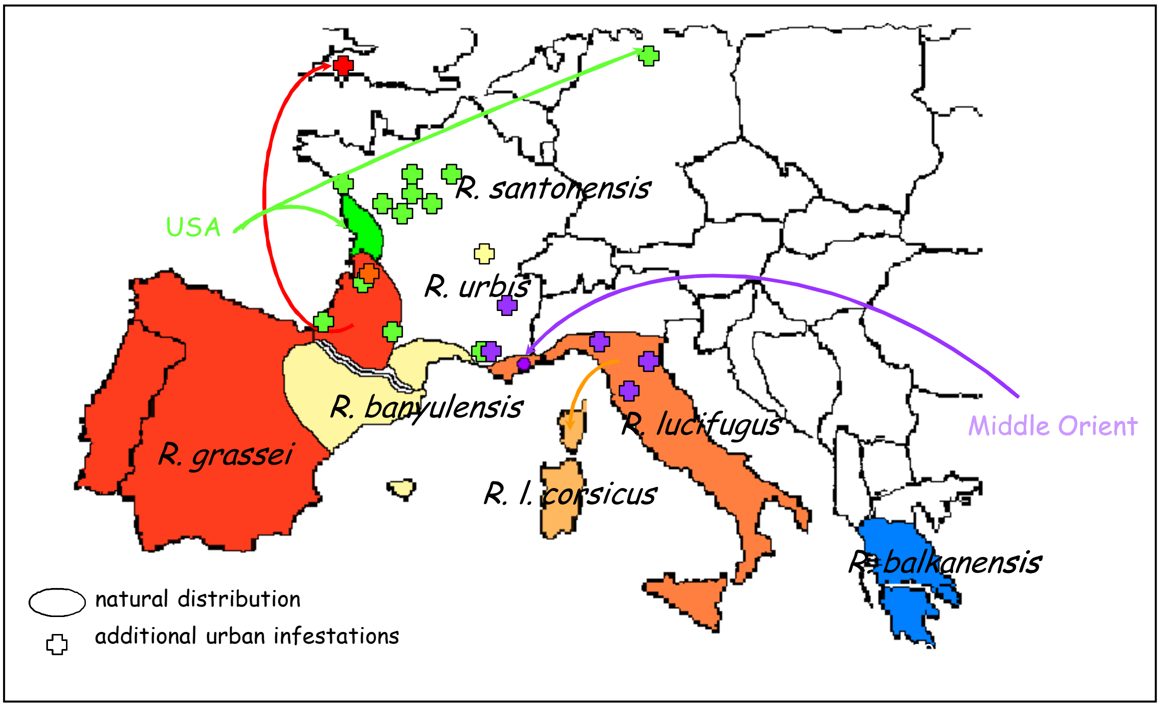


***Fig. 1: Natural and urban distribution of Reticulitermes subterranean termites in Europe***

All the European *Reticulitermes* species display similar feeding behaviour and social organization. All subterranean termites are social insects that live in social units called colonies. Colonies may contain thousands to millions of individuals which are organised in different castes (workers, soldiers, and nymphs developing into primary or secondary reproductives) according to their behaviour and/or morphology. Differences in the social organization of colonies (for example size and reproductive patterns) occur between and within various species and may be influenced by ecological and environmental factors (DeHeer *et al*. 2005, Dronnet *et al*. 2005). The majority of the population comprises immature forms (different instars larvae), the latest larval stages in charge of finding and collecting food for the rest of the colony being called workers. They are the most numerous caste and are characterized by developmental flexibility - which means that they can switch to another caste (for example to become secondary reproductives). This flexibility is the basis of the success of termite infestation, particularly in urban areas. If a colony happen to be divided – for example when an attack by ants destroys a part of it, when an underground tunnel collapses isolating a group of workers from the rest of the colony or when infested materials are moved for building purposes - even very small groups of workers can produce secondary reproductives which may initiate a new colony (Pichon *et al*. 2007).

Termites can attack any species of temperate softwood and hardwood timber and eat both sapwood and heartwood. The natural durability of wooden species which are important for the timber construction market in Europe is reported in the European standard EN 350-2 (Durability of wood and wood-based products – Natural durability of solid wood), which is currently being revised. All but three European timber species are classified as being non-durable to termites; two of them are classified as moderately durable (oak and chestnut tree) and one as durable (*Robinia pseudoaccacia*) - however termite attacks on the latter have already been reported (FCBA unpublished data). Consequently, timber needs to be protected against termites in areas where they occur. Recent new regulations introduced in France impose the obligation to use only protected wood (naturally durable or treated) for structural purposes (solid-wood - wooden frames, load-bearing elements, and wooden panels if used for racking) in buildings located in infested areas, which means more or less a half of the country. In other words, if wood which is not naturally durable may come into contact with subterranean termites, it should be treated.

***Wood modification and related performances against wood borers***

Low durability of most of European timber species and their poor dimensional stability when used outdoors, combined with the trend towards reducing the use of timber products treated with conventional biocidal wood preservatives, have inspired research on treatments that both improve stability and increase durability to biological agents such as fungi and termites. As a result, new wood-based materials are constantly developed and enter the building materials market offering improved behaviour in terms of reduced moisture uptake and increased resistance to decay when compared to conventional solid-wood materials.

In countries which are free of termites, decay caused by rot fungi is the principal risk faced by manufacturers of modified woods. Resistance to fungal attack is generally improved by the different modification treatments which reduce wood’s hydrophilic properties and also break up sugars inside it into a form that is no longer recognised as a nutrient by fungal enzymes. However, durability of modified wood to a large extent depends upon several factors, such as what kind of wood species is treated, what kind of process is used, and how long the process is.

Generally, the insect risk, and especially the termite risk, must be taken into account in the countries of southern Europe. Several studies focused on the resistance of modified wood to termite attacks have been performed during the last years and all have yielded similar results. Many of the different modification processes improve resistance to termite attacks (sometimes very slightly), but do not avoid visual damages. Examples include high temperature treatment, high temperature treatment combined with oil impregnation (Smith *et al*. 2003), retification, DMDHEU (dimethylol dihydroxy ethylene urea) treatment (Yusuf *et al*. 1995, Schaffert *et al*. 2006, Militz *et al*. 2008), acetylation, furfurylation (except for highly furfurylated wood which is not attacked, Lande *et al*. 2004, Hadi *et al*. 2005).

Many laboratory tests focused on the resistance of different kinds of modified wood to insects have been carried out by research institutes in Europe (including the FCBA) an elsewhere. In the past few years several tests have been performed by the FCBA on heat treated, oil treated (Podgorski *et al*. 2007), densified, retified and acetylated wood specimens, which were assessed for their resistance against termites and other xylophageous insects The results of the tests have not been published because of their confidential nature, so we can only summarize here the "philosophy" behind this research. We were able to demonstrate that heat treatments prevents larval development of wood boring insects such as *Hylotrupes bajulus, Lyctus brunneus* and *Anobium punctatum*, but heat treated wood was attacked by *Reticulitermes santonensis* termites nearly as much as untreated wood. Laboratory tests performed on densified, oil treated and acetylated wood demonstrated that *Reticulitermes santonensis* subterranean termites were not repulsed by the product and were are able to attack it, but the damages done were less important than in the untreated samples used as control. Generally, among all the tested products none was demonstrated to be totally resistant to termite attacks.

***Laboratory tests and assessment methodology***

Many different laboratory test methods - standardized or not - are used worldwide to assess the efficacy of wood preservatives against termites. These test methods include laboratory evaluation of treated cellulosic material in terms of its resistance to subterranean termites, and as such they can also be used to assess modified wood. Using different methods means using different performance criteria, such as termite mortality rates, mass loss of the tested samples or subjective rating of degradation due to termite attacks.

The standardized protocol which is currently employed in Europe to assess the resistance of treated wood against termites is described in the standard **EN 117** (Wood preservatives – Determination of toxic values against *Reticulitermes santonensis* de Feytaud - Laboratory method). However, many research institutes, as well as manufacturers of modified wood, also carry laboratory tests according to American (**AWPA E1-97** - Standard Method for Laboratory Evaluation to Determine Resistance to Subterranean Termites), Australian (Australian Standard **AS 1604.1**. Specification for preservative treatment), or Japanese (Japanese Industrial Standard **JIS K 1571** - Test methods for determining the effectiveness of wood preservatives and their performance requirements) standards, which differ from the European one regarding the tested termite species, the number of termites used for the test, the wood species used as control, the duration of the test, and the criteria used to assess the performance of the tested specimens. The specificities of the different test methods are presented in the table below (Table 1):

***Table 1: assessment methodology described in four different standards***

| | EN 117 | AWPA E1-97 | AS 1604.1. | JIS K 1571 |
|---|---|---|---|---|
| **Termite species** | All European *Reticulitermes sp* (but mainly *R. flavipes*). | *Reticuliterme flavipes* or *Coptotermes formosanus* | *Coptotermes acinaciformis* or *Mastotermes darwinensis* | *Coptotermes formosanus* |
| **Number of termites per jar** | **260** (250 workers + 5 soldiers + 5 nymphs) | **400** (360 workers and 40 soldiers) | **256** (10 g *C. a.* / 15 g *M. d.*) | **165** (150 workers + 15 soldiers) |
| **Timber species used as control** | **Scots Pine** *Pinus sylvestris* | **Southern yellow pine** | *Eucalyptus regnans* | **Japanese Cedar** *Cryptomeria japonica* |
| **Dimensions of the test specimen (mm)** | 50x25x15 | 25x25x6 | 50x25x15 | 20x10x10 |
| **Placement of the test specimen** | above | in | above | above |
| **Test duration (weeks)** | 8 | 4 | 8 | 3 |
| **Mass loss evaluation of the test specimen** | no | yes | yes | yes |
| **Termites' mortality recording** | yes | yes | no | yes |
| **Visual evaluation of the test specimen** | yes | yes | no | no |
| **Visual rating system** | 0 = no attack<br>1 = attempted attack<br>2 = slight attack<br>3 = average attack<br>4 = strong attack | 0 = failure<br>4 = heavy attack<br>7 = moderate attack<br>9 = light attack<br>10 = sound, surface nibbles permitted | - | - |

Additional test methods, adapted from the standardized ones, have also been developed by different European laboratories. The termite species *R. flavipes* (ex-*santonensis*) has been chosen as the reference species for laboratory tests because it is believed to be the most representative (in terms of behaviour and sensitivity to biocidal products) of the European *Reticulitermes* species.

Laboratory tests should therefore be considered rather as "screening tests", which require further evaluation of the treated material by field methods (for example, above ground termite field tests according to AWPA E3-93). Actually, a single laboratory evaluation of treated and/or modified wood will not provide an accurate idea of what may happen at the scale of an entire colony (termites' feeding and foraging behaviour, the repulsive effect of the tested product, mortality rates).

***Interpretation of tests and modified wood performance requirements***

Product features

Manufacturers of modified woods aim to provide products which are durable, sustainable, user friendly, aesthetic and competitive in terms of service life economy and maintenance requirements. Products currently entering the market of building construction are mainly those dedicated to cladding and decking, as well as window frames and load bearing elements. Obviously, termite risk is not a factor in all Europe, and it varies in the areas affected. This variability depends on the density of termite colonies, the number of termite species occurring in the area concerned, and on the location of the construction site (urban or sub-urban).

To meet high aesthetic and maintenance standards, a wood products such as those used for cladding, must demonstrate total resistance to termite attacks, and merely improved resistance is insufficient. Wood products used for structural purposes should be particularly resistant to termites, for their severe degradation may dramatically reduce their mechanical properties. And even degradation that is very superficial and does not seem to affect the mechanical resistance of the wood, is aesthetically damaging and may require additional maintenance.

Therefore, it is essential that different products made with modified wood be assessed for the risk of being exposed to termite attacks and possibly damaged. As an example, wooden claddings used in the city centre of Hamburg, Germany, may be considered as less exposed to termite attacks than the same product used in south-western France or Spain.

<u>Performance criteria and interpretation of the laboratory tests</u>

The relevance of the three main criteria used in the different laboratory methods, *i.e.* termites' mortality, mass loss of the product and visual examination, deserves consideration, and especially the first one. High mortality rates reported at the end of the tests performed, together with the damages observed on the tested products, indicate that termites are able to damage it, ingest it, but not digest it. That means that when exposed to a product, the termites will die after a period of x days/weeks if they consume it without having access to another source of food. But, under natural conditions and at the scale of a huge colony, we may assume that 1) hundreds of termites attacking a product may dramatically damage it before some of them die and 2) termites which have not consumed the product may benefit from the galleries foraged by their nestmates in the treated parts of wood to reach and damage the untreated heartwood if it is non-durable. Consequently, the mortality rates of termites under laboratory conditions are not a relevant criterion to assess the efficacy of the treatment. In other respects, visual rating of the damages or the calculations of mass loss provide an indication of the termites' ability to consume the wood, which is much more relevant information to be reported. Together with these assessments, it may be also interesting to perform both choice and no-choice tests, with choice tests often demonstrating that termites prefer to feed on untreated controls even when they are also able to attack a treated product. At this point of the discussion, one essential issue should be emphasized: if termites are not repulsed by devices made with modified wood, the probability that they will try to attack it anyway is very high. Even if they do not recognize modified wood as being "real" wood or cellulose-based material, termites will consider it as a "barrier" and may choose to dig into it or to bypass it. Their capability to forage into a given type of material is closely correlated to its hardness, which means that if modified wood is soft enough it may be damaged by termites. No strong correlation has been found between wood density and termite resistance under field conditions (Peralta *et al*. 2004) but the importance of wood hardness was acknowledged as a deterrent to termite damage. Another important factor is the species of termite used to perform tests. Several studies demonstrated that differences exist between species in terms of sensitivity to a treatment, highlighting the importance of testing modified wood against the termite species which occur in the areas where the wood items are intended to be marketed. Imamura and Nishimoto (1986) performed tests on acetylated wood exposed to two different species of subterranean termites and demonstrated that *R. speratus* hardly ingested acetylated wood, while *C. formosanus* were able to attack it. The resistance of acetylated wood to termite attacks was assumed to be due to the inability of termites' symbiotic protozoa (which vary according to the termite's species) to use acetylated wood. Most of the products marketed in Europe have been tested on different termite species. For example, DMDHEU treated pine and beech have for example been tested on Asian subterranean *C. formosanus, Mastotermes* and *R. speratus* termites, and also on European *Reticulitermes* termites (Schaffert *et al*. 2006, Millitz *et al.* 2008). Furfuryl alcohol treated wood demonstated very good performance against the subterranean species *C. formosanus* and *Macrotermes gilvus* and the drywood species *Cryptotermes cynocephalus* (Hadi et al. 2005) which occur in Asia, Australia and/or in United States. But as far as we know, furfurylated wood has never been tested against European *Reticulitermes* termites.

## CONCLUSIONS

As new wood-based products developed in Europe quickly enter the construction market, builders in countries of both northern and southern Europe have to consider the various biological agents that may damage wood. Therefore, it is essential to accurately identify the biological risks to be apprehended and choose the right methodology in order to reliably assess the durability of the product to be used.

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