PROBABILITY OF DAMAGE IN TIMBER STRUCTURES BY MONITORING OF BIOLOGICAL ACTIVITY - MONITOR PROJECT

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ABSTRACT

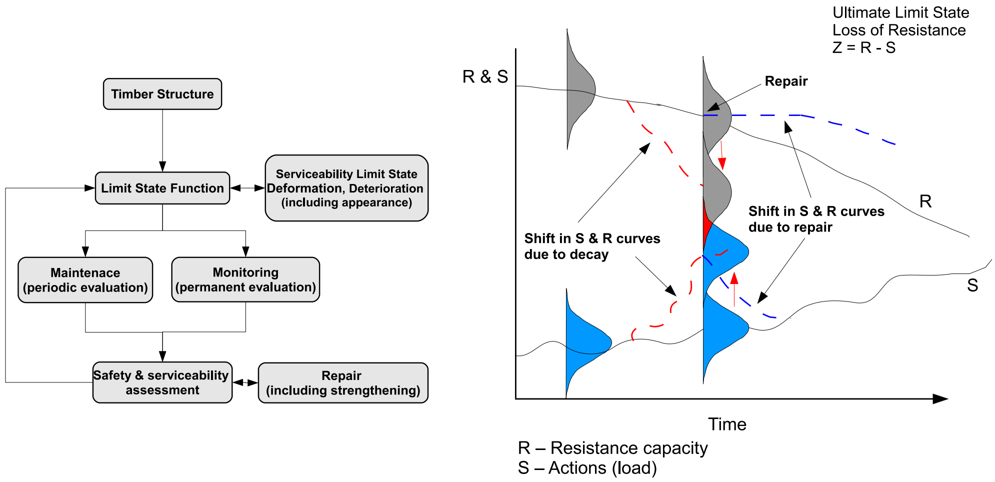
The service life of timber structures is often affected by biological deterioration processes. In Portugal the gross of cases are related with biological degradation by termites or fungi. If detected in an early stage, small scale repairs may solve the causes of the degradation at a reasonable cost. For this to happen it is necessary to develop a network of sensors that could provide a continuous surveillance of the structure and give early signs of possible biological agents or abnormal wood conditions that can promote deterioration. The present paper reviews the results in this field, having in mind the ongoing studies within the research project MONITOR - Sustainability of timber structures by monitoring and control of degradation mechanisms.

KEYWORDS: Wood, Acoustic Emission, Conservation, biological deterioration.

1 INTRODUCTION

Wood as a construction material is often disregarded or replaced by other materials due to its alleged scarce durability. Wood durability can be affected by chemical, physical, mechanical or biological deterioration. From all these deterioration processes the most important and unpredictable is the biological, since it depends on living beings and natural processes. Service life of timber structures could be preserved or even extended if early warnings about deterioration events are available. This can be accomplished through a permanent evaluation of the probability of occurrence of a deterioration process (Fig. 1). The catastrophe of Bad Reichenhall, which occurred in January 2006 in Germany, provided an alert to the need to implement monitoring systems in wide-sapn timber structures[1].

Given the costs involved in general survey inspections these action are usually carried out not more than once a year. Continuous surveillance of timber structures can be conducted in the same principles that nowadays are applied to steel or concrete structures (Fig.1).



General actions

Service life extension by early detection of deterioration (dashed lines – alteration of mean curve due to deterioration (red) or a conservation action (blue))

Fig. 1 Service life insurance scheme

Such a system should be based in a wireless network of sensors providing alerts about the need to carry out subsequent actions on site (inspection, maintenance). Different steps are involved before such a network can be fully implemented in a particular timber structure. The design of the sensor networks should take into account the type of timber structure (wood species, design details) as well as its surrounding conditions (local factors that can enhance the risk of deterioration). A proper monitoring system has to address issues as: what deterioration processes is intended to be controlled; what are the risk parameters that should be controlled; and what equipment (sensor) should be used and where it should be placed (Fig 2). Other different causes of failure of timber structures should be taken into account in a monitoring process based on a case-to-case analysis[2].

In the case of the Monitor project the aim was to detect initial signals about existence of deterioration by decay and/or termites. The monitoring design proposed by the project is presented considering the state of the art on causes, detection and alert of damage concerning deterioration of timber structures by biological sources.

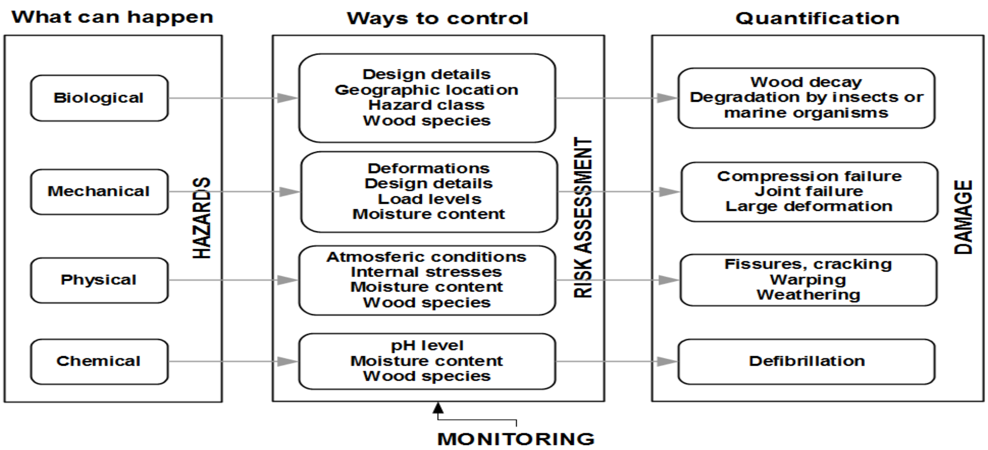


Fig. 2 Some factors that should be taken into account while setting up a monitoring system

2 BIOLOGICAL DEGRADATION MONITORING

2.1 CAUSES OF BIOLOGICAL DEGRADATION

Timber structures durability is affected by different actions along its lifespan. Biological degradation happens generally due to a combination of the presence of ideal conditions (type of wood species and presence of biological agents) and occurrence of accidental events (e.g. persistent water leakage). In the present paper the discussion will focus on decay fungi and subterranean termites. Decay and subterranean termites degradation is dependent on high values of moisture content (> 20%). Wood as a hygroscopic material is prone to variations of its moisture content (MC) when exposed to vapour or liquid water. Nevertheless, application of dry timber cannot be seen as ensuring that timber will be protected from future deterioration from wood decay fungi or termites. Thus normal variation of moisture content can cause physical (fissures and/or delaminations in composite elements) and mechanical deterioration (creep) of the timber members. When unexpected situations of exposure to high air's relative humidity or liquid water presence happen, biological durability can be a hazard. Also in this condition more severe situations of physical (delamination of glulam beams) of mechanical deterioration (compression failures) can occur.

Subterranean termites

Decay

Fig. 3 Biological decay by subterranean termites and wood-decay fungi

Besides accidental events also deficient construction design details can lead to a shorter service life due to decay fungi or subterranean termites' activity[2].

2.2 BIOLOGICAL DAMAGE DETECTION

The risk of biological deterioration (a priori probability that such deterioration could occur) can be evaluated by defining the general use classes using the European Standard EN 335-1. This information should be combined with information on: biological agents present at a particular geographical region; wood species used (durability defined for most of them in EN 350-2); and, construction design details or protective measures provided that could modify the local use classes[3]. Biological degradation by fungi and termites is the major cause for the shortening of the service life of timber structures in Portugal. For that purpose early detection of decay or termite's activity is important to ensure adequate safety conditions during the use of timber structures. Damage detection can be efficiently accomplished by using a continuous surveillance system, which should be designed in accordance with the risk parameters associated with the biological damage (Fig 2). This analyse will allow a proper perception about where the risks have higher probability to occur and assist in the implementation of the different sensors inside and outside the building.

Regarding subterranean termites, the anticipation of attack by these insects begins by using in-ground monitoring stations which may be replaced with a poisoned bait if termites presence is detected[4. These stations should be installed in the soil near the building under surveillance. Although monitoring stations are easily installed, a careful planning of the risks should guide the definition of the number and location of the stations[4].

Inside the building termites activity may be monitored using aboveground monitoring stations[4] or sensors based in Acoustic emission sensors[5]. Acoustic emission is based on the sound generated by the breaking and chewing of wood material. Vibrational signals below 2kHz and acoustic emission between 60 and 150kHz are usually reported in bibliographic references.

The activity of subterranean termites requires timber elements to have regularly moisture content above 20%. This threshold is also applied to the development of wood-decay fungi. Therefore the monitoring of moisture condition is essential to predict the possible deterioration of timber due to subterranean termites and decay fungi attack[6]. The use of moisture content sensors is being mainly based on the electrical resistance method. Resistance sensors are already applied in the monitoring of timber structures in Portugal. These sensors, especially those based on nails, present generally some problems in the long run (entrance of water in the capillary interstices along the electrode – lowering the resistance; loosening the contact pressure between electrode and wood – raising the resistance). Therefore other solutions are being studied based on electric resistance method using screws, electric capacitance method or microwaves.

All these sensors should be incorporated in a network system for structures health monitoring. The model designed for surveillance should have in mind: the need to provide information on future activities to be carried out; and, at the same time, the uncertainty associated with these natural hazards. Video camera monitoring systems can also be used to remotely access critical points of the structure.

3 THE PROJECT MONITOR

The project MONITOR aims to develop a sensor network (SN) (Fig. 4) devised to detect early wood deterioration due to decay or subterranean termites activity. Subterranean termite’s point of entry is mostly probable from the foundations. Therefore, the SN comprises the monitoring of possible presence of termites in the soil in the vicinity of the building. For that purpose in-ground monitoring stations are being used[7].

The project is currently undergoing tests to select appropriate sensor technology. The developments and tests carried out are being made under laboratory conditions. The baits are in a more advance stage and some field results are already available. The detection of termites’ activity and sending of the signal to the acquisition module will be analysed in parallel with the testing of acoustic emission sensors for indoor monitoring of timber members. Besides acoustic emission sensors also microphones and accelerometers are being tested.

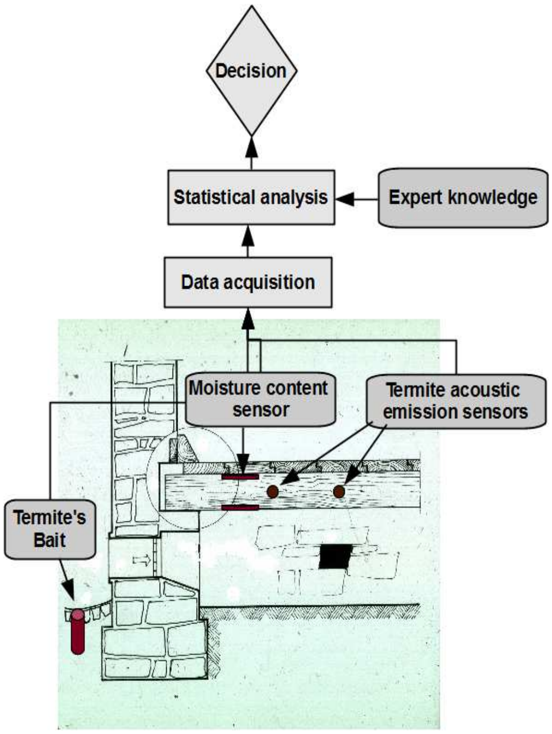


Fig 4. Sensor's network proposed by MONITOR

Decay sensors based on the electric capacitance method is now being tested. The decision making process has to take into account that a certain margin of uncertainty is associated with each sensor data. Therefore for each type of sensor it should be checked its probability of detection (PoD) capacity.

A robust statistical analysis is then necessary to examine the data received from the different sensors and to provide an alert. Since the NS system only provides an indirect evaluation of the presence of termites a probabilistic approach should be used. The aim is to provide an Event Probability Index (EPI) variable. This EPI depending on its strength can lead to a warning about the immediate necessity to take an action or to propose a short or long-term plan of maintenance/repair. In the latter case available deterioration models and the expert knowledge should be used. In the case of decay the EPI value will be adapted from an available decay deterioration model [3] (Fig. 5).

In the case of termites it will be used a Dynamic Bayesian Network (DBN) model. BNs models are used to characterize systems probabilistically, and to update probabilities with new evidence. DBN models are applied in modelling deterioration processes where significant uncertainty is present [8]. The generic DBN that is being considered for the Monitor project is shown in Fig. 6.

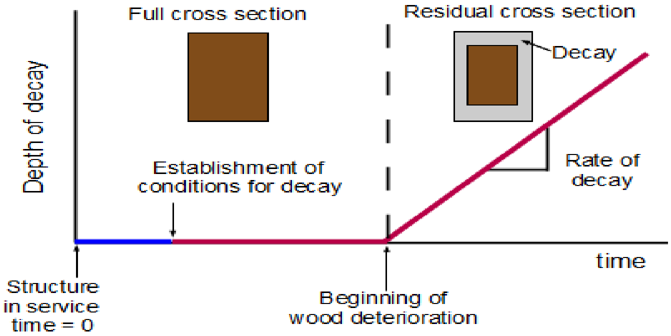


Fig. 5 Idealised deterioration process due to decay[3]

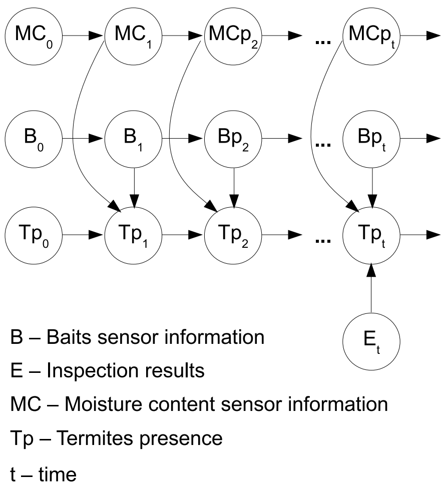


Fig 6. Bayesian network model for MONITOR

4 FINAL CONSIDERATIONS

The lack of adequate monitoring schemes of timber structures is one of the factors affecting its future application. The development of sensors dedicated to early detection of specific problems associated with this type of structures can maintain or extend its service life. The research activities of the MONITOR project are inline with this goal.

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