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The biology and ecological control of timber decay organisms in historic buildings

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ABSTRACT

The built environment is the product of complex interactions between the external environment, the building materials, the design, the contents, the activities in the building and the occupants, both human and commensal. To try to manipulate any one of these factors without consideration for the effects on the others can be at worst ineffective and at best inefficient and costly. Timber decay organisms cannot be eradicated even by the most Draconian pesticide treatments. However, they can only flourish in buildings if the environmental conditions are suitable. Even with the loss of traditional skill and the complexities introduced into building by new materials and uses, these conditions can easily be avoided with a little thought and scientific understanding. Indeed new materials and techniques can often be used to advantage if their properties are analysed as potential environmental controls. This more rational approach to the treatment of timber decay is really only good building practice which independent surveyors and their scientific consultants should promote in the interest of sound building and public health.

INTRODUCTION

Timber is still one of the most useful structural materials in a world of diminishing resources and is a major component in most historic buildings. It has many structural and aesthetic properties as well as being an energy-efficient and renewable resource. In living trees the sapwood is much more resistant to decay than heartwood and this situation reverses when the tree is dead or felled. On the forest floor the wood is decayed by several thousand saprophystic microorganisms and eventually add nutrients to the humus soil and this process is called biodegradation. Fortunately most such organisms live in the forest floor where dead would naturally be found. However, timber used in historic buildings, provide specialised ecological niches and many organisms have evolved to utilise it as a food. Timber decay in buildings is caused by a broad spectrum of fungi and insects [5,7,8,9,10 & 11]. The most common and destructive to timber are dry rot *(Serpula lacrymans)*, wet rots *(Coniophora puteana)*, common furniture beetle *(Anobium punctatum)* and death watch beetle *(Xestobium rufovillosum)*.

The traditional understanding has developed construction techniques that avoid the conditions that allow decay. These are: minimise water penetration; ensure adequate air movement around all structures; and allow all permeable materials to 'breathe'. Traditional buildings were also often built so that each part could be inspected, repaired or replaced without disposing of and wasting the whole. Such techniques evolved to suit local materials and conditions by a process of trial and error [3]. This knowledge was then passed on from master to apprentice and formed part of a craftsman's understanding of his trade. In recent times, especially in the last 50 years, the old system of craft training has been destroyed, while new materials and techniques have been introduced at an ever-increasing rate.

This lack of knowledge leads to instant 'spray on' solution to timber decay [4]. The attraction of chemical timber treatment was irresistible and it was hoped that deficiencies in the quality of materials, workmanship or maintenance could be covered up by the ubiquitous application of a cheap, general-purpose pesticide mixture. The problems with this approach soon became clear. Remedial treatment of the infestations with insecticidal fungicidal chemicals is not only expensive, inconvenient, unneccessary, hazardous

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to the operatives and occupants but also environmentally unacceptable [6]. Orthodox measures could entail the loss of irreplaceable decorative finishes, floors and ceilings. Eradication of dry rot spores or insect pests in an historic building and its contents is in practice, impossible. The volumes of chemicals necessary and the toxicity required would be damaging both for the buildings and all its occupants.

Remedial timber teatments and exposure work may result from panic induced by the reputation of dry rot; it is frequently destructive and continued failures of treatment to control decay consistently led to a demand for 'guarantees' [6]. Apart from a risk to the health of operatives and occupants, the type of treatment may not matter; the objective may be merely a guarantee for mortgage purposes. These could only be provided if measures were taken to control the environmental conditions favouring decay, and comprehensive exclusion clauses had to be incorporated to disclaim liability if such conditions occurred. A proportion of turnover had to be set aside to cover these guarantees because, in spite of the best efforts of the specialists, treatments continued to fail.

Environmental control and preventative maintenance are preferred to draconian chemical treatments, as they provide a long-term solution to the health of the building and its occupants [2,12]. A correct scientific analysis can provide an alternative, less destructive solution. Controlling the environment around a susceptible material, is still the most widely-used method of preventing biological decay. Correct identification of the fungi and insect material is important as not all fungi are equally destructive. Some rots are present in timber when it is cut or are acquired in storage. Fungal materials may also be dead or dormant, representing conditions now past.

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BIOLOGICAL AGENTS

DRY ROT

The ravages of dry rot are familiar, as is the destruction caused by attempts to eradicate it [13,16]. Dry rot *(Serpula lacrymans)* is a fungus belonging to the same group of fungi as most common mushrooms and toadstools [1]. Reproduction is by rust-coloured spores, which are produced in enormous numbers by a fleshy, pancake-shaped fruit body, a sporophore, which can sometimes measure more than a metre in width. A sporophore less than one metre square can produce more than fifty million spores per minute for several days [8 & 12].

The appearance of the fruiting body, together with a distinctive 'mushroom' odour may be the first indication of an outbreak of dry rot (see photograph 1).

Spore germination requires a precisely favourable microclimate at the wood surface - a timber moisture content of 20% to 30% (see figure 1). Fine filaments known as hyphae appear. These form a white mass called mycelium, which can colonise timber with a moisture content of 20%, growing at an optimum rate when it is between 30% and 40%. The mycelium produces an enzyme called cellulase which can digest the cellulose in the cell walls, but is unable to attack the rigidifying polymer (in the cell walls) called lignin. The lignin therefore remains as a brittle matrix which cracks into cubical pieces (see photograph 2). Cuboidal cracking is also a characteristic of many wet rots (longitudinal cracking is more common in timber affected by wet rot (Coniphora puteana) or (cellular rot fungus) and does not necessarily indicate dry rot.

The fungal strands have the ability to spread through plaster, brickwork and masonry owing to a relatively impervious, alkaline-tolerant, outer layer, and can extend a distance of several metres from its food source to attack sound timber using specialised hyphal strands (rhizomorphs). Rhizomorphs are conducting strands, formed by the mycelium, able to transport nutrients and water. They may be up to 6mm in diameter and are relatively brittle when dry, and flexible when moist. The mycelia produce water by metabolic breakdown of wood and can translocate it from one timber to another via these thick strands. It has been suggested that dry-rot fungus can live on this metabolic water alone, but in practice the water is reduced by evaporation and dispersed within the dry timber by capillary action. To thrive, dry rot requires a timber moisture content of over 20%, below which it will become dorment and eventually die within nine months to a year.

Wood thoroughly rotted with dry-rot fungus is light in weight, dull brown in colour, crumbles under the fingers and loses its fresh resinous smell. It is also called brown rot, a term relating to the manner in which it destroys the cellulose, but leaves the lignin largely unaltered so that the wood acquires a distinctive brown colour. As a result of this, the structural strength is almost entirely lost.

WET ROT

Wet rot is caused by a number of Basidiomycete fungi. Some wet rots are also called white rots as they destroy both cellulose and lignin, leaving the colour of the wood largely unaltered, but producing a soft, felty or spongy texture. They attack both softwoods and hardwoods causing a darkening of the timber or bleaching. Wet-rot fungi usually occur in persistently damp conditions, needing an optimum moisture content of 50-60%. Unlike dry rot the conducting strands of wet-rot fungi do not extend far from their nutrient wood, hence they cannot travel through masonry and brickwork. Wet rot has been known to hollow out giant beams and is responsible for up to 90% of wood decay in buildings.

There are many fungal species causing wet rot including the most common species, for example Coniophora puteana, C. marmorata, Antodia sp, Phellinus contiguus, Pleurotus ostreatus, Asterostroma sp and Donkioporia expansa (5,7,8 & 9).

INSECT ATTACK

Among the many insects found in buildings, beetles are the more dangerous, causing serious damage to building timbers, because they are able to use wood as a food source. Most of the wood-boring insects will attack only damp wood and some have a preference for wood which is already predigested by fungal attack, for example deathwatch beetle and weevils (10 and 11).

Deathwatch beetle is a pest of hardwoods, predominately oak in historic buildings. It also attacks softwoods, particularly when in contact with infested hardwood and other hardwoods which have previously been modified by fungal attack. Emergence holes and tunnels are circular, 3 to 4mm in diameter, extensive mainly in the direction of the grain of the wood and produce cream-coloured, disc-shaped pellets (bore dust). Deathwatch beetles are not active fliers and are found on or beneath the timbers, window sills and carpets between the months of March and June.

The common woodworm or furniture beetle *(Anobium punctatum)* will attack the sapwood band of building timbers. Infestation is usually detected by emergence holes up to 2mm in diameter. Active infestation produces fresh frass (bore dust) which is cream-coloured or the colour of freshly cut wood.

ENVIRONMENTAL CONTROL OF TIMBER DECAY

ECOLOGICAL FACTORS AFFECTING TIMBER DECAY

The environmental factors favouring the decay of timber are temperature, water, humidity and lack of ventilation.

Fungi differ in their optimum temperature requirements, but for most the range is from about 20° to 30°C. The optimum temperature for dry-rot growth in buildings is about 23°C, maximum temperatures are about 25°C and the fungus is rapidly killed above 40°C. Timber moisture contents in buildings in the 20 to 30% range is ideal for dry-rot attack and other infestations.

MEASUREMENT AND SIGNIFICANCE OF MOISTURE CONTENT

The estimation of surface moisture contents in plaster and mortar are of limited value except for comparison. A surface capacitance meter may be used on plastered walls and panelling to detect areas requiring further investigation. Absolute readings should be made by means of a carbide-type gas pressure meter or by the oven drying method. Moisture reading contours on the surface and in the thickness of the wall help to define the source and type of moisture giving rise to decay.

The surface timber moisture content may be estimated by the use of a resistance type moisture meter, fitted with insulated needle probes. However, the actual deep moisture content at the core of the timber reflects the absolute values of moisture, and this can be measured with a hammer probe. The hammer probe is fitted with long insulating electrodes and is recommended for measuring the sub-surface moisture content [14 & 15].

NON DESTRUCTIVE INVESTIGATION

The technolgies include **Fibre Optic Inspection**, and **Canine Detection**

Fibre optic inspection of decay fungi

The correct identification of the infestations behind concealed cavities is important, as not all pests are equally destructive. By employing the use of high power fibre optic instruments, the type and extent of infestation in concealed cavities can be assessed. High intensity light is produced by the light source and is transmitted and illuminates the infested area under inspection through a liquid light guide and a rigid fibre optic eye-piece. The image can then be photographed using a 35mm SLR camera, attached to the eye-piece.

Canine detection

Canine detection, helps to discover the location of dry rot and whether or not it is actively growing. 'Rothounds' sniff Dry Rot Fungus in much the same way as dogs can sniff out drugs or explosives, uncover avalanche victims, and snuffle for truffles. Obtaining fresh

Dry Rot samples to train dogs is a tedius process because it
is difficult to duplicate the subtle conditions required to grow the fungus outside its normal habitat. Removing pieces of Dry Rot from infested areas does not work, for the fungus soon dies and the scent is lost, so becoming infective for training purposes. On the other hand, *Serpula lacrymans* produces specific secondary metabolities during its active growth period, and dogs can be trained to detect these metabolities.

ENVIRONMENTAL CONTROL POLICY

The causes of decay in materials and structures is influenced by the internal building environment, which has a varied microclimate dependent on the building's structural aspects [14 & 15].

The detailed investigation should include a complete external survey. For example, inspection of roof tiles or slates, chimneys, valley gutters, flatroofs, walls, downpipes. Damp proof course, external joinery and airbricks. The internal investigation of the vulnerable timbers should include skirting on damp walls, built in timbers for example ends of joists, wall plates, and bearing ends of timbers in non-cavity walls.

The source of moisture must first be traced and eliminated. Dry rot will die if the moisture content drops below 20% and stays there - there is no evidence that dry rot can produce and conduct enough water to enable it to live and infect new timbers after the original water source has been destroyed. The breakdown of wood by fungus does produce water and the fungus can translocate this water from one timber to another via strands, but only in a 'statically dry' area which is already moist. In practice the water is reduced by evaporation and the fungus is unable to translocate water through a 'dynamically dry' area, which evaporates water.

To restrict the activity of dry rot and to prevent it from spreading further all rotted wood must be removed. All dry rot fruiting bodies and dead strands should be taken away in a sealed bag and masses of dry rot spores if seen, should be vacuum cleaned. Environmentally it is easier to control wet rot, because it requires a much higher moisture content to establish itself.

When treating insect infestation it is advisable to undertake a thorough biological analysis before using chemical treatment. The presence of fresh frass (bore dust) is acceptable evidence of active infestation, but the occurrence of a few old woodworm holes in a piece of structural timber, perhaps several hundred years old, will indicate a past history of infestation not necessarily requiring treatment today. Woodworm and deathwatch beetle will not flourish if the moisture content of timber is below 14% and the infestation will eventually die out if the moisture content is maintained below 12%. Installation of a central heating system which can reduce the moisture content to about 9%, will therefore control any risk of insect attack.

REFURBISHMENT AND MAINTENANCE PROGRAMME

Refurbishment programmes should be aimed at drying out the building fabric to reduce the risk of future insect and fungal attacks. Saturation of masonry as a result of long-term leakage, groundwater penetration, flooding or dousing after a fire, should be thoroughly dried out before the commencement of any refurbishment programme. The introduction of dehumidifiers, central heating systems and adequate ventilation will encourage drying out of the fabric and can be monitored by the installation of remote sensing systems. Any new and existing healthy timber should be isolated from surrounding damp masonry. If an active infestation is detected, appropriate exposure work can be done immediately to stabilise the situation until the final method of conservation and repair is decided.

Wherever possible it is perferable to institute effective inspection and preventative measures causing minimum disruption. Repairs should be carried out in the original materials for purposes of authenticity and compatibility, and because new materials and methods can sometimes create problems, such as changes in vapour diffusion, air permeability, thermal movement and chemical and electro-chemical effects.

General maintenance should include frequent cleaning of gutters, hopper heads and downpipes a roofheating tape can be placed along gutters and downpipes to ensure a constant water flow in snow and frost. With careful conservation and good maintenance a building should be under no danger from the ravages of insect infestation and wood-rotting fungi.

BUILDING MONITORING SYSTEMS

In many cases remote monitoring systems can be very useful in increasing the efficiency and reducing the cost of maintenance programmes. They can be especially useful for checking the moisture content of inaccessible timbers in roof spaces, behind decorative finishes and in wall. Sensors can be placed at all critical points after the investigation or after the remedial building works. Areas can then be closed up and finishes re-applied: for example, sensors may be placed in lintels, joist ends, valley gutter soles or in damp walls to monitor drying. It is important to use enough sensors and to place them with an understanding of the moisutre distribution processes, because conditions can vary even in a small area. It is these local variations in conditions that produce the environmental niches which decay organisms exploit. This system can be programmed with logging intervals and alarm limits for each sensor and can be read via the telephone system via its own modem. Data from the system can then be analysed using CAD and programmes for statistical interpretation on a remote computer.

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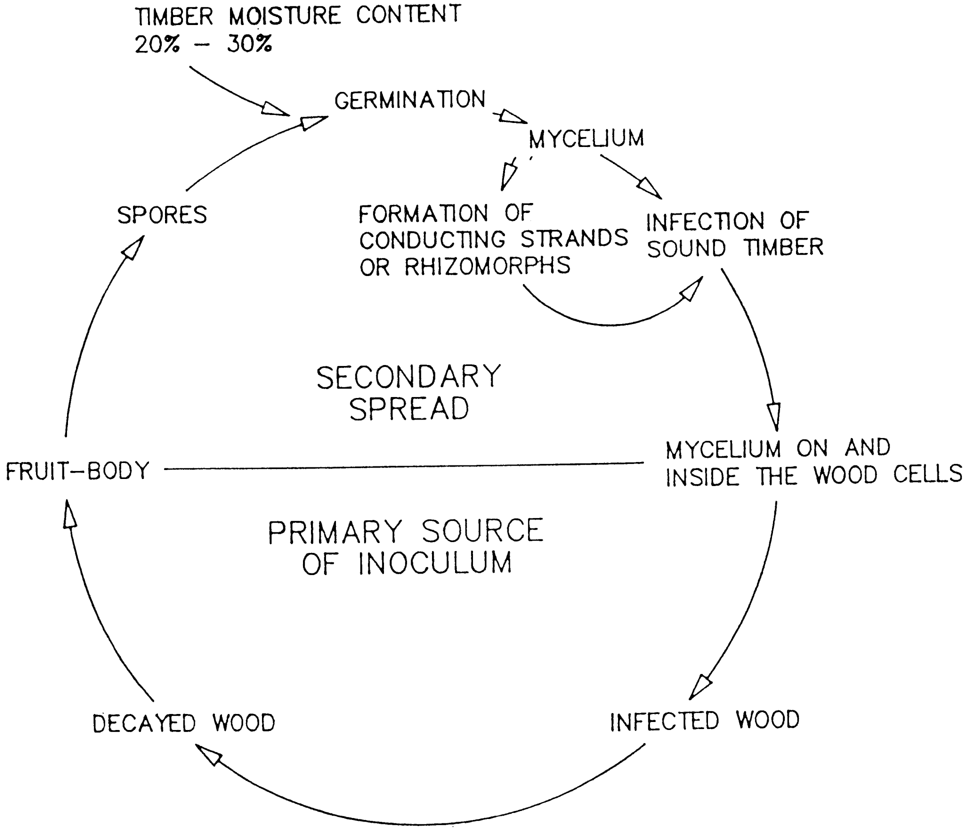

Figure 1 Life cycle of decay fungus

Figure 2 Dry rot fruiting body

Figure 3 Decayed wood