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Designing out Timber Deterioration: Environmentally Sustainable Conservation Solutions

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Author's Biography

Dr Jagjit Singh BSc, MSc, PhD, CBiol, FIBiol, FRSA, FRSH, is a Director of Environmental Building Solutions Ltd and specialises in building health problems, heritage conservation and environmental issues.

He has more than 17 years' experience as a building pathologist and expertise in heritage conservation, indoor air quality & health in the UK and abroad in both academic and commercial environments.

He has published in excess of 200 technical papers and communications, contributed to books and lectured widely on conservation, building pathology and building health problems.

He has edited several books including Building Mycology, Management of Decay and Health in Buildings, Environmental Preservation of Timber in Buildings and Allergy Problems in Buildings.

His current research focuses on interrelationships of building structures and materials with their environment and occupants.

Dr Singh is BBC Expert on matters of dampness and timber decay in buildings.

Introduction

Timber is environmentally friendly material and is natural, non-toxic, organic, recyclable, renewable, and biodegradable. Timber is oldest material used by mankind in construction and in structural integrity it can be equivalent to pre-stressed concrete lintel, if it is kept dry and well ventilated in buildings. It is easy to use in construction, causes low pollution and requires far less energy to convert into usable products than materials such as steel and concrete therefore less environmental impact.

Timber in historic buildings, abbeys, churches, timber frame buildings, barns, castles, jetties, bridges and other structures is inherently susceptible to fungal and insect infestation and decay, if it is not well designed, kept dry and well ventilated. Once the infestation has started it will continue to propagate, if the conditions are favourable, until eventually the timber member can no longer sustain loads (see photograph 1).

In Great Britain we are the champions of the following facts;

- Misdiagnosis of timber infestation and decay in buildings
- Misunderstanding of timber infestation and decay in buildings
- Mistreatment of timber infestation and decay in buildings

In addition to the above I would like to inform you today that the damage and destruction caused by timber decay organisms is less than the damage and destruction caused by the professionals who treat these infestations.

In my presentation today, I will further corroborate the above three points with some case studies.

Fungal Infestation and Timber Decay

Timber decay in buildings is caused by a variety of insect and fugal decay organisms. The most common fungi to cause damage to building structures are the dry rot fungus (*Serpula lacrymans*), cellar rot fungus (*Coniphora puteana*) and wet rot fungi (*Antrodia vaillantii, Antrodia xantha, Asterostroma* spp*, Donkioporia expansa, Paxillus panuoides, Antrodia xantha, Phellinus contignuus* and *Tyromyces placentus*).

The dry rot fungus, *Serpula lacrymans* (*Schumach. ex Fr. Gray*), (previously known as *Merulius lacrymans*), is the most important timber decay fungus in buildings in northern and central Europe, and is also of serious concern in Japan and Australia. *Serpula lacrymans* is the most virulent form of fungal attack in building timbers, and buildings of traditional construction are particularly vulnerable to this form of decay.

Not only does the fungus bring about the dramatic decay of timber, but it is also able to spread through a building from one timber location to another across non-nutritional surfaces. The fungus has a serious impact on the housing stock of the United Kingdom and also causes concern when dealing with the conservation of buildings of architectural or historic value.

Characteristics of Decay

Main Characteristics of Timber Decay

There are four key characteristics that can be used in the identification of fungal growths: mycelium, appearance of decaying wood, strands and fruiting bodies (Sporophores).

The environmental conditions in the building, combined with the quality of timber in construction and use of the building play an important role in the type and characteristics of infestation and decay.

The first sign of decay in the building sometimes is the fruiting bodies of the decay fungi, and this is an indication that the environmental conditions are not suitable for the infestation and decay. This sometimes mainly the results of fixing water leaks and introducing ventilation in the infested areas.

The following notes compare these characteristics for dry rot with those of wet rots.

Main characteristics of fungal decay of timber.

Characteristic	Dry rot	Wet rot
Mycelium	Damp conditions: masses of tears on silky white surface, with bright lemon patches. Drier conditions: thin skin of silver grey in colour, with deep lilac tinges.	High humidity: yellow to brownish in colour
Decayed wood	Deep cuboidal cracking associated with differential drying shrinkage. Reduction in weight. Dull brown in colour. Resinous smell gone	Cuboidal cracking on smaller scale. Thin skin of sound wood. Weight loss. Localised infection
Strands (Rhizomorphs)	3–mm in diameter. Brittle when dry. Off-white/dark grey in colour.	Thinner than dry rot. Flexible when dry. Creamy white in colour.
Sporophores (Fruiting bodies)	Tough, fleshy pancake or bracket-shaped, varying from a few centimetres to a metre across. Ridged centre: yellow-ochre when young, darkening to rusty red when mature. Lilac/white edged. Distinct mushroom smell.	Not very common in buildings Musty smell, rather than mushroom smell associated with an active growth of dry rot

Photograph 1

Extensive timber decay caused by dry rot (Serpula lacrymans)

Dry Rot (Serpula lacrymans)

Dry rot infestation in building is treated as cancer of building. The fungus grows in cavities and voids, where the environmental conditions are conducive to its growth and proliferation. The development of the dry rot will not happen in timber of low moisture content. It is generally considered, though difficult to measure precisely, that moisture levels in wood need to be over 20% (weight for weight) before dry rot can develop. This is not much higher than the moisture level found in well seasoned wood (around 12-16%) but nevertheless it is a level that should not occur in a well maintained building. At low moisture levels water in wood is intimately associated with wood fibres. Above 20% moisture content allows 'free' water starts to appear in the wood structure and it is this free water which is essential for fungal growth and development. The 20% level is termed the 'fibre saturation point'. It is as well to be aware that precise moisture measurements in wood are probably of less importance than changes and trends within buildings. The dry rot fungus has occupied a specialized ecological niche in buildings in Europe with its unique biology, and is only known to occur in the wild in the Himalayas. The author has led several Himalayan expeditions for the search for wild dry rot in the Himalayas with a view to gathering information on its biology, ecology and genetics in the wild.

The ravages of the dry rot fungus are familiar (see picture 2), as is the destruction caused by attempts to eradicate it, particularly involving the use of chemicals.

The vast majority of properties in the United Kingdom contain a significant amount of wood, ranging from structural timbers (such as joists, breassummes, rafters, wall plates, purlins and timber safe lintels) and finishings (such as timber panelling and boarding, skirtings).

Photograph 2

Dry rot fruiting bodies to timber staircase, causing extensive structural damage.

Inspection

The correct and early diagnosis of dry rot requires an understanding of the pathology of the fungus as well as a sound knowledge of building construction. Determining the presence of hidden or built-in timbers is crucial to a full and accurate detection of the fungus. There are a number of non-destructive techniques that the surveyor can use to help in arriving at a correct diagnosis. In order to detect the type and extent of fungal decay, remedial measures could entail the loss of decorative finishes, extensive exposures and damage to the fabric of the building; such work can be very expensive.

Dry rot in its early stages is difficult to distinguish from other wood rots without the benefit of laboratory analysis. This involves growing samples of the fungi on an artificial medium under controlled conditions. Various media based on oatmeal, wheat flour and malt extract can be used as a nutrient to encourage fruiting of the fungus.

In its terminal stages when the fruiting bodies or sporophores have developed brown spore dust dry rot is relatively easy to distinguish from wet rot. The former, however, can spread to other timbers, even through masonry materials, whereas the latter is always restricted to the locus of the moisture source. This ability to spread is one of the distinguishing and menacing feature of *S. lacrymans*.

Other techniques used included microscopy, laboratory culture and identification of fungi and insects, hot wire anemometry and electronic moisture and RH measurement(see photograph). More exotic techniques may sometimes be useful such as infra-red thermography, short wave radar, automatic weather stations, ultrasonic detection of timber and total building monitoring using specialist data loggers. It is important to remember that any technique must be carefully justified because the value of the information from techniques not routinely used or properly calibrated can be very limited.

Photograph 3

Dr Jagjit Singh using hammer probe to measure deep moisture content of timber.

Remedial chemical timber treatment can cause damage to the health of building occupants and is a cause for concern to environmental health authorities.

It is the lack of understanding of the biology and ecology of the dry rot fungus that has led to this radical treatment and hence considerable damage to building fabric. It is hoped that the fundamental scientific knowledge gained through multi-disciplinary research should enable us to reach a better understanding of the fungus and to develop safer, more effective, ecological control techniques and strategies. Not only is fungal infection of timber unsightly and potentially hazardous to human health, it can also adversely affect the structural integrity of the timbers as well as disrupt the use of the building.

The increasing appreciation of unique environmental credentials of wood and the European Government vision 2010 will enable the wider use of timber in construction.

It is therefore important that the building or structure is regularly surveyed, monitored and evaluated for timber decay to prevent failure or collapse, which could result in loss of use or personal injury.

The lack of maintenance and knowledge about timber in construction, the environmental factors and the role-play by timber decay fungi and insects causing a range of failures to the timber used in construction.

The following pictures illustrate the typical failures of timber in construction (see picture 4 and 5).

Photograph 4

Dry rot mycelium growth to the timber floor, causing extensive structural decay to the floor.

Based on this information, environmental control measures can be put in place to prevent further advancement of the decay.

The Conservation Approach

The conservation approach involves carrying out regular inspections using a range of non-destructive investigation techniques. This approach enables a specific maintenance programme to be drawn up and ensures that the loss of historic fabric is kept to a minimum.

Photograph 5

Dry rot fruiting body to the under stair void causing structural damage to the staircase and wall panelling

A number of other in-situ methods for timber decay assessment are available; however, these involve destructive techniques and have had varying degrees of success in detecting decay and predicting the residual strength of timber members.

The analysis of decay organisms with destructive sampling is neither sympathetic nor acceptable to the conservation of historic churches, castles, abbeys, monuments and other landmarks. Furthermore, remedial chemical treatments for woodworm, death-watch beetles, dry rot and wet rots are very expensive and often cause more damage to the health of building fabric and people than the infestation itself.

The majority of environmental problems are associated with building defects leading to water ingress, condensation and dampness in the building fabric. Severe salt efflorescence, staining, blistering of finishes and timber decay in buildings are mainly the result of water penetration.

The causes of deterioration are influenced by the internal building environment, which has a varied microclimate depending upon the building structure and the envelope of the internal building fabric.

Site Investigation and Resistograph Methodology

The Resistograph drill does require a little time to penetrate into and back out of the timber member. Care must be taken to ensure the Resistograph is held steady while drilling, otherwise damage to the bit will occur. Care must also be taken to avoid any metallic obstructions that may be in the path of the drill bit.

Large numbers of timber members can be inspected in relatively short periods of time using the Resistograph. This is advantageous since the longevity and cost-effective maintenance of historic timber structures relies on early detection of decay and preservation of the members.

This methodology involves the use of a Resistograph drill which drives a 3mm diameter drill bit up to 440mm into the timber member. As the bit penetrates the wood the rotational resistance is shown on an LED display and recorded on a print-out chart. This gives an immediate profile and permanent record of the internal condition of the timber.

Regions of sound wood are shown as high resistance to forward motion of the bit. As the bit enters a decayed region, the resistance to forward motion is reduced and a low signal level is recorded.

Environmental Monitoring

To determine the causes of the above, environmental monitoring and investigation is best carried out. This is done by employing a range of hand held instrumentation, physical sampling and sensor technology to monitor various parameters within the fabric of the building.

The first step to investigation of a problem building is to carry out a thorough inspection of the building for defects. The second step is:

- to Establish moisture contents in affected materials, such as timber, plaster, masonry, insulation materials and textiles.
- to Establish the humidity, temperature and dew point in the environment. Both internally and externally.
- to Investigate in greater detail as necessary the moisture profiles in large dimension timbers and across masonry masses.

This information can be determined by:

- Moisture contents of timber can be taken directly by the use of resistance based moisture meters. Probes can also be used to measure moisture contents at depth in large section timbers and those built into masonry.
- Surface moisture readings in plaster and masonry can be taken using moisture meters. These will indicate if a wall is dry but can give false readings of dampness, see below.
- Were possible mortar samples should be taken of the areas affected to determine accurately the moisture and salt content of the masonry. This does however have the disadvantage of not being non-destructive.

- Data loggers can be used to measure the environmental parameters, temperature, Humidity and dew point both internally and externally.
- Specialist probes can be used to measure moisture across masonry walls.

The results of all or some of the above tests will establish the cause and enable a solution to the problem to be put forward.

Environmental Data Loggers

Data loggers measuring temperature and humidity are useful to determine whether there is for instance an abnormally high humidity or risk of condensation in a building.
If readings are taken on both the interiors and exteriors of the building dew points within materials such as masonry masses can be calculated.

Stabilising the Historic Environment

Once the above investigations have been carried out a strategy can be put forward to stabilise the building environment.

It is important to stabilise the historic building environment. For the holistic and sustainable conservation and preservation of the building, various building works will be required to prevent further water penetration and to maximise ventilation to damp affected materials.

Correction of these building defects, combined with measures to dry down the wet areas and to protect the decorative interior finishes by allowing ventilation of the wet areas, will prevent further deterioration.

Until the drying out of the building fabric and its associated timber elements is completed, any other actions to remedy the deterioration problems will be ineffective and a waste of time and resources. Continuous long-term monitoring and preventative maintenance of the building may be necessary and will provide the following information:

- on the state of moisture equilibrium and balance (moisture sources, reservoirs and sinks) in the building environment, building fabric and structural elements as the building dries out;

- will allow co-ordination and scheduling of work stages to prioritise the remedial work to achieve acceptable levels of moisture in the masonry and timber to prevent future deterioration problems;

- will allow a cost-effective, long-term holistic approach to environmental stabilisation of the historic environment.

Further Reading

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