TECHNICAL BULLETIN - UNDERSTANDING THE MECHANISMS OF NATURAL DECAY IN WATER REED ON THE REED BED AND AS THATCH

The art of growing, harvesting and thatching, is in understanding and delaying the inevitable process of wear and degradation for as long as possible.

Reed (thatch) is probably the oldest roofing material that is currently still used in Europe. The Roman writer Plinius wrote about it in the year 66 after Christ's birth: Thatch remains very popular today, especially in those regions where reed has been growing for a long time, e.g. in Holland, in the south of the United Kingdom, in the north of Germany and in Denmark. Over centuries reed has adapted again and again to the existing demands that are imposed on a roof.

There are many theories as to why thatch decays and if considered together it is easy to be overwhelmed making it almost impossible to separate the raw material from thatching and environmental conditions. It is important for those producing and using water reed for thatching to understand how quality parameters are chosen and evaluated. In a changing climate and with more demanding customers, what worked 50 years ago is very different now.

Reed cutting for thatch commences in November when the reed has hardened. It generally ceases in March to avoid damage to new shoots. The art of growing, harvesting and thatching with straw and water reed, is in understanding and delaying the inevitable process of decay for as long as possible

Until recently, premature decay of some thatched roofs was believed to be associated with poor reed quality linked to water condition in which water reed grows and are now containing high levels of nutrients. In 1991 Boar and 1994 Haslam carried out initial research on issues of water quality on reed decay and could find no links. They concluded that the length and durability of thatching reed is not affected by high nutrient levels in the reed bed environment. However, Haslam writing on understanding wetlands, notes that in acid bogs fungi become more important but in very wet conditions most fungi particularly basidiomycetes are not found.

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Natural cycle of decay in unmanaged reed beds.

In their natural habitat, all the plant material found in reed beds is broken down and decayed chiefly by fungi and small organisms. Breakdown organisms only attack mature/dead stems and since most deterioration start at ground level it is not until the toughest part of the plant (the butt end) has died that breakdown takes place.

Under natural conditions the reed then breaks and falls leaving a short stump above the living rhizome, fallen reeds then decompose as part of the natural cycle of the reed bed. If left un-managed these conditions can lead to poor water management, reduced quality in the reed and ultimately a reversion to secondary scrub or carr where trees such as willow and alder gradually replace water reed.

The organisms associated with breakdown of plant material

The biodeterioration of lignocellulosic material in nature plays an important role in keeping the carbon cycle functioning. Many of the authors on the subject describe a cycle initiated and maintained by specific groups of organisms at different stages of the decay cycle. Early colonisers include the Sapstain fungi, moulds yeasts and specialist bacteria which live on easily available nutrients, such as free sugars, low polymerised carbohydrates and proteins. These are followed by the lignin destroyers, soft rot fungi and tunnelling and erosion bacteria. The activity of the bacteria in addition to bringing about permeability changes also brings about chemical changes in the woody tissue, depletion of nutrients, formation of organic acids and discolouration.

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In attempting to investigate and to understand the possible causes and find solutions for the premature decay of water reed roofs thatched during the past ten years, it is first necessary to identify the organisms responsible for initiating decay found in roofs and secondly to explore the habitats and life cycles of identified organisms in order to identify changes that may alter conditions that can make the environment for growth of micro-organisms unfavourable; thus limiting the level of decay of water reed thatch on the roof.

Many saprophytic micro-organisms are involved in the degradation of plant biomass in the natural environments. However, the majority of these are unable to breakdown or modify the lignin component of cell walls and of wood. Only *Ascomycetes* are able to partly mineralise lignin or to transform it into water-soluble components. These then become available as a food source for other breakdown organisms in the feeding chain.

Ascomycetes

Ascomycetes area family of fungi growing in association with slime moulds and lichens. Of the ascomycetes group Kirby and Rayner identified *Dasyscyphus sp* on four roofs and *Sclerotinia sp* found on two other roofs appeared to cause a form of bleaching that may have been due to the ability of this fungus to produce hydrogen peroxide.

The Ascomycota, or sac fungi, is monophyletic and accounts for approximately 75% of all described fungi. It includes most of the fungi that combine with algae to form lichens, and the majority of fungi that lack morphological evidence of sexual reproduction. Like other fungi, Ascomycota are heterotrophs and obtain nutrients from dead or living organisms. If water is present, as saprotrophs they can consume almost any carbonaceous substrate, and play their biggest role in recycling dead plant material.

Basidiomycetes

The Ascomycota is a sister group to the Basidiomycota. Basidiomycetes fungi cause white rot in wood decay and are considered to be the most adapted to breakdown lignocellulose. These fungi are able to metabolise all biopolymers of plant biomass including lignin to CO_2 through the action of hydrolytic and oxidising enzymes and an ability to penetrate hard surfaces with mycelia. There are a broad-spectrum of white rot fungi in this group each group differs substantially in ligninolytic activity which depends on the natural habitats in which they have evolved.

Basidiomycetes Mycenae species

Fungi belonging to the class Basidiomycetes white-rot decay are considered to be the most adaptable in the breakdown of lignocellulose in turn delignification of plant structure leads to an increase in the accessibility of plant tissue to the action of cellulases and hemicelluloses. The most common basidiomycetes identified by Kirby and Rayner was *Athelia* which was recorded on every roof. *Resupinatus applicatus* were recorded on three roofs, *Pluteus cervinus, Tubaria furfuracea* and *Mycena sp* were each found once. Several enzymic systems interact directly with the target polymer, and others play an auxiliary role in natural thatch bio-deterioration.

Vyas *et al.* studied the production of breakdown enzymic system by white rot fungi capable of decaying wheat straw during the early degradation process. The first stage after colonisation consisted of rapid development of manganese peroxidase.
Elisashvili (1993) goes further in studying the enzyme systems in white rot fungi with special reference to Basidium fungi. Elishashvili describes the several enzyme systems that take part in lignin degradation, some of which interact directly with the polymer while others provide a secondary role in the production of hydrogen peroxide for the physical process of lignin destruction. The interesting part of this work is the examination of lignin extracts which it was demonstrated were unable to support growth of Basidiomycetes, because an additional energy substrate is required to stimulate the organism to grow. Lignin metabolization by fungi only takes place in the presence of an alternative carbon energy source. It is assumed that the cometabolization substrate is essential not only for the synthesis of lignin degrading

enzymes but also for the production of peroxide and the ligninolytic systems. Under natural conditions Basidiomycetes obtain energy and carbon through co degradation of cellulose and hemicellulose, this must be why degradation of lignin takes place simultaneously with the utilisation of polysaccharides. However, some Basidiomycetes respond to the addition of nitrogen sources in different ways; for example a Ph. Chrysosporium culture completely suppressed lignin degradation in barley straw. Based on some of the experiments described in this paper, it may be possible to devise a simple control mechanism for the decay process on thatched roofs (p483).

The most virulent identified decay fungus of reedbeds is *Coniophera cerebella* that can cause losses in weight up to 40% in four months and up to 70% in six months. It is noted that losses of this magnitude are rare, and any infected reed should be destroyed, the area disinfected and storage stacks should be constructed elsewhere.

Straight and Strong - Structural engineering analysis of thatching reed

Thatchers understand the structural design of a roof and can work out the optimum shape, pitch and design for load bearing beams, purlins and rafters. It is possible to apply exactly the same design principles to straw and water reed for thatching. It turns out that in plant materials the thin walled tube is the most efficient solution to load bearing where movement can occur through many axes. In the real-world, stems come in all shapes and sizes and in any container load stems are naturally intrinsically variable. Angold & Sanders found for most reeds the wall thickness increased in direct proportion to the stem diameter. Strength is also directly related to the diameter and wall thickness: the larger the diameter the stronger the reed.

One of the conclusions of the current Greef & Horlings water reed research indicated that from some reed beds, the stems are cut high, to overcome higher water levels on the reed beds. Under these harvesting conditions, based on engineering principles the strong butt ends close to the ground are being sacrificed, thus reducing the potential durability of the reed.

Water reed thatch today

It is becoming apparent that water reed thatch had a much longer life expectancy in the past than it has under current production and climate conditions. It is important to consider why this should be and what has changed. It is true for many thatched roofs that their durability has been reduced; there are a number of reasons for this:

Thatching reed is harvested in either the first or second winter - single or double wale. Most imported reed is single wale but home-produced Norfolk reed is double wale. Very hard reed can sometimes be found from reed-beds with slightly saline water and this reed may even be suitable for thatching in its third year. However, research (Greef & Horlings) has shown that more saline conditions can have a detrimental effect on the growing reed and can lead to premature decay in thatch.

- Through variation in environmental conditions the quality of water and air has been changed.
- Climatic conditions have changed, winters are milder, and summers are not long, very hot and dry. The roof environment has been altered with changes in climate.
- Owner expectations, of the perfect roof with the just thatched look remaining for all time.
- All aspects of reed bed management, harvesting processing and thatching are labour intensive and time consuming.
- Economic viability is essential where production costs are high.
- In mainland Europe conventional roof styles have replaced the beautiful traditional styles. In the UK, planning and listed building regulations have frozen thatch into past styles, which at times are compromised by modern conditions.
- Demand for high quality materials exceeds supply.
- To meet demand, in some circumstances, reed is cut prematurely, cut too high by heavy machines, sent to market uncleaned, stored and stacked badly and already arrives for thatching in poor condition.

- Reed can be delivered for thatching directly from the reed bed; before it has time for drying out and conditioning.
- Post-harvest stacks on the reed beds may be left on the ground or stored badly in uncovered batches.
- Damp or wet reed tightly packed in shipping containers may already become pre-disposed to early degradation.
- It is impossible to adequately air dry large tight damp reed bundles.

Management of reed post-harvest
After cutting, bundles of reed should be stacked to dry, and with proper treatment these will reach a proper level of dryness within 5 months.

Figures given in *The Reed (1972) quote for the process of drying of reed:*

• at harvest	50%
• which after 3 months drops to	25 – 30%
• at 5 months reaching	~15%

Reed (1972) In properly treated and stored stacks compositional losses are given as:

Lignin	4 - 7%
Cellulose	1 - 3%
Ash in cellulose	2 - 3%

Under adverse conditions losses would be higher.

Temperature variation in stacks can be quite marked and can rise considerable on hot days. High temperatures speed decay and "green" reed stacked in warm weather and damp conditions will decay rapidly.

The recommendations for stack building is on beams 30cm high with stacks 1.5 metres apart to allow free air circulation. Contact with the reed beds and soil should be avoided at all times.

Pointers to producing and recognising good/bad reed for thatching (The Reed 1972)

- For reed decaying on a roof, remove damaged areas and replace, treat with fungicide or varnish.
- Manganese can protect rice from some fungal infections
- The butt of reed will be wetter and more subject to infection than the rest.
- In wet reedbeds the butt may turn dark or black, this is a good sign of good water management in young reed beds but in old reed it indicates a rapidly decaying biotype with advanced fungal attack.
- Reed should be cut leaving a short reed bed stubble, the strongest part of the stem becomes the exposed surface during the process of thatching.
- Living reed is more liable to decay.

The roof decay process
The Pia Auri study examined the occurrence of macrofungi and the decay of roofs thatched with water reed, *Phragmites australis*. Sampling from 20 north - and 20 south facing roof sides showed that several ascomycetes usually associated with reed *in situ* are common on thatch. The only basidiomycetes recorded were *Mycena* species. There was no significant difference in the representation of macrofungi on north- and south-facing roof sides, but *Mycena* spp. only produced basidiomes on surfaces facing north, suggesting that the dry environment of the south side prevents fruiting. Eleven species were recorded in total, and the average of 2·4 species per roof did not increase with the age of thatch or degree of decay. The same species were generally present on young and old thatch, and no successional stages of fungal communities could be distinguished with increasing roof age.

Kirby and Rayner identified five basidiomycetes and two ascomycetes fruiting bodies on the study roofs. Generally fruiting bodies were uncommon, and identification was carried out in areas of bleaching similar to white rot in wood and microscopic observation of hyphae making clamp connections.

The observations recorded by Kirby and Rayner for thatched roofs in wheat reed bear a very close resemblance to the patterns and profiles observed for early decay water reed roofs. Early onset of evidence for decay can be detected as early as five years after thatching, after eight to ten years the problem has developed to a level when surface problems are obvious and cannot be ignored. Decay is not homogenous across the whole surface of the coat work but can be seen in either zones or patches; this type of decay is not necessarily associated with high wear areas of a roof such as the junctions of dormers, valleys or gullies. Often several areas are present each with their own appearance and decay rate. Reeds from within these patches loose both tensile and compression strength causing them to collapse and fragment.

For the purpose of examining thatch degradation Kirby and Rayner also considered the mechanism of thatch degradation as simply another lignocellulosic resource thus its deterioration could be expected to comply with a general conceptual model of the decomposition process.

Deterioration of thatch occurs at the exposed surface of the roof and progresses inwards. Within the layer of reeds outer, middle, and inner zones develop representing different stages in the decay process. The zones move inwards as thatch deteriorates. A comparison of the rate of decay among roofs with pitch 30°, 45° and 60° showed that the innermost zone appeared *ca* 20 cm from the exposed reed butts in the steeper roofs, whereas it was no longer present in the roof with low pitch. This suggests that the depth of the zones depends upon the roof slope, and the outer and middle zones move inwards at a higher rate in roofs with a low pitch, resulting in an increased rate of deterioration.

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Phragmites thatch appears to harbour its own characteristic macrofungal community, with certain *Mycena* species likely to represent the principal decomposers. A common feature of fungi occurring on thatch is that they must endure unfavourable conditions. Complaints are associated with soft, weak reed. Moisture is said to alter breakdown.