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DEVELOPING THE SCOTS PINE RESOURCE

USE OF SCOTS PINE AS EXTERNAL CLADDING

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Summary

This document outlines the potential for using Scots pine as external cladding on buildings in the UK. It describes the relevant performance requirements, assesses how Scots pine can meet these criteria and, based on this, gives recommendations for construction detailing. The document arises out of tests of external timber cladding made from Scots pine undertaken by Edinburgh Napier University. Other recent research by the University is described where relevant.

Contents

Background

In 2009 Edinburgh Napier University was contracted by Highland Birchwoods (www.highlandbirchwoods.co.uk) to prepare and test external timber cladding made from Scots pine. The work was co-funded by the European Union Northern Periphery Programme (www.northernperiphery.net) as part of a larger trans-national project. This report outlines the findings and implications of the research. It draws upon other work by the University, particularly a recent book on timber cladding design and performance [i] resulting from a previous Northern Periphery Programme project.

What is Scots pine?

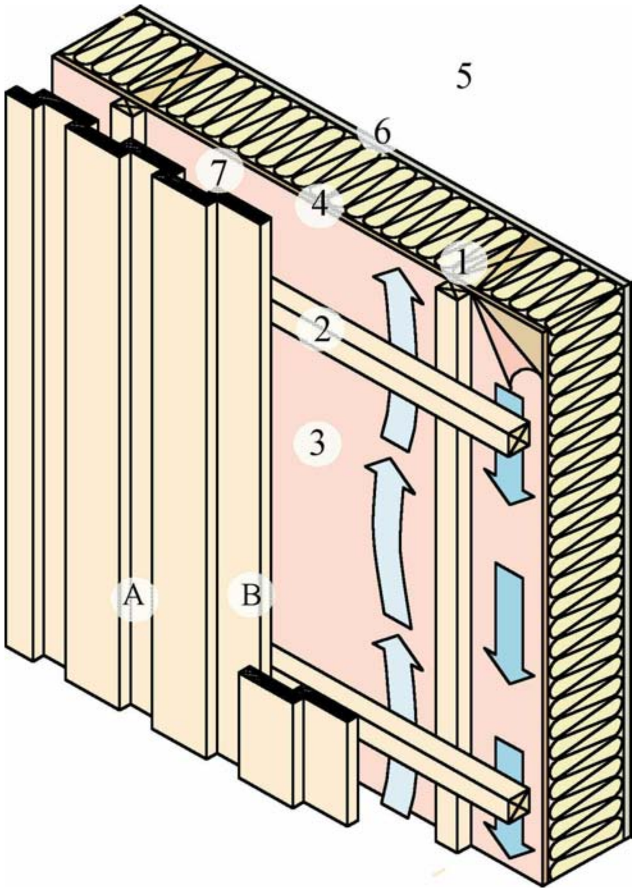
Scots pine is one of the trade names of the timber species Pinus sylvestris, which grows from Spain to Arctic Norway and from Scotland to eastern Siberia. This extensive range embraces a range of growth conditions and this is reflected in the variable character of the timber. The species has several trade names depending upon its colour or origin. This document follows the usage recommended in BS EN 13556 [ii] whereby the timber is known as European redwood unless it is UK grown in which case it is referred to as Scots pine If the species as a whole is being referred to, its abbreviated scientific name (P. sylvestris) will be used.

Historically, the timber of P. sylvestris has been widely used as external cladding throughout the UK, Scandinavia, and Russia. Virtually all of the UK timber was imported (i.e. it was European redwood), the exception being in a few remote rural areas such as Strathspey, but even these switched to imported timber in the mid 19th century once the railways were in operation. Nowadays, although European redwood is a popular internal joinery timber throughout the UK, its use as external cladding is mainly limited to small low status cladding applications such as gable triangles or garden sheds. Scots pine is rarely if ever used as contemporary external cladding in the UK, indeed its usage for any kind of joinery is extremely rare.

Types of external timber cladding

Prior to the 1960's, external timber cladding in the UK was fixed directly to the underling wall structure without an intervening cavity, a build-up known as siding. Any water that penetrated through the siding was able to dry to the building's interior. Nowadays most UK buildings are insulated and so a cavity is needed behind timber cladding. The cavity provides a route for drainage and ventilation as well as being a capillarity break between the cladding and wall structure. This cladding-cavity-structure arrangement is known as a rainscreen. Some cladding publications distinguish between ordinary and pressure equalised rainscreens. However, the latter type is not relevant to timber.

Figure 1 gives the most common build-up for a timber rainscreen in the UK. Other build-ups are possible. The sheathing board can be moved to the inner leaf of the wall, for example, in which case the vapour control layer can usually be omitted, this arrangement is termed a reverse wall. Timber rainscreens can also be used to protect masonry or massive timber walls, particularly those employing insulation on the outer face of the wall structure.



1. Cladding
2. Support battens and cavity
3. Breather membrane
4. Sheathing board
5. Timber frame
6. Insulation
7. Plasterboard

A. Drainage
B. Ventilation

Figure 1: *Build-up of a typical timber clad wall in the UK*

Performance requirements for timber cladding in the UK

Over the centuries, architects and builders developed many traditional materials and methods. From this experience came prescriptive ('do this, use that') building regulations and standards. While these are easy to understand they are inflexible and stifle innovation; they also deliver poor value for money and are a barrier to trade. Building regulation is, thus, shifting from prescribing the inputs into construction (i.e. materials and methods) towards ensuring that its outputs meet the user's requirements. This is termed a performance-based approach. Building regulations in many countries, including all of the UK, are becoming performance-based.

It is sometimes claimed that building regulations are becoming the same throughout Europe. This is not the case. European standards do not impose specific performance requirements but merely give a shared methodology for design, testing and verification. Each country will continue to set its own requirements in response to local conditions (e.g. climate or social conditions).

The UK does not have a single set of building regulations. Instead, England and Wales are covered by one set, whilst Scotland and Northern Ireland each have their own, as do the offshore Crown Protectorates of the Isle of Man, and the Bailiwicks of Jersey and Guernsey. Building regulation may be devolved to Wales in the near future. Because these regulations are performance-based, there are usually two ways of meeting their requirements. Designers can either follow the technical guidance in documents that support each set of regulations or they can develop their own alternative solutions based on established scientific and engineering principles.

Timber facades have to meet several performance requirements in order to comply with guidance documents supporting the UK's building regulations (Table 1). The most important criteria are usually fire spread and durability. Noise is an important consideration in flats and other buildings in shared occupancy. Unfortunately, the guidance for cladding contains a conflict between the requirements for fire safety, durability and noise reduction, with the result that one or other issue can be overlooked.

Criteria	Recommended solutions cover
Structure Cladding poses a hazard if it becomes detached from the wall and so must:	be capable of safely sustaining all static, imposed and wind loads and transmitting them to the building's support structure ;
	be securely fixed to and supported by the building's structure;
	accommodate, where necessary, differential movement of the cladding and building's support structure;
	be of durable materials; the design life of fixings and supports being not less than that of the cladding.
Fire spread Fire spread on the facade should be limited:	to nearby but non-adjoining buildings;
	on external surfaces;
	in cavities.
Health and safety Health and safety to be ensured:	during construction, maintenance, and demolition.
Noise Building envelopes must protect against:	noise from adjoining buildings (noise from non-adjoining buildings and other external sources is controlled via the planning system and not through
Durability and workmanship Protect against degradation from:	ground moisture;
	precipitation and spray;
	moisture from inside the building;
	moisture from the roof;
	wood destroying organisms;
	corrosion.

Table 1: *Build-up of a typical timber clad wall in the UK*

Rainscreens on normal buildings such as houses should give a service life of at least 25 years, whilst those on large, prestige, and public buildings should typically have a 50 year service life [iii]. To achieve this, the materials used in a rainscreen need to be resistant to the degradation risks that are likely to occur, these vary according to the type of materials used and their location. Where the rainscreen is made from timber the main degradation risks in the UK are:

- *Fungal decay and insect attack*
- *Weathering*
- *Dimensional change*
- *Corrosion of metal fixings and flashings*
- *Loss of robustness*

Scots pine timber

So how does Scots pine meet these criteria? The properties of Scots pine timber are described in several documents, most notably a 1977 publication by the UK Building Research Establishment [iv]. Those of most relevance to external cladding are discussed below and summarised in Table 2.

Resistance to fungi and insects is usually seen as the main challenge facing external timber cladding in the UK. The UK consumer favours cladding timbers that are resistant to wood destroying organisms and avoids species such as P. sylvestris that are not so resistant. In Scandinavia, by contrast, European redwood is widely used as external cladding on low-rise residential buildings. It is used without preservative treatment on all but the wettest sites. Maintenance is a key factor: Scandinavia has a culture of cladding maintenance whereas the UK does not (Figure 2).

Figure 2: *Late 19th century timber cladding in Trondheim, Norway. Similar facades are found in most towns in western Norway; they were constructed using non preservative treated European whitewood and redwood. These facades illustrate that durability class 3 and 4 timber in combination with elaborate detailing can achieve a long service life providing it is designed for durability and regularly maintained. Key measures include metal flashings on all horizontal projections, the avoidance of water traps, an opaque surface coating with fungicidal protection and the rapid replacement of any component that fails.*

Sapwood	Width of 50-100 mm in Scots pine timber and considerably less in European redwood particularly if slow grown.
Density	The density (kg/m^3) at 12% moisture content usually ranges from 500 to 540. The mean is 520. Unseasoned timber is about 800
Seasoning	Rapid and well although bluestain is a problem. Accordingly, the felled timber should be sawn and loaded into the kiln as quickly as possible. If the timber is only being air dried, the boards should be brushed free of sawdust and then stacked vertically (in the same way that sycamore is air dried).
Shrinkage	4.5% tangential shrinkage from green to 12% moisture content. The corresponding radial shrinkage is 3%.
Movement	The movement class is medium.
Resistance to fungal decay	The heartwood has variable natural durability ranging from class 3 (moderately durable) to class 4 (slightly durable). The inner heartwood (juvenile wood) zone is relatively wide occupying the first 20 rings. Like all timbers the sapwood is class 5 (not durable).
Resistance to insects	The sapwood is susceptible to attack by the common furniture beetle
Treatability by preservatives	Heartwood is either difficult or very difficult to treat. The sapwood is easy to treat
Thermal modification	European redwood is extensively used for thermal modification. There is little corresponding experience with Scots pine as yet although it is believed that knots will be a limiting factor.
Reaction to fire	Because the timber density is over 400 kg/m^3, most building products made from Scots pine will achieve Euroclass D reaction to fire classification. Being easy to treat, the sapwood can usually be impregnated with flame retardants to achieve Euroclass B
Fibre saturation point	The moisture content at fibre saturation is around 24%.
Machining	Dependant upon growth rate and knots. Homegrown timber generally works well though knots can loosen when dry. The fast growth rate means that the soft earlywood bands are wider than imported timber and thus have more tendency to tear. Cutters need to be sharp to accommodate this. Nailing is generally good although pre-drilling is advisable near board ends.
Coating	Takes most coatings well though a stopper may be needed when light coloured acrylic coatings are used externally.
Gluing	Generally satisfactorily though resinous timber can cause problems.
Acidity	The heartwood is around pH 4.5, which means that it is only slightly corrosive. The corrosivity will be increased if the

Table 2: *Timber properties of P. sylvestris relevant to external cladding.*

Resistance to wood destroying organisms is termed natural durability. The European classification for natural durability is given in BS EN 350-1 [v] (Table 3). There are five durability classes. Note the classification mainly applies to the heartwood (the inner part of the tree trunk) as the outer part – known as sapwood – only achieves the lowest durability class no matter what the species is. For clarity, Table 3 also gives estimates, taken from BS 8417 [vi], of how long timber of each durability class might last in different exposure conditions. Fungal decay only occurs if the timber becomes damp. All timber – even sapwood – can last for centuries in UK conditions if it is kept dry. The durability class of the timbers that were commercially important in Europe during the 1990s is given in BS EN 350-2 [vii].

Durability class	Description	Approximate minimum service life (years)	
		External timber out of ground contact (e.g. cladding)	External timber in ground or fresh water (e.g. fence posts)
1	Very durable	Over 60	30 to 60
2	Durable	30 to 60	15 to 30
3	Moderately durable	15 to 30	Less than 15
4	Slightly durable	Less than 15	-
5	Not durable	-	-

Table 3: *Natural durablilty classification against fungi (BS EN 350-1 and BS 8417)*

The heartwood of P.sylvestris is classed as varying from class 3 (moderately durable) down to class 4 (slightly durable). Much of this variation is due to the different characteristics of the inner and outer heartwood. Inner heartwood, termed juvenile wood, has a lower durability than mature heartwood. In most timber species the juvenile heartwood zone occupies the inner 10 to 15 growth rings. In P. sylvestris, however, the juvenile heartwood zone can extend to about the 20th ring. This variation has implications for how Scots pine is used as external cladding. A normal plantation grown Scots pine log will be about 60 to 80 years old when felled. The sapwood can occupy the outer 30 growth rings, whilst the inner 20 are juvenile wood (Figure 3). This means that the mature heartwood is restricted to a zone of only ten to 30 rings. It is, therefore, impossible to produce boards comprising mainly mature heartwood. Every board will contain large areas of sapwood or juvenile wood and this means that the natural durability classification of plantation grown Scots pine is, in practice, irrelevant [viii]. This limitation may not apply to European redwood as both the sapwood and juvenile wood zones tend to be narrower.

Figure 3: *Scots pine sawlogs showing the relative proprtions of heartwood and sapwood*

Corrosion is growing issue with external timber cladding. There are two reasons. Firstly, wood modification is becoming increasingly popular as an alternative to preservative treatment. Although most types of wood modified timber are not particularly corrosive, a few are. Acetylated timber is the most corrosive, but some types of thermal modification can also cause problems; in both cases the effect appears to be due to residual acetic acid. Secondly, the copper based wood preservatives now in commercial use are more corrosive than those employed up to 2006. Prior to this the main product was chromated-copper-arsenate (CCA), which was itself relatively corrosive. The replacement products – the so-called CCA alternatives – are much more corrosive. There are several reasons for this including the type of carrier and the tendency for copper to leach. Consequently, austenitic stainless steel fixings should be used and the risk of bi-metallic corrosion between copper (in the preservative) and aluminium (in flashings and cavity barrier foils) should be addressed by keeping these metals apart.

Dead knots are a further issue as they are unsightly and can fall out. Most external timber cladding in the UK is made from relatively knot free timber whereas Scots pine is known to be relatively knotty. Sawmills estimate that only 10% of Scots pine boards are free of dead knots.

If Scots pine is to expand its share of the UK cladding market then these issues – degradation resistance, maintenance, corrosion and dead knots – need to be addressed.

Methods

The research comprised an exposure trial of timber cladding boards along with a grading trial and a test of the corrosion risks arising from different types of preservative treatment. In addition to the quantitative research, a qualitative survey was undertaken of timber cladding on one early 19th century Scottish building clad in Scots pine. All of the timber used in the trial was provided by BSW Timber plc, it originated in Strathspey.

Grading trial

Timber is highly variable and so, in order for marketing to be rationalised and selection for specific uses simplified, the material is sorted into broadly similar groups according to appearance or fitness for purpose. Selection for appearance is known as appearance or joinery grading, the former is a general-purpose selection whilst the latter is more specific. Fitness for purpose grading usually involves structural criteria (mainly strength and stiffness) although others such as natural durability can be important for specific applications. There are two main types of structural grading: machine grading employs special machines to make the selection, whilst visual grading is based on knots, grain angle and other outward characteristics of the timber. Visual grading should not be confused with appearance grading – the latter does not involve structural criteria.

Appearance (particularly knots) is often seen as an important consideration for cladding boards although fitness for purpose criteria such as natural durability are usually more important. European softwood timber is appearance graded to either the Swedish Green Book [ix] (or its pan-Nordic equivalent [x]) or to European Standard BS EN 1611-1 [xi]. The approximate relationship between the categories in these norms is shown in Table 4. The main joinery grades used in the UK are those in BS 1186-3 [xii], this norm is frequently used to grade cladding timber. Specific grades for cladding timber are also published [xiii] although they are rarely used in practice. Cladding support battens are often visually graded for their structural characteristics. Selection criteria for battens are given in BS 5534 [xiv]; these are broadly equivalent to the GS visual grade in BS EN 1912 [xv]. For the purposes of this trial, the boards were graded to BS 1186-1, BS 1186-3 and BS EN 15146. This allowed the out-turn from these three methods to be compared.

<table>
<tr><th></th><th colspan="6">Highest quality</th><th colspan="5">Lowest quality</th></tr>
<tr><td rowspan="3">Green book</td><td colspan="5">U/S</td><td colspan="2">V</td><td colspan="2">VI</td><td colspan="2">VII</td></tr>
<tr><td colspan="7">U/S-V</td><td colspan="2">V1</td><td colspan="2">VII</td></tr>
<tr><td colspan="9">S/F</td><td colspan="2">VII</td></tr>
<tr><td>Blue book</td><td>A1</td><td>A2</td><td>A3</td><td colspan="2">A4</td><td colspan="2">B</td><td colspan="2">C</td><td colspan="2">D</td></tr>
<tr><td>1611-1 (4 sides)</td><td colspan="4">G4-0</td><td colspan="2">G4-1</td><td colspan="2">G4-2</td><td colspan="2">G4-3</td><td>G4-4</td></tr>
<tr><td>1611-1 (2 sides)</td><td colspan="4">G2-0</td><td colspan="2">G2-1</td><td colspan="2">G2-2</td><td colspan="2">G2-3</td><td>G2-4</td></tr>
</table>

Table 4: *Natural durablilty classification against fungi (BS EN 350-1 and BS 8417)*

Exposure trial

An exposure trial is an experiment in which a material or product is exposed to the exterior climate and changes in its properties measured. In the case of this trial the property of interest was the moisture content of the timber. This was measured using glued-in moisture probes connected to an automatic data-logger. The trail was replicated at two sites in north Scotland. The first near Fort William had a high rainfall, whilst the second, near Granton on Spey was relatively dry. In total 144 timber samples were used in the trial, 72 at each location. The timber used was predominately sapwood, heartwood was excluded as far as possible, because as already outlined, it was not of interest for this trial. The boards were machined to a standard size of 21.5mm x 140mm x 500mm. Their density was assessed gravimetrically. The samples were then divided into three groups, a third were left untreated whilst the others underwent either of two treatments. Tanalith-E® is a water based copper azole preservative system. MicroPro® is a water based, micronized copper quaternary preservative system. Half of the samples were fixed to a frame so that they were lying parallel to the ground whilst the others were fixed vertically (Figures 4 and 5). The trial ran for none months from April 2009 to January 2010.

Figures 4 & 5: *The exposure trial set-up at the two sites*

Corrosion trial

Figures 6: *Corrosion trial showing how the coupons were attached to the timber.*

The corrosion trial (Figure 6) involved 150 mm x 80 mm x 6 mm coupons (corrosion test samples) made from intumescent cavity barriers wrapped in aluminium foil. Each coupon was fastened onto a timber sample or ceramic control sample and then laid horizontally on a polythene base so that a water trap was created between the timber and aluminium. As in the exposure trial, the timber samples comprised: sapwood impregnated with Tanalith E or Micropro along with non-preservative treated sapwood. Each type of timber was replicated twice as were the ceramic controls. The trial ran from November 2009 to March 2010.

Site survey

The oldest surviving completely timber-framed timber-clad building in Scotland is Swiss Cottage near Fochaburs (Figure 7). It was completed in 1834 and, unusually, it appears to have been constructed using plantation grown Scots pine from the local area. The timber was not preservative treated although it was coated with a lead based paint immediately upon completion. The building was lived in until the mid 1990s since when it has lain unoccupied.

Originally it was intended to experiment with using acoustic tools as a non-destructive test of the condition of the cladding timber. However, this method proved unreliable and so a simple visual inspection was undertaken instead. The survey focused on the location and likely cause of any degradation.

Figures 7: *Swiss cottage.*

Results

The timber grades that were achieved are given in Figures 8 to 10. The A and B grades in BS 15416 are quite similar and are broadly equivalent to the mid grades in BS EN 1161-1. The six grades in BS 1161-1 give a more realistic idea of the spread of board quality observed in the trial. Grades 3 and above in BS 1186-3 are broadly similar to the top three grades in BS EN 1161-1.

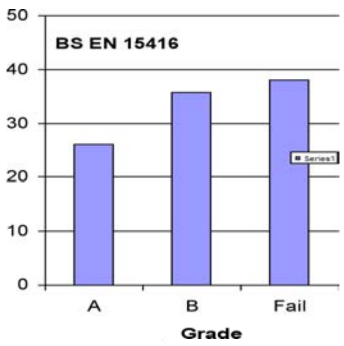


Figure 8: *Grading results to BS EN 15416*

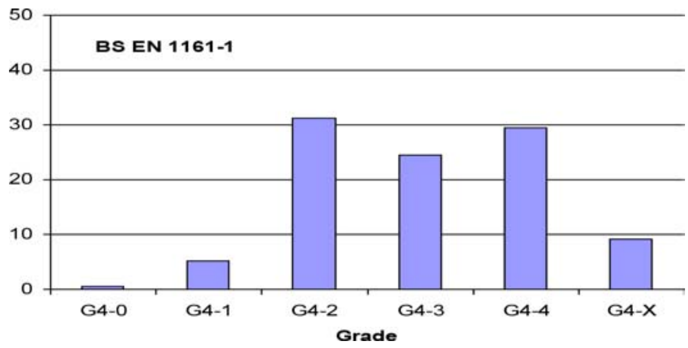


Figure 9: *Grading results to BS EN 1161-1*

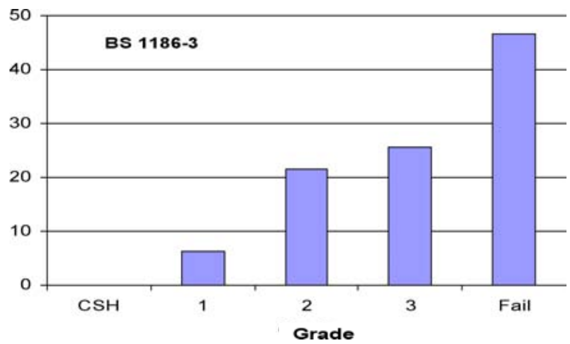


Figure 10: *Grading results to BS EN 1186-3*

When dried to a moisture content of 12% the density of the timber samples ranged from 390 kg/m3 to 688 kg/m3. The mean value was 507 kg/m3 (Figure 11). The moisture content of the timber during the trial fluctuated between a minimum of 10% up to a maximum of around 26%; these values are ± 2%. The timber was consistently wet through most of the winter but dried at a rate of about 2% per day during late April. Moisture contents fluctuated widely during the summer and tended to be highest on the horizontal boards.

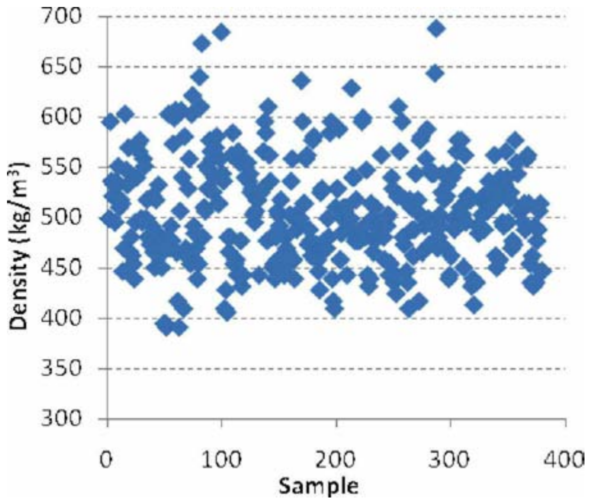


Figure 11: *Density of the samples used in the exposure trial*

Weathering was greatest on horizontal boards and those that were not preservative treated (Figure 12). The timber impregnated with micronised wood preservative tended to exhibit the least weathering.

No preservative treatment | Impregnated with Tanalith-E® | Impregnated with MicroPro®

Figure 12: *Weathering during the exposure trial (V - vertical board, H = horizontal board)*

Pitting corrosion occurred in the aluminium coupons in direct contact with the timber that had been impregnated with copper based wood preservatives (Figure 13). No pitting occurred in the coupons attached to the other timbers or the controls.

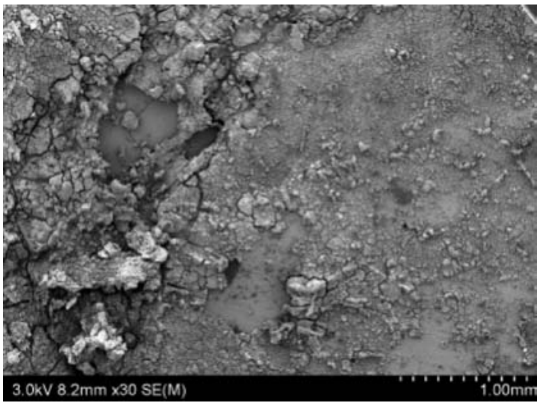


Figure 13: *Pitting corrosion of aluminium in contact with Tanalith-E® treated timber*

The survey of Swiss Cottage found localised fungal decay in many parts of the facade. The most common locations were at the bottom of boards, within passing joints, at butt joints and near the ground (Figure 14). There were signs of frequent repair work where timber had previously failed (Figure 15). No maintenance appears to have been done since the building became unoccupied and consequently the building appears to be decaying at an ever-increasing rate.

Figure 14: *Fungal decay at a mitre joint*

Figure 15: *The post at the bottom of this image has been replaced*

Implications of the results

About half of the timber can be graded to class 3 or above in BS 1186-3. This is just about adequate for painted cladding. Unpainted cladding would require grade 2 or better.

The exposure trial indicates that the timber was at or near its fibre saturation point for much of the winter and for short periods during the rest of the year. The survey indicates that localised water traps (such as overdriven nails or butt joints at corners) were even wetter. The associated degradation risks are therefore:

Wood destroying organisms. The timber was at risk of fungal decay although the rate will tend to be slow during the winter months due to low temperatures. Timber at or near horizontal (such as window sills or shingles) was at greater decay risk than if it is at or near vertical. Water traps (such as at knots or over-driven nails) were the most at risk from fungal decay. All cladding made from Scots pine sapwood will be susceptible to woodworm attack.

Weathering. The timber surface will turn grey after a few months exposure to sunlight and moisture. Horizontal surfaces and those exposed to wind channelling will stain faster and more intensely than vertical. The variation is due to differences in moisture availability affecting the rate of fungal staining. Preservative treated timber will initially tend to stain at a slower and more uniform rate although the difference will tend to diminish over time as the biocide is leached. Leaching of flame retardants is also an issue. The service life of even the most leach resistant flame retardant products will be limited to about 30 years.

Dimensional change. Horizontal or near horizontal timber will exhibit the largest movement. This will tend to result in splitting, creating water traps and thus accelerating fungal decay. Cladding boards made from Scots pine should be detailed to accommodate tangential movement of around 4%.

Corrosion. Although Scots pine is not a particularly corrosive timber the moisture conditions in cladding are such that crevice corrosion can occur. This can result in unsightly iron tannate staining wherever ferrous fixings are employed. Crevice corrosion will be accelerated wherever copper based preservatives are used. Pitting corrosion will be a risk wherever aluminium is used in contact with timber impregnated with copper based preservatives.

Loss of robustness. The moisture conditions in Scots pine cladding are such that the boards and their support assembly will be in structural service class 3 and should be designed accordingly. This is mainly an issue on -medium and high-rise buildings and those near the coas

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