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Dear Mr Alexander

Properties of timber acetylated to 20% WPG and its suitability for joinery

We understand that you are conducting technical due diligence on permeable timber that is acetylated to a weight percent gain (WPG) of 20% throughout the cross section and its suitability for use as a joinery substrate. You have requested that we provide you with comment regarding:

- The durability class of acetylated timber compared to timber species commonly used for joinery applications
- The dimensional stability compared to timber species commonly used for joinery applications
- The relation of durability class to compliance of joinery products to the British Standards for life expectancy and requirement for additional preservative treatment

Specification of timber for joinery

The suitability of a timber species for use in external joinery in the UK must first consider the natural durability of the chosen timber species (EN 350-2: 1994) and note that the intended end use is Hazard Class 3 (EN 335-1: 1992). EN 460 compares the requirements of Hazard Class with the natural durability and indicates whether natural durability is sufficient for the end use or whether preservative treatment is required. The European Standards related to specifying preservative treated timber, EN351-1 (1996) and EN 351-2 (1996), have been published for 10 years. They require the specification to be written in terms of the results of

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the treatment process. A required penetration of the preservative into the wood and the retention (concentration) of preservative within a defined zone (the analytical zone) of the treated timber is specified. EN351-1 (1996) lists nine options that can be used to specify penetration. The retention is specified in terms of the concentration of preservative formulation found to be effective in a series of standard biological test methods laid down in the European Standard EN599-1 (1997). The treater has to demonstrate to the specifier that the required level of treatment has been achieved. This can be done by obtaining a representative sample of the treated timber, randomly selected according to the International Standard ISO 2859-1 (1999), and analysing for penetration and retention. EN 351-2 (1996) prescribes methods of obtaining the samples for analysis from the selected components. In all cases the retention of wood preservative is described as the amount analysed in the analytical zone.

BS 8417 (2003) sets out a framework for UK specifiers to interpret the European standards and to base specifications on penetration and retention requirements thought to reflect what the old process specifications actually achieved. Provision is made in the document for the range of traditional preservatives with recommended penetration/retention combinations for different timber types, end uses and service life requirements. These are based on best estimates of what has been achieved in practice. Guidance is also given for new preservatives whose performance is demonstrated by testing according to EN599-1 (1997) but which have little or no evidence from longer term tests or service data.

There are no Standards specifically written to give guidance on or requirements for specification of acetylated timber. A permeable timber that is acetylated throughout the cross section to 20% WPG offers an opportunity for consideration as a joinery substrate for high quality fully factory finished wood windows.

Biological durability

What are the requirements for joinery?

In BS 8417 (2003) exterior window joinery is noted as Hazard Class 3 (EN 335-1: 1992) application and a 15, 30 or 60 year service life is satisfied by choosing as a minimum a timber of natural durability class 4, 3 or 2 respectively (EN 350-1: 1994). In addition the service factor based on safety and economic factors is Class C where remedial action or replacement would be difficult and expensive thus natural durability or preservative treatment is desirable.

What is natural durability?

Natural durability refers to the ability of a wood species to endure, or resist deterioration, by virtue of its inherent properties. In the UK this typically refers to the ability to resist attack from wood-destroying fungi. This ability to withstand fungal attack is assessed in laboratory and field experiments in line with European standard tests, which for natural durability include long running ground contact field trials (EN 252: 1990). In the UK the national field trials for determining natural durability have been managed by BRE for almost 80 years. The assessments classify each timber species heartwood into one of five different durability classes depending on their performance. The data is presented in BRE Digest 429 (1998).

Digest 429 or EN 350-2	**Durability class**
Western red cedar (*Thuja plicata*) old growth North America	2 (durable)
Siberian larch (*Larix siberica*)	3 (moderately durable)
Sapele (*Entandrophragma cylindricum*)	3 (moderately durable)
Douglas fir (*Pseudotsuga menziesii*)	3-4 (moderately durable to slightly durable)
Scots pine (*Pinus sylvestris*)	4 (slightly durable)
Acetylated wood*	1 (very durable)
Preservative-treated wood†	1 (very durable)

* Sources of information are consider later in this document

† The preservative treatment of 'not durable' or 'slightly durable' wood to a retention at the critical value (CV) or above derived from BS EN 599-1 enhances the wood to maximum durability as the <3% weight loss criteria in the test is equivalent to delivering durability class 1 'very durable'

There are a wide range of references related to the durability of acetylated wood that show that at WPG of 20% the wood is resistance to attack by wood destroying organisms and is classed as durability class 1. Sources of information relating to the durability of acetylated wood include:

1. SHR report to Titanwood (2006) is an extract from the European collaborative AIR project (1993-1995) and assesses the durability of acetylated wood (beech, pine and poplar) to brown and white rot fungi, soft rot fungi, blue stain in service and field trials.

The results are:

EN 113 (1997) reveals that data from tests conducted with leaching pre-conditioning (EN 84: 1997) were similar to those without – concluding that acetylation is fixed. For two of the brown rot fungi tested at WPG of 15% and above the three timber species were classified as durability class 1. At a WPG of 20% the specimens had less than 3% weight loss during the 16 week exposure period of the test. The other brown rot fungi (*Poria placenta*) revealed weight losses of about 5% at a WPG of 20%. For the white rot fungi tested the weight loss for acetylated beech and poplar during the test reached zero at a WPG of 12%.

ENV 807 (2001) soft rot tests revealed that for pine and beech at WPG of 15% and above the weight loss due to soft rot attack was 0 to 1%.

A non-standard soil block test where wood is exposed to the natural fungi present in John Innes No.2 soil revealed that at WPG of the order of 20% provided protection to pine, poplar and spruce restricting weight loss to approximately 3%.

EN 252 (1990) field test stakes that were assessed using 3 point bending tests showed that acetylation improved durability revealed as the reduce loss of strength in the specimens.

2. BRE tests conducted in collaboration with the University of Wales, Bangor (Suttie et al 1997 and 1998) showed that for EN 113 (1997) a WPG of approximately 18% protected pine sapwood and showed that an estimated WPG of 21% would give 0% weight loss in ENV 807 (2001). The work also showed resistance of acetylated wood to *Hylotrupes bajulus* larvae though no consistent trend could be established.

3. Hill (2006) reports that a large range of pure culture studies of the durability of acetylated wood have been conducted. The threshold WPG where there is zero weight loss during the experiment is often between 15 and 20% for brown rots and between 6 and 15% for white rot fungi.

4. Westin et al (2004) reports that at three field sites wood acetylated to a WPG of 23% prevented fungal attack and a WPG of 21% almost completely eliminated decay in laboratory fungal cellar tests. The field tests are part of the suite of test standards and assess performance in-ground contact. We would expect the performance in out-of-ground applications such as window joinery where the moisture risk is significantly reduced and the presence of some wood destroying organisms does not occur to be significantly better.

Dimensional stability

What are the requirements for joinery?

BS EN 942 (1996) notes in informative annex D dimensional movement as a serviceability aspect (small, medium or large) of timber for joinery and the suitability of timber species for external joinery. There are no specified requirements for dimensional movement of timber species for external joinery.

What is dimensional stability?

Dimensional stability (or anti shrink and swelling efficiency) is the ability of the wood to resist dimensional changes as the moisture conditions change. Data is presented in the Handbook of hardwoods (1972) and the Handbook of softwoods (1977).

Handbook of hardwoods Handbook of softwoods	Indicative movement class	Tangential and radial movement from 90%RH and 60%RH
Western red cedar	small	1.9% and 0.8%
Siberian larch	small	1.7% and 0.8% data for *Larix decidua*
Sapele	medium	1.8% and 1.3%
Douglas fir	small	1.5% and 1.2%
Scots pine	medium	2.1% and 0.9%
Acetylated wood*	small	-

* Sources of information are consider later in this document

The references related to the dimensional stability of acetylated wood that show that at a WPG of 20% the wood is more resistant to shrinking and swelling and is movement class 'small'. Sources of information include:

1. SHR report to Titanwood (2006) is an extract from the European collaborative AIR project (1993-1995) and shows that the higher the WPG of acetylated wood the higher the anti-shrink efficiency. This improvement in dimensional stability was postulated to be a result of the hygroscopic hydroxyl groups being replaced by acetyl groups that are less hygroscopic.

2. Hill (2006) presents evidence of the dimensional stability of modified wood. It is reported that by modifying wood with a range of anhydride reagents that the dimensional stability is not related to the hydroxyl substitution but is related to the WPG of the modification - the bulking of the cell wall.

3. SHR report (2005) details the performance of wood coatings on panels of envelope acetylated (<20%) Scots pine sapwood after almost 10 years of outdoor exposure. The dimensional changes with acetylated wood were noted as being reduced by 80% compared to the untreated Scots pine sapwood. Less shrinking and swelling of the substrate offers a significant opportunity to reduce stresses on exterior wood coatings. The panel trials reveal that after 9.5 years of weathering in the Netherlands at 45° facing south the coated acetylated wood is performing well compared to the untreated wood which has lost most of its coating. The transparent coatings on acetylated wood were failing as result of the coating itself whilst the opaque white coatings were performing well. Adhesion tests revealed good adhesion on the acetylated wood independent of the water uptake. As with untreated wood vulnerability of acetylated wood to blue stain fungi is noted and maintenance of coatings is recommended to avoid this issue.

British Standards for life expectancy

As there are no existing standards specifically for acetylated wood it is sensible to consider a natural durability class. This is noted as a departure from established UK custom and practice. BS 8417 (2003) links the durability requirement for external joinery to a service life. For exterior window joinery a 15, 30 or 60 year service life is satisfied by choosing as a minimum a timber of natural durability class 4, 3 or 2 respectively. In addition the service factor based on safety and economic factors is Class C where remedial action or replacement would be difficult and expensive thus natural durability or preservative treatment is desirable.

Considering the above the durability of permeable wood acetylated to 20% WPG is capable of delivering a 60 year working life window which is in excess of the natural durability of the selected joinery timbers considered in this document. There is no additional requirement for permeable wood acetylated to 20% WPG to be preservative treated for use in external joinery which is not the case for ‘slightly durable’ or ‘not durable’ timber species. For exterior joinery applications the enhanced dimensional stability of wood acetylated to 20% WPG is capable of extending the working life of coatings and thus the overall joinery product.

The evidence shows that the performance of permeable wood acetylated to 20% WPG throughout its cross section:

- Is resistant to attack by basidiomycetes, soft rot, insects
- Improves dimensional stability and enhances the performance of coatings
- Has a requirement to protect against blue stain in service through a maintenance and care package

We consider that a window prepared from a permeable timber species that is acetylated through the cross section to 20% WPG, will show significantly improved coatings performance properties. If the window is designed and built to the principles of best practice, installed by competent contractors and linked to the Sikkens Sentinel Plus coated wood care and maintenance package it will provide a window of outstanding durability and dimensional stability that would meet a 60 year service life requirement.

Yours sincerely

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