information paper

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Durability of timber in ground contact

IP 14/01

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Reliable classification and characterisation of the natural durability of timber species, and the effectiveness of preservative treatments, take several decades. They are essential, though, to provide a basis for robust specification of timber for use in construction and for satisfactory service life.

This paper reports recent findings from a programme of long term testing at BRE to benchmark the performance of timber in ground contact. It concludes that most of the new hardwood species becoming available in the UK market are, in fact, of limited durability. It recognises, though, that treatment can extend the service life of many softwood species, and also concludes that a significant improvement in the service life of treated spruce in ground contact situations can be achieved by incising prior to treatment.

This paper complements IP 6/99, IP 2/01 and Digest 429.

Introduction

The required service life of timber used in construction is usually specified in decades. Different timber species vary in their natural resistance to attack by wood-destroying fungi and, where necessary, this resistance (or natural durability) can be enhanced by the application of a preservative treatment. The BRE field testing programme was established in 1929 and has been maintained as a continuous programme of evaluation and additions ever since. It provides the UK national database for the natural durability of important commercial timber species and for the performance of wood preservatives, especially of new systems as they become available for industrial use. The results derived from these tests augment the national database, enabling it to be used to benchmark new products, processes and systems for improving the durability of timber used in construction applications.

In recent years, two new issues have arisen that emphasise the significance of this database. The first results from changes in worldwide forestry practices, including forestry plantation management; these have resulted in current timber supplies increasingly coming from trees grown under substantially different conditions than previously which can affect the natural durability of the timber. Furthermore, measures to get better value and utilisation from forest production have increased the availability and potential commercial importance of lesser-known timber species that, until now, have had no market in the UK. These new species must be evaluated for end-use applications in order to create markets for producer countries, encourage more sustainable use of forests and protect the interests of UK consumers.

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Table 1 European durability classes (BS EN 350-1)

Class	Description	Mean life (relative to reference species*)
1	Very durable	> 5.0 times
2	Durable	>3.0 but ≤ 5.0 times
3	Moderately durable	> 2.0 but ≤3.0 times
4	Slightly durable	> 1.2 but ≤ 2.0 times
5	Not durable	≤ 1.2 times

* Scots pine sapwood and beech.

The second issue relates to environmental concerns; this includes the use of chemicals considered as toxic and emissions of organic solvents into the atmosphere. These concerns are driving a change towards alternative active ingredients for wood preservatives, the wider use of water based preservative formulations and towards new processing technologies for enhancing wood durability. It is essential that these new developments are fully evaluated and compared with proven commercial products to ensure that they are fit for purpose. Recent BRE ground contact trials include several new products and processes but results reported here concentrate on tests of the improvement in the protective efficacy of copper/chromium/arsenic (CCA) in spruce following pretreatment incising to increase penetration.

The likelihood of timber being decayed by wood-destroying fungi during its service life depends on the circumstances of its use. Factors such as contact with the ground and exposure to water or atmospheric moisture increase the potential for decay. The risk of decay in timber used in contact with the ground (eg as a fence post) will be much greater than the same timber used out-of-ground-contact (eg in a window frame). A rating system for classifying the hazard class of the service conditions, on a scale of 1 to 5, is specified in BS EN 335-1: it is important that the tests used to determine the service life of timber appropriately reflect the relevant service conditions of its intended use. The BRE field trials database relates specifically to Hazard Class 4 (ground contact).

Several British and European standards tests have been developed to cover the classification of the natural durability of different timber species as well as to evaluate the effectiveness of preservative treatments. The test requirements and durability classes (Table 1) are given in BS EN 350-1. Much of the early material in the BRE test programme predates these standards and, in many cases, the methods specified in the standards have been based on those developed at BRE, and on BRE's information database and experience.

Description of test methods

Preservative efficacy

The performance of preservative treated timber is now assessed using the European Standard field test method described in EN 252 (the designation by which BS 7282 is usually known) which involves part-burying wooden stakes in the ground (Figure 1).

The test requires the preparation of ten replicate test stakes (size 500 × 50 × 25 mm) per treatment variable. The stakes are installed in the test field by burying to a depth of 250 mm. BRE has two field test sites: one at Princes Risborough in Buckinghamshire and the other at Thetford Forest in Norfolk. It is important to have at least two test fields in order to challenge the timbers and treatments with different soil conditions, climates and natural soil microflora. At least once a year each individual stake is tapped in a prescribed way with a wooden mallet to assess its integrity (Figure 1), then removed from the ground and inspected for biological damage against a rating scheme defined in EN 252. A nominal mean decay rating (NMDR) is calculated for the timber species, or preservative treatment, by dividing the sum of individual decay ratings for the test samples by the number of stakes. The NMDR can then be used to indicate service life before complete failure. It is also a useful measure for assessing how timbers and preservative treatments fail rather than just determining the point in time at which they fail. Where only a proportion of the stakes in the test set has failed, a provisional mean life can be calculated using Purslow's method (BRE Current Paper CP 31/77). This involves applying a statistically derived multiplication factor which takes into account the range of the lives of replicate stakes within a set, including the number not showing any failure. The mean value for the stakes which have failed at a particular time is adjusted to provide a predicted mean life for the whole set.

Figure 1 Inspecting and testing field test stakes to EN 252

Natural durability

The stake test method in EN 252 can be also used for determining the natural durability of timbers intended for use in ground contact conditions. The classification of the durability of timber species (Table 1), on a scale of 1 (very durable) to 5 (not durable), is given in BS EN 350-1. This Standard requires the simultaneous exposure of sets of Scots pine sapwood and beech stakes as reference timbers. The natural durability of the particular timber under test is calculated by reference to the mean life of the more durable of these two sets of control stakes. This allows the durability of the timber species under test to be assessed as a ratio of the durability of the control species. The resultant classification of the test species is then determined in accordance with BS EN 350-1.

Many of the original natural durability stakes that were installed in the BRE trials from 1929 onwards measured 50 × 50 × 600mm, predating the EN 252 method. Some of these timbers are still serviceable after over 70 years in the ground, but many of these species, requisite qualities and sources are unavailable commercially today. Accordingly, new material which is more representative of modern supplies has been installed in the field test sites. The original-quality material allowed a degree of cross-comparison with preservative treated timber, so it is important that new durability tests were introduced in accordance with the EN 252 protocol now established for wood preservatives.

Natural durability of timber species

The emphasis of the more recently introduced samples reviewed in this paper has been on a group of timbers often referred to as the secondary hardwoods. These are newer species being introduced to the market and so are potentially very important commercially. In earlier times, many of these species were not considered to be commercially viable, for only the most well established, naturally durable timbers were valued and traded. As well as assessing the natural durability of these newer species, their resistance to treatment is also being assessed so that, if necessary for the UK construction market, preservative treatments can be specified. Trials have also included samples of plantation grown species (eg teak) to check whether there have been reductions in natural durability compared with samples from original, virgin forest sources.

Results for 11 different species and sources are given in Figure 2 (on page 4) as NMDR values for the two field test sites derived from assessments conducted in 1997, 2000 and 2001. In all cases the Thetford Forest field site proved more aggressive than the Princes Risborough site, as expected. It was reasoned that the forest site has a naturally more aggressive fungal population in the soil. However, as the durability classification is derived by relationship to the performance of reference species in the same test, the choice of field test site should not affect the actual durability class assigned. Table 2 on page 5 lists the classifications for some of the most recent natural durability results added to the database.

NMDR values around 1.0 are not considered significant in relation to ultimate service life as they may be due solely to a discoloration or softening of the wood. Distinct discoloration of the below ground portion of the stake usually occurs in many of the highly coloured timbers due to the breakdown or movement of water-soluble extractive chemicals in the wood.

The mean service life for Scots pine, tested as the reference species, is about 2.5 years at Princes Risborough and 1.7 years at Thetford. The mean service life for beech, as the reference species, is about 2.8 years at Princes Risborough and 2.5 years at Thetford. Using these values as references, it seems likely that mersawa, andiroba and amboyna will achieve a classification of moderately durable (Class 3) while teak, vitex and jatoba will achieve durable (Class 2) or very durable (Class 1). The other timber species evaluated and presented in Figure 2 can be classified already as only slightly durable (Class 4).

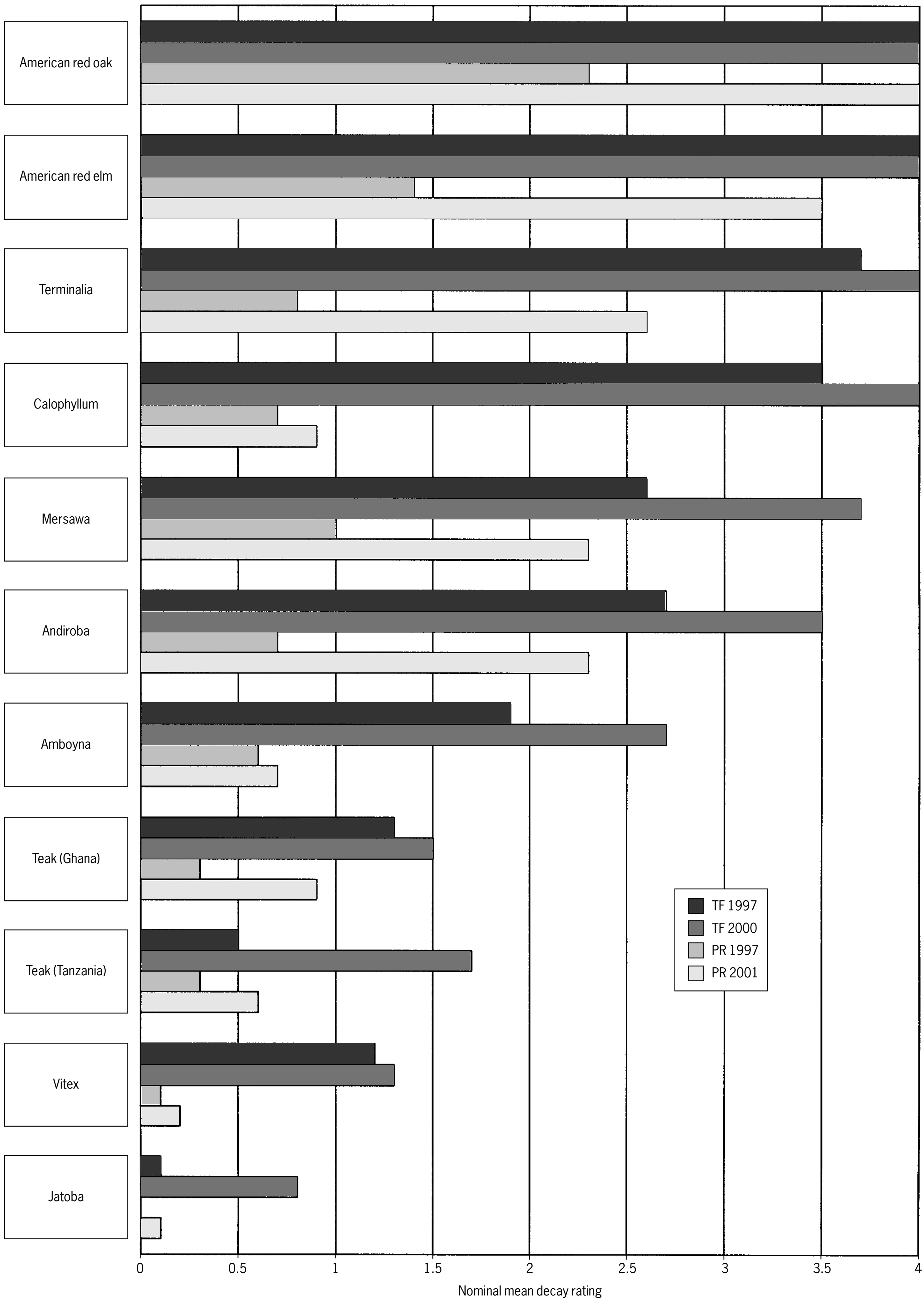


Figure 2 Nominal mean decay rating data for secondary hardwood timbers installed in field tests in 1993. (TF = Thetford Forest and PR = Princes Risborough. TF and PR are followed by the year of inspection)

Table 2 Classification of durability from EN 252 ground contact stakes material installed from 1991 *

European durability class	Princes Risborough	Thetford Forest
5	Tulipwood	Tulipwood
4	Southern yellow pine, rubberwood, American red oak	Terminalia, southern yellow pine, rubberwood, American red oak, American red elm, calophyllum
3	–	Chilean oak (eucalyptus)
2	–	–
1	–	–

* Most of the material is still in test which explains why mostly only the not durable or slightly durable timbers are recorded.

Evaluation of preservatives for use in ground contact situations

Acceleration using EN 252 size stakes

Most of the earlier stake tests were established to compare preservative treatments and different sources of creosotes and mixtures of CCA type preservatives. The sample sizes used then were chosen to be close to the real commodity size, including samples as large as 130 × 75 × 600 mm sections. Four main timber species were included and many of the stakes and preservative combinations are still performing very well in ground contact some 50 years after first being put into test. This database should give considerable confidence to the UK preservation industry and its clients: that newer products can produce comparable performance in extending service life and in maximising the sustainable use of the timber resource. The main drawback of any field test is that it takes a very long time to obtain any performance data; but once established, long term databases are very important. In order to accelerate the field test method, the new standard EN 252 was developed to use smaller stakes and these have been introduced progressively at the BRE field test sites. The smaller samples allow more rapid comparative studies of performance to be made.

Data from more recent BRE trials using EN 252 stakes treated with CCA wood preservatives are presented in Figure 3. The progress of decay with time is clearly illustrated indicating the possibility of predicting service life more quickly based on partially completed tests. For stakes treated with 0.3% CCA, early decay signs occur after only 3 years and by 8 years the batch of stakes have almost completely failed. In these tests, with Scots pine sapwood, the treatment with 0.3% CCA increased the service life of the stakes by a factor of 2.

Sets of stakes treated with more recently developed commercial preservative formulations have been introduced to maintain the currency of the field trials. The preservatives include the most modern formulations of 'copper azoles', some more traditional formulations of copper/chromium/boron (CCB), and other arsenic-free or chromium-free preservatives. These stakes have not yet been in test long enough to yield any interim performance data.

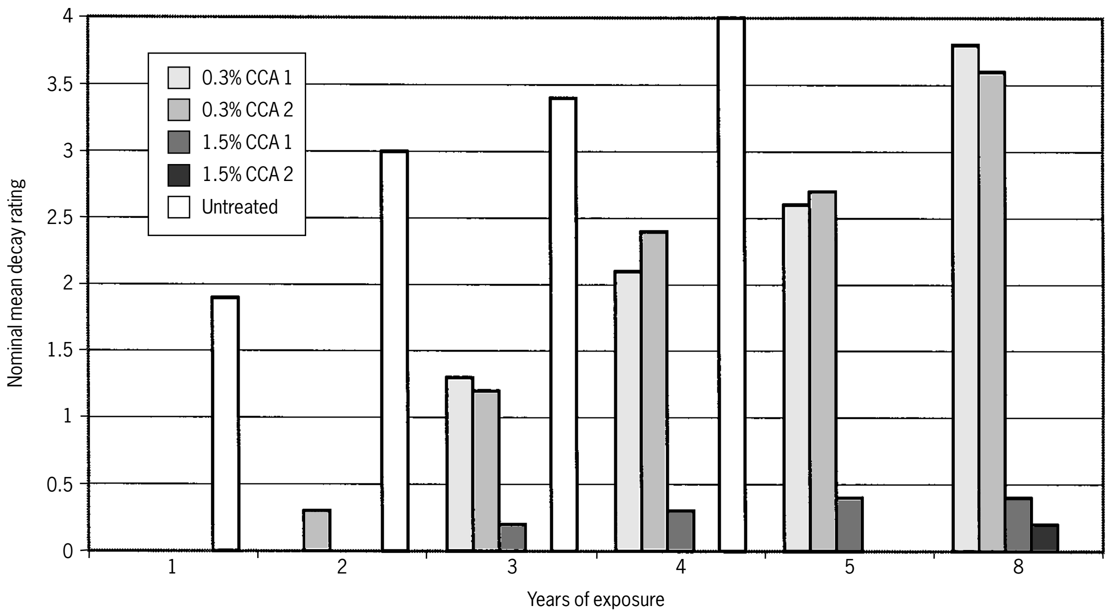


Figure 3 Nominal mean decay rating data for Scots pine sapwood tested at the Princes Risborough field site: treated with 0.3% CCA and 1.5% CCA, and untreated

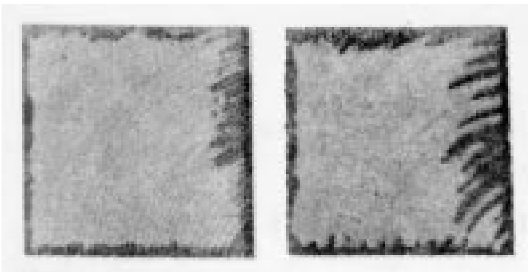
Incising spruce to improve service life

Although the durability of a timber species can be enhanced by applying a preservative, in practice timber species differ greatly in their resistance to impregnation by fluids, and therefore in the ease with which they can be treated. The treatability of a timber species is dealt with in BS EN 350-2 which classifies timber on a scale of 1 (easy to treat) to 4 (extremely difficult to treat).

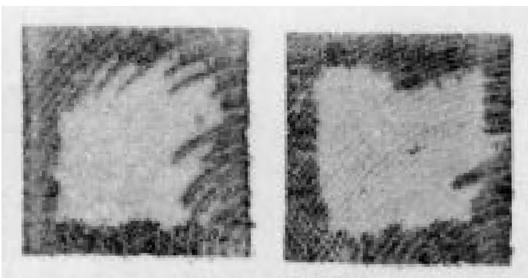
Spruce is a timber which is commercially very important in Europe and especially in the UK. However, it is classified as being only slightly durable (EN Class 4) but difficult to treat (EN Class 3). Incising techniques, in which a pattern of incisions is cut in the lateral surfaces of the timber, potentially offer a method of improving the effectiveness of preservative treatment by increasing the penetration of preservative through the lateral surfaces (Figure 4). While incising is not entirely suitable for timber intended for joinery applications, because the incisions detract from the surface appearance of the timber, the technique is already widely practiced for many other end uses in north America, Japan and continental Europe, but not in the UK. BRE field tests were set up in 1972 and are demonstrating that incising the surface of spruce can markedly improve the service life of the timber in ground-contact situations.

The BRE tests involve spruce stakes of size 600 × 50 × 50 mm sealed on their end-grain surfaces. The stakes were prepared with a pattern of staggered surface incisions. The incisions were cut to a depth of either 6 mm or 9 mm prior to pretreatment with either a CCA preservative or coaltar creosote, both applied by a full cell process. This ensured that the preservative penetrated the wood only through the lateral faces, forming an envelope of treated material, thus avoiding the influence of end-grain penetration. By weighing the stakes before and after treatment, it was demonstrated that the uptake of the preservative was doubled by incising.

The preservative treated stakes were buried in the ground at the Princes Risborough site to a depth of 380 mm. After nearly 30 years, the performance of incised spruce treated with creosote, 3% CCA or 5% CCA is markedly better than the performance of the equivalent unincised, treated spruce. Indeed many sets of the CCA treated incised stakes have yielded no failures at all after 29 years in service (Table 3). Only in the case of CCA used at a very low concentration (0.1%) did incising show no beneficial effect on service life.



Unincised timber



Incised timber

Figure 4 Cross-sections of unincised and incised spruce timber treated with wood preservative showing the improved penetration in the incised sample

Table 3 Mean service life of incised spruce posts at Princes Risborough field test site

Treatment	Incisions (mm) Stagger	Depth	Absorption (kg/m^3)	Number failed	Mean life (years)
None	No incisions	No incisions	–	20	11.9
0.1% CCA	No incisions	No incisions	0.2	10	15.4
	3	6	0.3	10	15.1
	4.5	6	0.3	10	12.7
	6	9	0.4	10	14.3
3.0% CCA	No incisions	No incisions	3.2	6	28.5*
	3	6	6.6	0	>49.0*
	4.5	6	6.1	0	>49.0*
	6	9	7.3	0	>49.0*
5.0% CCA	No incisions	No incisions	5.2	4	30.3*
	3	6	10.9	0	>49.0*
Creosote	No incisions	No incisions	79.0	0	>49.0*
	3	6	136.0	0	>49.0*

* Predicted service life using Purslow's method (CP 31/77).
The service life of >49 years is predicted assuming a stake fails at the next inspection.

Conclusions

Results from this ongoing work show that:

- most of the secondary hardwood species so far tested are only slightly durable;
- teak from plantation sources may be less durable than that normally to be expected for the species;
- tulipwood can be classified as not durable (Class 5);
- American red elm, American red oak, southern yellow pine, terminalia and calophyllum can be classified as slightly durable (Class 4);
- Chilean oak can be classified as moderately durable (Class 3);
- traditional preservatives (CCA, creosote) are highly effective, and difficult for more modern preservatives to emulate;
- newer preservatives, at specific retentions, can give performances comparable to the traditional products;
- incising spruce prior to preservative treatment doubled the uptake of preservative and appeared to double the service lives of the treated stakes;
- incised spruce stakes treated with 3% CCA gave a predicted service life in excess of 49 years.

Recommendations

Maintenance of these long term field tests, together with associated commodity tests of timber durability, is essential in order to deliver independent durability and performance classifications on which UK industry and end users can rely. Without the data from these trials, implementation of European Standards for the specification of durable construction timber cannot operate economically and effectively. Of equal importance, the objective of developing optimised wood preservation (ie the correct amount of preservative for the desired service life, thereby minimising the environmental impact of treated timber) becomes unattainable.

Regular monitoring of current field trials should be maintained and any significant new developments in preservative products or processes included in the trials.

Timber species new to the European market should be incorporated in current trials to allow assessment of their natural durability. The commercially important UK timbers in construction should be re-evaluated where changing forest practices or sources indicate possible changes in properties.

New, non-conventional durability enhancing technologies being introduced as alternatives to conventional preservatives (including heat treatment and chemical modification), should be included in the BRE trials as these processes begin to be commercially important elsewhere in Europe.

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British Standards

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BS EN 335-1:1992. Hazard classes of wood and wood-based products against biological attack. Classification of hazard classes

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