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The development of blue stain in service in sapwood of European softwood species

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THE DEVELOPMENT OF BLUE STAIN IN SERVICE IN SAPWOOD OF EUROPEAN SOFTWOOD SPECIES

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ABSTRACT

The utilization of softwood species for window joinery applications is gaining importance in countries frequently using tropical hardwood species up to now. Since wood preservation is not always part of the total concept of window frames manufactured from sapwood containing wood elements it is essential to know the impact of durability on the performance. Moisture content control is a major tool in achieving an acceptable service-life regarding wood rot. The development of blue stain can be prevented in a similar way but other parameters than natural durability are to be considered, too. This study evaluated the development of blue stain in service in sapwood of four European softwood species : Scots pine, spruce, douglas fir and larch. The results were compared with data on porosity of the same samples. As a conclusion it can be stated that not only the physical protection from water penetration is important but that the wood water relationship of a softwood species plays a major role in the development of blue stain in service, as well.

INTRODUCTION

The sapwood of 4 softwood species was selected for comparative tests:

Softwood species	Botanical name
Spruce	*Picea abies* (L.) Karsten
Scots pine	*Pinus sylvestris* L.
Larch	*Larix x eurolepis*
Douglas fir	*Pseudotsuga menziesii* (Mirb.) Franco

Especially in the Netherlands there is some concern about the susceptibility to blue stain of these timber species. Besides a major use of spruce and Scots pine an increase in availability

of home grown larch and home grown douglas fir started discussion on the suitability of these resources. The sapwood for this investigation was selected from commercially available material. The tree circumference was used as basis including also wane on samples selected. Additional colour differentiation using also specific staining agents proved that the sapwood selection was correct.
From practical experience differences in development of blue stain fungi in the sapwood of the 4 species was expected. In order to get better insight in this phenomenon blue stain tests as well as the determination of the wood water relationship was part of a total set up.

MATERIALS AND METHODS

Two sets of sapwood material were used in the experimental set up. A first set originated from the Netherlands and was used for all tests, while additional material from a different European origin was used for extra blue stain testing. Since differences of blue stain development could be related to wood permeability characteristics (Boutelje and Hägglund, 1988) part of the experiments dealt with the wood water relationship using both time related water uptake and swelling rate as criteria. For the blue stain tests both laboratory and outdoor exposures were used.

* Wood-water relationship

From each wood species 10 samples measuring 18 x 18 x 18 mm were conditioned at 20°C and 65% RH. Half of the samples were end grain sealed while the other 5 samples were sealed on all sides except the cross cut surfaces. The sealer used is an opaque polyurethane paint applied in two coats. Samples were weighed prior to the immersion in tap water of 15°C. Water uptake was recorded after 1 and 2 hours, 1 and 2 days, 1, 2, 3, 4 and 5 weeks. The uptake figures are calculated as kg/m^2.
In addition to the water uptake measurements another 25 identical samples were evaluated on their radial and tangential swelling from equilibrium at 20°C and 65% RH to total soaking saturation. Percentage swelling was based on the dimensions at equilibrium moisture content situation by means of conditioning prior to water uptake.

*** Blue stain tests**

A first series of 5 small boards of each softwood species containing over 50% sapwood were exposed horizontally outdoors and evaluated after 1 and 5 months respectively.

Additional blue stain testing was performed under laboratory conditions. The European standard EN 152 was used as basis for this experimental part. This standard is based on the development of two test fungi in Scots pine sapwood being *Aureobasidium pullulans* (de Bary) Arnaud - strain P 268 and *Sclerophoma pithyophila* (Corda) v. Höhn - strain S 231. The test method described is supposed to determine the protective effectiveness of a (coating) preservative against blue stain development. For this purpose treated and weathered Scots pine sapwood (*Pinus sylvestris* L.) samples are introduced after sterilization with ionizing radiation in culture vessels on a layer of moistened vermiculite after being dipped in a spore suspension of the above mentioned fungi for 1s to 2s. Finally a 15 ml spore suspension is poured over each block which is positioned with the treated or coated side uppermost. Standard samples measure 9 cm in length, 4 cm in width and 1 cm in thickness having rounded longitudinal edges on the upper side and are given a groove in the middle of the untreated side of 2 mm width and 4 mm depth parallel to the end surfaces (figure 1). The test is continued for 6 weeks from the time of inoculation. The evaluation of the test boards is using two criteria. First there is a surface assessment by means of examination for the presence of blue staining. The evaluation with figures 0 to 3 is described as follows :

0 - not blue stained: no blue stain can be detected visually on the surface

1 - insignificant blue stained: the surface exhibits only individual small blue stained spots with a largest diameter of 2 mm and moreover, not more than 5 or 10 in number, depending on the type of coating

2 - blue stained: the surface is continuously blue stained up to a maximum of one third, or blue stained partially or in streaks up to half the total area

3 - strongly blue stained: more than one third of the surface is continuously blue stained of more than half is partially blue stained.

For more detailed evaluation a more commonly used rating scale for fungal surface growth can be used as well:

0 : no growth

1 : trace of growth of up to 1% coverage

2 : growth more than 1% and up to 10% coverage

3 : growth more than 10% and up to 30% coverage

4 : growth more than 30% and up to 70% coverage

5 : growth more than 70% coverage.

Note that this rating 0 to 5 does not correspond to the same numbers in the standard EN 152. Similarity can be seen as follows : 0 = 0, 1 = 1 and 2, 2 = 3, 3 = 4 and 5. But as such this extra ratings do not give additional information when testing wood finishes. The second criterion for the evaluation of test boards in EN 152 is the examination of the interior by means of cutting the samples parallel to the end faces at points 30 mm from each end. For the determination of the protective action of a wood coating system the blue free zone is measured. This way of evaluation is entirely linked to the development of the blue stain fungi from the vermiculite medium upwards to the coating layer on top of the samples. For the examination of the development of blue stain fungi through the paint film into the wood substrate an alternative test method had to be developed. Somewhat shorter samples (5 cm) are now positioned on the vermiculite substrate with the coated or painted side downwards while all other sides are sealed preventing the fungi to establish on the non coated sides (figure 2). This last layer of sealant is therefore loaded with a blue stain fungicide.

The methodology for testing here is not equivalent to the one evaluating treatment and finishing systems. Besides some difficulties in interpretation of results from EN 152 (Gründlinger et al, 1989, Van Acker et al, 1992) the basic idea in this standard for laboratory blue stain testing of the sapwood samples selected was found suitable. The only alteration in sample preparation was the absence of a coating system. Both the standard method and the alternative, reverse test method are used to characterize the blue stain growth rate and the mode of development. Surface evaluation after 2 weeks already showed major blue staining and it was decided to end the test after 3 weeks of test.

RESULTS

In table 1 details are given on the blue stain development in laboratory tests using the EN 152 standard method and the reverse method. After 3 weeks the blue stain was already well established giving top surface ratings of 3 to 5 for individual samples. No clear differentiation is possible from the surface rating data recorded but more details seem available when dealing with the mode of development. The blue stain fungi prefer the outer wood layers to grow in Scots pine sapwood while in spruce predominantly the earlywood zones throughout the matrix are stained. The set 2 of Scots pine was the least stained while in the set 1 samples were totally stained indicating major impact of the origin of the timber and/or the seasoning system used. Both larch and douglas fir from both origins tested show a minor staining inside the samples however this was not visable considering the surface rating. Especially for douglas fir a distinct development along the wood rays was observed.

Table 1: Evaluation of softwood sapwood samples after 3 weeks of blue stain development using the surface rating with a scale 0-5 for both the EN 152 and the alternative reverse test method and the mode of blue stain development for the latter test

Wood species	Origin*	Surface rating		Development (reverse method)
		EN 152 method	reverse method	
Spruce	1 2	5 4-5	3-5 5	full matrix earlywood
Scots pine	1 2	4-5 3-4	3-5 2-4	predominantly the surface areas
Larch	1 2	3-4 3-4	5 5	matrix locally blue stained
Douglas fir	1 2	3-4 3-5	5 5	ray linked deve-lopment

* : origin 1 = set from the Netherlands
2 = different European origins

The outdoor exposure test data recorded after one month showed that Scots pine sapwood was already severely blue stained and little blue staining was visable on spruce sapwood but nearly no blue stain was observed on larch and douglas fir sapwood. After 5 months sapwood of all species was severely blue stained. The observations after one month outdoor exposure can be compared with the results of the EN 152 surface rating after 3 weeks using the material of origin 1. The maximum surface rating values for the EN 152 method are indeed lower for larch and douglas fir when considering set 1 only. The fact that set 2 of Scots pine is no longer significantly different from larch and douglas fir makes prediction of in situ behaviour unlikely based on solely the selection of wood species. Furthermore better results with the EN 152 method for douglas fir and larch sapwood are not highlighted when evaluating the development of blue stain up to the sealant applied on the reverse positioned samples. Although minor presence of blue stain in the matrix of douglas fir and larch sapwood a surface rating of 5 was given to nearly all samples when evaluating blue stain underneath the top sealant. This is a clear indication that the development of blue stain in service can be influenced by the presence and type of coating system applied. For both spruce and Scots pine this development system was not observed pointing out that the pathways for fungal

growth and probably also local humidity or permeable zones can influence the staining of a specific softwood sapwood material.
Trying to explain some of these observations the material of origin 1 was also evaluated on water related properties. Water uptake figures after 1 hour and 5 weeks in longitudinal as well as in transverse direction are shown in tables 2 and 3 respectively.
Water uptake after 1 hour is significantly higher in longitudinal direction for Scots pine and spruce sapwood. The figures for transverse porosity are showing evidence of the more open anatomical structure of Scots pine sapwood.
Referring to the surface rating of samples of origin 1 in table 1 water uptake figures show an obvious correlation indicating that early staining of non coated sapwood is linked to the porosity and water uptake. The evaluation of samples from outdoor exposure confirmed these findings, too. Though not measured in detail the presence of higher amounts of latewood in both spruce and Scots pine sapwood of origin 2 coincides with lower blue staining which can be linked to the lower permeability of this material.
The total water uptake after 5 weeks reveals a major difference only for Scots pine sapwood. From this figure it can be stated that Scots pine sapwood will contain more water over longer periods when exposed and hence is more susceptible for blue stain establishment than sapwood of the other softwood species.
Differences in cell wall moisture uptake at water saturation of the sapwood is not obvious when interpreting the swelling percentage data (table 4). The percentage water uptake at saturation is another figure that coincides fairly well with the blue stain surface rating of EN 152 as well with the ratings after outdoor exposure, which emphasizes again a major impact of water sorption properties of softwood sapwood. The equilibrium moisture content at 20°C and 65% RH (table 4) at the beginning of a blue stain laboratory test could not give any additional indication.
From this research it can be stated that although the sapwood of softwood species are different in susceptibility to blue stain in service the major impact is to be expected from the water sorption characteristics. These can be significantly different using various origins and/or seasoning methods. In addition blue stain in service is not identical in its mode of development or establishment for coated and uncoated material.

Table 2: Water uptake of softwood sapwood samples after 1 hour

Wood species	Water uptake after 1 hour (kg/m^2)	
	longitudinal	transverse
Spruce	2.3 ± 0.2	0.13 ± 0.04
Scots pine	2.8 ± 0.7	0.22 ± 0.02
Larch	1.5 ± 0.2	0.14 ± 0.02
Douglas fir	1.4 ± 0.2	0.13 ± 0.02

Table 3: Water uptake of softwood sapwood samples after 5 weeks

Wood species	Water uptake after 5 weeks (kg/m^2)	
	longitudinal	transverse
Spruce	4.9 ± 0.3	1.2 ± 0.04
Scots pine	7.7 ± 1.8	1.4 ± 0.04
Larch	4.6 ± 1.8	1.1 ± 0.05
Douglas fir	4.3 ± 0.2	1.3 ± 0.06

Table 4: Equilibrium moisture content, total saturation and swelling percentage of soft-wood sapwood samples

Wood species	Equilibrium m.c. (%)	Water uptake at saturation (%)	Swelling percentage	
			radial	tangential
Spruce	12.0 ± 0.4	160 ± 17	2.5 ± 0.3	6.0 ± 0.4
Scots pine	12.4 ± 0.7	160 ± 5	3.0 ± 0.2	5.2 ± 0.3
Larch	14.3 ± 1.3	130 ± 9	2.9 ± 0.2	5.4 ± 0.6
Douglas fir	12.7 ± 0.3	148 ± 10	2.9 ± 0.3	5.0 ± 0.4

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Figure 1: EN152 sample

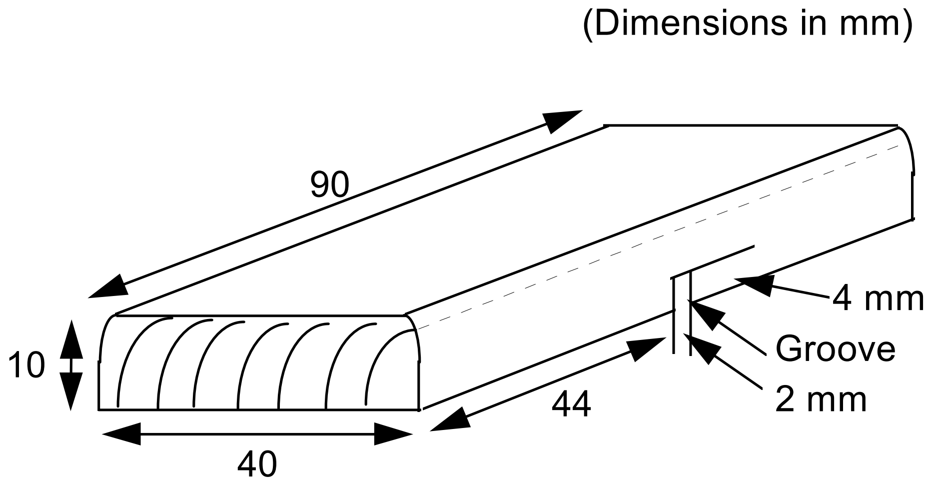

Figure 2: reverse sample