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Section 4 Processes

Influence of a dipping preservative treatment on the performance of wood finished with waterborne coatings

Mari de Meijer [(1)], Jos Creemers [(1)], Wiro Cobben [(1)], Pirjo Ahola [(2)]

1: Foundation for timber research SHR
PO Box 497
NL-6700 AL Wageningen, The Netherlands
2: VTT Building Technology, Espoo
PO Box 1806
FIN-02044 VTT, Finland

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ABSTRACT

Influence of a dipping preservative treatment on the performance of wood finished with waterborne coatings

Mari de Meijer [(1)], Jos Creemers [(1)], Wiro Cobben [(1)], Pirjo Ahola [(2)]

1: Foundation for timber research SHR   2: VTT Building Technology

Within a larger European research project on the performance of joinery finished with waterborne coatings, the influence of a water based dipping preservative treatment was studied in several ways. Six different waterborne coatings were tested with and without a preservative underneath the coating. The performance was tested on pine sapwood and spruce panels in a 2-year outdoor weathering trial on two different sites in Europe. The panels were evaluated visually with respect to cracking, flaking, surface mould growth and development of blue stain underneath the coating. In several cases the preservative treatment improved the performance of the coating, not only with respect to biological deterioration but also for cracking and flaking of the paint.
A limited number of coatings were also tested on L-joints according to the EN-330 and of national dutch design. The EN-330 L-joints appeared to be a more challenging substrate compared to the national type, which had a glued connection between tenon and mortise.
The influence of the preservative on the moisture content of the wood was evaluated by monthly weighing of the samples exposed outdoors and by laboratory measurements of the coating permeability. At least in laboratory trials the dipping treatment caused a slight reduction of the water permeability. This is most likely the result of the polymeric binder material present in the preservative. The presence of polymeric material underneath the coating was also confirmed in a microscopic evaluation of the distribution of the dipping preservative. The preservative was not equally distributed in the wood, but showed a clear preference for the ray-tissue.

Key words (3-6): waterborne coatings, dipping preservative treatment, weathering resistance, moisture permeability, coating penetration, coating performance

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Mari de Meijer [(1)], **Jos Creemers** [(1)], **Wiro Cobben** [(1)], **Pirjo Ahola** [(2)]

1: Foundation for timber research SHR, PO Box 497, NL-6700 AL Wageningen, The Netherlands
2: VTT Building Technology, Espoo, PO Box 1806, FIN-02044 VTT, Finland

1. Introduction

The work presented here is part of a larger European research project called "Performance and durability of wooden joinery painted with low-VOC coatings". The aim of this project is to study the performance of several combinations of waterborne coatings, wood species and substrate designs, reflecting the various building traditions in European countries. The project includes outdoor weathering trials in five countries and laboratory studies on specific topics.
In order to meet objectives on environmental and health and safety issues, the use of waterborne coatings has become increasingly important during the last decade. Broad practical experience with waterborne coatings however is still limited in many countries, in particular in relation to questions dealing with the nature of the wooden substrates. One of these questions is the possible advantage of a dip-preservative treatment of the wood prior to the application of the coating. In some countries a preservative treatment is considered to be necessary e.g. Denmark, whereas in other countries this is not common practice e.g. The Netherlands.
The objective of this study is to systematically investigate the influence of a dip-preservative treatment underneath several waterborne coatings applied on various substrates.

2. Materials and methods

Six different waterborne and one solventborne reference coating system have been used in this study. The coating systems varied with respect to binder-type, type and amount of pigment used (Pigment Volume Concentration PVC) and first and second coat. Depending on the coating type, the application was either done by brush or airless-spray to a total dry film-thickness between 53 and 188 µm. The preservative was water-based and formulated in a specific way with the relatively high polymeric binder concentration of 20% (w/w) and a relatively low content (0.5%) of the active ingredient 3-iodo-2-propynyl butyl carbamate (IPBC). It was applied by dipping the samples for about 0.5-1 minute, resulting in a preservative uptake between 100 and 120 g/m^2 for both wood species, being Nordic grown, kiln dried, spruce (*Picea abies Karst.*) and Scots pine sapwood (*Pinus sylvestris L.*). Density of the wood was between 360 and 570 kg/m^3 for spruce and between 470 and 670 kg/m^3 for pine and initial moisture content was between 12 and 14%.

The outdoor exposure test was carried out on the following substrates: flat panels with an untreated backside according to prEN927-3 (3 replicates), L-joints without a glued connection between tenon and mortise according to EN-330 (5 replicates) and a fully glued, real-size window-corner joint also used in a national Dutch standard (SKH-publication 95-01) for testing waterborne coatings (3 replicates). All different substrates have been exposed outdoors (facing south) for 2 years (from October 1995 to October 1997) in Wageningen

(The Netherlands). Additionally, panels have also been exposed for two years (from January 1996 to January 1998) in Espoo (Finland). An overview of the various combinations of coating types, substrates and sites is given in table 1.

Table 1 Description of coating systems, substrates and sites

Code	First coat	Top coat	Wageningen EN 927 panel	Wageningen EN330 joint	Wageningen National joint	Espoo EN 927 panel
A	waterborne alkyd opaque	waterborne alkyd opaque	pine spruce	pine spruce	spruce	pine spruce
B	acrylateA PVC25% opaque	acrylateA PVC15% opaque	pine spruce	pine spruce	spruce	pine spruce
C	acrylateA PVC25% opaque	acrylateA PVC25% opaque	pine spruce	-	-	pine spruce
D	acrylateB PVC25% opaque	acrylateB PVC15% opaque	pine spruce	-	-	pine spruce
E	acrylate stain semi-transparent	acrylate stain semi-transparent	pine spruce	-	spruce	pine spruce
F	alkyd-acrylate opaque	alkyd-acrylate opaque	pine spruce	-	-	pine spruce
G	solventborne alkyd opaque	solventborne alkyd opaque	pine spruce	pine spruce	spruce	pine spruce

PVC = Pigment Volume Concentration

The coatings have been evaluated visually, according to appropriate standards, with respect to cracking (ISO 4628-4), flaking (ISO 4628-5), surface mould growth / blue-stain development (prEN 927-3), X-cut adhesion (ASTM D3359-93) and decay (EN330) inside the wood.

Table 2 gives an overview of the rating schemes used to determine the density or size of the defects.

Table 2 Description of rating schemes

Class	Flaking: Flaked area	Flaking: Size of flakes (S)	Cracking: Quantity	Cracking: Size of cracks (S)	Mould / Blue stain: Description
0	0 %	not visible at 10X	none	not visible at 10X	no evidence of blue stain / mould
1	0.1 %	up to 1 mm	very few	only visible at 10x	slight attack slight discoloration
2	0.3 %	up to 3 mm	few	just normal visible	moderate attack / distinct discoloration, not more than 25 % of visible area affected
3	1 %	up to 10 mm	moderate	clearly visible	severe attack, distinctly more than 25 % of the visible area affected
4	3 %	up to 30 mm	considerable	large up to 1mm wide	failure severe and extensive blue stain or mould growth
5	15 % or more	larger than 30 mm	dense	more then 1 mm wide	-

Evaluation of flaking and cracking is expressed as a combination of two aspects: density (area or quantity) and size, separated by a capital S. A single panel with a flaked area of 1% and a flake size up to 3 mm, in this sense would be evaluated as '3 S 2'. Three replicate panels of the same coating system with evaluations '3 S 2', '2 S 2', and '3 S 3' respectively, would lead to a mean evaluation result of '2.7 S 2.3'.

The moisture content during exposure was determined by monthly weighing of the samples.

The determinations of moisture permeability on laboratory scale have been made according to the Rosenheim method (Institut für Fenstertechnik, 1991). In this method, end-grain sealed blocks are exposed to liquid water or water vapour (98 % RH) for 10 days, followed by drying at 50 % RH and 23 °C. The samples are weighed with intervals of one or two days and the weight change is plotted against time followed by integrating the area under the time-weight plot. The reduction in moisture permeability is subsequently calculated by dividing the area of the coated samples by the one belonging to the uncoated sample.

The penetration of the dipping preservative and the coating into the wood has been determined by fluorescence microscopy at magnifications between 25 and 200 x. In order to improve the contrast between coating and wood the coating has previously been stained with an orange-red fluorochrome (Rhodamine-B). Because the polymeric binder in the preservative had good auto-fluorescent properties, it could also be determined without the addition of a fluorochrome. For a quantitative determination of coating penetration the maximum depth into the longitudinal direction of early- and latewood has been measured. For this purpose the coating has been applied on a microtome smoothed axial surface; for more details see Meijer et al. (1996).

3. Results and discussions

3.1 Coating durability during outdoor weathering

Flaking and adhesion:
The preservative treatment had a positive influence on the durability of coating applied on the panels. On pine sapwood coatings A, B, C and E showed serious flaking without a preservative treatment whereas flaking was absent (A and B) or reduced (C and E) on pre-treated wood. Coatings D and F hardly showed any flaking at all, regardless whether the wood was preservative treated or not. On spruce a similar pattern has been observed but the degree of flaking is far less. An overview of the flaking assessment of the panels is given in table 3.
The flaking in Espoo was found to be higher in comparison with the site in Wageningen. As January is the coldest month in Finland, it is felt that this difference should partly be attributed to the beginning time of the exposure.

After two years the adhesion of the coatings has also been tested. From the results (not shown in detail here) it can be concluded that the preservative treatment had no influence on the adhesion as long as the coating retained its integrity. If heavy flaking occurred, the adhesion was also negatively influenced. Under these circumstances the preservative treatment improves adhesion.

Table 3 **Flaking on EN927 panels** (mean value of 3 replicates)

Wood species	coating type	preser-vative	Wageningen 1 Year	Wageningen 2 years	Espoo 1 Year	Espoo 2 years
Pine sapwood	none	yes	-	-	-	-
		no	-	-	-	-
	A	yes	0	0	0	0
		no	0	0.3 S 1.0	0	0
	B	yes	0	0	0	0
		no	0.7 S 2.0	1.0 S 2.3	0	1.7 S 3.7
	C	yes	0	0	0.3 S 0.3	1.0 S 1.3
		no	1.3 S 2.0	2.3 0 2.3	3.0 S 2.3	4.7 S 4.3
	D	yes	0	0	0	0
		no	0	0	0	0.7 S 1.3
	E	yes	0.7 S 2.0	1.0 S 2.3	0.3 S 0.7	1.3 S 3.7
		no	2.0 S 2.3	1.7 S 2.3	5.0 S 5.0	5.0 S 5.0
	F	yes	0	0	0	0
		no	0	0	0	0
	G	no	0.3 S 1.0	0	0	0
Spruce	none	yes	-	-	-	-
		no	-	-	-	-
	A	yes	0	0	0	0
		no	0	0.3 S 1.0	0	0
	B	yes	0	0	0	0
		no	0.7 S 1.5	0.7 S 1.0	0	0.3 S 1.7
	C	yes	0	0	0	0
		no	0.7 S 1.3	0.7 S 1.0	1.0 S 2.0	2.0 S 3.0
	D	yes	0	0	0	0
		no	0	0	0	0
	E	yes	0.3 S 2.0	0.3 S 1.0	0.0 S 0.0	1.3 S 1.3
		no	1.0 S 1.3	1.0 S 1.7	1.3 S 1.3	2.3 S 4.0
	F	yes	0	0	0	0
		no	0	0	0	0
	G	no	0	0	0	0

For explanation of the ratings see Table 2 and the accompanying example

Cracking:

All panels showed cracking after the two year exposure. An overview of the ratings is given in table 4. The preservative treatment caused a slight reduction in the degree of cracking on pine sapwood panels coated with A, B, C and E. The rate of cracking development during the 2 years exposure has also been reduced by the preservative treatment. On spruce panels there is no clear positive influence of the preservative treatment.

After two years cracking on panels exposed in Espoo is somewhat larger compared to panels exposed in Wageningen. Apart from the difference in sites the beginning time of the exposure may have influenced this.

The preservative treatment had no effect on the development of wood cracks in the uncoated panels.

Table 4 Cracking on EN927 panels (mean value of 3 replicates)

Wood species	coating type	preser-vative	Wageningen 1 Year	Wageningen 2 years	Espoo 1 Year	Espoo 2 years
Pine sapwood	none	yes	5.0 S 4.0	5.0 S 4.0	-	-
		no	5.0 S 4.0	5.0 S 5.0	-	-
	A	yes	0	2.0 S 2.0	1.0 S 1.0	1.7 S 2.3
		no	0.7 S 2.0	3.0 S 2.0	0 S 1	3 S 2
	B	yes	0.7 S 2.0	1.7 S 2.0	0.7 S 1.0	2.3 S 2.3
		no	1.3 S 2.3	2.3 S 2.3	1.7 S 2.0	3.0 S 3.0
	C	yes	2.7 S 3.0	3.3 S 2.7	2 S 2	3 S 3
		no	4.3 S 3.3	4.7 S 4.0	5.0 S 3.0	5.0 S 3.0
	D	yes	0.3 S 3.0	1.0 S 1.7	0	0.7 S 0.7
		no	0	1.3 S 2.0	1.0 S 1.3	2.7 S 3.0
	E	yes	1.0 S 3.0	1.0 S 1.3	1.0 S 1.7	2.7 S 2.7
		no	1.3 S 3.0	1.7 S 3.3	5.0 S 5.0	5.0 S 5.0
	F	yes	0.3 S 2.0	1.0 S 1.3	0.3 S 0.3	1.0 S 1.3
		no	0	0.7 S 2.0	0.3 S 0.3	1.0 S 2.3
	G	no	0.7 S 3.0	1.0 S 2.3	0	1.0 S 1.7
Spruce	none	yes	5.0 S 4.0	5.0 S 5.0	-	-
		no	5.0 S 4.0	5.0 S 5.0	-	-
	A	yes	0	2.7 S 2.0	0.7 S 0.3	2.0 S 1.7
		no	0	2.0 S 2.0	1.0 S 1.7	2.3 S 2.3
	B	yes	0.3 S 2.0	2.0 S 2.0	1.3 S 1.3	1.7 S 2.0
		no	1.0 S 2.3	2.7 S 2.0	1.3 S 1.3	1.7 S 2.7
	C	yes	2.0 S 2.0	2.7 S 2.0	1.7 S 1.3	1.3 S 2.3
		no	1.7 S 2.3	3.0 S 2.3	4.7 S 2.0	5.0 S 3.0
	D	yes	0	1.0 S 1.7	0	1.0 S 1.7
		no	0.3 S 0.7	1.3 S 1.7	0	1.0 S 2.7
	E	yes	0.3 S 1.0	1.0 S 1.7	0	2.3 S 3.0
		no	1.0 S 2.0	1.0 S 2.0	0.7 S 1.0	2.3 S 3.0
	F	yes	0	0.3 S 2.0	0.3 S 0.3	1.3 S 1.7
		no	0		0	1.0 S 3.0
	G	no	0	1.0 S 1.7	0.7 S 0.7	1.0 S 2.3

For explanation of the ratings see Table 2 and the accompanying example

Blue-stain and mould-growth:

The intended reduction of blue-stain development by the preservative treatment was confirmed in case of the pine sapwood panels. An overview of the results is given in table 5.

Coating B, C, D and E showed a large amount of blue-stain development under and inside the coating which was reduced, but not completely prevented, by the dip preservative treatment. Coatings A and F showed less blue-stain development, even without a preservative treatment. It should however be taken into account that the concentration of the active ingredient was not optimised with respect to the uptake of the preservative.
On the surface of the coating A (alkyd-emulsion) and G (solventborne alkyd) surface moulds have been found. The differences between coatings shows that the coating formulation has also an influence on the growth of surface moulds and blue-stain. Similar findings from other tests have been reported previously (Bjurman 1992). On the spruce panels hardly any blue-stain has been found. Most of the observed microbiological activity on the coating surface

comes from surface moulds which can often be partially or fully removed by washing. Only under the coatings B, C and F some blue-stain may have been present.

Table 5 **Blue stain and surface mould on EN927 panels** (mean value of 3 replicates)
(for explanation of the ratings see Table 2 and the accompanying example)

			Wageningen				Espoo			
			1 year		2 years		1 year		2 years	
Wood species	coating	pres.	washed	unwashed	washed	unwashed	washed	unwashed	washed	unwashed
Pine	none	yes	-	3.0	n.a.	4.0	-	-	-	-
sapwood		no	-	4.0	n.a.	4.0	-	-	-	-
	A	yes	0	0	0.3	1.3	0	0	0.3	2.3
		no	0	0	0	2.0	0	1	1.3	3
	B	yes	0.3	0.7	1.0	1.0	0	1.0	1.0	3.0
		no	0.7	0.7	2.0	2.3	0.7	1.3	3	3.7
	C	yes	0.7	0.7	0.7	1.0	0.7	1.7	0.7	1.7
		no	0.7	0.7	3.0	3.0	-	4	4.7	5
	D	yes	0	0	0	1.0	0	0	0	1.0
		no	0	0	1.7	2.0	-	0.7	3.3	4.3
	E	yes	0	0	0.3	0.7	0	0	0	0.3
		no	0	0	1.3	1.3	-	4	5	5
	F	yes	0	0	0.3	1.0	0	0	0	1.0
		no	0	0	0.7	1.0	-	0	0	1
	G	no	2.0	2.0	2.0	3.3	1.7	1.7	1.0	3.0
Spruce	none	yes	-	3.0	-	4.0	-	-	-	-
		no	-	4.0	-	4.0	-	-	-	-
	A	yes	0	0	0	1.3	2.0	2.0	0	1.3
		no	0	0	0	1.3	1	1	1	3
	B	yes	0.7	0.7	1.0	1.0	0	1.0	1.0	3.0
		no	0	0	1	1.0	0	1	1	2
	C	yes	1.3	1.0	1.0	1.0	0	1.0	1.3	2.7
		no	1.0	0.7	1.0	1.0	-	1	1.3	1.7
	D	yes	0	0	0	1.0	0	0.0	0	1.0
		no	0	0	0	1.0	-	0.7	0	1
	E	yes	0	0	0	0.0	0	0.0	0.0	0.7
		no	0	0.0	0.7	0.3	-	0	0.7	1
	F	yes	0	0	1.0	1.0	0	0	0.3	1.0
		no	0	0	1.0	1.0	-	0	0	0
	G	no	2.0	2.0	1.3	3.0	2.0	2.0	1.0	3.0

Typical differences between the observed blue-stain eruptions and surface moulds are shown in figures 1 and 2. In laboratory tests on mould-growth with the same acrylic coatings, a similar higher amount of mould growth was found on pine sapwood compared to spruce (Viitanen and Ahola 1997a). The surface mould-growth and the blue-stain development on the uncoated panels was only reduced during the first year, later on no differences between treated and untreated wood were found. This is most likely the result of leaching of the active ingredient by rainfall (Wakeling et al. 1994).

Influence of substrate design:
The coatings A and B have also been tested on EN330 spruce and pine sapwood L-joints (5 replicates) and coatings A, B and E on national type spruce L-joints (3 replicates). An overview of the assessment results after 2 year exposure is given in table 6.

Table 6 Influence of substrate design on outdoor weathering performance

Substrate type	Wood species	Coating type	Preser-vative	Flaking	Cracking	Blue-stain surface / inside joint	Surfacemould tenon/ mortise
EN 330	pine	none	yes	-	5.0 S 4.0	4.0 / 4.0	1.0 / 0.0
L-joint	sapwood		no	-	5.0 S 4.4	4.0 / 3.0	0.8 / 1.0
		A	yes	0.4 S 1.0	1.8 S 2.4	0.2 / 0.8	3.0 / 1.0
			no	0.8 S 1.3	2.4 S 3.0	0.4 / 1.2	3.0 / 1.0
		B	yes	0	1.6 S 2.0	0.6 / 1.0	1.8 / 1.0
			no	0	2.0 S 2.0	2.6 / 4.0	2.0 / 1.0
		G	no	0	0.8 S 2.3	2.6 / 4.0	2.4 / 1.0
	spruce	none	yes	-	5.0 S 4.0	4.0 / 0.2	2.0 / 1.0
			no	-	4.2 S 4.2	4.0 / 1.2	1.2 / 0.0
		A	yes	0.6 S 2.7	1.2 S 2.0	1.2 / 1.6	2.0 / 0.6
			no	0.6 S 2.3	1.6 S 2.2	1.2 / 2.0	2.0 / 1.0
		B	yes	0.2 S 1.0	2.6 S 2.2	0.4 / 1.0	2.2 / 1.0
			no	0.8 S 2.8	2.8 S 2.6	0.4 / 2.2	2.0 / 1.0
		G	no	0	1.0 S 2.8	1.0 / 3.0	2.0 / 1.0
National	spruce	none	yes	-	5.0 S 4.0	3.0	-
type			no	-	5.0 S 4.7	3.0	-
L-joint		A	yes	1.0 S 1.3	2.3 S 2.0	0	-
			no	1.0 S 1.7	2.0 S 2.0	0	-
		B	yes	0	1.7 S 2.0	0	-
			no	0.3 S 1.0	2.3 S 2.3	0	-
		E	yes	0.3 S 3.0	1.0 S 1.7	0	-
			no	0.3 S 3.0	1.3 S 2.3	0	-
		G	no	0	1.0 S 3.0	0	-

For explanation of the ratings see Table 2 and the accompanying example

The preservative pre-treatment reduced the development of cracking and flaking on the EN-330 L-joints. On the national type L-joints the cracking and flaking is so small that no serious influence of the preservative can be observed. Just opposite to the results from the panels, flaking and cracking is higher on spruce compared to pine sapwood. This can however be explained by the moisture content of the samples (see section 3.3). The pine samples mostly have moisture content values above fibre saturation point (above 30 %), whereas in spruce the moisture content varies between 18 and 50 %. This means that the dimensional change in spruce was much higher than in pine sapwood which was almost permanently in swollen condition.

Striking differences in blue-stain development have been observed between the differently designed substrates. The coated national type L-joints did not show any sign of blue-stain development, whereas severe blue-stain was observed on the EN-330 L-joint. With the exception of coating A and B on pine sapwood, the EN-330 samples showed no difference in blue-stain development at the surface between treated and untreated wood after two years exposure. The rate of blue-stain development was however reduced during the first year of exposure. The amount of blue-stain in the uncoated inside of the EN-330 corner joints is decreased by the preservative treatment. The surface mould-growth, which was separately assessed on the EN-330 L-joints is not influenced by the preservative under the coating. The limited protection against blue-stain under very moist conditions indicates that the active ingredient concentration of 0.5% is not sufficient in a dipping treatment where an uptake of 100 to 120 g/m^2 is feasible. This idea is supported by laboratory mould-growth tests which showed better protection by combinations of various fungicides in both dip-preservative and coating itself (Viitanen and Ahola 1997b).

3.2 Moisture permeability in laboratory tests

The relative moisture permeability of the coatings with and without a preservative has been determined on both pine sapwood and spruce with liquid water and water vapour. Table 7 shows the ratios relative to the uncoated control. A value of 100 % means no reduction of permeability, for example in case of an uncoated sample whereas a (theoretical) value of 0 % would mean no water permeation at all.

The moisture permeability of the coating with the preservative is in most cases slightly lower compared to the same coating without preservative, but the differences are small.
Although not principally intended as a water-repellent, the preservative treatment itself (without a coating) slightly reduced the water absorption, except in case of pine sapwood where a small increase has been observed. The calculated moisture reduction ratio is lower if liquid water is used as moisture source when compared to vapour. It is also lower for pine sapwood compared to spruce. This can both be explained by the higher water uptake in the untreated sample which reduces the permeability ratio.

Table 7 Moisture permeability of coated samples relative to uncoated controls, according to Rosenheim method (uncoated = 100%)

Wood species	Coating type	Preser-vative	Adsorption (vapour)	Desorption (vapour)	Adsorption (liquid)	Desorption (liquid)
pine	none	yes	105	-	84	99
sapwood		no	100	100	100	100
	A	yes	40	48	13	35
		no	43	51	15	39
	B	yes	53	59	19	54
		no	52	63	20	53
	C	yes	58	58	19	51
		no	56	60	23	52
	D	yes	58	69	20	57
		no	57	71	23	59
	E	yes	26	64	7	53
		no	25	64	10	47
	F	yes	48	47	21	35
		no	49	55	21	39
	G	no	22	52	11	51
spruce	none	yes	98	100	89	98
		no	100	100	100	100
	A	yes	45	44	23	38
		no	51	49	25	39
	B	yes	52	61	26	52
		no	58	66	31	59
	C	yes	53	56	29	52
		no	57	64	32	55
	D	yes	54	68	33	58
		no	60	75	37	62
	E	yes	26	56	12	49
		no	30	60	17	53
	F	yes	47	51	38	45
		no	44	50	38	47
	G	no	24	46	12	44

3.3 Moisture content during outdoor weathering

An overview of the influence of the preservative treatment on wood moisture content during weathering is given in table 8.

Table 8 Trend in wood moisture content of exposed samples at SHR site (coating - sample type - wood species)

Lower moisture content in preservative treated wood	Higher moisture content in preservative treated wood	No difference or varying
X - national - spruce	X - panel - pine	A - panel - spruce
X - EN330 - pine	X - panel - spruce	B - panel - spruce
X - EN330 - spruce	A - panel - pine	C - panel - spruce
A - national - spruce		D - panel - pine
A - EN330 - pine		D - panel - spruce
A - EN330 - spruce		E - panel - spruce
B - national - spruce		F - panel - pine
B - EN330 - pine		F - panel - spruce
B - EN330 - spruce		
B - panel - pine		
C - panel - pine		
E - national - spruce		
E - panel - pine		

For all EN 330 and national type window corner joints the wood moisture content is somewhat reduced by the preservative treatment. For coating B the moisture content during exposure for the different substrates is given in figure 3. Especially on the EN 330 joints the effect of the preservative treatment is rather strong, which can be explained by the water repelling effect of the preservative at the inside of the uncoated and not glued joint and partly to the preservative induced reduction of cracking and flaking and associated water entry.
For the panels no effect of the preservative treatment was observed. This can easily be explained by the untreated backside of the panel which does not provide a barrier for water transport. For the uncoated panels even a higher moisture content for the preservative treated samples has been observed. It is also noteworthy that during the second year a much higher moisture content has been observed. This is the result of the formation of coating defects (cracks, flakes, eruptions of blue-stain) in the second year.
In general, the effect of the preservative treatment is small in comparison to the effect of substrate design and coating type. The wood moisture in the national type L-joint ranged from 12 to 20 %, in the panels it was between 12 and 30 % whereas in the EN330 L-joints values between 18 and 120 % were observed. A more detailed analysis of these differences is however beyond the scope of this paper and will be reported in future publications.

3.4 Coating and preservative penetration into the wood

The preservative is not equally distributed within the anatomical structure of the wood. Most of the material is present in the ray-cells, in pine sapwood up to a depth of 1200 - 1800 µm

and in spruce up to 180 - 240 µm. Penetration into rays located in earlywood is deeper compared to those located in latewood. From the ray-cells penetration into adjacent longitudinal tracheids takes place by transport through the cross-fields (Meijer et al. 1998). This happens predominantly in the latewood. Direct penetration from the surface into the outer longitudinal tracheids is also observed. The depth of this type of penetration is controlled by two factors: the ability of the liquid to flow into the wood and the angle between the surface and the grain of the wood (Meijer et al. 1998). The preservative is found in the first and second tracheid row under the surface in pine sapwood and to a lesser extent also in spruce.
The penetration of the waterborne coatings, applied on wood without a prior preservative treatment, is limited to the ray cells (60 to 450 µm deep) and occasionally the first and second tracheid row under the surface. If the wood is previously treated with the dip preservative, the penetration of the coating is very much reduced or even absent.
A quantitative analysis of the axial depths of penetration of preservative and coating is given in figure 4. The results confirm the fact that the preservative treatment reduces the penetration of the coating. Comparing the individual coatings, the solvent borne coating (G) shows the deepest penetration, followed by the waterborne alkyds (A and F) and acrylic stain (E). The lowest penetration is with the opaque acrylates (B, C and D). These results are consistent with earlier findings (Meijer et al. 1998, Nussbaum 1994, Rødsrud and Sutcliffe 1993).

4. Conclusions

The following conclusions can be drawn from the results of this research:

1. Although originally not intended as a water-repellent, the preservative treatment reduces the moisture content of the wood as is shown in both laboratory permeability tests and outdoor weathering. The effect is absent in panels with an uncoated backside.
2. The effect of the preservative is limited. The moisture content during outdoor exposure is most strongly influenced by the substrate design (EN-330 L-joints > panels > national L-joints) and wood species. These differences have a direct influence on coating defects and blue-stain development.
3. Coating defects like flaking and cracking are reduced by a pretreatment with a preservative primer. This is most likely the result of the reduced fluctuations in moisture content. The positive influence is strongest on pine sapwood if compared to spruce. Only on EN-330 L-joints an opposite effect is observed due to the permanently swollen state of pine sapwood.
4. The reduction in moisture permeability and the decrease in flaking and cracking is most likely not the result of the fungicidal ingredient (IPBC) but of the polymeric material in the preservative. In this respect it should be noted that the formulation of the preservative is rather untypical, the results most probably being not representative for all preservatives.
5. The preservative treatment decreases the growth of blue-stain on panels, in particular for pine sapwood. On substrates with a very high moisture content, blue stain development was not prevented, which means that the concentration of the active ingedient has to be further optimised.
6. On spruce L-joints of national design, blue stain development is also absent without a preservative treatment. This is due to the much lower moisture content in the window corner joints, which are sealed all the way round by either coating or glue.
7. The polymeric material in the preservative solution penetrates into the wood, preferentially in the rays. The pretreatment with the preservative reduces the penetration of the coating itself, due to the filling of the wood capillaries with the polymer in the preservative.

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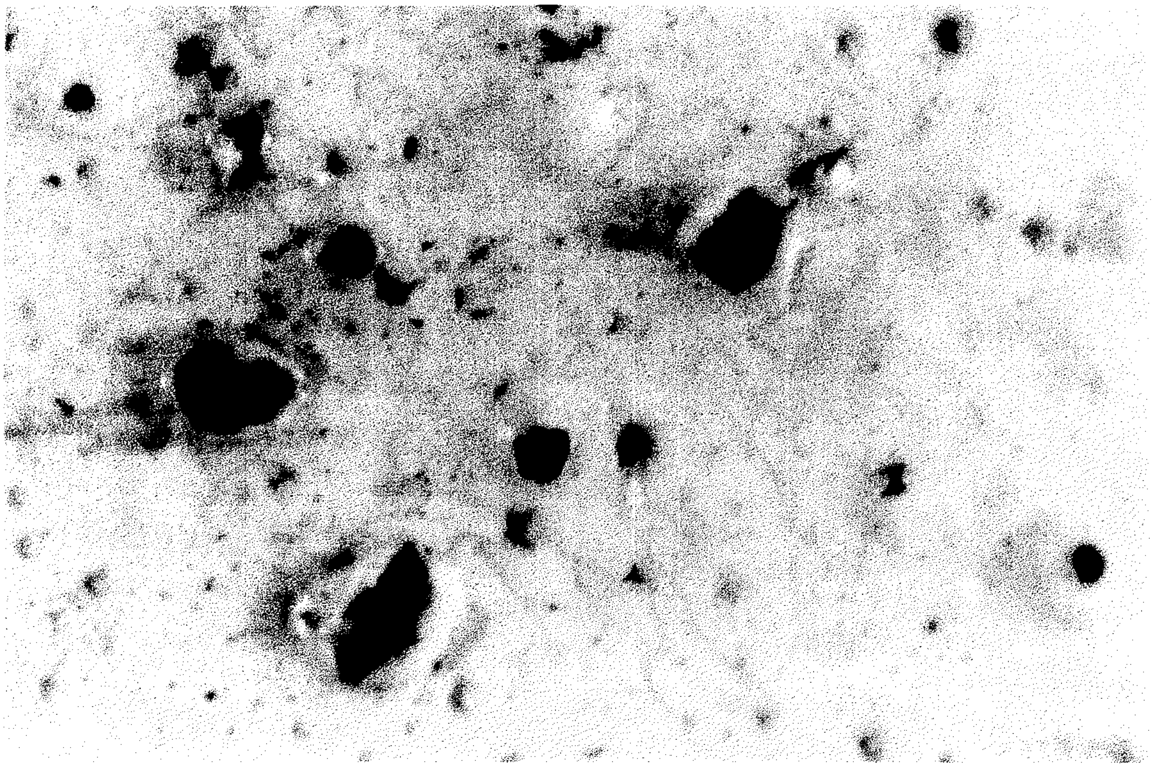

Figure 1 Impression of blue stain eruption through the coating
Magnification ca. 15x

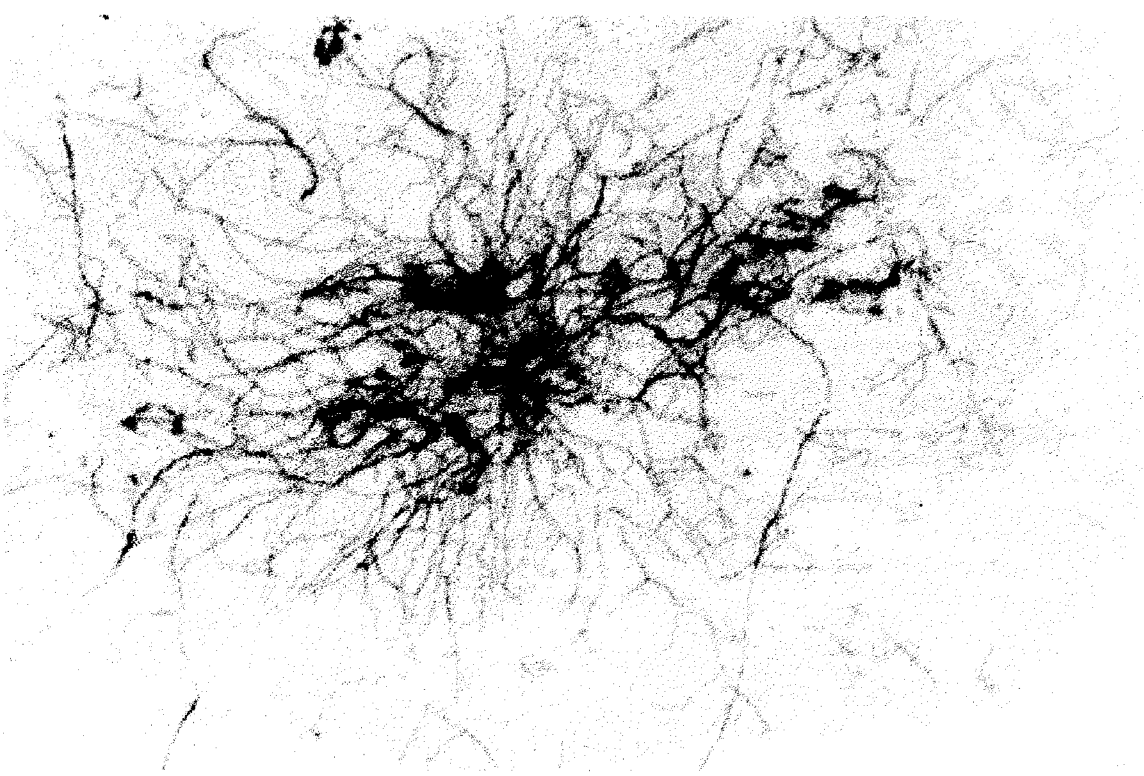

Figure 2 Impression of surface mould growth
Magnification ca. 15x

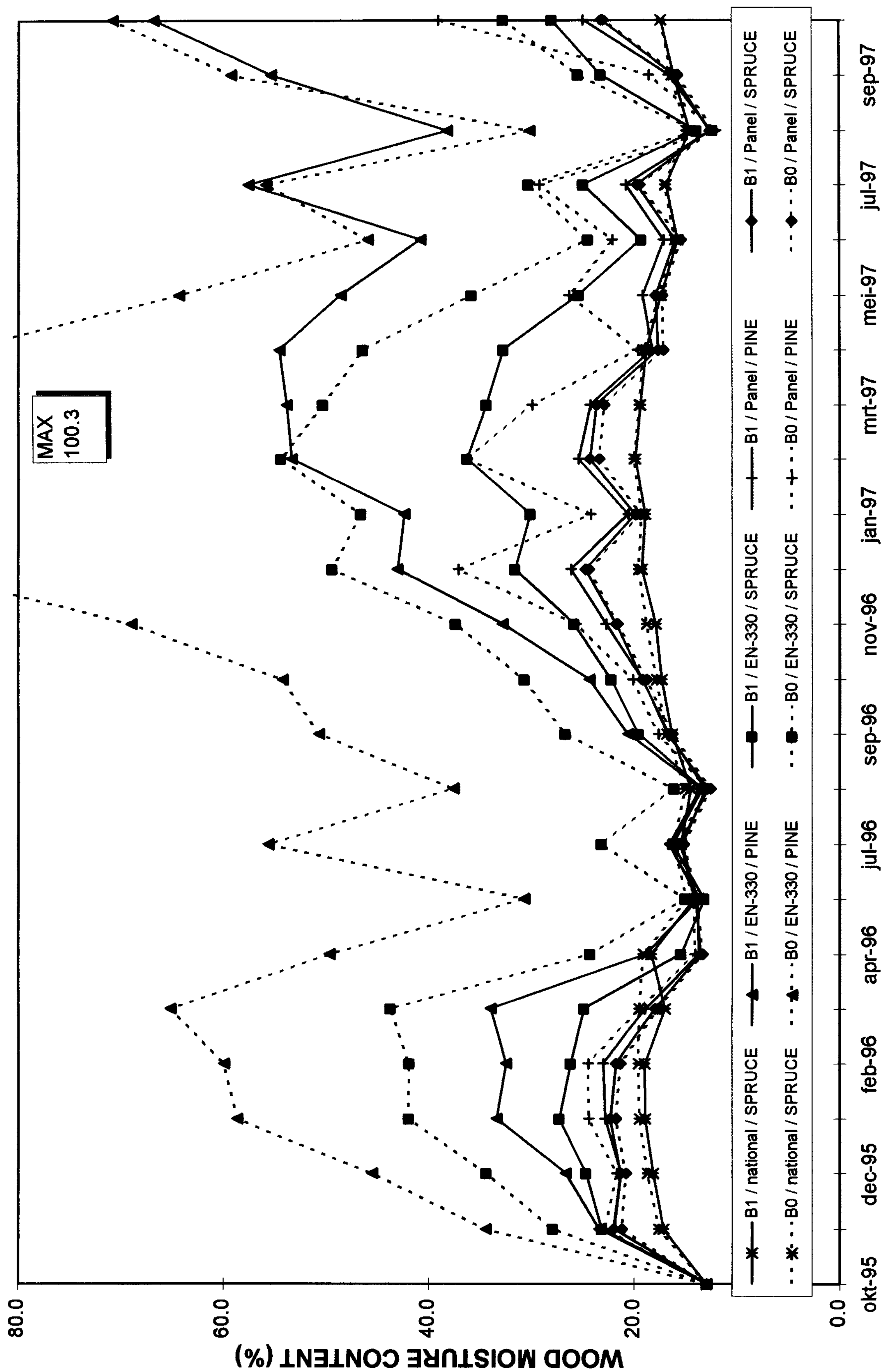

Figure 3 Variation in wood moisture content during exposure - Coating B

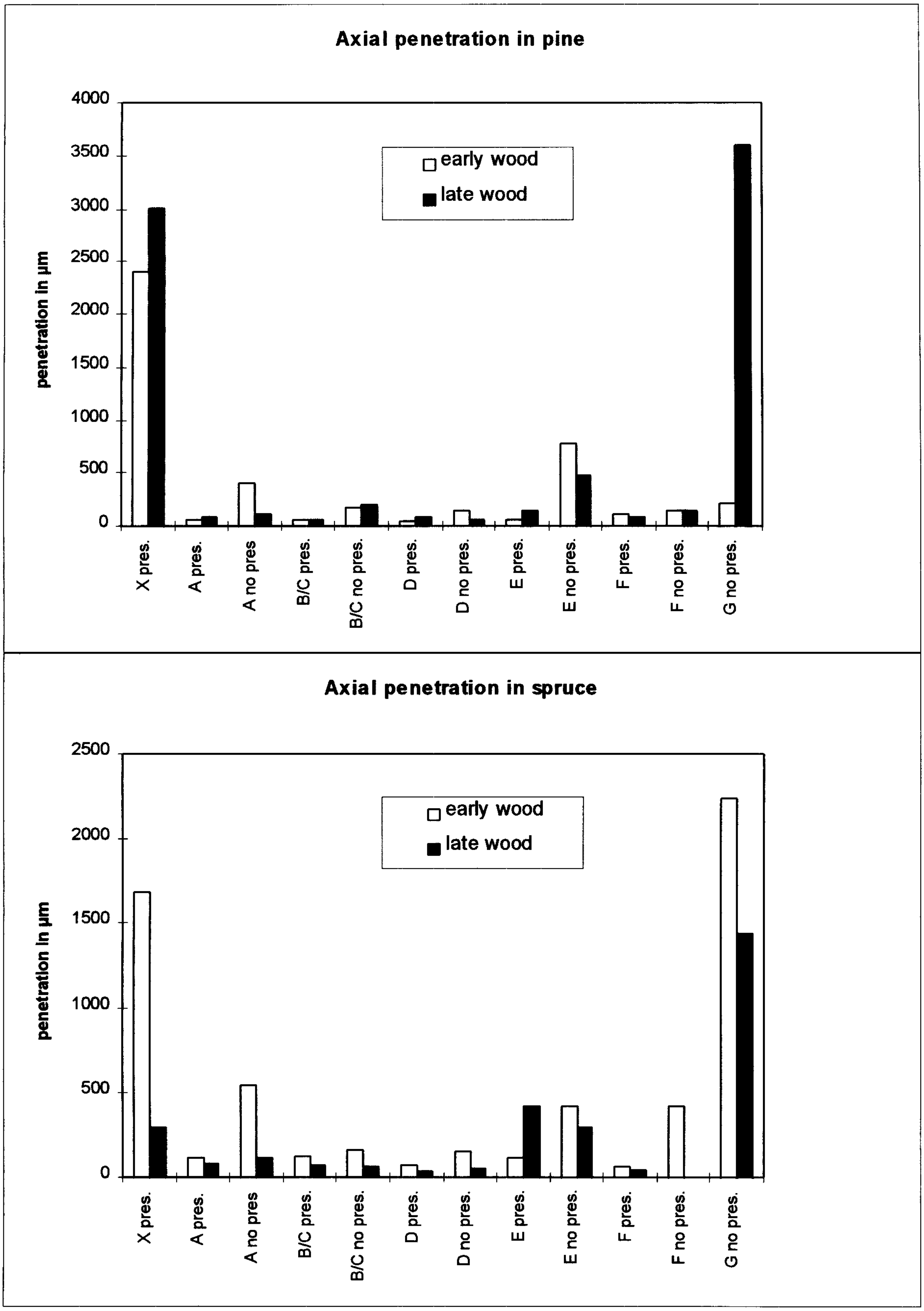

Figure 4 Axial depths of penetration of preservative and coating