QUALITY ASSESSMENT OF LAMINATED WINDOW SCANTLINGS FROM MIXED TROPICAL HARDWOODS AFTER LONG-TERM EXPOSURE TO WEATHERING

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RICHTER, H. G., SCHWAB, E., VON ARPS-AUBERT, T. & NOCK, H-P. 2004. Quality assessment of laminated window scantlings from mixed tropical hardwoods after long-term exposure to weathering. Laminated window scantlings made from mixed tropical hardwoods were finished with five coating systems and subjected to natural exposure for a period of 54 months. Post-weathering quality assessment of the scantlings showed that in-service performance largely depended on type of the coating system, i.e. its long-term resistance to weathering. However, distinct differences in wood properties, notably density and related magnitude of movement under changing climatic conditions, are liable to adversely affect product quality once the coating loses its protective function due to physical deterioration.

Key words: Glue-laminates – density – dimensional stability – surface coating

RICHTER, H. G., SCHWAB, E., VON ARPS-AUBERT, T. & NOCK, H-P. 2004. Penilaian kualiti beluti tingkap berlapis daripada pelbagai kayu keras tropika selepas pendedahan jangka panjang terhadap luluhawa. Beluti tingkap berlapis yang dibuat daripada pelbagai kayu keras tropika diberi kemasan lima sistem salutan. Kemudian beluti tersebut dibiar terdedah secara semula jadi selama 54 bulan. Penilaian kualiti pasca luluhawa menunjukkan bahawa prestasi dalam perkhidmatan beluti bergantung terutamanya kepada jenis sistem salutan, yakni ketahanan jangka panjangnya terhadap luluhawa. Bagaimanapun, perbezaan ketara dalam ciri kayu, khususnya ketumpatan serta magnitud pergerakan disebabkan keadaan iklim yang berubah, besar kemungkinan akan mempengaruhi kualiti produk sebaik sahaja salutan hilang fungsi perlindungannya akibat kemerosotan fizikal.

Introduction

A consignment of laminated window scantlings originating from Southeast Asia and manufactured from mixed tropical hardwoods was studied with regard to quality parameters such as wood species, density, and glueline shear strength. The results were evaluated in terms of suitability of such product for window manufacturing published in Richter *et al.* (1999). However, experience has shown that general in-service performance of laminated window scantlings cannot be derived from biological, physical, and mechanical parameters of the timber as well as its glueline quality alone. Long-term exposure of the final product to weathering is equally important for quality assessment. This paper describes and evaluates the behaviour

of the material studied earlier, protected by different exterior coating systems, after a 54-month weathering experiment. Two industrially manufactured and coated window frame units were also included with the tests.

Materials and methods

A consignment of laminated window scantlings (82 × 76 mm, length variable) from Southeast Asia, marketed under the trade name 'durian', consisted of more than 30 different timbers identified by the senior author, had mean densities between 0.5 and 1.0 g cm^{-3} (Richter *et al.* 1999). By means of assigning each individual lamella to one of three density classes, i.e. L (light = less than 0.6 g cm^{-3}), M (medium = 0.6 to 0.9 g cm^{-3}), and H (heavy = above 0.9 g cm^{-3}), each of the three-layered scantlings was attributed to one of 18 density profiles; for instance HMM (heavy-medium-medium), LLL (light-light-light) or HLM (heavy-light-medium). From all density profile groups a sample of mostly five scantlings (some more, some less—depending on availability) was separated for the weathering experiment totalling 95 test pieces, among them:

(1) 69 offcuts, 53 cm long (through core),
(2) 16 scantlings, 127 cm long (through core),
(3) 10 scantlings, 168 cm long (core finger-jointed with different timbers).

Of these, 91 were subjected to post-exposure evaluation (see Table 1), four were considered ineligible for quality assessment and discarded. Among the test pieces, 20 different timbers were represented, i.e. bintangor, geronggang, kempas, red meranti, mempening, kelat, kedondong, sentul, surian batu, pasak, bekak, rengas, merpauh, machang, simpoh, melunak, mertas, durian, nyatoh/bitis, and kasai.

All test pieces had bevelled edges and the end grain surfaces sealed with an epoxy-tar resin before coating. The five pieces of a density profile group were then top-coated with different stains, varnishes and paints for exterior use commonly employed by the relevant industry, each with one of the following systems, all consisting of three layers (primer, intermediate and top coat) applied on all four sides:

(1) Thick-layer semi-transparent stain, water-borne (LH)

Manufacturer:	GLASURIT®
Primer:	Glassomax TauchLasutect ahorn BL20-1114
Intermediate coating:	Glassohyd Natura Finish esche BW19-1110
Top coat:	Glassohyd Natura Finish esche BW19-1110

(2) Thick-layer solid colour stain (dark brown), water-borne (LD)

Manufacturer:	GLASURIT®
Primer:	Glassomax TauchLasutect nussbaum BL20-8102
Intermediate coating:	Glassohyd Natura Finish nussbaum BW19-8300
Top coat:	Glassohyd Natura Finish esche BW19-8300

(3) Opaque dark green stain, water-borne (DG)

Manufacturer:	GLASURIT®
Primer:	Glassomax TauchLasutect nussbaum BL20-8102
Intermediate coating:	Glassohyd FensterColor Decklasur BW19-9999
Top coat:	Glassohyd FensterColor Decklasur BW19-9999

(4) Opaque white stain, water-based; on solvent-borne white primer (DWL)

Manufacturer:	GLASURIT®
Primer:	Glassomax Fenstertauchgrund weiß BG61-0016
Intermediate coating:	Glassohyd Grund- und Decklack BW590200
Top coat:	Glassohyd Fensterweiß BW60-0100

(5) Opaque white stain, water-based; on water-borne white primer (DWW)

Manufacturer:	GLASURIT®
Primer:	Glassohyd Ratio Primer C
Intermediate coating:	Glassohyd Grund- und Decklack BW590200
Top coat:	Glassohyd Fensterweiß BW60-0100

The coated material was exposed to weathering on the premises of the Federal Research Centre for Forestry and Forest Products, Hamburg, following instructions for the experimental set-up stipulated in the German standard DIN 53 166, i.e. southern exposure at an angle of 45° (Figure 1).

The two window frame units (ca. 80 × 170 cm) were coated with systems LD (dark brown thick-layer stain) and DWL (white paint on solvent-based primer). Both were fully mounted and placed vertically near the scantlings, without cover, with the front and back facing south and north respectively.

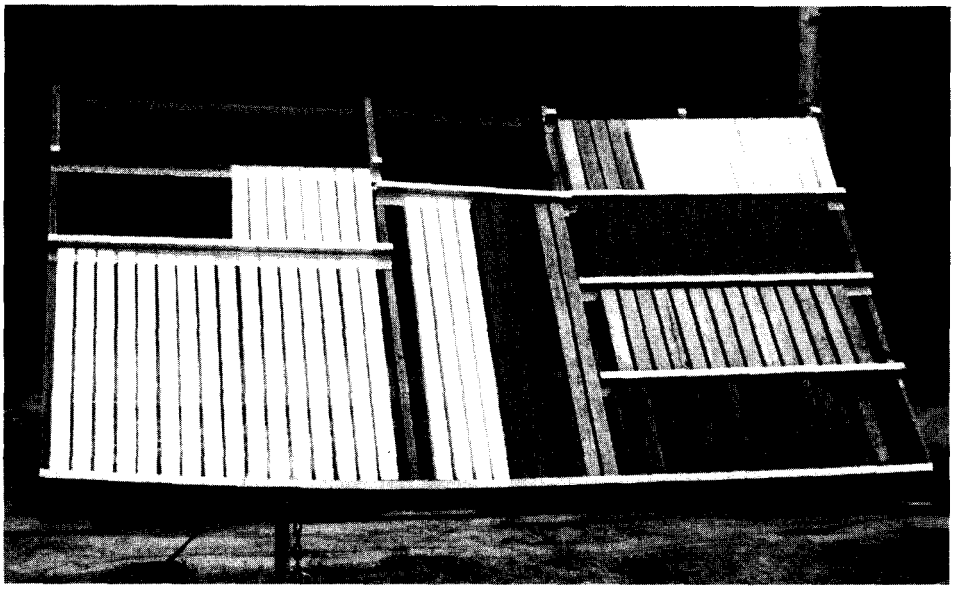

Figure 1 Long-term weathering experiment—layout of test pieces with different coatings

After 54 months of exposure, all scantlings were assessed by visual inspection for damage to the coating and the glueline. Each scantling was then checked for distortion (bow over the entire length) by direct measurement. Material with still intact (closed) gluelines was separated and the glueline shear strength determined in accordance with DIN EN 392. Finally, the two window frame units were subjected to visual quality assessment (coating, glueline) and functional tests.

During the 54 months of exposure, neither maintenance nor repair service was administered to scantlings and window frames. For post-weathering quality assessment, attention focussed mainly on weathering-related damage to the coating and the glue joints. The possible effect of differences in density between individual lamellae on overall quality of the scantlings is also discussed in this paper as part of the final evaluation.

Results and discussion

Coating quality

The coating on the three faces not directly exposed to weathering had remained largely intact and did not show any significant physical damage. However, the upper faces directly exposed to solar radiation, rain and wind had visibly deteriorated and showed physical damage of varying magnitude depending on the coating system employed (Table 1). The white paints (DWL, DWW) were least affected. The thick-layer stains (LH, LD) were almost completely destroyed and had lost their protective function; glue joints were partially open, most of the now unprotected surface area had turned grey and surface checks were rampant. The condition of the dark green top coat (DG) varied from largely undamaged to almost totally destroyed.

The significant differences between thick-layer stains (LH, LD) and the white paints (DWL, DWW) were expected since the two systems are generally rated differently in terms of long-term performance under exposure, i.e. two- to three-year-service intervals are commonly recommended for the former and three- to six-year-service intervals for the latter (DGfH 1981). Heavily pigmented stain, namely DG, was represented almost uniformly in all five damage classes. This can be explained by different levels of physical stress to the film due to the generally high but variable heat absorption from solar radiation (see, for instance, Sell 1984).

Table 1 Degree of degradation of top coats on directly exposed upper faces

Damage class	Definition	No. of scantlings per coating system subjected to quality assessment				
		LH	LD	DG	DWL	DWW
0	No visible damage	0	0	3	19	19
1	Few minor, just visible defects in their early stages	0	0	3	1	0
2	Well developed defects, few	0	0	4	0	0
3	Well developed defects, frequent	1	1	3	0	1
4	Well developed defects, very frequent	15	17	4	0	0
	Total	16	18	17	20	20

Glue joints

By visual inspection, in 71% of the scantlings, the upper (below the exposed surface) and, in 85% of the scantlings, the lower (more distant to the exposed surface) gluelines were still firmly closed. Open joints of different lengths had developed in the remaining scantlings, all characterised by a partially defective or largely destroyed top coat. When rated in accordance with the requirements for glue joint quality (Schmid & Laurich 1999), 35% of the scantlings were rejected because at least one of the two joints was partially defective. The amount of open joints clearly depended on the type of coating employed. The percentages of defective gluelines for scantlings finished with a given coating system were 47% LD, 38% LH, 21% DG, 18% DWW and 5% DWL. The corresponding damage assessment (Table 1) clearly indicated that weathering stress on the glueline increased with decreasing physical protection by the coating. Moreover, the comparison between the two white paint systems, i.e. DWW (water-based primer) and DWL (solvent-based primer) showed that the latter was more effective in protecting the glueline during weathering.

Density is an important indicator for estimating other wood properties, among them swelling and shrinkage. In order to explore in more detail the possible influence of density (r) variation within individual scantlings on glueline quality, the density difference (Dr) of pairs of adjacent lamellae was determined and correlated with the degree of damage to the respective glue joints. For pairs of lamellae with $Dr \geq 0.2$ g cm^{-3}, 28% of glue joints were rated defective, for pairs with $Dr < 0.2$ g cm^{-3} the defect rate dropped to 18%. Hence, the higher the differences in density and, by the same token, in magnitude of swelling and shrinkage between adjacent lamellae, the more difficult it becomes to satisfy the requirement for permanently closed glue joints.

Distortion

Maximum values for deformation over the wide (bow) and narrow (spring) faces of the 26 long scantlings were determined as 3.1 and 2.2 mm respectively per linear meter. The overall mean calculated from both measurements was 0.6 mm/m. Corresponding values for twist, measured separately along the core layer, were 1.9 and 0.5 mm respectively. According to the IfT (1998) guidelines for laminated and finger-jointed window scantlings, a maximum deviation from the straight line of 1 mm/m is admitted to pass the stringent quality requirements for this kind of pre-fab product. If this threshold were to be applied to the material after long-term exposure to weathering, 7% of the scantlings would have failed due to a mean deviation higher than the allowable maximum. When the three categories (bow, spring, twist) were considered separately, the reject rate increased to 28%. Distortion beyond the allowable maximum was about three times higher for the scantlings finished with dark coloured coating systems (LD and DG) than for those finished with transparent and white coating systems (LH, DWL, DWW).

Glueline shear strength

The portion of the test material with still intact (closed) glue joints was subjected to a block shear strength test according to DIN EN 392. Individual shear strength values varied from 3.1 to 15.0 N mm^{-2}, a variation similar to that obtained with glueline shear strength before weathering (Richter *et al.* 1999), i.e. after dry conditioning (normal climate) and after wet storage (24 hours in water of 20 °C, followed by 72 hours drying under normal climate conditions). The respective mean values for glueline shear strength obtained before and after weathering are presented in Table 2. As expected, the 54 months exterior exposure resulted in a reduction of overall glueline shear strength when compared with the material tested in dry condition. However, the data in Table 2 also show that weathered gluelines were equal to or even a trifle stronger than those obtained from laboratory wet storage testing. This partial result is one more step in proving the often questioned usefulness of laboratory wet storage simulation tests for predicting in-service performance of glue-laminated structures under long-term outdoor exposure.

Overall, upper glue joints were more severely affected by weathering stress than lower glue joints. Glueline shear strength of the upper joints is also clearly correlated with the type of coating system, i.e., mean strength values were least in scantlings with a dark coating systems (LD and DG), slightly superior in scantlings with white paint systems (DWL, DWW), and highest in scantlings finished with a semi-transparent varnish system (LH). This suggests that the higher temperatures developing in dark-coated wood under solar radiation are largely responsible for reducing glueline strength. However, in this context it must be borne in mind that only intact glue joints were tested whose proportion was low for scantlings finished with the semi-transparent varnish (LH).

Window frame units

The quality of the two vertically placed window frame units did not suffer appreciably after the nearly five years of exterior exposure. The DWL-coated unit (white paint on solvent-based primer) was free of visible and functional damage. The LD-coated unit (dark brown thick-layer stain) did not show any significant damage to the coating, but some distortion of the movable frame was recorded. Hence, the white paint afforded a somewhat better protection against weathering than the dark pigmented varnish. However, the difference observed between the

Table 2 Mean glueline shear strength data from dry conditioning, wet storage and long-term exposure to weathering studies

Storage condition	Mean shear strength (N mm^{-2})	
	Upper glueline	Lower glueline
Dry condition*	13.1	13.6
After wet storage*	9.1	9.4
After long-term exposure to weathering	9.4	10.3

* Richter *et al.* (1999)

two systems was rather subtle as the effects of solar radiation, rain and winds on a vertically aligned surface (window frame units) were less severe than on surfaces exposed at a 45° inclination (individual scantlings, see Table 1). According to Kühne *et al.* (1972), under equal exposure conditions, a given coating system lasts on average 1.5 times longer on vertically aligned than on inclined wood surfaces.

Conclusions

The present study of laminated window scantlings, manufactured from mixed tropical hardwoods with distinctly different property profiles, confirms the outstanding role of the coating on long-term performance under exterior exposure. Distinct differences in physical and mechanical wood properties were overshadowed by the dominant influence of the coating system applied to the wood surface. Notwithstanding this general conclusion, the observed variability of glueline quality expressed in percentage of defective (open) joints and shear strength of still intact gluelines can be traced to distinct differences in density of adjacent lamellae in a scantling. Under the prevailing exposure conditions (northern Germany), a density difference of more than 0.2 g cm^{-3} is liable to lead to a significantly higher number of defective glue joints than a lower density difference. Hence, as long as the density difference between adjacent lamellae is below 0.2 g cm^{-3} and the glueing itself is up to standard, glue laminates for window and door framing manufactured from mixed tropical timbers can be expected to remain functional for a long time provided the wood surface is effectively protected by a suitable coating system.

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