A high-performance water-based coating system. Background, experimental evaluation and practical experience

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Background

Scandinavia has a very long tradition of using wooden joinery especially based on Nordic Pine (Pinus sylvestris). Contrary to conditions in other European countries in which especially the use of PVC-based joinery has gained tremendous importance over the last two decades, so far the competition from other materials such as PVC, aluminium or steel has been of minor importance.

From an ecological point of view it makes sense to continue the use of wood as a building material for the future. In Scandinavia wood has been the natural choice for window frames etc. and the continued use of wood has been assured by the use of appropriate techniques of wood preservation and industrial surface coating that result in durable window joinery.

The normal treatment schedule of a Scandinavian window today is:

1. Double vacuum treatment with solvent-borne wood preservative according to the previous Nordic standard INSTA 140 adapted to the equivalent CEN standards.
2. Two spray applications of water-borne (or solvent-borne) coatings with an increasing tendency towards water-borne coatings.

Compared to the practical treatment of wooden joinery today, especially in central European countries, it is interesting to note that there is a clear correlation between the diminishing market share of wooden components and their frequent demand for maintenance and their generally poor durability. In our view the cause of this dubious reputation is the inferior surface coating systems used, as well as the lack of appropriate wood preservation. However, the good practical experience derived from Scandinavian practice is likely to be of little use in future because the new VOC directive from Brussels will limit the continued use of solvent-borne treatments and coatings for wood.

The aim of this paper is to describe the development of a water-based coating system for practical use throughout Europe in the light of the excellent practical experience gained from Scandinavian treatment practice.

Wood is a biological material

The coating of wood represents a special challenge insofar that the substrate is not dimensionally stable and is vulnerable to microbial attack. Exterior exposure of coated wood may result in moisture absorption, cracking, splitting and fungal infection and ultimately to the deterioration of both coating and wood.

In the authors' opinion the development of an exterior coating for wood requires that exterior exposure testing has been undertaken thoroughly. The overall effect of physical, chemical and microbial factors cannot be measured or simulated by laboratory techniques.

Assessing and measuring the durability of a coating system for wood by exterior exposure is not a simple task and the results may vary considerably due to different climatic conditions and a number of other factors. However, there is one single factor that is of major importance with regard to durability of coated joinery. This factor can be expressed as follows:

'Keep the joinery as dry as possible over as long a period as possible'

Thus the authors' development strategy has been to use sapwood of Scots pine as the most vulnerable 'wood species' and to develop a series of natural exposure trials in which the rate of water absorption is measured.

In this way it is believed that the overall condition of the coating and the wood substrate before and after exposure can be assessed.

Experiments

Sample description

Dimensions: 30 × 2 × 11.5 cm planed dimensions
End sealing: 2 × solvent-based alkyd resin coating
Wood species: Scots pine sapwood
Replicates: 4 replicates (3 exposed, 1 unexposed)
Exposure: 17 months, 45° south, DK-6000 Kolding, Denmark
Application: Opaque primer + finishing coat = 110 μ dry film thickness
Transparent primer + finishing coat = 90 μ dry film thickness

Procedure

The samples were conditioned in a climate chamber at 70% RH and 20°C (about 13% wood moisture). Subsequently, the samples were dipped completely in water and then weighed after 1, 2, 3, 4 and 24 hours' immersion. The moisture content is calculated based on the dry weight.

Mechanisms of coating failure

Water absorption

Several years ago the authors found that panels of pine sapwood exposed to weathering showed a progressive increase in variation in moisture content. This development during
weathering is not surprising and has also been observed by other authors. The rate of water absorption increases gradually in the course of time and is accompanied by an increased biological infection.

The weathering process alters the ratio of water absorption against water desorption. The two processes are related to the water permeability and the water vapour permeability of the coated wood and if these properties change significantly there is the risk of water accumulation.

An obvious method for measuring and assessing the increasing water absorption is to undertake controlled water absorption measurements in the laboratory.

The authors have carried out several trials using this measuring scheme. Particularly they have looked at different commercial multiple coating systems for wooden joinery.

The water absorption after exposure is shown in Figure 1 for three different systems.

Figure 1: Water absorption in exposed panels
After outdoor exposure the panels were conditioned to constant humidity (-15%) and, thereafter, immersed in water for 24 hours. Wood: Pine. Exterior exposure: 17 months. Surface coating: 1 × alkyd/acrylic primer, 1 × acrylic finishing coat (water-borne).

The results show clearly the beneficial effect of wood preservation. Wood preservation creates a biological barrier under the coating and it is believed that this is a key factor in obtaining high durability wood coating systems.

Besides coating defects, an increase in water absorption due to microbiological activity is partly explained by morphological changes in the wood structure, i.e., degradation of the pit membrane, and partly by the presence of hydrophilic fungal hyphae and spores.

The effect of bluestain infestation of wood and its change in water absorption properties are well known. In Figure 3 the moisture content of bluestain infected wood is compared to sound wood during one year of natural exposure.

Excessive water ingress and subsequent drying out periods may lead to macro cracking and end grain splitting. Due to the anisotropic properties of wood much more water is absorbed through the end grain compared to lateral surfaces. Premature failure and microbial attack are often associated with the end-zone of wooden constructions.

Figure 3: Moisture content of bluestain infected wood compared to sound wood after natural exposure.

The beneficial effect of pre-treatment with a wood preservative is obvious, insofar that the untreated sample shows a higher water absorption in comparison to the pre-treated ones. Even though the increase in average moisture content (as shown in Figure 1) is moderate the absorption of water may be quite considerable in certain areas due to cracks or other defects in wood or coating. The importance of film defects and localized water absorption has been demonstrated previously by Trætek using x-ray tomography.

The initial rate of water absorption is related to coating defects and is, therefore, a good indication of the coating integrity.

Therefore, measurement of the initial rate of water absorption was undertaken with panels exposed outdoors.