U.S. and European finishes for weather-exposed wood—a comparison

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Abstract

This paper describes different types of wood finishes and compares their use on wood used outdoors in the United States and Western Europe. The primary objective was to provide a mutual exchange of information and to show comparisons. Apart from different traditions in using wood as an outdoor building material, there are interesting differences in the wood finishes used for protective and decorative purposes. Latex (waterborne) paints are generally not used to a large extent in Western Europe, but they are extensively used in the United States and are one of the most important types for exterior siding. Also, solid color (opaque) stains are widely used in the United States but are rarely used in Europe, even though their advantages are obvious in many finish situations. In Europe, semitransparent stains based on oil-modified alkyd resins are often film-forming and play an important role as "natural finishes" for millwork. In the United States, semitransparent stain finishes are also oil- or alkyd-based but have lower viscosity oils or alkyd resins and are usually penetrating so no surface film forms. A comparison study has been initiated between researchers in the Wood Section at the Swiss Federal Laboratories for Materials Testing and Research (EMPA) and the Forest Products Laboratory (FPL). Outdoor wood finishes available commercially are being evaluated on test fences in Madison, Wis., and Dübendorf, Switzerland, on commonly used American and European wood species.

A review of the pertinent literature on wood finishes for outdoor applications may produce several hundred papers written during the last 30 years. However, the main part of the research work done in this field has been carried out since the 1970s, most of it in North America and Western Europe. Recently, research activities in this area have increased, probably because of an increasing demand for so-called natural (semitransparent or fully transparent) finishes as well as a desire to find solutions to still unsolved. (or not optimally solved) problems of finishing wood surfaces exposed outdoors.

Generally, there is agreement in the literature on the factors important in wood weathering, the degradation mechanisms they cause, and on the basic properties required of wood finishes. On the other hand, there are many different opinions on which types of finishes to use, and where to use them. Many of these differences are the results of heterogeneous traditions of home building in different countries. This paper gives an overview of these differences, their background, and the resulting consequences.

It is impossible to include all the details of the various finishing systems used outdoors in the United States and Europe, so a number of generalizations have been made for simplicity. Also, the European finishes described are generally those found in Western Europe.

Weathering effects on wood and wood finishes

Several literature reviews summarize the current knowledge of the weathering phenomena as well as the main techniques for the surface protection of wood (1-3,5,7,8). Weathering is a complex long-term process consisting of photochemical reactions and physical phenomena mostly due to moisture influences and temperature changes. Wood, being a product of nature, is also subject to biological attack by fungi and insects. Most of these stress factors interact and depend on numerous influences. Relationships between the elements of weathering and their effects on the finished

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wood surface are presented as a simplified scheme in Figure 1.

All the factors and weathering mechanisms are important in achieving a good performance of finished wood surfaces. But the two most important factors are photochemical degradation of the surface wood substance as well as of the finish itself, and dimensional changes of the wooden member. These reactions combined with tensile, compressive, shear, and bending stresses at the surface zone cause decreasing adhesion between the finish and the wood.

A main problem in wood finishing for outdoors lies in the fact that architects as well as homeowners often prefer to use fully transparent or semitransparent finishes because they like the look of the "natural" color and texture of wood. Because these popular types of finishes (clear finishes, stains) have to transmit some visible sunlight, they contain only small amounts of pigment and may have a rather low moisture-excluding efficiency, especially those with low or negligible film thickness. Both the properties of high light transmission and low moisture exclusion are opposite to the requirements for a long-term durable finish.

Most wood finishing experts suggest that the wood surface itself needs to be modified to achieve both better photochemical resistance and better dimensional stability. Such pretreatments or modifications could also reduce other weathering effects such as surface colonization by dark coloring mildew. Nevertheless, the finishing products themselves have to be optimized to provide more ultraviolet light protection, less moisture permeability, and more mechanical flexibility. Reasonable design criteria and construction details are also necessary for good durability and performance of both wood and finish.

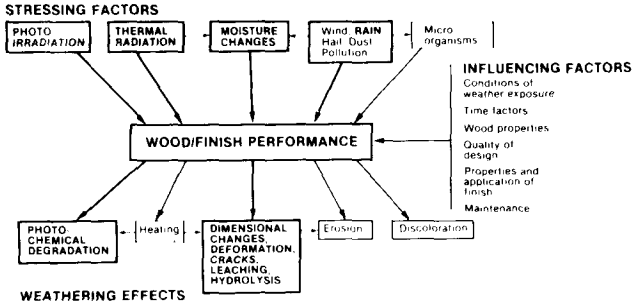

Figure 1. — Schematic illustration of the weathering of finished wood.

TABLE 1. — *Exterior siding in the United States.*[a]

	Product shipments — surface basis				
	1982	1981	1980	1979	1978
	(million ft.^{2})				
Hardboard	987	976	963	1,213	1,282
Plywood	816	722	732	925	1,001
Redwood	130	119	135	148	150
Cedar	125	114	131	148	150
Others (aluminum, vinyl, steel, brick)	1,325	1,592	1,847	2,224	2,322
Total	3,383	3,523	3,808	4,658	4,905

[a]Sources: American Hardboard Assoc., American Plywood Assoc., Western Wood Products Assoc., U.S. Dept. of Commerce. See reference (6).

Traditional uses of wood

The use of wood for home building in most of Europe differs substantially from that in the United States. Wood housing is dominant only in Northern Europe (Scandinavian countries) and in some mountain regions. In Western Europe, however, modern one-family houses and especially apartment houses are constructed mostly of brickwork and/or concrete with insulation in the middle or outside, where it is covered with plaster consisting of latex and cement as binder. When wood is used as outdoor wall material, it is usually for decorative purposes, e.g., as weather boards for the upper gable facade. Thus, in Western Europe, only about 10 percent of all siding (cladding) consists of solid wood; panels of particleboard are used occasionally.

The weak market position of wood houses in Western Europe stems partly from the traditional use of mineral-based materials, but mostly from the fact that wood construction is normally not less expensive than non-wood construction. This is due to a variety of reasons, e.g., there is a remarkable lack of lumber size standardization among European countries except for prefabricated houses. Because of this lack of standards, sawmills mainly "custom cut" lumber to local sizes and thus lose the economic benefits of producing large inventories for general distribution. In American home building, costs are reduced by better planning and organization, inexpensive wood frame construction, and use of less costly material (6).

As opposed to European practice, wood-frame houses are dominant in most regions of North America. The weather-exposed parts of the walls of modern houses are covered with wood siding (redwood and cedars as solid wood, and Douglas-fir or southern pine plywood) or with non-wood siding materials such as metal, brick, or plastics (3,4) (Table 1). Only 8 percent of the siding material of new houses consists of solid wood. mostly redwood and western redcedar. More than 50 percent of new homes have wall siding made from plywood or medium-density hardboard. Although window frames are often made from metal, wood millwork (joinery) or wood/metal and wood/plastic combinations dominate in residential construction. The wood is generally ponderosa pine sapwood, although other species are now being used.

Similarly, in Western Europe wood is mostly used for window frames, although competition from plastic and metal is intense. In addition, wood balconies, fences, pergolas, etc. are quite popular. Softwoods are mostly used for all these applications, mainly, the European species of spruce, pine, and white fir. However, in countries with close overseas relations (like France), tropical hardwoods are used on a large scale, particularly for windows. Normally, the design details of European windows provide for good protection (e.g. no weather-exposed wood cross sections), except in the

United Kingdom, which has a different tradition of window design, and in Mediterranean regions, where such requirements are not as necessary.

Other forest products like plywood and particleboards have achieved only small market penetration as outdoor siding material (cladding) in Europe. These panel products, however, play an important role as wall construction material in prefabricated houses, which have achieved increasing market segments in some countries.

Types and application of finishes

In Europe today, mildewcidal pigmented primers (sometimes also with a fungicidal and water-repellent effectiveness) are usually applied to millwork under controlled workshop conditions. This practice avoids the disadvantageous preweathering effects at the building site and improves the adhesion of the finishes. Window framework is mostly pretreated by short dipping or by spraying processes, whereas siding boards are occasionally preprinted by brushing or spraying techniques. Recently, some producers have improved the surface protection of window frames by also applying the first topcoat in their workshops as recommended by most finishing experts. Structural members such as balconies, terraces, etc., are quite often only protected by a dip treatment and then painted or stained. However, wood that has been pressure treated with waterborne preservatives is becoming more and more popular and is being used quite frequently when wood is in ground contact. Siding boards are occasionally factory primed using a penetrating stain and then usually finished at the building site by applying two to three coats of semitransparent stain.

In the United States, all quality millwork is treated in the factory with a water-repellent preservative, followed by a primer and sometimes a topcoat. Most solid wood and plywood siding are sold untreated or unpainted. At the building site, semitransparent or solid color stains are commonly applied as one coat; paints are usually applied in two coats, one primer and one topcoat. Most hardboard siding is factory primed and sometimes completely finished.

Concerning the characteristics of the common finishes such as film thickness, gloss, color, and type of resin, some important differences between the United States and Western Europe can be observed depending upon the end use (Table 2). In the United States the tendency is to prefer flat to satin paints (sometimes semigloss), and flat, nonfilm-forming stains that have a relatively low to medium resin content. In most European countries, satin to high gloss solvent-borne alkyd enamels with high resin contents are quite usual. Even some types of semitransparent stains have a sheen or satin surface in Europe.

There are significant differences between the most commonly used types of wood finishes in the United States and those in Western Europe (Tables 3 and 4). In the United States more than 50 percent of the film-forming outdoor paints for wood are based on acrylic latexes, whereas in Europe these paints are hardly used as outdoor topcoats. However, interest in waterborne paints is increasing in Europe because of the well known environmental concerns and economic advantages. Today in Western Europe, acrylic paints and even acrylic semitransparent stains are starting to be used successfully as exterior wood finishes. Most of these products have a rather high resin content and, thus, are distinctly film-forming and generally semigloss. Nevertheless, it appears that the oil-modified solvent-type

TABLE 2. — *Comparison of the most common types of finishes for different outdoor wood applications (see also Tables 3 and 4).*

Type of application	Most common finishes	
	United States	Western Europe
Millwork (joinery)		
e.g. windows, doors	1. Latex paints 2. Oil (alkyd) paints 3. Solid color stains (used but not recommended)	1. Semigloss to gloss solvent-borne paints 2. Film-forming, semitransparent stains 3. Nonfilm-forming stains (used but not recommended)
Siding		
Solid wood	1. Latex paints 2. Solid color stains 3. Oil (alkyd) paints 4. Semitransparent stains 5. No finishes	1. Nonfilm-forming, semitransparent stains 2. Film-forming, semitransparent stains 3. Solvent-type paints 4. Latex paints (seldom)
Panel products		
Plywood	1. Semitransparent stains 2. Solid color stains 3. Latex paints	Very little use
Hardboard (fiberboard)	1. Latex paints	Only particleboards used to a considerable extent (prefab. houses). 1. Waterborne reinforced acrylic plaster, finished with latex paint.
Balconies, terraces, fences, pergolas	(Most new installations in ground contact are pressure treated mainly with waterborne preservatives.)	
	1. No finishes 2. Semitransparent stains 3. Latex paints 4. Oil (alkyd) paints	1. Semitransparent stains 2. No finishes

TABLE 3. — *Surface finishes (architectural coatings) for exterior wood in the United States.*

Finish type (technical definition)	Practical name	Total solid content	Film thickness[a]	Durability (2 or 3 coats)[b]	Expense of refinishing	Recommended applications
		(%)	(μm)	(yrs.)		
1. Water-repellent pretreatment	Water-repellent preservative	16-20	0	NA	NA	Dip pretreatment for millwork; brush pretreatment for siding
2. Natural (penetrating)	Water-repellent preservative; penetrating oil; clear wood finish	10-75[c]	0	2-3	Low	Wood exposed outdoors, above ground contact
3. Transparent (film-forming)	Clear varnish (alkyd, urethane, phenolic, latex)	30-50	50-100	1-3	High	Indoors; outdoors only under shelter from weather
4. Semitransparent, pigmented penetrating stain	Semitransparent stain (oil or latex)	30-75[c]	0	3-6	Low	Indoors and in particular outdoors for flat-grain, rough wood siding
5. Opaque stain (hiding)	Solid color stain (oil or latex)	35-60	25-75	2-6	Medium	Outdoors for wood siding and panel products
6. Primer (fully pigmented)	Primer paint (shellac, oil, alkyd, latex)	50-80	25-50	NA	NA	First coating for topcoat paint
7. Topcoat paint	House paint, trim and shutter paint (oil, alkyd, latex)	45-65	75-125	4-10	High	Indoors and outdoors for all woods and all exposures

[a]2-3 coatings; 1 μm = 0.001 mm = 0.00004 in. = 0.04 mils.
[b]Period until extensive breakdown (peeling, erosion, etc.).
[c]Despite the high solids content, the oil-based stains penetrate the wood surface and do not have any measurable film. The latex stains have a low surface film since they are not truly penetrating.

alkyd resins will remain the most important binder for both paints and stains in Europe at least for several more years because of their strong economic and technical position.

The solvent-borne alkyd resin paint is still the most widely used finish for millwork in Europe. However, during the last 5 to 10 years, the film-forming semitransparent alkyd-based stains have become more widespread. The demand for this type of finish, which is practically unknown in the United States, resulted from the general interest in natural finishes and the simultaneous need for good dimensional stability of millwork. Thus, such a finish has to be as transparent as possible, but also film-forming, to achieve a good moisture-excluding efficiency. These film-forming finishes tend to peel, but this can normally be avoided by observing the proper maintenance requirements. In several European countries, the use of a moisture-protecting finish (in particular for windows) is supported by relatively strict recommendations and/or by official guidelines.

The waterborne acrylic latex primer and topcoat paints are very popular in the United States because of their durability, retention of flexibility, ease of application, easy cleanup, as well as for economic and environmental reasons.

Another important difference between the use of wood finishes in the United States and Europe is the popularity of oil-based or acrylic latex solid color (opaque) stains in the United States, whereas they are hardly used in Europe (except in Scandinavia). However, these stains were introduced 10 years or so ago in some European countries. The reason for this low use today might be that opaque stains cover the color and grain pattern of smooth wood totally like a paint, a fact which is not consistent with the primarily decorative character of wood siding for modern houses in Western Europe. On the other hand, solid color stains do allow the surface texture of the wood to show through, and thus seem to be a reasonable compromise as a wood finish with good weather resistance. As mentioned above, however, solid color stains as well as latex paints with low acrylic resin content would be judged inadequate finishes for window joinery (millwork) in Europe. Similarly, they are not recommended for horizontal surfaces (decks or window sills) in the United States.

Summary

The good performance of surface protection measures is a very important requirement for the outdoor utilization of wood. A comparison of the types of the most common finishes in the United States and Europe, and of their traditional uses, shows some interesting differences.

1. Latex paints that are extensively used on outdoor wood in the United States have been almost unknown as exterior wood finishes in Western Europe. However, a definite trend to use more waterborne products is developing there.

2. Oil-modified alkyd resins are now the standard binder for both wood paints and stains in Europe. The resin content is often high and produces paints with semigloss to high gloss surfaces. Even certain film-forming stains have a sheen or satin surface. In the United States, most outdoor wood finishes have a flat to satin surface.

TABLE 4. — *Surface finishes (architectural coatings) for exterior wood in Western Europe.*

Finish type (technical definition)	Practical name	Total solid content	Film thickness[a]	Durability (severe exp., 2-3 coats)[b]	Expense of refinishing	Recommended applications
		(%)	(μm)	(yr.)		
1. Unpigmented, completely transparent varnish	Clear varnish	55-85	50-100	1-2	High	Outdoors, only under shelter
2. More or less pigmented, semitransparent finishes	Semitransparent stains and finishes ("natural finishes")					
2.1 Nonfilm-forming, penetrating	Impregnating stain, nonfilm-forming stain	12-35	"pigment agglomeration" <20, no real film	2-3	Low	For parts requiring no dimensional stability (sidings, etc.)
2.2 (Rather) film-forming, nonpenetrating, satin to glossy	Semitransparent varnish "film-forming stain"	30-45	30-50	3-4	Medium	For parts requiring some dimensional stability (windows, glulams (glued laminated timber), etc.)
3. Fully pigmented, opaque, film-forming finishes, mostly glossy	Alkyd resin paint	55-70	70-100	5-8	High, except for early maintenance	For parts requiring a high dimensional stability (windows)
	Latex paint,[c] etc.	50-60	60-80	5-7		Like 2.1
4. Primer, unpigmented to fully pigmented	Primer	40-70	10-30, mostly no real film	—		Primer for coatings 2 or 3
5. Water-repellent pretreatments, unpigmented to lightly pigmented	WRP-surface treatment; penetrating	15-25	None	– <1	Low, if in time	For members, requiring dimensional stability outdoors under shelter (glulams, etc.); protect during construction phase; also as primer for 2.2

[a]2-3 coatings; 1 μm = 0.001 mm = 0.00004 in.
[b]Period until extensive breakdown (peeling, erosion, etc.).
[c]Not often used.

Remarks: The most common type of resin in both stains and paints is an oil-modified alkyd. A few stains consist also of other resin types like polyurethane or phenol-formaldehyde. Waterborne latex paints, based on acrylic resins, or acrylic/polyvinylacetate copolymers, are used only to a small extent both for paints and stains, however their use is increasing. Paints normally have a relatively high resin content and have an eggshell to gloss surface.

3. Solid color (opaque) stains are rarely used in most European countries, even though they are durable and easy to maintain, because their high pigment/volume concentration obscures desired architectural wood grain effects. These solid color stains are extensively used in the United States, particularly on siding.

4. Semitransparent, film-forming alkyd resin stains are widely used on millwork (joinery) in Western Europe. Such finishes are a compromise between a "natural" finish and a paint film with sufficient moisture protection, for example, for window frames. Semitransparent stains in the United States are generally oil- or alkyd-based but are always of the penetrating type with essentially no surface film buildup (due to a relatively low degree of polymerization). Latex semitransparent stains are now being introduced and are becoming popular.

It is useful and interesting to develop a mutual exchange of information in this field of outdoor wood finishing, and to evaluate the performance of the different representative types of American and European wood finishes on representative wood species under a variety of exposure conditions. Such a comparative study has been initiated between researchers in the Wood Section of the Swiss Federal Laboratory for Materials Testing and Research (EMPA) and the Forest Products Laboratory (FPL) in the United States. Outdoor wood finishes available commercially in Europe and North America have been exchanged and are being evaluated on test fences at Madison, Wis., and Dübendorf, Switzerland, on commonly used American and European wood species. Results of these studies will be the topic of future publications.

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