

Changing Nature of Wood Products—What Does it Mean for Coatings and Finish Performance?

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Most current recommendations concerning the application and performance of coatings and finishes on exterior solid wood substrates are based upon knowledge gained decades ago. Chapter 16 of the "Wood Handbook: Wood as an Engineering Material,"¹ discusses the properties of wood and the interaction of these properties with wood finish systems. A major part of this discussion is the result of research conducted by Browne² on wood properties and paint durability during the 1950s and 1960s. Since that time dramatic changes have occurred to both the country's timber base³ and to exterior wood finish formulations. The shift from exterior wood products originating in the old growth forests of the Pacific Northwest (British Columbia, Washington, Oregon, and northern California) to products originating in the vigorous second and third growth forests of the northeastern, midwestern, southern United States and eastern Canada, as well as the Pacific Northwest, has accelerated in the past decade. The species mix in almost all areas of the United States is vastly different today compared with 50 years ago. Environmentally driven restrictions on certain chemicals and volatile organic compounds (VOCs) have resulted in a reformulation of nearly all paints, stains, and natural wood finishes during this same time frame. The objective of this paper is to examine how the changing timber base has affected the characteristics of the products derived from that base and how these characteristics af-

fect the performance of the new generation of wood finishes.

Old growth timber is generally defined as being 200 or more years of age. Lumber products derived from such a resource are characterized by high percentages of clear (free from knots and other defects) grades, with very fine, uniform rings of annual growth. Another natural consequence of the manufacture of lumber from the larger logs typical of old growth is the yield of relatively high percentages of heartwood grades and lumber with vertical grain (i.e., quartersawn). Today's commercial forests are typically harvested at an age which may range from 20-30 years for plantation-grown southern pine to 60-70 years for West Coast species such as redwood and Douglas-fir. A result of harvesting timber from such forests is a difference in the characteristics exhibited by the wood. Smaller diameter, more rapidly grown trees yield higher percentages of flat-grained lumber containing knots and other natural characteristics including sapwood. Restrictions on harvesting in West Coast forests have given more interest to other regions of North America. Species harvested from these other areas may not be as well suited for exterior applications as redwood and western redcedar.

WOOD PROPERTIES

Wood properties affect the efficiency and methods of application and service life of finishes (finishability). These properties include natural properties such as density, growth rate, knots, extractives

content, and juvenile wood and manufacturing characteristics such as grain orientation, surface texture, and moisture content. These properties were discussed previously.^{4,5} The link between the properties of wood and its finishability developed over 75 years by numerous researchers from many laboratories remains valid today. For example, for a specific species and grain orientation, the effect of density on the weathering rate of wood remains the same whether the wood is obtained from an old growth tree or a fast-grown plantation tree. The weathering rate/density relationship is the same, but the wood obtained from the fast-grown tree tends to be less dense. It is the changes in the tree size, growth rate, and species mix of the trees being harvested, changes in manufacturing practices, and a greater reliance on wood composites that have led to vastly different substrates, not any inherent differences in the properties of a given tree species. These recent changes must be superimposed on the properties described previously.^{4,5}

EXTERIOR WOOD PRODUCTS

Architectural Products and Species

The vast majority of wood used in residential and nonresidential construction is used for the internal structural framework and therefore does not need a protective coating and/or finish system. Wood and wood products are also used to protect the structure and are exposed to the weather. Exposed wood may in-

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clude architectural applications such as siding, fascia, trim, doors, and windows, and landscaping elements such as decks, trellises, gazebos, and fences. These exterior wood products are usually protected by various finish systems. These systems will enhance the long-term performance and appearance of wood exposed to the weather.

Considering only solid sawn wood products as opposed to composite products such as plywood, hardboard oriented strandboard (OSB), etc., a wide variety of species may be used in exterior exposure as architectural or landscaping elements. These elements are typically constructed from softwood (coniferous) species such as pine, fir, cedar, or redwood. Premium wood siding, trim, or fascia is usually redwood or cedar. These species have heartwood that possess natural resistance to wood-destroying organisms such as fungi and termites, as well as outstanding inherent dimensional stability. Redwood, cypress, and the various species of cedar have traditionally been rated as those species with the best characteristics for painting and weathering.¹ Fir, pine, and to a lesser extent, hemlock and spruce, may also be used for exterior architectural and landscape purposes. Pressure preservative treatment with waterborne arsenicals such as chromated copper arsenate (CCA) is commonly done with these species to provide decay and termite resistance. These species all rank below vertical-grained redwood and cedar in their ability to hold paints.¹

Imported Wood Species

The decade of the 1990s has been a time of unprecedented change in the wood resource within North America. Several factors have come into play to drive these changes. In addition to changes in the size and species mix of the log harvests, there is an increase in log imports into the United States. Radiata pine from Chile, Australia, and New Zealand and a variety of species from the former USSR (larch, pine, and spruce) are being imported. Although radiata pine has been used for many years in other countries, and its properties are well known in those countries, users within the United States are not familiar with this wood. Radiata pine grows extremely fast often giving one to three growth rings per inch. The logs from countries of the former USSR will likely be small diameter and slow grown given the latitude and climate conditions for those forests.

Increased imports of tropical hardwoods should be anticipated. The den-

sity, machinability, weathering properties, paintability, and extractives bleed of these species, have not been fully researched. Many of these species are high in extractives and oils and it is not known whether paint formulations available in the United States and Canada will block them. Paint companies generally do not test formulations on tropical wood species.

Another change in the lumber resource is the small but growing amount of recycled wood being used. This wood may be available from a wide variety of sources, have many different species, and be used in a variety of ways. In some cases, large timbers are being used as is or they are being sawn into lumber. Some of this wood is being used in composite materials.

Silvicultural Practices to Enhance Wood Quality

Silviculture is the practice of controlling the establishment and development of stands of trees to achieve the objectives of management. Most commercial timber production is primarily concerned with maximizing the volume of wood fiber produced per acre per year with secondary consideration being the quality of the fiber. There are ways, however, to improve quality while at the same time not sacrificing the primary objective. Intensive management practices such as pruning can result in the formation of more clear lumber. Deferred rotations allow the best quality trees to add greater volumes of high value clear vertical-grained lumber. Growing trees to larger sizes and older ages, however, involves significant financial risk that some landowners might not be willing to take.

In addition to the physical manipulation of trees and stands, the genetic selection of "super trees" can also improve lumber quality. Trees can be selected for certain genetic characteristics such as density, juvenile wood content, heartwood content, and branch angle. While much research has been conducted to improve stands through selection and the development of hybrids, the availability of genetic engineering techniques has made possible additional techniques for designing "super trees." There is much more work to be done and significant potential gains in lumber quality from genetic engineering but it may take decades to achieve. Despite this, it is apparent that silvicultural practices and genetic selection have had a significant impact on sawn lumber grade yields from managed forests, particularly in the increased amounts of fiber per year per acre.

The primary result of these practices has been faster growth rates that give lumber with wide bands of earlywood and latewood. These wide bands become more problematic when the lumber is flat-grained.

Lumber Grades and Quality

Lumber is generally graded according to structural grade rules or appearance grade rules according to well defined characteristics by various rule writing agencies. Wood characteristics include both natural characteristics such as the size and location of knots and manufacturing characteristics such as chipped grain, raised grain, and skips in surfacing. All permissible characteristics of a grade, such as knots, are never present in maximum size or number in any one piece. Likewise, a particular parcel of lumber will not consist of only pieces containing characteristics of the maximum number or size permitted in the grade.

Recently, much controversy has centered around the belief that the quality of lumber grades is slipping. Several factors have contributed to this widely held belief. Harvesting smaller diameter young growth trees gives a greater proportion of common or knotty type grades in the lumber. A much smaller proportion of the clear higher grades is recovered from today's resource. The result is a significant shift in the recovery ratio of clear grades to common grades. Twenty-five years ago, clear grades may have represented up to 40% of the lumber produced. Today, only 10-20% of all lumber production gives clear grades. In the past, when an order of "No. 2 and Better" was delivered, a healthy percentage of the boards would be "Better" because the time it took to sort through and separate them from the others was worth less than the price differential. That is no longer the case.⁶

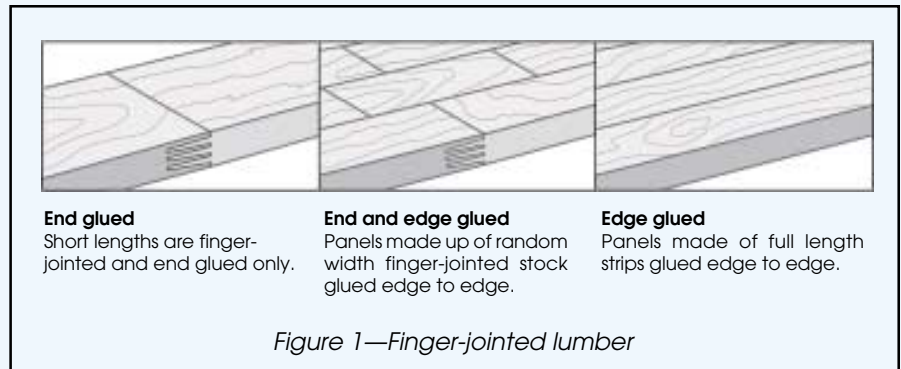
The allowable characteristics in a particular grade have not changed dramatically over the last 25 years. An analysis of the grade descriptions in the various species grade rule books from 20 years ago reveals descriptions very similar to those published today. What will actually be found in today's lumber products is a higher percentage of pieces that possess more numerous maximum allowable characteristics for the particular grade in question than in the past.

Two changes have occurred in appearance grades of lumber, which often include siding and trim boards. These are changes in dimension and a greater reliance on finger-jointed lumber.

PRODUCT DIMENSION: To increase yield, some manufacturers have decreased the thickness of siding and other products. The cross-sectional profile of a product (the aspect ratio of thickness versus width) can significantly affect product performance. Thicker narrower products will perform better from a dimensional stability standpoint than thinner wider patterns or products. There is often a choice of product dimension for a particular use and the specifier (architect, owner, contractor, etc) must select a particular product. As an example, $3/4 \times 6$ -inch bevel siding would be expected to be a more stable product on a building's exterior than $1/2 \times 8$ -inch bevel siding. The consideration of product dimension is even more important with today's lumber products which are predominantly flat-grained and therefore inherently somewhat less dimensionally stable than vertical-grained products.

FINGER-JOINTING AND EDGE-GLUING: Finger-jointing and edge-gluing have been utilized for decades to increase recovery of clear, knot-free lumber (*Figure 1*). The amount of glued product using these manufacturing techniques has increased dramatically over the past decade as the need for clear lumber increased and the amount of clear sawn lumber has decreased because of the harvest of smaller diameter trees. The advantage of finger-jointing and edge-gluing is that longer and wider knot-free boards can be produced from a young growth resource that otherwise would produce a large proportion of lower quality material. Glued products also significantly increase the dimensional performance of a board by decreasing the wood's natural tendencies to shrink and warp. Finger-jointed and edge-glued boards stay straighter and perform better than solid sawn lumber as a result of their improved dimensional stability. These advantages are more obvious in glued lumber made from vertical-grained stock where the differences in grain from piece to piece are less noticeable. Vertical-grained finger-jointed lumber provides a more uniform substrate for finishing, eliminating the wide variation in grain associated with flat-grained lumber and avoiding the poorer quality wood fiber found near knot locations.

While flat-grained finger-jointed lumber also eliminates problems at knot locations, it will also tend to have more grain raising. The short stubs used to manufacture flat-grained finger-jointed lumber usually exhibit a wide range of texture, grain angle, ring count, and other physical characteristics. As a result, lumber made from flat-grained fin-



ger-joint stubs tends to be non-uniform in appearance and performance. Sometimes little care is used to match grain patterns, growth rate, or heartwood/sapwood during manufacture. Each piece may then contain both vertical-grained and flat-grained sections. The characteristics of this lumber are controlled by the lowest quality component, i.e., the flat-grained portions. The service life of the finish is determined by these flat-grained sections. It is not uncommon for spotty failure to occur only on the flat-grained portions, often within a year or two, while the vertical-grained portions last for years. For this reason, saw-textured surfaces or rough-sanded surfaces are highly recommended for flat-grained glued products to help decrease the effects of the wood variables on the appearance and performance of the finished product.

Flat-Grained Siding and Lumber—Effect on Finishing

It is well known that the paint holding characteristics of latewood are not

as good as those of earlywood. In slow-grown vertical-grained lumber, particularly with species having narrow latewood bands (such as redwood and cedar), these latewood bands are easily bridged by the coating and there is little stress induced in the coating at the latewood/earlywood boundary. The amount of latewood in contact with the coating system is small and there is little raised grain or other dimensional changes at the latewood/earlywood interface. In wood species having thick latewood bands (such as southern pine), the bands of flat-grained lumber can be quite wide. In some cases, more than an inch (25mm) and the difference in density between the earlywood and latewood at the interface can lead to severe grain raising and stress on a coatings system. The changes in a surface are shown in the two book-matched cross-sections of a board following planing before and after wetting with water (*Figure 2*). Note that the latewood bands were crushed into the less dense earlywood bands during planing and then rebounded when wet to give the raised

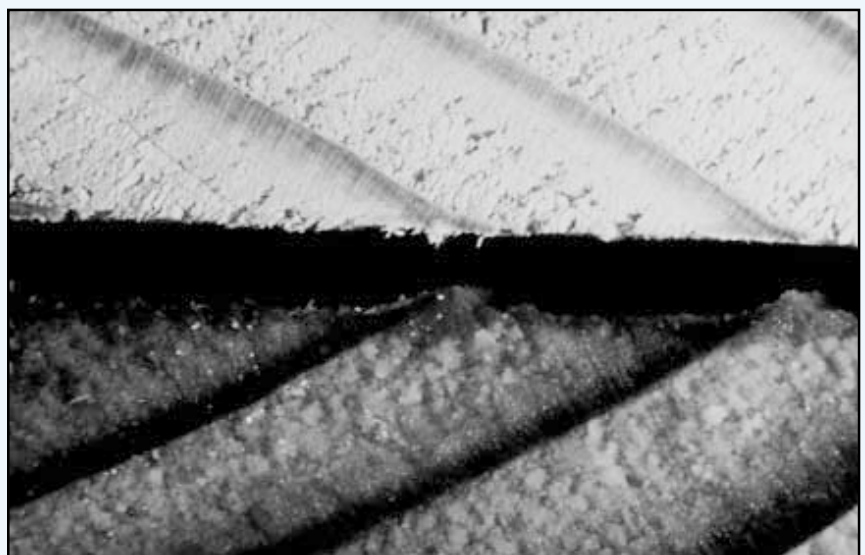


Figure 2—Raised grain on book-matched specimens of planed lumber. The cross-sections of a planed board illustrate grain-raise caused by water. Surface immediately following planing but not wetted (top); the same planed surface but wetted (bottom).

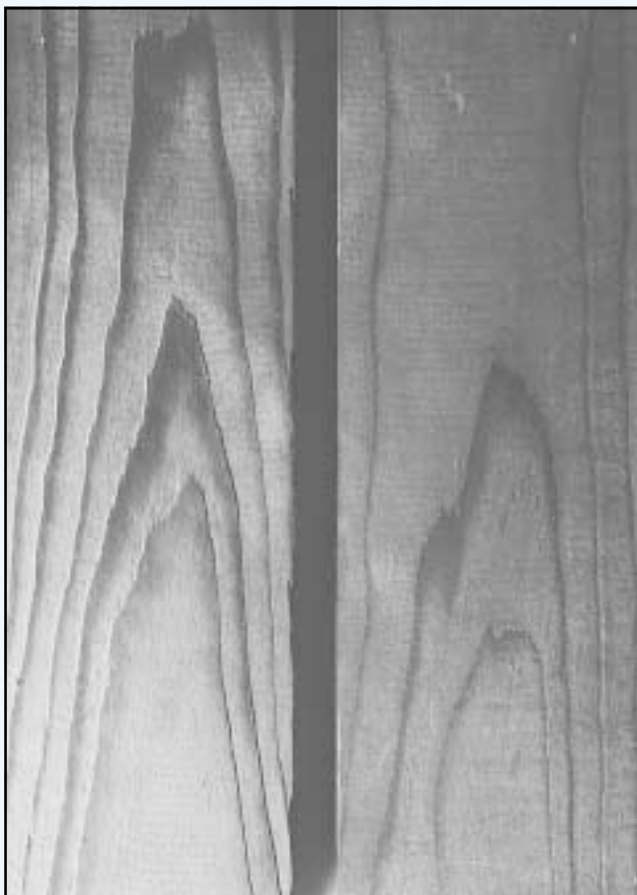


Figure 3—Raised grain on the pith side of a board (left), and the bark side of the same board (right) without raised grain.

grain. This type of raised grain is usually more severe on the pith side and it can easily crack a coating system, particularly an alkyd paint system (Figures 3 and 4).

The effect of surface quality and texture play an important role in the performance of a finish. Saw-textured (also referred to as “resawn”), sanded, and smooth-planed surfaces all influence finishes differently. Generally speaking, saw-textured surfaces accept more finish than smooth-planed surfaces and thus the finish lasts longer. These roughened surfaces provide more tooth for finish adhesion and actually have much more surface area. These types of surfaces also dramatically decrease grain raising problems associated with flat grain lumber by decreasing grain compression and other damage sometimes caused by planing processes. As the timber resource changes from an old growth to a young growth supply, there is less vertical-grained wood available. For this reason, saw-textured surfaces are being used more frequently in an effort to decrease grain raising and improve finish performance on flat-grained wood products. Saw-textured surfaces greatly decrease problems with raised grain. For flat-grained lumber or siding, the single

best procedure for finishing is to begin by using the saw-textured side. Other suggestions are included in the section on painting.

A special problem exists with lap or bevel siding. This siding is manufactured by ripping a piece of dimension lumber on a diagonal to form two pieces of siding. The side that is ripped is saw-textured. If the original board is vertical-grained, both pieces of bevel siding will be vertical-grained and there is no difference with regard to bark/pith side. If, however, the original board is flat-grained, the two pieces of bevel siding have opposite bark/pith orientations. One piece will have bark side grain on the smooth side and pith side grain on the resawn side, whereas the other will have pith side grain on the smooth side and bark side grain on the resawn side. It is not possible to use only the bark side regardless of whether the smooth or saw-textured side is used. Fewer problems will occur if the saw-textured surface is used.

Flat-grained lumber often has knots and there is no easy solution for avoiding cracking of the finish and bleed-through of extractives and/or resins. The amount of extractives/resins available from the end-grain and the diver-

sity of these chemicals makes blocking them extremely difficult. The only way to seal the knots is by using shellac or a comparable commercial product. These products tend to be alcohol-based and are therefore water sensitive. They should only be used over the knots, not on the whole board. Their use adds another step to the finishing process. It might be better to recognize that the knots are a characteristic of the wood and one that can add beauty. Instead of working against nature and trying to cover them, selection of a finish system that works with the knots might be an easier alternative. White paint and other light-colored film-forming finishes are extremely difficult to use on knotty wood. If the knots are large, they will eventually crack. These cracks will cause any film-forming finish to crack; alkyds are more susceptible to cracking than are latexes. Suggestions for finishing knotty wood are contained in the section on painting.

Wood/Wood Composites

Wood-based composites are being used to a greater extent than in past years. Traditional wood-based composites will continue to be used for many structural and decorative components. These include plywood, hardboard, oriented strand board (OSB), and various types of particleboard. Many will include veneers and/or paper-overlaid products for the surface. Panel products will continue to be used because of their competitive pricing and ease of installation. A number of siding materials using wood furnish of flakes, strands, particles, and fibers are being produced with a paper-overlaid surface. These products have an excellent surface for painting; however, edge sealing will continue to be a challenge for these materials. These products are usually produced in large sheets, which may then be cut to give siding of various styles. These products are often edge sealed during manufacture, but field application of a paint to ends cut during construction is necessary to give protection against water. Species mix will change with increasing dependence on temperate hardwoods such as aspen, red maple and yellow poplar, tropical hardwoods, and radiata pine. Research on wood composites and adhesives for wood composites is continuing and, almost every year, new products are being introduced into the marketplace. The burden for assuring their compatibility with finishes often falls on the coatings industry.

Wood composite products often lack the robustness that is characteristic of

solid wood products. Whereas solid wood performs amazingly well in spite of abuse during shipping, storage, and handling at the construction site, wood based composite products may fail prematurely if not handled properly. When these products are used in accordance with manufacturer's instructions, they often perform quite well for decades. For example, plywood siding, particularly siding having a saw-textured surface, last for decades when protected by a finish system. Plywood can give excellent performance even without a paper overlay, however almost all other wood/wood or fiber-based composites perform best if they are manufactured with a paper overlay.

Wood/Plastic Composites

Wood/plastic composites such as decking, pallets, furniture, automotive parts, etc., have become available during the last five years. For example, one wood/plastic decking board is a wood-fiber/polypropylene extruded 2 × 6. Although this material has made some market gains since its inception, it lacks the thermal, flame resistance, and mechanical properties necessary to replace dimension lumber. These materials initially used wood fiber as an inexpensive source of filler, however, this is changing. As chemicals are developed for modifying the fiber/plastic interface, these materials will be engineered for greater strength, stiffness, and toughness. Efforts are continuing to improve products such as these, and it is anticipated that similar products will be introduced to be used as siding materials, sheathing, decorative moldings, etc., in the near future. Some of these materials are already available for interior use.

These wood/plastic composites will also be made using substitutes for the wood fiber. Many other fiber sources are being investigated for use in these materials, such as jute, flax, and hemp. Considering the vast array of fiber types and polymers, their properties, and the different manufacturing methods, the range of products available seems almost infinite.

Paper-Overlaid Products

Paper-overlaid products are usually manufactured by bonding a resin-impregnated kraft paper to the surface of the composite during manufacture. The paper eliminates surface defects and makes the overlay surface less moisture sensitive. The edges must still be protected and this is the weak point for all of these products.

Fiberboard

The surface of fiberboard, whether overlaid with paper or not, has a homogeneous surface and accepts paint rather well. As with other composite siding materials, the edges are moisture sensitive and must be protected with a finish.

PAINTING GUIDELINES

The painting guidelines in this section are neither recommendations nor are they intended to be the only method that would give good protection to the wood. Almost every situation is different. The design of the building, construction practices, customer/owner preferences, cost, and weather conditions make it impossible to make finishing recommendations that can apply for all situations. Using knowledge of the properties of wood, the use conditions, customer/owner preferences, and costs, the painter must make the final decision. This decision often involves compromises. This section includes a discussion of challenging areas; it is not a comprehensive guide to wood finishing. Since much of the changing resource relates to flat-grained lumber, finger jointed lumber, and composites, these areas are stressed.

Flat-Grained Solid Lumber and Siding

The single most important method for improving finish performance on flat-grained lumber and siding is to finish a saw-textured surface. If the lumber does not have a saw-textured sur-

face, scuff sand it with 50-grit or rougher sandpaper. If a film-forming finish is to be used, an all-latex system is best, however, if highly colored wood, such as redwood or cedar is used, the primer must be a stain blocking primer.

Siding having knots can be divided into two groups, those having small intergrown knots and those having large knots. The division between these two groups is not clear in terms of size but in the property of the knot. If the knot can split, then it is large; if it can not split, then it is small. The guidelines for finishing depend on this distinction. Siding having small intergrown knots can be finished with either a film-forming finish or a penetrating finish. Since it is almost impossible to eliminate discoloration, avoid the use of light-colored finishes.

If the knots are large, finish the wood with a penetrating finish, preferably one that is pigmented to enhance the knots.

Finger-Jointed Lumber and Siding

The only difference between the flat-grained lumber previously described and finger-jointed lumber is the absence of knots. Although some manufacturers sort by grain angle to produce vertical-grained and flat-grained products, the vast majority of manufacturers do not sort by grain angle during the manufacture of finger-jointed products. Therefore, unless the finger-jointed product is specifically marked as vertical-grained, all boards must be treated as being flat-grained. As with other flat-grained products, the resawn side will perform best. Semitransparent stains are suitable for this substrate and all latex

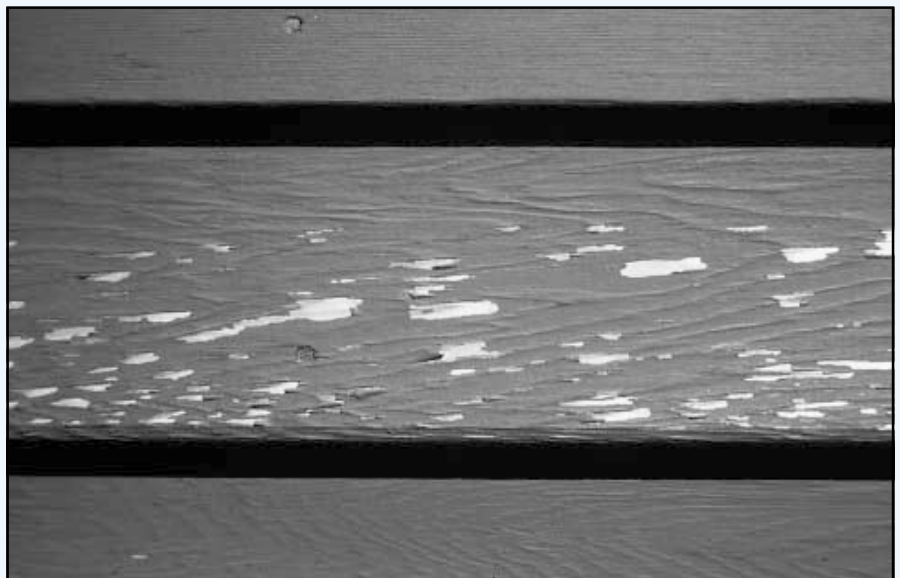


Figure 4—Paint failure caused by raised grain.

paint systems perform better than oil/latex or oil/oil paint systems. Boards will have a mix of pieces with various extractives content and resins. It is imperative that a stain blocking primer be used. Even with slightly colored species, such as pine, the resins can cause discoloration with light-colored finishes. It is best to avoid the use of light-colored finishes.

Plywood

Plywood is a flat-grained surface, therefore finishing guidelines are similar to those previously described for flat-grained lumber. Plywood panel products intended for exterior use are often given a saw-textured surface. These products can either be stained or painted and give far superior performance to smooth-planed plywood. Best paint performance is obtained from saw-textured surfaces using all latex paint systems; penetrating semitransparent stains also give good performance on these saw-textured surfaces. Plywood having a paper overlay cannot be finished with a penetrating finish such as a semitransparent stain. Film-forming finishes will perform better on these paper-overlaid products than on the non-overlaid plywood, particularly if the surface is not saw-textured.

Wood/Wood Composites

Other than plywood and fiberboard, wood/wood composites should have a paper overlay if they are used outdoors. The edges must be protected from moisture with a coating. The paper-overlaid surface cannot be stained, but it can be finished with any type of film-forming finish.

Wood/Plastic Composites

Wood/plastic composites are generally not designed to be painted or stained. The paints are likely to debond and stains do not absorb properly. Those products used for decks tend to weather, become porous, and develop mildew. Cleaning and application of WRP, after they become weathered, improves their performance.

Paper-Overlaid Products

Paper overlay of wood composites (including plywood) provides an excellent surface for painting, and the overlay eliminates grain raising, extractives bleed, and problems with knots. The paper-overlaid surface of these materi-

als cannot be stained with solventborne semitransparent stains or treated with water-repellent preservatives. However, improved performance is obtained if the edges are treated with a WRP prior to being painted.

Fiberboard

Fiberboard, whether overlaid with paper or without a paper overlay, can be finished with any type of film forming finish. If not overlaid with paper, take care to use a primer that will block extractives. These substrates cannot be finished with semitransparent stains.

Factory Priming and Finishing

Finishes adhere to the wood substrate and perform better when they are applied under ideal conditions. Generally speaking, finishes should be applied to dry wood, at a moisture content of 10-15% and at temperatures above 50°F. These conditions are not always present during field application. To help avoid poor finishing situations, many lumber manufacturers are offering factory applied primers and finishes. Factory applied primers and finishes are usually more uniform because of better quality control during application. Substrate and drying temperatures, wet and dry mil thickness, finish viscosity, and line speeds are regulated with a much higher degree of accuracy than can be accomplished in field applications. The result is a better performing, more economical coating than one manually applied at the job site sometimes under adverse weather conditions.

SUMMARY AND CONCLUSIONS

As the fundamental nature of North American forest has changed over the past 200 years, so have the properties of the building products derived from those forests. Smaller diameter second and third growth trees yield lumber with higher percentages of knots and sapwood and less of the clear fine grain lumber traditionally used for architectural applications. Many of the current recommendations for finishing exterior wood products are based upon dated information. The more knotty solid wood products used today may have coarser grain and be predominantly flat-grained. Flat-grained lumber is more prone to grain raising and dimensional change. Saw-textured surfaces decrease the potential for grain raising and they enhance finish performance. Saw-textured knotty flat-grained wood products may perform better if they are fin-

ished with penetrating finishes (semitransparent stain) rather than with film-forming finishes (paints). Semitransparent stains and other types of penetrating finishes do not peel and tend to be less likely to show knot or extractives bleed. Film-forming finishes may also be used on knotty saw-textured flat-grained surfaces, however discoloration because of bleed-through at the knots continues to be a challenge, particularly with light-colored finishes.

Use of different wood species, flat-grained knotty wood, and composites may require some changes in finishing practice and more careful selection of products for specific uses. For example, if a white painted look is desired, it may be better to use a paper-overlaid product to eliminate problems with knot bleed than to try to seal the knots using shellac. If finger-jointed lumber is used, extra care may be required to assure that the finish can adequately block the extractives. Sealing and painting the edges of composites is necessary to assure good performance. Paper-overlaid products give a good surface for painting.

Advances in finger-jointing and factory prefinishing will add to the performance of modern wood products. In the coming decade, the transition to lumber from rapidly grown intensively managed forests will continue. New species and composites will become more available in the marketplace. Much of the burden for assuring the compatibility of finishes with new wood products will probably rest with the coatings manufacturers and their suppliers. The technology of paints and other finishes and the protocols for testing finishes must advance to keep pace with the changes in the substrates.

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