Emerging Materials: What Will Durable Materials Look Like in 2020?

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Abstract

What materials will emerge from today's research ideas to become the commonly accepted building products of 2020? What will durable materials look like in 2020? This paper attempts to address these questions by considering some current trends and then presenting a series of ideas of what the next 2 decades may hold from an emerging materials standpoint for North American light-frame construction.

Still, no one can predict the future. This paper reviews a series of recent trends in materials usage, construction engineering, and laboratory research. It also attempts to explicitly state its assumptions, which of course seriously affect any ensuing predictions. From the analysis of past trends and given the assumptions made, a series of current trends are extrapolated into the next 2 decades. The opinions expressed are merely those of the author and not that of any organization or association.

Introduction

Forest resource issues will increasingly affect the building materials used in North America and worldwide. The use of smaller-diameter, lower quality, and faster grown timber, in addition to currently lesser-used species of timber, will result in an increased dependence on engineered wood-, wood agro-fiber-, wood cement-, and wood thermoplastic-composites. Over the last 25 years, the use of wood-based composites (by volume) has grown by three- to five-fold and their use is now virtually equal to that of solid-sawn wood. All users, including traditional pressure treaters, will find it increasingly difficult to find solid-sawn commodities in the grades, sizes, and volumes they have traditionally grown to expect. Users and engineers will continue to increasingly demand more reliable and more durable building materials. To meet this long-term change in markets, all material suppliers, but especially wood treaters, will need to adapt their business plans to create the knowledge and the infrastructure critical to producing durable building products that meet this inevitable demand for more-durable wood-based composite products. If not, the markets of the future will turn from wood to more durable alternative materials. We will all need to facilitate basic research to make more durable composites.

In 2000, the United States had approximately 1.8 million housing starts and used 21 million board feet of lumber, 20 million ft.^{2} of wood composite panels (3/8-in. basis), and 641 million linear feet of I-joists. We estimate that □3 trillion board feet of lumber and wood composites are now in service in United States. There are two points of view for the future and for our vision of emerging materials in the first quarter of the 21st century.

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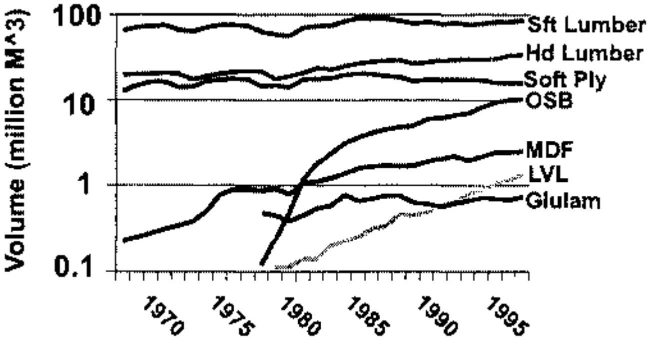

Figure 1.—*U.S. production of wood and composites (2).*

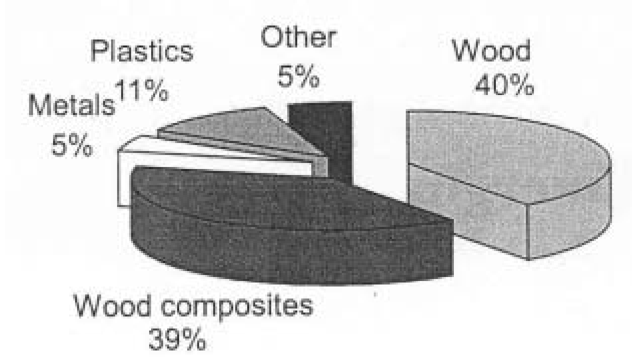

Figure 2.—*Materials used in light-frame residential construction (2).*

First, the future looks bright for increased use of wood and wood-based composite materials. Forest resource issues will increasingly affect the building materials used in North America and worldwide, and these resource issues will continue to drive materials usage toward composites rather than solid-sawn lumber. But issues such as product durability and serviceability will also be crucial to the continued growth and user acceptance of wood composites. We will need to better develop our fundamental understanding of how to best use smaller-diameter, lower quality, and faster grown timber. In addition this use of currently lesser-used species of timber will result in an increased dependence on engineered wood composites and hybrid composites of wood, agro-fibers, wood cement, and wood thermoplastics.

Second, durability issues have often been the domain of the traditional wood preservation industry. Today, however, there are as many social and political issues driving much of the change in the modern day wood preservation and durability marketplaces as there are scientific issues. The point is that in days prior, cause and effect in the wood preservation/durability marketplace happened on a 10 to 30 year scale. Change was slow in chemicals, processes, standards, and codes. However, that has all changed. Look at how quickly the chromated copper arsenate (CCA)-registration issue turned about. Change is now inevitable. Those in the design, construction, and treating communities who embrace and adapt to this rapid and on-going change will succeed; those who don't will have millions of dollars invested in buggy-whip factories.

Background

In the post World War II world, many far-sighted people laid the groundwork for the wood composites industry, as we know it today. That industry developed because academic, governmental, and industrial research was freely shared and multiple-institute collaborative efforts were encouraged. The wood composites and the wood preservation industries could both succeed in this new world economy if they follow this "post WWII-wood composites model":

1. fund and publish basic fundamental research
2. set performance standards based on user needs
3. open market competition.

The example of the early fundamental research of the 1950s, 1960s, and early 1970s lead to great market breakthroughs in new wood composite products such as laminated veneer lumber (LVL), oriented strandboard (OSB), and I-joists (Fig. 1). Note how these new composite products virtually exploded on the scene in the mid-l970s, quickly replaced there replacement targets (long-span and high-grade timbers, plywood sheathing, and 2 by 10/2 by 12 floor joists, respectively) and have now become the standard of comparison. For an even earlier example of change from base materials to engineered systems, recall that from the late 1950s to early 1970s the metal-plate-connected 2 by 4 roof truss virtually replaced hand-cut lumber rafters in North American light-frame construction because they were easier to install and required less labor even though the trusses usually did not present a sizeable cost savings over rafters.

Today the amount of wood composites or engineered wood nearly equals the use of solid-sawn lumber (Fig. 2). Twenty years ago, the use of composites was less than half of that of solid-sawn

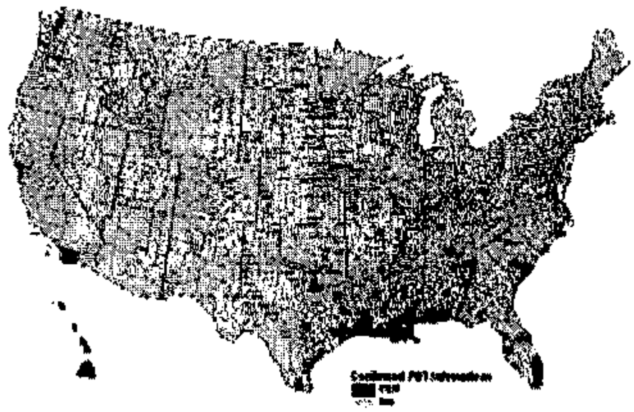

Figure 3.—*Distribution of Formosan Subterranean termite infestation in the United States (4).*

lumber. In 20 more years, that ratio may be 2:1 or more in favor of composites. So what kinds of wood products will emerge over the next 20 years and what will durable wood materials look like in 2020? The answer to these questions will be answered by technology and by political, market, and forest resource forces.

Assumptions

My predictions will be based on three personal assumptions that are based on 20 years of experience in forest products research. First, systems and composites will continue to increase their dominance in the building materials market. Second, solid-sawn lumber markets will probably at best be static. Finally, solid-sawn lumber will be more refractory, with more juvenile wood, from smaller diameter timber, and from more diverse timber species than we now use. Based on these assumptions I believe four issues will dictate the future of materials usage and define which construction materials and building systems emerge over the next 2 decades. For each issue you should ask yourself if you think this issue will decrease, increase, or maintain the same level of importance to our North American and world public.

The four critical issues that will define emerging materials are:

1. Demand for engineered systems
2. Demand for durability
3. Forest resource and management policies
4. Public and user perceptions.

Demand for engineered systems will continue to increase in the coming years. This growth in engineered systems will be driven by our insatiable demand for lower labor costs, longer spans, larger homes and the increasing demand for higher quality and tighter tolerances. As mentioned earlier, when engineered systems are used it is often ease of assembly and subsequent reliability that drives fundamental materials decisions as much as, if not more than, initial costs. Other factors which contribute to the increased demand for engineered systems will be the change in user demand for quality and the prospect that the future construction work force will be less educated and more capable of assembling pre-engineered systems rather than building on-site manufactured constructions.

Demand for durability will increase. Recent attempts to increase air-tightness have resulted in more moisture-related problems such as mold, mildew, and decay. We also have seen the introduction into the United States of a major exotic invader, the Formosan subterranean termite (Fig. 3).

The introduction and spread over the last 50 years of the Formosan subterranean termite has resulted in some building codes requiring preservative treatments of all wood used in construction such as in the state of Hawaii. Further it has lead to several similarly affected areas considering similar building code requirements. We have also had some problems with long-term thermal stability of treated roof sheathing (5). In addition, there will be an on-going demand for more information on fire safety of light-frame wood construction as more and more Americans begin to reside in multi-family constructions rather than single-family units. This increased demand for fire safety will also be a critical issue before wood can make serious impacts into non-residential construction.

Forest resource issues and management policies will dictate that forest managers increase reliance on the use of smaller diameter timber. For example, we are currently concentrating on removing timber from many forests to lessen hazardous fuels that have recently lead to serious forest fire hazards. Related forest management policies have recently promoted management practices intended to reduce forest insect and disease hazard by releasing suppressed stands, which currently result in considerable tracts of timber having a exceptionally high susceptibility to insect or disease damage and currently have little or no economic value to compensate for harvesting costs. In yet

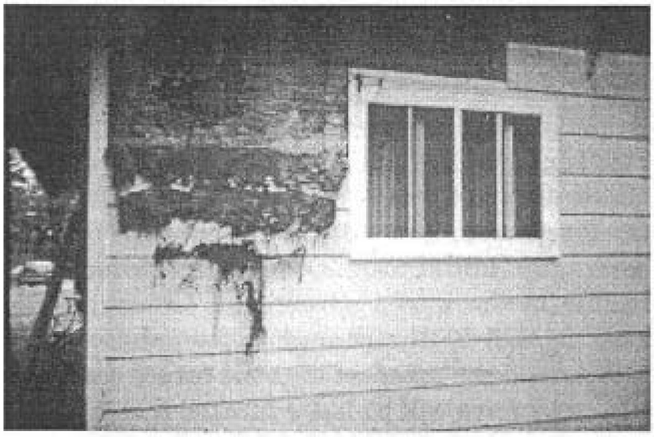

Figure 4.—*Mold and decay caused by lack of vapor barriers in the walls of high moisture areas such as bathrooms and kitchens.*

Figure 5.—*Mold and decay caused by insufficient roof ventilation and lack of vapor barriers in the ceilings.*

yet another example of a 'forest resource and management policy' issue recall how during the early phases of the environmental or "green" revolution of the 1960s, the public perceived wood as a renewable resource. However, over the last 20 years public perceptions seem to have changed. Today, the use of wood is sometimes considered by the public in a less favorable context due to their concerns about a loss in biodiversity, the relationship of forests to the environment, and overall concern about shrinking forest resources, both nationally and internationally. In many ways the resolution of any of these issues is well beyond the scope of this paper. However, the consensus philosophy that emerges on forest resource and management issues will become a crucial factor that defines what materials the consumers and the forest products industry have available in the future.

Public and user perceptions will also be critical in addressing which building and construction materials emerge over the next 20 years. An increasingly vital public perception is that wood construction is not durable. Foliente (1) used the following example " ... when steel or concrete construction fails, it is considered a design problem, but when wood construction fails it is considered a material problem rather than a design problem ..." Recent well-published durability related problems with wood construction support such assumptions (Figs. 4 through 6). These public perceptions will need to seriously addressed by public and private sector researchers, engineers, and building code authorities if increased use of wood is to again be viewed favorably. In many ways the resolution of

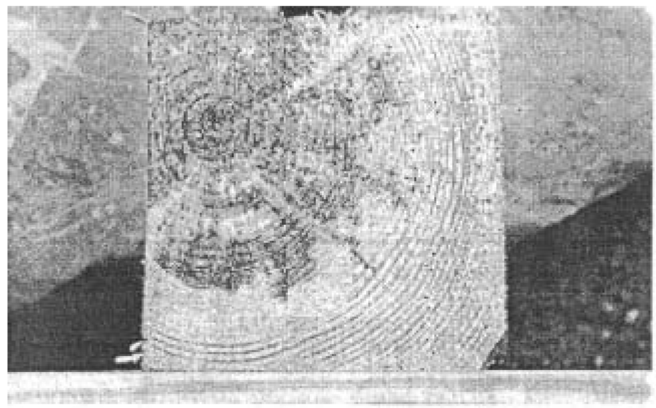

Figure 6.—*Wood decay resulted from poor treatment and/or allowance by standards of untreated heartwood and juvenile wood in some species.*

these user perceptions will define what materials we use in the 21st century and beyond.

Discussion

I have repeatedly mentioned that research will be vital to how wood and to what extent wood is used in the near future. To address what research is needed, we need to again review the problems we now face. How we address these problems will define which materials emerge and control the building and construction markets over the next 20 years.

From a materials resource perspective, we will need to deal with solid wood and lumber which has more heartwood, refractory species, small diameter, plantation grown, short rotation, hardwood treatments, imported/exotic species, and species. independent treatments (Figs. 7 and 8).

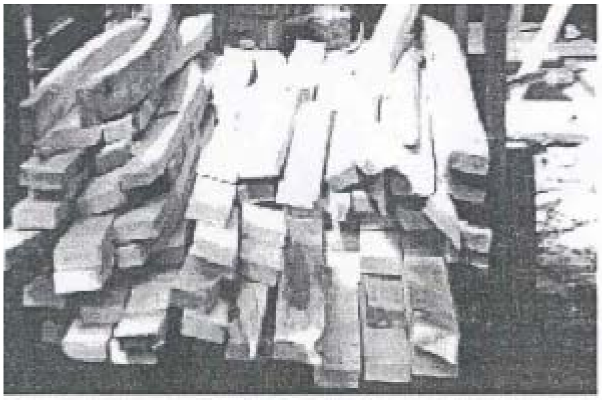

Figure 7.—*Stability problems for hardwood lumber with juvenile cores.*

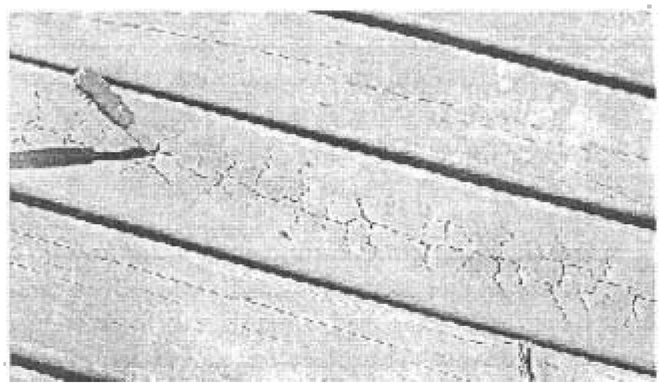

Figure 8.—*Treated pine radius-edge decking with juvenile wood related cracking.*

As saw log grade materials become progressively more difficult to obtain, finger-joined lumber (Fig. 9) may revolutionize the stud market as we currently know it. If such a revolution is to occur, we will need to develop a fundamental knowledge of material properties and define the salient durability issues for finger-joined materials. This will include the structural performance under moisture load, suitable preservative treatments which do not affect the integrity of the finger joints when moisture cycled, and finally the dimensional stability of this material.

Recent problems with sheathing and cladding related to wall system and roof system moisture problems (Figs. 4 and 5) have required researchers and engineers to begin to develop a fundamental knowledge of the important durability issues of building systems. In particular, we need to develop an understanding of the susceptibility to moisture and its affects on performance of sheathing and cladding used in those systems. These issues include structural performance, treatment needs, and precise definition of moisture and temperature thresholds for mold and decay.

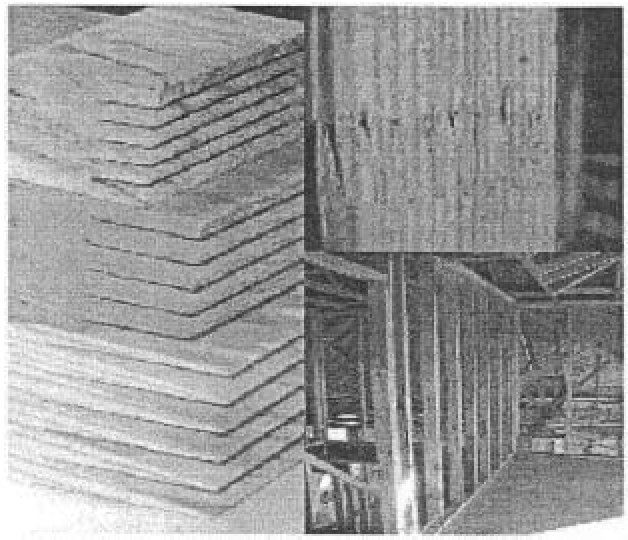

Figure 9.—*Examples of structural finger-jointed lumber.*

To retain the critical markets of wood-based composites we must target durable products to the right structural need. For traditional markets of wood-based composites, it is critical that we develop fundamental knowledge of durability issues, structural performance, and treatment needs.

The likely furnish for the natural fiber composites of the future will also include many alternative fiber sources rather than just wood. These fiber sources may include straw, sugarcane bagasse, kenaf, hemp, guayule, and wheat straw. Inorganic bound composites using wood and any combination of natural and/or recycled fiber will also gain popularity. This latter product has the benefit of proven biological durability and has proven itself as a durable siding and as a material suitable for sound-absorbing barrier systems.

If current process-related problems can be overcome related to the service life of the high-speed screening and molding forms, then the use and market attractiveness of structural fiber products like FPL Spaceboard and 3D Fibercore will increase. These new innovative products are light, strong for their weight, can use virtually any fiber source, and rely on fiber-to-fiber bonding similar to paper meaning no supplemental adhesives are required.

Wood-thermoplastic composites will continue to gain market share in decking, exterior signage and

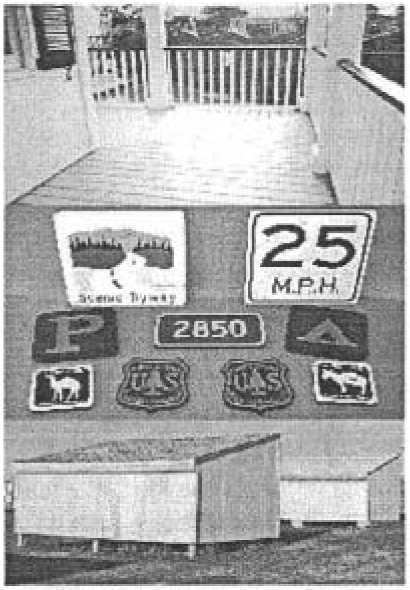

Figure 10.—*Examples of recent innovations in decking, signs, and roofing materials using wood-themoplastic composites.*

roofing (Fig. 10). In my opinion, the wood-thermoplastic composite markets can be thought of as similar in growth potential to the waterborne preservative-markets of the 1970s and 1980s. In those 2 decades, waterborne preservatives grew from <5 percent of the treated wood market to greater than 50 percent. The wood-thermoplastic composites market for decking was estimated by Smith (3) to be <1 percent of the total outdoor decking market in 1995 and had expanded to approximately 5 percent of this market by 2000. He further projected continued growth to exceed 10 percent by 2005. I believe that the recent loss of CCA-preservatives, which was the number one treatment used in outdoor wood decking, may actually accelerate the acceptance of wood-thermoplastic composites as decking. Additional new wood-thermoplastic composite products will include siding and roofing materials. There continued acceptance and potential market growth will depend on our developing a fundamental understanding of the wood-plastic materials and defining the formulation chemistry, engineering performance and serviceability, UV durability, fungal durability, and an understanding of thermal/solar loads.

Summary

For lumber, changing forest resource and management issues will mandate using more hardwoods, refractory species, imported/exotic species, small-diameter timber, plantation grown timber, and timber from short-rotation hybrids. Treatment and durability issues will involve the need for treatment of heartwood and refractory timber. This should eventually lead to species-independent treatments based solely on performance.

Changing forest resources and the economic advantages of using engineered-wood systems will mandate using more wood composites, I-joists and finger-joined lumber, and LVL and structural composite lumber. We will also see increased use of recycled materials in composites, structural fiberboard products, agro-fiber composites, and wood-cement systems.

Wood-thermoplastic composites have recently experienced a five-fold increase in use in the outdoor decking market and continued growth is anticipated. New markets will probably soon develop in both the siding and roofing markets.

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