THE GROWING EFFICIENCY OF WOOD IN BUILDINGS[1]

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ABSTRACT

Over the years significant improvements have been made in the efficiency of wood used in buildings as a result of technological advances by wood technologists and engineers. Some of our achievements are spelled out here because of the concerns expressed by some people prominent in associations and government that such advances are unattainable. Greater understanding of the strength properties of structural sizes of wood members has led to stress-rated lumber grades that allow buildings to be designed for efficiency and for decisions to be made as to size and quality (price) of construction lumber. Building and product design improvements, such as trussed rafters and use of plywood rather than one-inch sheathing boards, have reduced the amount of wood needed to perform given tasks. Wood technology can make future significant improvements in performance of timber in homes, stores, warehouses, stadiums, bridges, and schools. Technological innovations in traditional building industries have been and shall increasingly become available. We need wood technologists with the conviction and perseverence necessary to ensure adoption of these available and developing technological advances through well-thought-out and executed extension activities.

Additional keywords: Lumber grades, stress-rated lumber, building design, efficiency, application of technology, applied research, research and development.

Rather than striving to enumerate the great number of opportunities to improve the efficiency of wood in buildings, I would like to examine the impact of technology over recent years on this great market for forest products. The technical program of this year's FPRS Meeting will testify to the flourishing state of the technology.

PERSPECTIVES

The gains from technology tend to occur in small but continual increments, often not accompanied by great fanfare and not readily recognized by the general public. When we achieve a goal that seems really significant to us, we naturally become anxious that it be recognized and exploited effectively. The exploitation involves us in interacting social, technical, and economic considerations that go beyond our immediate control as wood technologists and engineers. We have become increasingly aware of this set of conditions as we have become more and more experienced. It seems useful to review this process from time to time so we will have a good perspective on our life work as researchers and also as users of the advances occurring in our technology.

We have frequently been disappointed in the rate at which we have been able to produce what we view as desirable change. Sometimes we are directly criticized for our enthusiasm to that end. Yet without enthusiasm along with reasonable patience, technical response to needs will not occur. So I would like to speak about this climate as it has existed in recent years.

About 1969, some national goals in housing were laid before us. The goals seemed to portend a healthy market for wood in housing. We were generally quite happy with these goals. They did imply a strong pressure upon our timber supply, and the right people began to consider that aspect of the proposals and to seek enlightened legislative action to encourage forest land productivity along with the most effective use of the timber from it.

I recall preparing some background on the possible impact of an accelerated cultivation of the use of existing wood technol-

[1] A paper delivered before the Society of Wood Science and Technology at the 1975 Annual Meeting on 15 June in Portland, Oregon.

ogy by builders. It seemed that this could develop rapidly and provide some relief upon the resource pressure while the foresters brought their skills to the important task of maximizing the yield of the timber resource. Like most of you, I was dealing with my own area of specialized knowledge and wished to offer a useful contribution.

Dr. Jerry Seamans, speaking on behalf of all of us from his position in research management at the Forest Products Laboratory, presented utilization potentials to the President's Advisory Panel on Timber and the Environment. The reception accorded his report was interesting. In the *Journal of Forestry* in June 1974, Ralph Hodges, Executive Vice President of the National Forest Products Association, encouraged the continuation of utilization research but did not place any confidence in it as substantially useful to the problem at hand—adequate housing for Americans.

Reviewing Seaman's report, which emphasized opportunities in the improvement of lumber and plywood yield per log and of various building practices that collectively could add about 25% to our home-building capacity, Hodges made the following remarks.

"His enthusiasm must be tempered by the record that, over the years, utilization engineers have held out comparable prospects *which have failed to materialize* (my italics). It may be possible that some day technology and economics will combine, as they did for softwood plywood, to prove him right. But significant breakthroughs on such a scale are rare in any industry. Continuing efforts to attain these objectives are worthy of support, but these possibilities should not divert attention from the job of *increasing timber growth.*"

Considering the natural biological process of timber growth, one cannot, would not and did not argue for the diversion of effort to increase timber growth. But Hodges' statement quite clearly said that the NFPA did not seriously believe that the wood technology community had much to contribute to the immediate concern. It was a rather black moment for those of us who espouse utilization opportunities. A preoccupation with timber supply in high levels of government has dominated the picture in the ensuing years.

There is, however, a body of the technological community sufficiently large to weather the unfavorable climate that appeared to be setting in. In their usual way, attending to matters in which they have confidence, utilization researchers have moved inexorably forward. The Forest Products Laboratory, without too much industry encouragement, has attended to its tasks in this area and fielded some well constructed programs. One thing we have learned from experience is to be prepared with useful new technology so it can be applied when the time is right. We are also learning that we have a responsibility to speak forth and to influence the arrival of that "time which is right."

OUR ACHIEVEMENT RECORD

The notion that the "prospects held out by utilization engineers had failed to materialize" is a curious one if one examines the historical facts.

Let us look at what the technology we advocate has involved. Most of our ideas enhance the performance of wood products. We believe that performance is what the consumer of forest products finds most interesting. We have witnessed a steady acceptance of concepts that have improved the performance values that industry assigns and engineers and technologists develop. Let us consider a few.

In 1932, lumber grades were presented in a very simple way. There were two stress-rated grades of lumber: select structural and dense select structural. Wood for beams, stringers, joists, and planks had no compression ratings. Posts and timber had no bending strength ratings. No grades had any tensile ratings.

Further, the lower grades, the ones that builders actually used for housing, had no stress ratings at all. Most lumber was not capable of being used in a legally de-

fensible design. Tradition was the cornerstone for building wood homes. It is pretty nearly impossible to innovate in a framework firmly set in tradition.

Today all lumber used in the load-carrying structure of a house is stress-rated. The builder may not know this, but the people who write the codes and survey the building practice know it. It is possible today to make choices between large pieces of lower-grade and possibly less costly wood and small pieces of more expensive and structurally superior wood, all within a performance standard for safety and quality.

It is not too hard to see what caused this change. Certainly the responsibility for public safety laid upon the building and safety departments of government had much to do with it. Code engineers, faced with 1930s and 1940s lumber specifications, simply inserted reduced strength values or, where none existed, their own concepts of safe strengths into their codes to permit them to operate with comfort. The results were not comfortable for either the industry or the builder. This rather drastic trend threatened the stance of wood as a competitive building material. The possible usefulness of technology became quite evident as the technical arms of the lumber manufacturers' association fielded this issue and headed straight to the forest products research institutions. The technical people were not entirely unprepared for this. They had foreseen the need and they had both information resources and some techniques available to produce effective stress-grading systems.

In the ensuring years, grading technology has made some sizable contributions to the economy of wood in housing. All grades have stresses, lending economic flexibility to the work of knowledgeable builders. Repetitive stresses for framing recognize the interaction that connected structural systems add to performance. Almost all elastic values are up 10% or more over conditions in 1940–41. Reliable *tension* properties have opened up the use of wood in trusses. Moisture-related lumber sizes recognize what practice had suggested, and actual seasoned lumber sizes are now more in keeping with need.

Today we get more lumber from a log and more performance from that lumber. I am going to suggest that during this 40-year period of time the amount of house per unit of forest timberland has increased 50%. This isn't obvious, in part because the delivered amount of wood per board foot has been reduced without any change in the board footage the builder orders and the statisticians employ. But the economy is there and it is the result of research and applied technology.

What has occurred here would not be favored in a straightforward proposal set out to reduce the amount of wood used in a house. Yet the manufacturers, the distributors, and in large part the builders and consumers are happy with what has evolved. Less wood per house hasn't really hurt the forest products business.

In 1964 the roof truss was mistrusted by some and denied by others. I have heard leading builders say that they can frame a roof by conventional methods so efficiently that the fabricated roof truss has no interest for them. Today they are all using fabricated trusses, and we know they do so because it pays them and it meets the structural standards of building authorities more effectively. Trusses knock 40 to 50% of the board footage out of a roof system.

Consider plywood in contrast to 1-inch sheathing boards. In 1960 I recall strong industry effort to combat the encroachment of sheathing plywood on the board market. It has not prevailed. Plywood provides the performance and the economic incentive builders need. If ever a product came of age via technology, this is it. Strength, rigidity, economy, convenience—all are there. But, for the purpose of this talk, the amount of wood in the plywood sheathing of the roof, walls, and floors of a house is about 60% of that needed to make the 1-inch boards that once were used.

Again, less wood per house has added to

the health of our wood building products industry.

The grades identified by the machine grading system are fundamental to a growing number of structural specialties. It has permitted certain lumber producers to receive value for material formerly not even recognized. The consumer has been willing to pay for performance. And, in the process, less wood goes into a building. A truss-framed warehouse uses less wood in the trusses than it formerly used in beams, and also permits extensive use of thin plywood where, formerly, heavy decking or extensive systems of purlins were needed.

In spite of all these incursions into the amount of wood in a wood house, we are consuming all the wood we can produce and demanding that the Forest Service squeeze even more growth per acre out of the nation's timberland.

These are a few more obvious technological achievements. They wouldn't have occurred if someone didn't have the knowledge to show they were sound improvements or if those people had not been able to say so in a very convincing way to all the building safety engineers and builders and house buyers who have such a vital say in the producing-marketing-consuming chain.

There are many more. Veneer-laminated lumber has been in its birth throes for 10 years. Today it is finding its place. Four-ply plywood is accepted. Structural panels from wood flakes and particles are beginning to move. All these things mean more houses from every acre of forest land.

I personally feel that adhesives have an overdue place in our building technology, and I expect to see them established there before 1985. If this occurs, another 20% may be added to the housing from our basic resource.

The emphasis has been on timber supply since the legislative arm of government became concerned about per capita wood resources. Even the NFPA devotes its energies largely to the timber supply problem these days.

GOALS

It is obvious that wood technology has a remarkably important impact to make upon the problem of meeting consumer needs, not for timber but for performance, for *homes* and *stores* and *warehouses* and *stadiums* and *highway bridges* and *schools.*

On several occasions this year I have compared timber to steel for specific structures. In every case, wood was economically superior *if* an *extra* ingredient of technology would be added, to depart from tradition.

Traditional though the building industry seems to be, it has actively adopted many technological innovations. Plywood-lumber components and steel-wood structures are common today. The builders have managed to *change enough* when the *justification* became evident.

These changes evolve when people with *convictions* and *ideas* and *ambition* and *staying power* see their personal opportunities. They are not the result of federal programs or sweeping reeducation of the builders or the propounding of intellectual forces. It is our task as technologists to play our role, continuously and unflaggingly. We must not be impatient. I have seen half a dozen gifted people walk away from this business, disappointed by its long response time. I have seen suppliers of potentially useful supplementary materials for housing turn to other things when a few years of effort didn't produce pots of gold. It's sad, but it is evidently necessary, human nature being as it is. The redeeming virtues are the real progress we see, *if we persevere long enough.*

Technology is being used effectively today in the forest products business. It is reaching into the world of distribution, where it must come to feel at home. Good salespeople comprise our most attentive audience. Conscientious builders are grasping the engineering they need to better implement research results. There is an important task for teachers to equip today's engineers and architects and builders and home owners with the technology that will

provide a receptive climate for the kinds of innovation that will make our timber resource serve a population twice the size of that it serves today.

I would hope to see the wood technologist extend his effort in the area of extension, to really concentrate on helping the builder do what he can do. We have long aided the farmer and the small mill operator. I would like to see more federal and state money devoted to extension work in the building field. Today I receive two or three unsolicited requests for help a month.

I would like to see an aggressive extension program, properly funded, that would produce two or three calls a day.

I am not sure we have educated enough wood technologists for these kinds of roles. If not, that is because we haven't recognized this need and we haven't created a place for people to be gainfully employed in this work.

If we do this, the research demands will mount and there will be a flourishing wood science and technology profession associated with the extension work and the new building practices it will stimulate.

It can truthfully be said that *the prospects held out by those engineers have materialized again and again.* Twenty years from now, when we look back at what has happened, these and other "prospects" will be clearly in the record.

It is very gratifying to read the kind of remarks made by George Weyerhaeuser last year before the Society of American Foresters in Vancouver, Washington, when he insisted on the long-term importance of utilization improvement and when he included it as a vital part of managing timber supply.

It is not uncommon to see items in the trade press advocating efficiency in the use of wood in housing. Industry funds have been directed at studies to demonstrate the adequacy of the lower grades of lumber in wall and roof systems and the optimum spacing of framing for efficiency. The NSF grant that Colorado State has used so effectively to develop the advantages of integral structural action and the resulting large potential economies was strongly supported by the NFPA Technical Department. The National Association of Home Builders has consistently aimed its work at material efficiency in housing.

There is an absence of unity in the attitude toward research directed at reducing the amount of wood in buildings. Obviously for some minds the thought of marketing less wood per house produces reservations, despite the fact that a steady trend in this direction is historic. The important point is that this trend is what has permitted wood to hold the housing market. If the reduction is the result of efficiency rather than substitution of nonwood materials, it need not be cause for concern. So, although we may not be unified, there is substantial acceptance that employment of technology to produce the most economical use of wood in quality housing has a role comparable in dimension to the improvement of forest productivity.

DISCUSSION

Fred Brown: Construction particleboard has been mentioned several times. I've been apprised of many discoveries in particleboard, but when they talk about structural particleboard, I get the connotation that all one has to do is simply arm particleboard with a phenol-formaldehyde resin to have a structural particleboard. I think they are misinformed.

Bob Hoyle: First of all, structural particleboard has just begun to emerge. Just a few firms are making what might be called structural particleboard. Generally, structural materials must have well-defined mechanical properties. They have to meet standards of durability for particular use applications. Interior or exterior? They don't have to be exterior quality panels, but they must have specific durability characteristics. I think that all that we are think-

ing about in structural particleboard is material manufactured to meet structural specifications and with quality control programs to assure that they continuously do that, as plywood and lumber do. There aren't too many such boards today. We see a tremendous potential for them. And they don't have to have oriented flakes although many people are thinking in those terms—we *know* we will be able to control properties through the orientation of particles just as we control, to some extent, the dimensional stability of plywood though correct orientation of the veneer.

George Marra: Structures require load-carrying members to be quite durable. So wouldn't it be true then, that with structural particleboard we might expect it to be made from phenolic resins?

Bob Hoyle: Durability is important, of course. We also need to understand the rheology of this material better. We're beginning now to develop this. The Forest Products Lab and others are studying this problem.

I don't think that phenol adhesive is the sole criteria of structural quality. There are some swelling considerations and some strength considerations not resolved by phenolic bonding. Under some conditions, some existing particleboards have structural utility. With a little more quality control their reliability might be enhanced. But under the kind of goals we're really shooting at for structural particleboard, the important feature is to suitably and systematically produce a specification with respect to physical and strength properties.

Fred Brown: How are the moisture and irreversible flow characteristics of particleboard related to phenol vs. urea formaldehyde resins, or any other kind of a resin?

Bob Hoyle: We had thought for a while that just more and more phenol would provide what was needed, but I don't think we believe that is the only requirement.

F. A. Tayelor: I think in this area of so-called structural particleboard or reconstituted panel products, that initially these products were seen as a means of achieving higher profitability from what was a waste or residue material. They found a market and use that suited the properties of those products that they were manufacturing. Now people are beginning to see the potential for structural applications that involve long-term durability and other physical characteristics, and I think that the manufacturers really need to be told what properties these boards must have to satisfy requirements that will vary. Introducing phenol for urea is certainly, to my way of thinking—and I'm far from a panel products expert—not the answer because phenol-bonded boards can exhibit pretty wild stability characteristics when exposed to moisture fluctuation.

Ed Sprague: I want to address some remarks to the matter of getting technology implemented in the building field. First of all, more and more of our states are adopting a national code, and more and more enforcement is coming down to the local level. While we've got a uniform code, the responsibility falls on the shoulders of the local inspector as to what is done. I wonder what your reaction is to this so far as getting new technology applied. Somehow, I feel that there is an opportunity. Right now it seems like a problem because each man has this responsibility and refuses to adopt something new until he has documents to show him that it is okay. It has to come from some source that he trusts. Did you have good results in getting new technology applied?

Bob Hoyle: The major building codes have provisions that permit innovation. The processes are formal. They require much of our time as manufacturers and developers of new products. They don't cost us a lot in fees. In fact, I don't see how the building code authorities can afford to do the work they do, in terms of product approval, for what they charge. When you've worked your way through the new product approval processes, you achieve something of enormous value. The resulting documentation makes it possible for the new glued floor system or the new truss or the new type of prefabricated roof panel to be

widely used and recognized for its quality throughout the jurisdiction where that code is used. I haven't thought of the code as an obstacle for many, many years. There's the occasional code that is politically drawn and is pretty difficult to deal with. But they're rather unusual. My thought is that at least the codes, themselves, recognize innovation and they're really an advantage to anybody that wants to establish new product concepts.

Ed Sprague: I'm just wondering if, when you work on a one-to-one basis with these building inspectors, are there ways of documentation—that certain things have been done in such and such a place?

Bob Hoyle: You have to tell the building inspector what's in his own code sometimes, show him what products have been approved. The code itself doesn't contain approvals of new ideas. As new concepts become well established they find their way into the code. Most of the building code authorities have a process of product approval and they issue reports on each of these innovations, describing the circumstances under which they can be used. This provides the building inspector with some place to hang the responsibility, a committee composed of fellow building inspectors who pass on these approvals. Once he is made aware of these actions, you usually don't have much trouble getting his approval to use the new ideas.

Ed Sprague: How do we get our hands on these changes?

Bob Hoyle: Every building department that is using the Uniform Building Code, for example, should have a current file of all the approved special products, usually called "research recommendations." Other regional codes have similar means for recognizing new innovative products. The manufacturers of new products who are trying to promote their materials generally will be glad to hand you a copy of the "research recommendation" that covers their product. They probably will distribute it with their advertising.

F. A. Tayelor: Could I address myself to the question the gentleman asked. The local building man, the so-called authority having jurisdiction, who is the man who puts his stamp on, often will not accept something from you, even if it's very well documented, if he's had no input into it. Most building officials—I think this is a human reaction—are reluctant to accept a package all tied up in a blue ribbon that says "Here it is, put it to work." But if you invite them at the outset to participate in it and say "Here's some new technology we've developed. We're going to demonstrate it and test it. We'd like your participation. We'd like your critical comment on our testing program." If they had that input initially and they have the opportunity of going back to their city council and are asked "Do you know about this?" they can say "Oh, yes, we participated in this. We made some critical comment on the testing program." They're much more apt to accept it and put it to work. They understand it. If you've got some technology you want to introduce in Los Angeles or San Francisco or Denver, you can pick building authority groups from those areas and invite them to have a look at your program. If they do and have committed themselves and say "Yes, if you demonstrate, if you prove through your testing program that such and such is so, we'll accept it," this is generally a pretty good way of getting most of the way to your goal.

Bob Ethington: I just wanted to comment on Ed Sprague's question and suggest that perhaps that we use codes as a whipping boy too much in many of our problems. About five years ago, the National Association of Home Builders began studying why innovation didn't take place among the members. They did this by polling and taking a representative sample of their own members and dealing with them through questionnaires. But I guess that when they did this they really expected that they were going to learn that building codes were the greatest barrier to innovation on the part of home builders. It turned out this wasn't the case at all. Their own members said the biggest reason why they didn't pick up innovations was their own lethargy. I think

building codes were about the fourth thing down the list. But that seems to suggest to me in terms of Bob Hoyle's talk that maybe, indeed, some kind of extension activity is one of our biggest needs. There must be some way to reach people with ideas packaged up in such a way that they will make use of them.