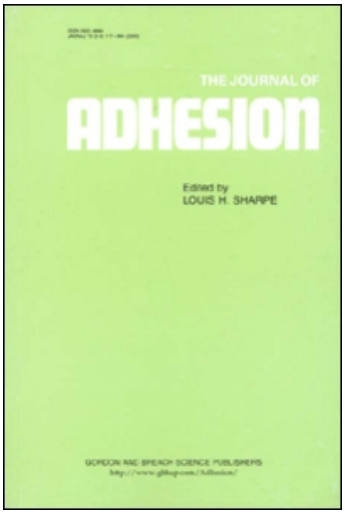

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The Importance of Bonded Structural Material

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Gluing is of tremendous importance to the wood industry. About 70% of all wood used today involves gluing. As an increasing amount of lower quality wood is used in the future, gluing will become even more important. Additional developments in harvesting previously unused species and forest residues and cleaning dirty material, and a means to reclaim urban waste wood, are needed to assure an adequate wood supply. New or improved economical adhesive systems will be important in accelerating the development of glued products. The future of the wood products industry lies with the use of glue, since the wood raw material will continue to be harvested in ever smaller sizes.

THE IMPORTANCE OF BONDED STRUCTURAL MATERIAL

The importance of bonding structural wood materials of all descriptions to non-wood materials is a difficult subject to address because of the numerous and varied applications available. A wide range of products forms the array of materials which are bonded. It has been estimated that up to 70% of the wood materials in the US are bonded in some way.[8] At the opening of this symposium it is therefore appropriate that we consider the value of glued wood materials as well as their potential (which may evolve into an absolute need), and what we must do to expand the glued materials field. This paper primarily discusses North America's practice but, as will be noted, the supply of wood is already at crisis levels in other parts of the world. Glued wood materials are thus important world wide in developing maximum use of the forest resource.

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The present economic impact

Wood is one of mankind's most valuable raw materials. It is easy to use and serves as raw material for a wide range of products such as fuel, building materials, industrial products, paper, chemicals, and even food. Its availability and abundance has lulled much of the world to sleep—so much so that a worldwide scarcity has developed. This has been known in forestry circles for some time and was brought home to the general populace by the *Newsweek* article, "Vanishing Forests", where it was stated, "The real crisis today is not oil but wood."[9] The value of wood, as compared with other major industrial raw material resources, is shown in the following table.

TABLE I

Industrial raw materials, 1977[14]

Material	Billions of 1972 $	% of Total
Industrial timber products, not including fuel	6.18	26.8
Minerals except fuel	12.64	54.8
Agriculture & fishery nonfood	4.23	18.4
	23.05	100.0

The increasing demand for timber in the US is presented in the next table. By 1990, the demand and value will increase over 50%. These estimates are on a medium projection and cover industrial timber products only (sawlogs, veneer logs, pulpwood, miscellaneous products, and fuelwood).[14]

Considering actual value of product or service, the data published in 1977, using 1972 dollars as the base, show about $6.4 billion in harvesting, $23 billion in primary products, $35.5 billion in secondary products, about $159 billion when looking at the wood used in the construction industry,[14] and $116 billion in wholesale and retail trade. Value added to these economic

TABLE II

Year	Timber demand (billion cu ft)	Value (1972 $ billion)†
1976	13.3	6.18
1990	20.3	9.43
2000	22.7	10.55
2030	28.3	13.15

† Values calculated by author based on 1976 data.

activities as a total attributed to timber was about $49 billion. The total impact on the economy of the US is staggering.

Even allowing for large estimating errors, it is apparent that wood is of tremendous economic significance. And an important facet of this economic impact is that a majority of the wood materials used are in some way glued.

Consumption of various wood products is generalized in the following table:[11]

TABLE III

Product	Consumption (million cu ft) World	US
Paper & paperboard	5,646	2,110
Sawnwood & sleepers	15,563	4,017
Wood-based panels	3,632	1,168
	Per capita consumption (cu ft)	
Product	World	US
Paper & paperboard	1.3	9.7
Sawnwood & sleepers	3.7	18.4
Wood-based panels	0.9	5.3

Lastly, the economic impact in the US also can be measured by the number of primary processing plants involved (including logging). A good estimate is:[2,14]

13,200 Logging operations
10,000 Sawmills
230 Softwood veneer & plywood plants
360 Hardwood veneer & plywood plants
125 Composition board plants
330 Pulp mills

Thousands of secondary processing plant workers and on-site construction crews, in combination with the primary processing plant personnel, total an enormous number of people who derive their livelihoods from the forest. In 1972, one out of every 25 individuals employed in the US was in a timber-based economic activity.[14] The manufacture and use of forest products is one of the largest, if not the largest, industrial complexes in the country—and glue is an integral part of this complex.

The immediate future

We know that there are about 500 million acres of commercial forest land in the US and that this amount is slowly being reduced because of urban sprawl,

expanding rights-of-way, converting forest land to non-wood uses, *etc.*[15] We also know that the sizes of the harvested logs are now much smaller and because of this the wood quality is lower. To utilize this wood efficiently, smaller pieces must be glued together.

The US is a net importer of wood and some forecasters are predicting that this will continue to be the case in the future. Therefore the situation throughout the world must be viewed as well as that within the US. Many countries are already running out of the preferred species for export and indeed some countries are no longer in a position to export.[6] There is a world-wide movement to increase the cost of export logs and some countries are demanding that most of the logs be converted to products before any material can be exported.[10] In some countries increasing amounts of wood and wood products are being used at home for domestic building needs.[4]

Probably the greatest impact on wood availability is the need of many countries to burn their wood for fuel. When considering that about half of the world's roundwood goes to fuel,[13] it is a sobering realization that there just isn't a vast, untapped wood resource available for use by the industrialized countries at a low price. Furthermore, in the tropical countries where most of the forests which have been harvested for export grow, more than 80% of the harvest is used for fuel.[12] Canada, a great wood exporter, cannot be counted on for continued export to the US.[16]

It has been shown that our forest land can grow much more wood by proper care and management. A large amount of industrially owned forest land is successful because of such attention. But about half of our forest land is federally owned and has not been well managed because of lack of funds. Much private land has also not been properly cared for for a variety of reasons, including tax disincentives and lack of concern. The forests must be managed more efficiently—but this is something that can only be done in the future.

The important point that must be stressed is that for the immediate future, the trees for all present-day uses are growing now. Moreover, as discussed, the US may well have to rely mostly upon its own forests as the import sector may disappear—and the only possible way to get more product from the forest, according to our present harvesting schedules, is through the use of glue.

The new raw materials

The new raw materials are those small pieces of forest residue left behind during harvest, low quality trees not previously used, dead standing timber, the unused hardwood forest, and wood available through recycling. These materials are present in staggering amounts, but research and development is badly needed before much of these materials can be used economically.

In Table IV we see that the bond area for gluing 1 sq ft of lumber into a cu ft

TABLE IV

Comparison of adhesive usage in consolidating 1 cu ft of various wood elements of Douglas-Fir, original density 28 lb/cu ft[7]

Wood element	Bond area (sq ft)	lb of resin/ lb wood	Thickness of glue line (in)
1 in boards	11	0.015	0.005
0.100 in veneer	119	0.032	0.0012
0.050 in wafers	240	0.050	0.0009
0.010 in flakes	1,200	0.050	0.00019
0.001 in fibers	24,000	0.050	0.000009

block is 11 sq ft and the thickness of the glue line is 0.005 in. We supposedly understand the gluing of lumber. But as we reduce the element size from lumber through veneer, wafers, flakes, and finally fiber, the bond area per sq ft increases tremendously from 11 to 24,000 sq ft (an increase of 2,180 times) while the glue line thickness decreases from 0.005 to 0.000009 in. (a decrease of 555 times). We cannot explain the bonding found in fiberboard. We logically could expect no bonding with the fiber—but there is, and this degree of bonding yields boards of good quality.

Scientists are working on all the subject matter mentioned above as well as on new and improved adhesives. We need a far greater effort, however. We have a very large industry. We can justify large research expenditures because of the needs and the potential rewards from such research.

In total, the wood industry has a very significant research expenditure when all government, university and industrial research is considered.[5] But we don't compare with other industries that are now working on research for implementation 15–20 years from now. The Boeing Company, for example, in its aerospace operation, has an annual sales (1980) of $9.4 billion. Its research and development budget was 8.2% of sales, or $767.5 million.[1] The wood industry will have to spend similarly on its high research priorities, and adhesives and adhesion has to be one of the highest priorities, if it is to remain a leading US industry.

What is needed

We are far behind in the research and development needed to use our wood resources wisely. We have the raw material, but we have to develop economical means for harvesting the material not now being used. This calls for new harvesting methods, ways to clean "rough" material (usually chips with the bark on and contaminated with dirt), new processing equipment in the mills, and new product designs to use all of our raw material efficiently.

We need to understand the fundamentals of gluing. Much excellent work has been done in the past. Now, however, we have sophisticated new equipment for gluing research. This equipment is allowing scientists to make significant observations and much new knowledge should be gained in the near future. As an example of the understanding needed, consider Table IV.

It is difficult to be precise about the amount of such material available. Inventories have not been estimated until recently, so there is no historical data. The amount of wood available and used is normally shown as *roundwood*--not the total volume available. There has been speculation that the total volume grown cannot be used because certain amounts of the wood may have to be left in the forest to maintain the soil and help generate the next crop. Researchers are addressing this subject, and it has been determined that in the US generally the forest material can be totally harvested and used, except in areas with dry and fragile soils, with no adverse effects.[3]

We know that there are tremendous amounts of material for use. Approximately 81 billion cu ft of unused forest residues, or about six times the total annual demand of roundwood, is now available.[14] Mostly unused hardwood forests, equalling the southern pine forest in wood volume, are growing right along with the southern pine. There are large hardwood forests in the Lake States and the Northeast. The hardwood forests make up about 58% of our total land[15] and produce about 34% of our wood. About 2.8 billion cu ft of urban wood wastes are available annually.[14] This wood is located primarily in the heart of heavily populated areas. It may be more difficult to use, but the exhorbitant shipping costs associated with products made with virgin wood may more than offset the higher production costs associated with urban wood wastes.

The wood is there. Economic production processes and adhesive developments are needed to make efficient use of this "other wood".

We are looking for adhesives that are resistant to deterioration from heat, moisture, oxidation, fungi, and bacteria. Further, some adhesives must be tolerant of a variety of wood moisture contents and processing temperatures, some must be gap-filling, some must be able to glue dissimilar materials, some must be rapid curing, and others must be cold setting at lower temperatures than are now possible for field applications. Wood products must also be more dimensionally stable.

We must deliberate and agree on terminology and specifications. We must agree on test methods and quality control procedures. It may even be necessary to develop international agreements on these matters.

CONCLUSIONS

Wood is one of the most important raw materials in the world. The days of an abundant supply of easy-to-use wood are over. Therefore, gluing is not only economically important in the wood industry, gluing is the future of the industry.

All those involved in wood bonding research and development are struggling to develop a solid foundation for the expansion of the industry. Those involved now are among the pioneers. Many have made important contributions in the past. The stage is now set to build upon these contributions.

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