JUVENILE WOOD: PROCESSING AND STRUCTURAL PRODUCTS CONSIDERATIONS

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Abtract.--The increasing amounts of juvenile wood reaching wood products companies present problems in manufacture of the products as well as problems for the consumer, particularly for users of structural products. Processing problems include warpage and excessive drying degrade in lumber manufacture and reduced grade recovery in MSR operations. Low or unpredictable strength properties of juvenile wood may result in poor structural performance; high longitudinal shrinkage characteristics may lead to severe warpage, as in the "rising truss" problem in home construction. Lumber grading and product performance (quality control) will need to be changed to accommodate the plantation resource as juvenile wood percentages in lumber products increase. Continued research in genetic heritability, appropriate silvicultural tactics for plantations, and lumber or product quality assessment is recommended.

Keywords: Plantation conifers, fast-growth, juvenile wood, wood quality, structural lumber, strength properties.

INTRODUCTION

Fast-grown, short rotation plantation softwoods are reaching the processing plants and the consumer in increasing amounts. Indications are that in the future the forest industries will rely heavily upon plantations of genetically selected fast-growth trees for raw materials. As has been pointed out by previous speakers, this means that the proportion of juvenile wood in the material reaching the mills will probably increase dramatically. Although this trend is in motion, and very likely unalterable, we can anticipate numerous problem in using this "new" resource. The problems are relatively easy to enumerate; the solution8 are much more difficult to prescribe.

Juvenile wood is defined as wood formed early in the life of a tree, usually including the first 8 to 20 annual growth increments. It occurs in both softwoods and hardwoods. It is generally characterized as having lower than average density for the species, wider annual increments, shorter cell length, lower cellulose content, higher microfibrillar angle (and, hence, longitudinal shrinkage several times higher than normal), and significantly lower strength properties (1). Bendtsen and Senft (4) have pointed out that, depending, of course, upon species and rotation age, logs reaching the sawmill from plantations may well have 25-40 percent juvenile wood prior to being slabbed for lumber production. It is obvious that the characteristics and quality of the finished product are directly related to the properties of the wood in the forest. And for products of a structural nature, juvenile wood is particularly detrimental. The purpose of this paper is to point out and discuss the potential problems arising from the use of increased amounts of juvenile wood in products, primarily those whose use depends upon strength and/or dimensional stability.

There are two problem categories to be considered: problems in wood processing and problems in product quality or consumer acceptance. There may be some overlap in these categories since a cause–effect relationship may often appear at several stages of manufacture or use of a product. For purposes of this symposium I prefer to adopt the stance of a "user" of wood in the form of lumber or in the form of a finished product, whether it be a joist in a building or a chair frame in my office. Most of these problems will tend to raise costs through extra handling or closer inspection of finished product and/or to lower profits due to lower product value.

PROCESSING PROBLEMS

There are several examples of general processing problems which arise from, or are aggravated by, the presence of juvenile wood. Many of these effects, naturally, carry over into the finished item in some way.

1. Pulp and paper. Because juvenile wood has shorter cell length than normal wood and is lower than normal in cellulose content, pulps from juvenile wood are reported to have good tensile, burst and fold properties and good sheet smoothness, but have lower than normal tear strength and opacity than pulps from mature wood. For chemical pulping processes, digester capacity is a major determinant of pulp output. Low density juvenile wood chips result in reduced digester output per cubic foot of input. Thus, it may be supposed that pulp mills will pay less for fast–growth plantation thinnings. Mechanical pulping processes, however, use less energy in processing low density material and may prefer larger percentages of juvenile wood in their mix. Pulp may still be the preferred use for juvenile wood.

2. Short–rotation plantation conifers have a lower percentage of knot–free wood. Since knots are areas of structural weakness which are taken into account in the visual stress–grading process, plantation conifers may be anticipated to produce more knotty lumber. However, genetic research may lead to smaller diameter knots.

3. Juvenile wood has a microfibrillar angle orientation in the S–2 cell wall layer that is larger than that of mature wood. As a result, there is abnormally high longitudinal shrinkage. Furthermore. since juvenile wood characteristics in general tend to gradually change from the pith outward until maturity is reached, juvenile wood may be expected to warp due to unbalanced shrinkage characteristics. This will be particularly true in pieces cut close to the pith or if the pith is not centered, or balanced, in the piece. As a consequence, larger amounts of lumber containing juvenile wood will result in increased degrade during drying and storage. The presence of compression wood compounds the problem. And since one or two badly warped pieces in a stack may distort many adjacent pieces, banding or a restraint system of some sort may be necessary. Degrade and increased handling costs in seasoning will be associated with juvenile wood.

4. Any wood member to be used for structural purposes must be stress-graded, that is, evaluated in terms of its strength properties. This may be done visually or by machine. In the visual grading system a grader looks at all four sides of a member and at the ends to locate any strength–reducing characteristics (primarily knots, splits and slope of grain). This is accomplished in a matter of just a second or two. Several years ago the softwood grading rules recognized four rate of growth categories - dense,

medium grain, close grain, and open grain. These categories were set up to acknowledge the fact that slowly grown wood with many rings-per-inch was quite dense and had higher than normal strength. Conversely, wood with faster growth rates was usually less dense and was weaker. Thus there were categories within structural grades which had growth rate restrictions in addition to defect restrictions. "Dense" material was defined as having 6 or more rings-per-inch and 1/3 or more summerwood in each ring or less than 6 rings-per-inch if 1/2 of each ring was summerwood. "Close grain" was to average 6-30 rings-per-inch and "medium grain" was to average 4 rings-per-inch. Open grain had no restrictions. Southern and western softwood rules were similar in this respect. The 1977 SPIB rules dropped the medium grain and open grain categories (6); the 1980 WWPA rules (7) dropped the close grain category. Part of the reason for this action is that several studies have shown that ring width and density are poorly correlated and that rate of growth is often confused with juvenile wood, which often has wide growth rings. However, recognition of this fact has, in effect, overlooked the serious negative effect of juvenile wood. For the structural lumber user the question arises as to how one can assess quality categories for softwood lumber if rings-per-inch is not a recognized criterion. Proximity to the pith would perhaps be a better factor; but for the present there is no way to delimit juvenile wood or exlude it from stress grades. If, as Bendtsen and Senft contend, juvenile wood on the average is about one-half the strength of mature wood, stress grading rules which do not take this into account permit tremendous variability in lumber performance to enter the structural arena with much of it well below expected strength levels. There are obvious cost-value ramifications, which will be discussed further under product quality problems.

5. A potential solution to the problem of identifying weak juvenile wood in the grading process is to machine-stress-rate the lumber. In this process lumber is sent through a machine which flexes each piece slightly to evaluate its stiffness. A grade is assigned through a statistical stiffness-bending strength correlation. The system has proven to be accurate and reliable and is the desired grading system whenever high strength levels or consistent accuracy in stress assignment is necessary. Truss manufacturers, for example, prefer MSR lumber. The problem lies in the fact that the MSR system properly identifies low stiffness-low strength pieces and places them in the lower grades or non- stress grade categories. Hence, a relatively expensive mechanical grading apparatus, which is justifiable because it can identify those valuable, very high quality members that the structural component industry demands, will reject juvenile wood and relegate it to a low value product class. The economic justification for an MSR system disappears when short rotation stock becomes the raw material source.

PRODUCT QUALITY PROBLEMS

These may be termed producer or consumer problems and reflect the fact that juvenile wood often results in inferior product performance. There are numerous problems; I'll mention just a few outstanding ones.

1. The low specific gravity - low strength properties associated with increasing amounts of juvenile wood probably raise the most serious potential problems. Joist and beam strength is reduced on the average and strength variability is increased,

Truss manufacturers and laminators must have high strength, reliably graded members if they are to, first of all, compete with steel and concrete as a building material and, secondly, avoid disastrous law suits when structural failures occur. There are currently instances of structural failure in trusses wherein members are of juvenile wood. For many years the laminating industry has had restrictions on "pith-associated" wood to eliminate the earliest juvenile wood from laminated beams. Increased amounts of juvenile wood (or less mature wood) will increase the probability of leas than adequate beam strength and increase costs for added quality control measures. A short-term alternative will be for producers of products requiring special wood quality characteristics to become more selective in their purchase sources to avoid plantation sources.

2. A closely related problem exists in the ordinary grades going into the housing market as framing lumber. To pursue the rather dire assumption that a joist containing significant amounts of juvenile wood will, on the average, have about 60 percent of the strength of a joist cut from mature wood, we may calculate equivalent lumber sizes based upon bending strength and member depth considerations. It should be pointed out that although we may be thinking primarily of southern pine at this symposium, these structural considerations apply equally to any species or region. Bending strength in a beam is dependent upon the section modulus, $bd^2/6$. of the beam. For a beam, simply supported, and changing member depth. d, to produce equivalent section moduli, member depth would have to be increased by a factor of 29 percent. Thus,

a nominal 2 x 4 is replaced by a 2 x 6 (30-40% cost increase)
a nominal 2 x 6 is replaced by a 2 x 8 (50-60% cost increase)
a nominal 2 x 8 is replaced by a 2 x 12 (100% cost increase)
a nominal 2 x 10 is replaced by a 2 x 14 (?)

Integration of large amounts of juvenile wood into the market place through size-strength equivalence is, obviously, economically absurd.

3. Another related problem lies in the extensive use of chipping head-rigs. These rigs have been developed to efficiently reduce smaller trees, primarily from thinnings of six to 20 inches in diameter, into marketable two-by material. It's a good example of' high technology being applied to improving the utilization of our wood resource. But many of the joists produced in this manner are predominantly juvenile wood and inferior from a consumer point of view.

4. The same problem, expressed from a more philosophical point of view, has to do with the fact that allowable design stresses published by the National Forest Products Association (4) are direct modifications of average strength values derived from ASTM tests. The design stresses are modified for material property variability, but the lower strength, higher variability represented by members manufactured from juvenile wood are not properly represented in the current stress derivation procedure. Add to this the situation of a small builder who may receive his material from one log run at one mill and get predominantly juvenile wood, and obvious problems arise. Also, at the present time the vast majority of builders/consumers have no knowledge of juvenile wood or its characteristics. For that matter, most architects and wood engineers rely almost entirely upon published design values and lumber grade information and pay little, if any, attention to job-site lumber quality. Declining quality, on the average or in specific instances, will ultimately reduce consumer confidence in wood.

5. Juvenile wood poses problems with design of wood fasteners - nails, screws, bolts, and metal plates. The Wood Handbook (8) and the National Design Specification (4), which are major sources of information and design methodology for engineers and architects, list methods for fastener design, For both with– drawal and lateral resistance for nails and screws allowable loads are related either to tabled values of wood density or to species groups, where the groups are directly dependent upon species average density. Bolts, metal plates and timber connectors are similarly dependent upon wood density. Low density juvenile wood can result in reduced joint strength and design errors.

6. As referred to earlier, juvenile wood has a large longitudinal shrink–age component. This leads not only to shrinkage–warpage problems in lumber manufacture but also to product use problems. Stress imbalance in panels, warped beams, twisted framing, etc. may be expected to lead to customer dis–satisfaction. One possible solution could be to dry wood at some stage of manufacture down to or close to its anticipated final moisture content, a costly process followed in the furniture industry but rarely done in the struc–tural products field.

A problem unique to the housing industry has recently made headlines in the research literature. It is the "rising truss" phenomenon (3,5), which has been traced to unusually high longitudinal shrinkage of juvenile wood often compounded by the presence of compression wood in the lower chords of house trusses. Separation between the lower chord of a truss, to which the ceiling is attached, and room partitions may be as much as three–quarters of an inch. Since the phenomenon is sporadic in occurrence, it has builders and new home–owners frustrated. Numerous lawsuits have already been initiated. The increase in this phenomenon in recent years nay well reflect the "new timber resource".

7. As the engineering and structural design tactics of designers has grown more sophisticated and as the size and complexity of wood structures has increased, new design methods have appeared. One of these new methods is reliability–based design; it has come of age for steel and concrete and is being developed for wood. One of the keystones of this technique is the abil–ity to accurately and reliably assess the physical–mechanical properties of the material being used. Cost effectiveness is directly related to accuracy in grading and to the ability to control or reduce variability in lumber proper–ties. Fast–growth, short rotation trees tend to do the opposite, and struc–tural lumber from this source may well be shunned by progressive manufacturers in the future.

8. An area where wood quality impinges directly on structural applica–tions is in performance standards and performance testing, Truss tests, tension testing of finger joints, testing of floor constructions, and the in–grade lumber testing program are some examples of performance testing applications. This tends to be a two–edged sword in that it may be used to ascertain performance in a prototype or to prove performance as a quality control measure. Strength in place is required; poor quality is proven and rejected. Performance standards in some instances may prove to be a means of utilizing lumber from the inner portion of a tree, but the process will be costly in material since larger sizes will probably be dictated.

9. The export lumber market is growing, but primarily for higher quality material since transportation costs represent a substantial portion of the total cost and are independent of lumber grade. Uniform, reliable quality is a necessity. Juvenile wood is probably not well suited to this market.

10. A possible outlet for low density juvenile wood is as furnish for particleboard. Particleboard favors lower density material and strength is apparently not seriously impaired by the inclusion of juvenile wood. However, indications are that thickness swell and dimensional stability may be significantly altered. But the advent of "engineered shapes" of particleboard presents a different picture; structural particleboard, oriented strand board, I–beams with particleboard webs and lumber flanges may be another matter. Reliable property values accurately assigned will be extremely important; the source of the furnish for boards going into this market will also be very important, at least as much as it is in the structural lumber markets.

11. There are other unresearched, unresolved problems regarding fast–growth material. We know little about how this material will perform in regard to treatability (preservatives, fire retardant treatment), durability (probably reduced resistance to fungal and insect attack), machining, finishing, and the rather involved duration of load–temperature-moisture equilibrium relationships,

CONCLUSIONS

Fast–grown, short rotation tree crops may be anticipated to have a large proportion of low density, inferior strength juvenile wood. The average structural quality of wood products which depend upon wood strength for their marketability will be lowered, This will raise problems not only of how to process products to overcome increased shrinkage–warpage problems but also of how to accurately identify quality. Non–destructive testing or machine–stress–rating techniques will probably be used. Growth rate in relation to proximity to the pith may be a useful quality criterion, but cumbersome, A rapid test for specific gravity as an indicator of acceptable density would also be useful. Ascertaining quality in the end product (truss, laminated beam, ladder rail, etc.) will be even more difficult, but the consumer will demand this in the future and economics will force some means of product quality verification.

Potentially rewarding avenues of research, It seems to me, could include:

1. The continuation of the on–going program to genetically select plantation species for increased specific gravity and other desirable, heritable traits, such as rate of change from juvenile wood to mature wood, cell length. degree of juvenile wood, etc.

2. Further research on improved silvicultural techniques for plantations. Less intensive thinning to reduce growth rates somewhat until maturity is reached to reduce the percentage of juvenile wood in a harvested stem may be productive. Once maturity is reached, greatly increased growth rates through fertilization and thinning may be profitable.

3. Lengthening rotation times should be considered; this may be an economic dictate imposed by consumers. Obviously, economic constraints and consumer

attitudes will need to be studied.

4. Study of the feasibility of separating material. from the inner core from more mature wood. Such material could be diverted to paper or particle-board manufacture while mature, stronger wood could be graded via MSR or a quality control test into structural lumber or finished products. Research at Purdue and other laboratories is designed to study various means to assess quality and promote maximized, efficient resource use commensurate with safety and end product use.

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