CURRENT STATUS AND FUTURE OF STRUCTURAL PANELS IN THE WOOD PRODUCTS INDUSTRY

by

Henry M. Montrey, III

B.S., University of Missouri - Rolla
(1967)

Ph.D., University of Wisconsin - Madison
(1972)

SUBMITTED TO THE SLOAN SCHOOL OF MANAGEMENT AND THE DEPARTMENT OF MECHANICAL ENGINEERING IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE IN THE MANAGEMENT OF TECHNOLOGY

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

June 1982

Signature of Author..
Sloan School of Management and
Department of Mechanical Engineering
May 7, 1982

Certified by..
James M. Utterback, Thesis Supervisor

Accepted by..
Warren Rohsenow, Chairman, Departmental Graduate Committee

CURRENT STATUS AND FUTURE OF STRUCTURAL PANELS IN THE WOOD PRODUCTS INDUSTRY

by

Henry M. Montrey, III

Submitted to the Sloan School of Management and the Department of Mechanical Engineering on May 7, 1982 in partial fulfillment of the requirements for the degree of Master of Science in Management of Technology

ABSTRACT

For decades plywood has been the dominant structural panel in U.S. light frame construction markets. In recent years, however, its status has been threatened by new generations of replacement products.

This report analyzes the causes which have led to these new product introductions. Each new panel type and its associated process technology are described, and a summary of current production status in the industry is presented. Key variables affecting future success of the new panels are analyzed. Plywood's vulnerability and the potential counter-offensive strategies available to it are analyzed. The role of product performance in establishing markets via building code approvals is discussed and a summary of current code approvals in the industry is assembled. Potential new markets available to the replacement panel types are described.

On the basis of technological, economic, political, and market arguments, a forecast for the future of the U.S. structural panels business is presented.

Thesis Supervisor: Dr. James M. Utterback

Title: Associate Professor of Engineering

ACKNOWLEDGMENTS

I wish to acknowledge gratitude to my thesis advisor, Professor James Utterback, for his help and guidance in researching and writing this document. I would also like to express appreciation to Professor Edward Roberts for his review and critique of my work.

Speical thanks are extended to Messrs. Charles Anthony, Harry Chase, and Francis Hefty of the Weyerhaeuser Company for the information, insight, and assistance which they extended to me. I would also like to thank Mr. Thomas Flint and Dr. Michael O'Halloran of the American Plywood Association for their help.

I am especially indebted to Ms. Jane Morse who, as Manager of the Joint Program in the Management of Technology, has been a continual source of help, advice, and encouragement throughout my tenure at M.I.T.

Finally, I would like to acknowledge appreciation to Miss Debra DiFiore for her expert typing of the manuscript.

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

One of the most highly fragmented and decentralized industries in the United States is that of building construction. This is particularly true for the construction technique which is most often applied to the activity of building residences -- known as "light frame construction". The decentralization and fragmentation inherent to this branch of the construction industry historically has created roadblocks to innovation both in construction systems and in the materials and components which provide the ingredients to those systems. The problems of innovation are in large part problems associated with sophisticating an activity which by its very nature is required to take place at numerous decentralized sites.

Arthur D. Little (1) has viewed the fragmentation in the light-frame construction industry as occurring on two levels. First, the industry is made up of thousands of relatively small companies (although trends over the last decade have been toward some consolidation of construction contractors). Second, these small firms represent many diverse segments of construction activity: architects, designers, structural engineers, and suppliers and manufacturers of components and construction materials. Because each of these participants carries out his activity in the context of his own concerns and standards and attempts to maximize his own personal individual profit, no one emerges with responsibility for the overall building task. For a newly initiated innovation to be diffused throughout this system, each participant must recognize and accept it. However, he is unlikely to do so unless it provides him with an incremental economic pay-off or, at most, does him no economic harm. All participants must, therefore, be sold on the merits of an innovation before it can be successfully implemented. Because the interests of these key actors are frequently incompatible, getting such a consensus is difficult.

As an example of system-fostered conflicts, consider the architect, whose output is motivated by his personal concepts of style and functionality; the engineer, whose preferences are with structures which analysis and experience label as safe; the construction contractor, who favors methods and materials he has experience with and who is concerned with reducing on-site costs; the construction laborer, who is naturally suspicious of new building materials with which he has no prior experience and who institutionalizes his resistance to change through his trade union; and the materials supplier or manufacturer, who is unreceptive to any innovation which may threaten the markets for his products. The conflicts built into this system severely reduce the likelihood of any innovation being carried to fruition.

In addition to these conflicts, another traditional roadblock to innovation has existed in the light frame construction industry which has arisen from the control over building activity held by government agencies which enact building codes. While the primary objective of building codes -- life safety of structures -- is laudable, the way such codes have historically been structured and administered has had an inhibiting effect on change in construction practice. Such codes are enacted at the federal, state, and municipal level and have traditionally been based not on general statements of performance requirements, but on specifications for particular components and materials. Because of this, a new material typically is forced to conform with geometric specifications -- often at the cost of being non-economic -- which were drawn up based on the characteristics of a traditional material the new material could replace, even though the properties and characteristics of the new material might make different dimensions or construction details more appropriate.

The wood products industry is the primary construction materials supplier to the light frame construction industry. For decades it has supplied lumber and panel products to suppliers or directly to contractors for on-site assembly into single- or multi-family residences. These wood products are standardized commodities, manufactured and distributed in standard grades and sizes. Combined with the institutionalized conservatism within other sectors of the light frame construction industry, they have led to proliferation of house configurations and sizes chosen so as to make optimum economical use of the standard component sizes available.

Despite the anti-innovation climate in light frame construction the wood products industry has been responsible for initiating significant changes in building practice. Especially notable were changes in the area of structural panels. After World War II plywood, which had actually been introduced over forty years earlier, began to be utilized in light frame construction in ever-increasing volume. Because of the structural flexibility inherent to a panel, plywood gradually displaced lumber as the dominant sheathing material for floor, wall, and roof construction. Because its overall in-place costs were lower than those of boards, builders across the U.S. gradually shifted to the use of these structural panels and, in the process, willingly absorbed short-term discomforts and inconveniences within their operations.

Since the early 1950s plywood has been the dominant structural panel in light frame construction. In recent years, however, for a variety of reasons, plywood as a product has been subjected to intense market pressure. New generations of replacements for plywood are being introduced by the wood products industry. A revolution is underway the proportions of which are highly unusual for such a conservative and tradition-bound industry. Complicating -- or, perhaps facilitating -- this rush of new product introductions is the present plight of the light frame construction industry, which is currently embroiled in what is perhaps its most severe recession since World War II.

This thesis is intended to focus on the family of new products being developed and introduced as replacements for plywood in light frame construction applications. In so doing, the following objectives will be addressed:

- Documentation and analysis of the causes which have provided impetus for and led to the new product introductions;
- Description of each new product and its associated process technology, and compilation of a comprehensive roster of producing firms, locations, and production capacities;
- Analysis of the key advantages and disadvantages of the new product types both relative to plywood and relative to each other;
- Analysis of the key variables affecting future success of the new panels;
- Rating of the vulnerability of plywood to incursion of the new products into its markets, by end use categories;
- Analysis of the counter-offensive strategies available to plywood to combat the invasion of its traditional markets by the new panels;

- Analysis of the role of product performance in establishing market entrees via building code approvals, and comparison of the characteristics and properties of each sheathing product type;
- Identification of new product opportunities available to the new panel technologies, leading to further potential advantages over plywood;
- Forecast of the future for the entire structural panel business both from a market end use and a geographical perspective.

The thesis will include discussions of implications of the analysis to other situations, particularly within the light frame construction and wood products industries. Forecasts for the rate at which the new products will substitute for plywood in light frame construction applications will be assembled.

CHAPTER 2

PLYWOOD HISTORY

Before delving directly into recent developments and new product introductions, it is illustrative to first take a retrospective look at enough of plywood's past to place the present and future in historical context.

The first production run of softwood plywood (while plywood is also manufactured from hardwoods, sheathing grade plywood -- used in light frame construction -- has historically been processed from softwoods) took place on the U.S. west coast in 1905. Within 20 years there were twelve plywood plants in existence, together producing a total in excess of 150 million square feet. (Note: In the plywood industry, convention dictates measuring production volumes in square feet on a 3/8 inch basis. Although several thicknesses are produced, production quantities of other thicknesses are normalized to a 3/8 inch equivalent to facilitate assembly and communication of data. For example, one square foot of 3/4 inch thick plywood is equivalent to two square feet on a 3/8 inch basis. Because this convention is generally understood and for reasons of brevity, the "3/8 inch basis" phrase is usually omitted in tabulations of production volumes.)

Following traditional patterns in the U.S. forest products industry, producers banded together to form the Douglas Fir Plywood Association in 1933, and this organization set about the task of developing standardized plywood specifications. Until World War II production of plywood remained essentially static. During World War II, however, plywood began to be utilized in many military, aircraft, and construction applications and, in so doing, established itself as an acceptable structural building material. Production and use of plywood began to increase markedly.

After the War, plywood production began to mushroom on the West Coast. Through the 1950s plywood gained significant market share from lumber as it was used extensively in construction applications. Because it offered structural capabilities in a standardized panel-shaped form, it led to and facilitated changes in housing construction practices, replacing lumber boards in wall, roof, and floor construction configurations.

The boom in West Coast plywood production started to fade in the 1960s as prices of western timber (particularly Douglas fir, which provided the bulk of plywood raw material requirements) began to escalate. These timber price increases had adverse effects on lumber, as well as plywood, production. Because of this, the wood products industry began to look to the southern U.S. for relief, eyeing reservoirs of untapped, and relatively fast regenerating, Southern pine. Production of acceptable Southern pine plywood was, at first, not a simple task for a variety of technical reasons. These hurdles were first overcome by Potlatch Forest Industries, thus kicking off the Southern pine plywood industry. The first full-scale commercial, all Southern pine, plywood plant was built by the Georgia-Pacific Corporation, initiating a large industry expansion program which continued well into the late 1970s. At this point, total southern plywood production volumes began to approach those of the West Coast.

Some plywood production has been introduced in what has been referred to by the industry as the Inland region (the mountainous states of Colorado, Idaho, and Montana, and regions of Washington and Oregon east of the Cascade Mountains). Production volumes from this area are, however, quite small when compared to West Coast and southern volumes.

In 1964, to reflect the changes in geographical emphases of the industry it represented, the Douglas Fir Plywood Association changed its name to the American Plywood Association (APA). The APA has served as the industry's custodian of historical softwood plywood production volumes. The most recent compilation (2) by the APA provides regional and total production and distribution data for the industry from 1925 through 1980 (data from 1925 to 1938 are sketchy, however). From these data it is possible to generate a historical sales curve for plywood, which appears as shown in Figure 2-1.

As a product life cycle model, the curve of Figure 2-1 possesses several extremely interesting features. First, it has a classical S-shape, with a relatively flat (except for the years of World War II) introduction phase up to about 1948, followed by a rapid growth phase from 1948 through about the mid-1970s, followed by what appears to be a flattening, albeit erratic, mature phase since that time. Growth of plywood production through the 1950s and early 1960s was, as alluded to earlier, primarily due to west coast expansion, while growth through the late 1960s and early 1970s was due principally to increases in Southern pine plywood volumes.

The violent up-and-down swings in plywood production throughout the 1970s are due to the erratic nature of the overall wood products economy during that decade. The steep drop in production in the mid-1970s coincides with the nation's recession during that period, during which housing construction sank to very low levels. The steep decrease through which

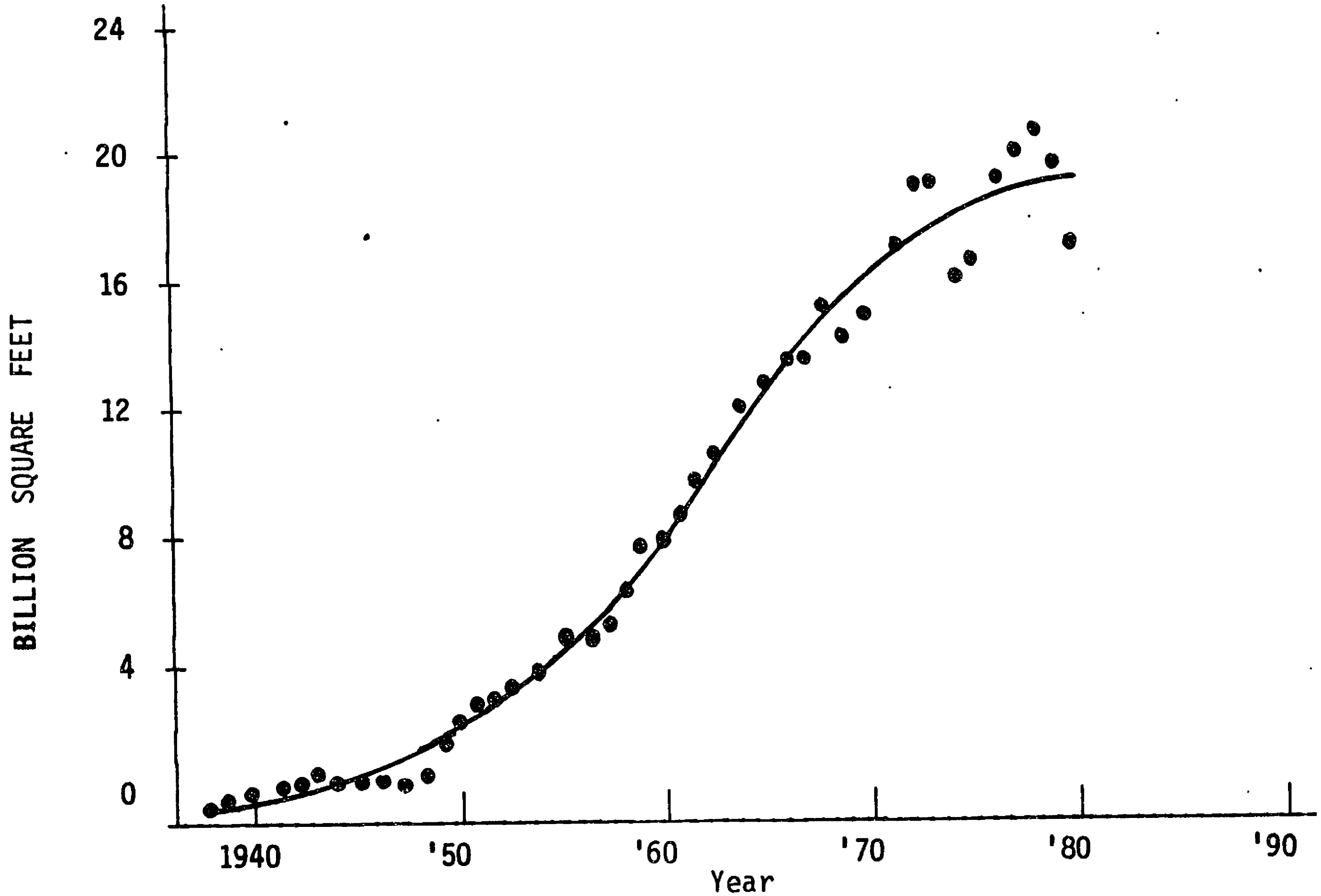


FIGURE 2-1

HISTORICAL PLYWOOD SALES

the industry is currently suffering is largely due to the ongoing severe slump in housing construction, perhaps the worst in magnitude since the Great Depression.

To graphically illustrate the evolution of geographical emphases in plywood production, the data of Figure 2-1 can be partitioned to generate similar curves for production in each of the three major regions -- westerns, southern, and inland. Plywood historical sales curves for each of these regions are shown in Figure 2-2. It is clear from this figure that production of western plywood has entered a phase of decline. Inland production has essentially stabilized. Southern production, while still exhibiting potential for some future growth, appears to be levelling off. In short, plywood appears to be a very mature product with little prospect for future growth and, as is more likely, with significant potential for overall production decreases.

What have been the reasons for plywood's decline? One obvious cause for the most recent slides in overall volume, as has been mentioned, is the most recent housing construction slump. This has been brought on primarily by extremely high mortgage interest rates and sharp decreases in availability of money. The implications of such a housing construction slump on plywood production is illustrated by the data in Table 2-1, which summarizes plywood demand in 1976 by major end-use category, as assembled by the APA. As can be seen from the table, more than 62% of plywood's markets are either tied directly to new residential construction or to construction activities associated with repairing or remodelling existing houses. A slump in housing construction, such as the current one, consequently leads directly to large decreases in overall plywood demand.

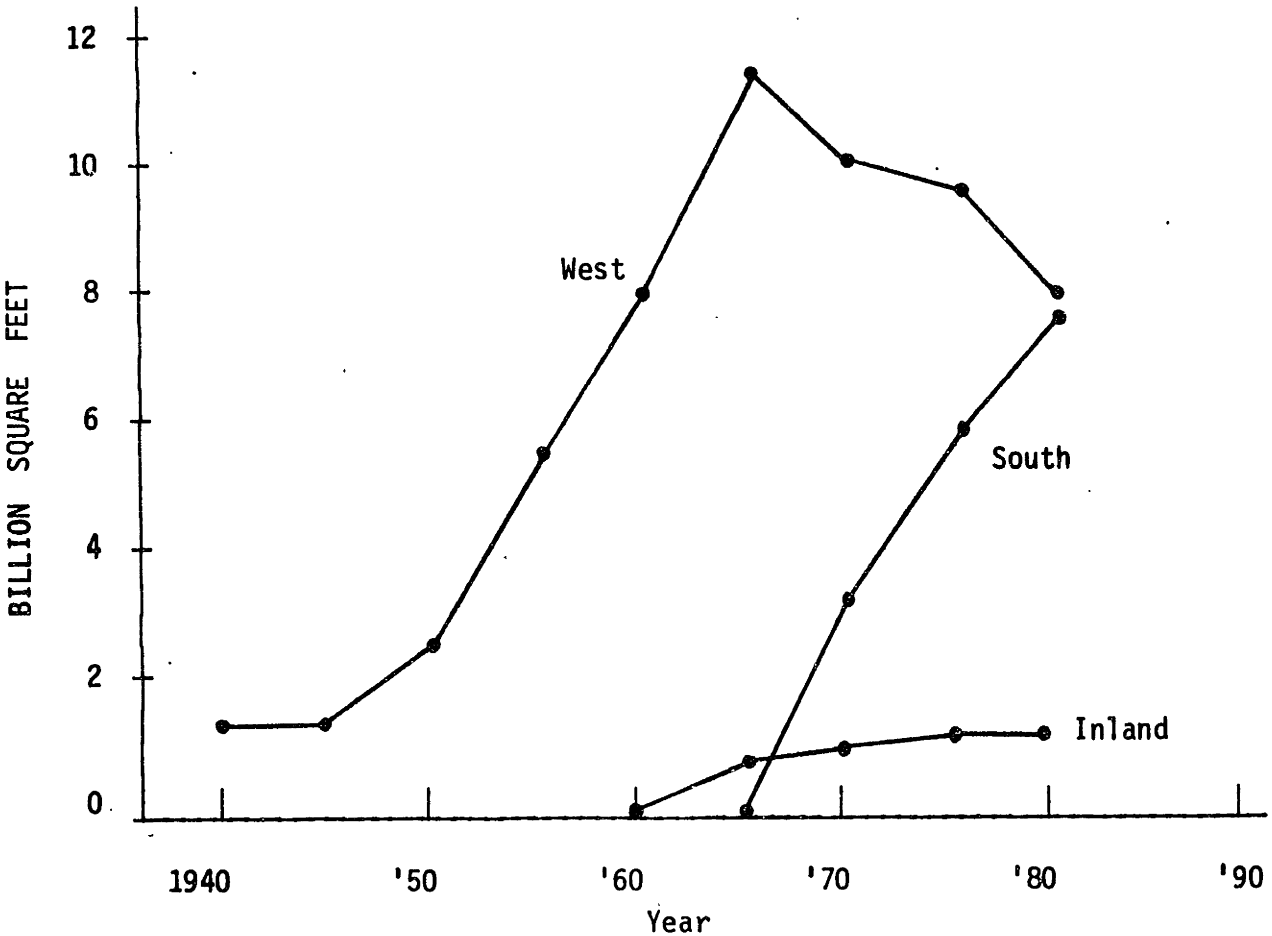


FIGURE 2-2

HISTORICAL REGIONAL PLYWOOD SALES

TABLE 2-1

PLYWOOD SALES (1976) BY END USE MARKETS

End Use Category	Per Cent Of Total Plywood Markets
New Residential Construction	
Roofs	16.8
Floors	14.5
Siding/Trim	5.2
Walls	2.7
Soffits/Overhangs	1.6
Cabinets/Shelves	0.2
Garage Doors	0.2
Interior Walls	0.1
Other	0.6
Total New Residential Construction	41.9
Repair and Remodelling	
Additions/Repairs	12.7
Shelving/Furniture	4.2
Small Buildings	1.7
Crafts/Games/Toys	0.6
Transportation	0.2
Other	1.1
Total Repair and Remodelling	20.5
Industrial Markets	
Products Made for Sale	9.2
Materials Handling	2.4
Plant Repair	2.3
Retail/Wholesale Trade	0.2
Other	2.1
Total Industrial Markets	16.2
Nonresidential Construction	
Nonresidential Building	7.3
Auxiliary Uses	1.5
Concrete Forming	4.4
Farm Building	1.9
Total Nonresidential Construction	15.1
Other Uses	6.3
Total	100.0

Current thinking within the industry is that, even if strong resurgences in housing construction occur, plywood's long-term outlook is one of no growth. End use markets have saturated as the process of plywood substituting for lumber has been completed. More significantly, plywood's long term outlook in its significantly large volume structural applications in construction is threatened by an emerging family of replacement products. The analysis of these new products forms the crux of this thesis.

What factors have led to the development and market introduction of new panel products to substitute for plywood, which itself was a significant commercial innovation? An analysis of the technological, raw material, market, and political influences driving this ongoing wood products revolution is the subject of the next chapter.

CHAPTER 3

REASONS FOR DEVELOPMENT OF PLYWOOD REPLACEMENTS

There have been several recent developments in both the construction industry and in the wood products industry which have together provided impetus for major producers to introduce panel products to replace plywood in the construction end use applications in which historically plywood has been dominant. These developments can be categorized and analyzed under four general headings:

(1) Technological;

(2) Raw Material;

(3) Market;

(4) Political.

Technology-Related Developments

It has been well-known for years among researchers and forest products technologists that it is possible to process particle-based panels in the laboratory so as to achieve panel physical and mechanical properties at a sufficiently high quality level to suggest the possibility of using in structural applications panels not made entirely of veneer. It is only fairly recently that production scale technologies have demonstrated the feasibility of duplicating these laboratory panels at an acceptable level of quality and in commercial quantities. Process development the last few years has been rapid as wood products manufacturers and processing equipment manufacturers have together sought out and developed alternative means of manufacturing varieties of flat structural panels. Resulting processes in use are similar in configuration and overall flow to those used in the industry for production of particleboard and fiberboard. Demonstration of the viability of these processes to producing truly structural panels has provided great impetus to the introduction by the industry of new panel types.

Raw Material Developments

During the last decade the most critical problems affecting the plywood industry have been timber supply and cost. Primarily as a consequence of withheld and withdrawn timber from public lands, the cost of timber throughout the 1970s and into the 1980s escalated far beyond inflation rates (3). Extremely rapid increases in timber costs started in the mid-1970s as the timber management teams of public lands began to withhold timber that could conceivably have been offered for sale to producers under the U.S. Forest Service sustained yield allowable cut philosophy. During succeeding years, characterized by litigation, politics, and inadequate government funding for sale, the average timber stumpage prices for western Oregon logs escalated as shown in Table 3-1 (3). (Note: The term "stumpage" refers to the value of timber "on the stump"; i.e., prior to harvesting and transport to a production facility.) The rate of stumpage price increses has slowed noticeably in 1980 and 1981, due to the ongoing housing and plywood industry recession. The APA points out (3) that, even though the rate of increase has slowed, it is nevertheless still increasing which is counter to experience in past recessions during which stumpage prices <u>decreased</u>. Complicating this severe raw material problem have been inexorably increasing labor, energy, and adhesive costs, with

TABLE 3-1

RECENT TRENDS IN WESTERN OREGON STUMPAGE PRICES

Year	Average Stumpage Price ($ Per 1000 Board Ft.)	Year-To-Year Change
1976	141.54	--
1977	181.51	+28%
1978	210.96	+16%
1979	332.09	+57%
1980	354.60	+ 7%

the end result being immense cost pressures on the plywood industry.

Rates of raw material price increases in the southern and inland region, while not a steep as in the west, have nevertheless exceeded inflation rates.

Concurrent to these plywood raw material cost pressures has been the wood products industry's recognition of the attractiveness of vast pockets of a hitherto ignored species -- aspen -- in Canada and the upper midwestern U.S. This species has characteristics making it essentially ideal for production of particle-based structural panel types. The industry has also recognized the equally attractive spruce and mixed soft hardwood stands in the northeastern U.S. and the slightly less attractive mixed hardwood stands in the south as candidates for raw material sources. In contrast to the escalated prices thrust upon plywood producers for their raw material, these emerging raw material sources for new panel production have had little or no historical demand. Hence, they have affixed to them negligible or very low stumpage prices.

Thus, from the perspectives of both plywood processing technology and emerging panel processing technology, raw material issues have provided significant impetus to the development of new panel types.

Market Developments

In addition to -- and perhaps contributing to -- the rapid price increases for plywood raw material has been the gradual disappearance of the types of round, straight, large diameter, old-growth logs historically ideal for plywood production. As these have gradually been used up, in their place have appeared lower grade old-growth logs, and second-growth logs emerging as a result of government and private firm forest regeneration practices. Neither of these two categories represent raw material quality on a par with that historically preferred by plywood manufacturers. As a result of having to accomodate lower quality raw material, plywood producers have over the last decade been producing a product having gradually diminishing quality. While it is difficult to find in the literature a succinct appraisal of the decline in plywood's quality, there is throughout the wood products industry and among the construction and retail sales sectors a prevailing feeling that "plywood is going downhill". Even western plywood, which because of Douglas fir's quality advantage over Southern pine has had a performance and acceptability edge over southern plywood, has exhibited steadily declining quality during the last several years.

This inexorable decline in product characteristics has not been lost upon the market. It has been assimilated and reacted to to such a degree that even such a conservative industry as light frame construction has expressed receptivity to alternate types of structural panels. The prevailing feeling in the construction market has been: "If a panel will do plywood's job and does not require me to significantly change my on-site practices, and if I can get it at a lower cost than plywood, I'll try it".

Political Developments

A major incentive for current and future planned expansions in structural panels has been the emergence in the last two years of an alternative approach for the qualification and certification of sheathing products. Historically, the plywood industry, as well as the particleboard and fiberboard industries, have manufactured products against and according to the provisions in industry product standards. The APA and the National Particleboard Association (NPA) have been the primary industry bodies representing their respective generic product types. Recognized by the building code regulatory agencies, these product standards -- PS1-74 (4) for plywood and ANSI A208.1 (5) for other panel products -- have been the vehicles by which the industry has qualified products. Furthermore, they have provided criteria against which production panels can be tested to certify their quality.

Since 1976 the APA has worked on revolutionary new procedures for accomplishing these qualification and certification objectives. This work has culminated in publication and acceptance of new standards based on the concept of product performance. The main features of these new standards, as well as an analysis of the advantages and disadvantages of the new performance-based approach versus the prescription approach embodied in the historical product standards, will be presented in a subsequent chapter of this thesis. It is sufficient at this point to state that the emergence of these standards provides an obvious philosophical incentive for introduction of a sheathing panel differing in characteristics from plywood assembled according to an existing prescription standard.

Having laid sufficient plywood historical background to put the current sheathing market in context, and having analyzed the incentives and issues which have set the stage for development of new sheathing panel types, it is timely to present a discussion of the innovative new product types which have been introduced by the industry. This discussion is the subject of the following chapter.

CHAPTER 4

THE NEW PANELS

The new structural panel products recently introduced fall into three basic types. The first, referred to under the generic heading of waferboard, had its commercial introduction in 1966 in Canada, and has recently been experiencing considerable growth in production volume both in Canada and the U.S. The second type, known generically as COM-PLY^{R}, has been commercially available since 1976. The third type, usually discussed under the general label of oriented strand board (OSB), has only recently been introduced to the sheathing market, having been first commercially produced in 1981. Each of these three product types possesses characteristics making it unique from the other two. These differing characteristics range from appearance to physical and mechanical properties.

All of these three plywood substitutes are marketed as structural sheathing commodities, although their characteristics, appearance, and performance differ to a considerable degree. In spite of significant differences, each of these three product types has emerged as a viable substitute for plywood in structural uses.

Waferboard

Waferboard is an unveneered, structural use panel. First produced in Canada in 1966, it has since spread to several Canadian and U.S. manufacturing locations. In the past few years, waferboard production has expanded as manufacturing firms have taken advantage of the previously mentioned low cost raw material supplies in central and eastern Canada and upper midwestern and northeastern U.S.

Though it is manufactured under various tradenames, waferboard is essentially a generic product type with only minor differences from one manufacturer to the next. It is generally manufactured from low density hardwoods (most predominantly aspen), although at least one manufacturer accomplishes production using spruce. Such species are ideal for two reasons. First, low density facilitates the material compaction which must take place during processing to achieve adequate panel properties. Second, woods such as aspen possess inherent morphology conducive to flaking, which is the type of raw material refining required in the process to ensure adequate panel mechanical properties without resorting to objectionably high overall panel weights. Researchers (6) have known for years the beneficial relationships between the geometry of "flakes" (large particles having significantly large length-to-thickness ratio characteristics) and resulting panel properties. Waferboard's construction is derived in part using knowledge of this relationship.

Waferboard is composed of rather large, square (2-inch by 2-inch to 3-inch by 3-inch), somewhat thick (0.030-inch to 0.035-inch) chips -- wafers -- flaked from log segments and bonded together with a powdered phenolic resin. A typical waferboard product made from aspen is shown in Figure 4-1. A detailed discussion of its manufacturing process and comparisons of its properties with those of the other new panels and with plywood are subjects of succeeding chapters. Marketed as a commodity sheathing panel, waferboard has enjoyed acceptance in several applications.

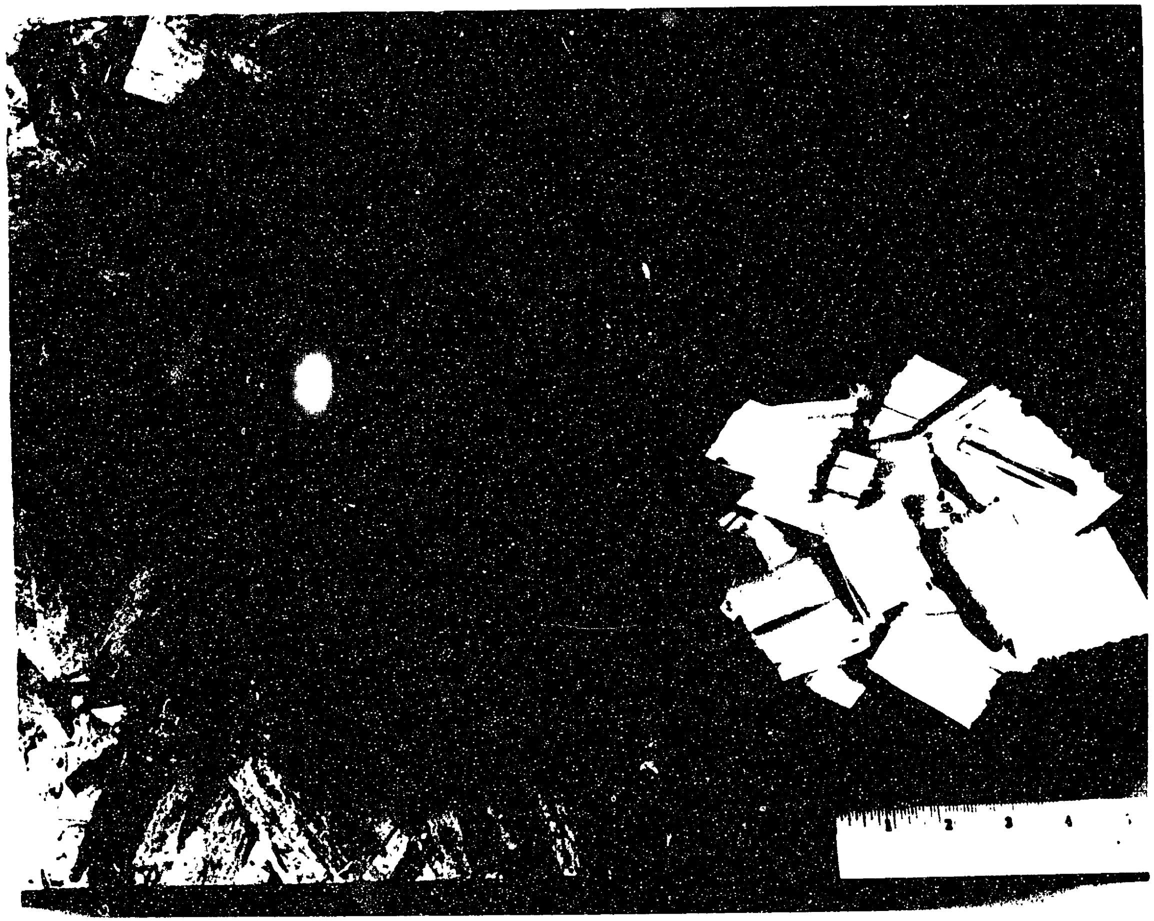


FIGURE 4-1

TYPICAL WAFERBOARD PANEL

COM-PLY[R]

The term COM-PLY[R] was coined by the APA to describe a class of hybird panels composed of a combination of wood flakes or particles and resin, sandwiched between two sheets of veneer which make up the face and back of the resulting panel. On the surface, COM-PLY[R] looks much like plywood because the veneer used for the face and back is identical to that used for the same purposes in softwood plywood production. While plywood utilizes veneer in its interior laminations -- usually laid up with wood grain orientation alternating at right angles from layer to layer -- COM-PLY[R] utilizes wood particulate material formed in a number of ways as a single inner core "ply" between two sheets of veneer. One existing commercial plant uses particleboard as its interior core material. Two other commercially available products utilize as core material wood strands which have been mechanically aligned in the cross-panel direction (i.e., perpendicular to the direction of the grain orientation of the surface veneers). Cross alignment of the particulate core material considerably enhances overall cross-panel dimensional stability (i.e., results in a lower cross-panel expansion and contraction due to changes in moisture content brought about by environmental conditions such as water soaking, high humidity, etc.) over what is the case with an unaligned core.

It is worth noting that two distinct panel lay-up procedures are used by different COM-PLY[R] producers. Two manufacturers make the particulate core layer separately and then transfer it to a conventional plywood lay-up line where it is treated as core veneer in the process of converting COM-PLY[R]. The remaining manufacturer lays wood particles coated with resin directly on the bottom veneer sheet, places the top veneer over these, and then cures and consolidates the entire assemblage in a one-shot pressing operation. With either process there remains the necessity for two separate capital-intensive processes for the manufacture of COM-PLY^R. This suggests that companies will opt for production of COM-PLY^R primarily in those locations and instances where it is critical to stretch an existing veneer supply.

A typical COM-PLY^R panel is pictured in Figure 4-2. Its properties and performance characteristics will be presented in a succeeding chapter, along with those of waferboard, OSB, and plywood.

OSB

One drawback to waferboard has been its inherently low structural stiffness and strength characteristics relative to plywood. For example, a typical waferboard panel has approximately one-third of the modulus of elasticity in flexure of west coast Douglas fir plywood. A perceived need for panel stiffness and strength greater than that provided by waferboard has spurred the evolution of technology -- both product and process development -- which has led to the introduction of OSB.

OSB is composed of three layers of aligned strands which are similar to wafers but possess length much greater than width. In essence, strands are wafers which have been split across the wood grain so that they are much longer in the wood natural grain direction than across the grain. Strands in the panel top and bottom surface layers of OSB are aligned parallel to the panel direction, while strands in the core layer are aligned parallel to the cross-panel direction. In essence, the OSB panel configuration is a mimic of plywood's construction. Strand alignment in the

FIGURE 4-2

TYPICAL COM-PLY^{R} PANEL

surface layers imparts panel stiffness and strength, analogous to the role of plywood face and back veneers. Cross alignment of strands in the core elevate cross-panel dimensional stability, as do core veneers in plywood.

Another significant difference exists between waferboard and OSB. Whereas powdered phenolic resin is used as the adhesive in waferboard manufacture, OSB is currently bonded with phenolic resin which is applied in the liquid state during manufacture. The liquid type of adhesive application technology has advantages over powdered resin technology in the areas of product performance and process economics.

OSB has been demonstrated to be a product whose panel properties are very nearly equivalent to those of plywood. A typical OSB panel made of aspen is pictured in Figure 4-3. In appearance it differs significantly from waferboard in two respects: first, OSB is darker, due to the use of liquid resins; and second, OSB's strand geometries are different from waferboard's wafer geometries, causing differing surface appearances.

The introduction of OSB, the most innovative of the new product types, has been greatly facilitated by the emerging sheathing performance standards, an analysis of which provides the basis for the next chapter of this thesis.

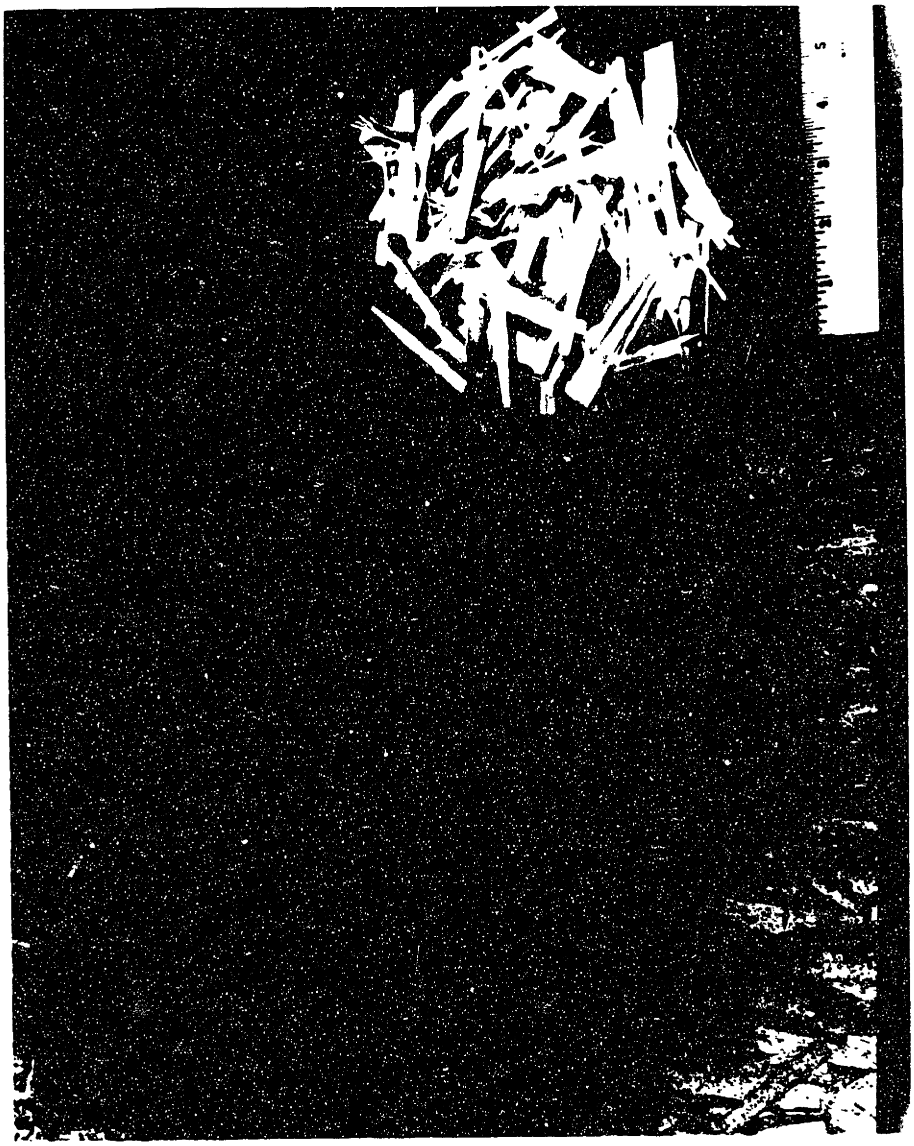


FIGURE 4-3

TYPICAL OSB PANEL

CHAPTER 5

ROLE OF PERFORMANCE STANDARDS

As has been discussed, the historical standards against which wood-based panel products have been manufactured have been product standards developed and promulgated by industry associations such as the APA and the NPA. Such standards as PS 1-74 (4) for plywood and ANSI A208.1 (5) for particleboard provide what are essentially prescriptions as to how a minimum product is to be manufactured so that consumers can be assured of some degree of quality regardless of the manufacturer's identity. These prescription standards define precisely how each product is to be manufactured, the bonding systems and materials which are to be used, the dimensional tolerances (geometric constraints) which must be met, and the physical and mechanical properties (stiffness, strength, durability, dimensional stability, fastener performance, etc.) which the product must possess.

Property values documented in these product standards are mimimum values which are not presented as engineering design values. In essence, these prescription-based standards as they have evolved avoid the issue of product application and do not address the question of how well the product can be expected to perform in a given end use in an explicit way.

Over the years, under the product standard system, a manufacturer desiring to introduce a new manufacturing process or significantly alter either his product or process has been forced to endure a lengthy industry consensus process to modify the existing standards.

In an effort to remedy this shortcoming of existing product standards, the APA has during the last few years pioneered a process for explicitly addressing the expected performance of structural panels in specific end uses via development of performance standards. To quote from the preface to the APA's recently published "Performance Standards and Policies for APA Structural-Use Panels" (7):

> "A performance standard is oriented toward the end use of the product and does not prescribe by what means the product will be manufactured. The overall objective is to assure, for a particular end use, that the product will satisfy the requirements of the application for which it is intended."

With this underlying philosophy in mind and utilizing the results of several years' research and testing at its research laboratory, the APA has developed a set of standards to cover the use of all structural panels in sub-floor, roof, and wall sheathing and combination sub-floor/underlayment (the so-called "single floor system") applications in light frame construction. These performance standards concentrate on panel characteristics critical to their performance in these end uses -- structural stiffness and strength, dimensional stability, and durability. The standards include tests for required physical properties; namely, resistance to concentrated, impact, and uniform loads, linear expansion, and fastener performance, as well as panel durability, panel dimensional tolerances, and overall out-of-plant panel moisture content.

The existing product standards have been accepted for many years by the three major building code agencies: the International Conference of Building Officials (ICBO), the Southern Building Code Congress (SBCC), and the Building Officials and Code Administrators (BOCA). Though building regulation throughout the U.S. is highly localized, thousands of municipalities across the country utilize one or the other of model building codes as their individual local building code, per the recommendation of one or more of these agencies. Hence, acceptance of a standard by these three code groups is tantamount to large-scale regulatory acceptance of products conforming to it. Thus producers of new building products typically achieve nationwide acceptance for their products via approvals from these agencies.

The APA has worked closely with the Council of American Building Officials (CABO) and its research arm, the National Research Board (NRB), which have recently achieved jurisdiction over the above three code agencies, in development of its performance standards. One recent result of these efforts has been publication of NRB-108 (8) which has ushered in acceptance by all three model building codes of the APA performance standards for sheathing and single floor systems.

Concurrent to APA activity, the NPA has been attempting to alter its particleboard product standards to include provisions for the new unveneered panel types. If this is achieved, waferboard and OSB producers will have the opportunity to choose between the traditional prescription route of product qualification embodied in the NPA program or the new performance-based procedures of the APA.

What implications have these standards developments -- particularly the performance standards -- had on the introduction of new structural panels and how will this emerging sector of the wood products industry be affected in the future? According to the APA (9) numerous producers have submitted requests for code approval for their new panel products to the building code authorities based on test data acquired by testing their products against the new APA performance criteria. All announced OSB producers have used this route toward achieving code approvals. It is obvious that, by its very philosophical nature, the performance-based approach is more conducive to providing entry for innovative or non-standard products such as OSB than is the prescription approach. According to the performance-based approach, a product is acceptable as long as it performs. The APA performance standards in no way constrain the manufacturing process (although the standards do stipulate, in a protectionist caveat, that the panel must be <u>wood-based</u>; hence, they are not truly pure performance standards). Product standards, on the other hand, place considerable constraints on the manufacturing process by stating exactly how the product should be put together.

While a product standard creates product standardization for multiple end uses, which can be beneficial, a performance standard encourages both product and process innovations. From a societal standpoint, a performance standard can contribute to more efficient utilization of material resources. It does this by allowing a producer latitude in using his ingenuity to convert raw materials into a product which has only to "perform" in a given end use to be acceptable. While an argument can be made in favor of the product "sameness" that results from adherence to product standards, which thus leads to minimal consumer confusion, such a structure diffuses product liability responsibility from single producers to the industry as a whole via the commodity philosophy. Performance-based qualification results in product responsibility being pinpointed exactly on the individual producer manufacturing the product.

The conceptual procedures associated with the performance and prescription approaches for qualification and certification of structural panels are depicted in chart form in Figures 5-1 and 5-2 respectively.

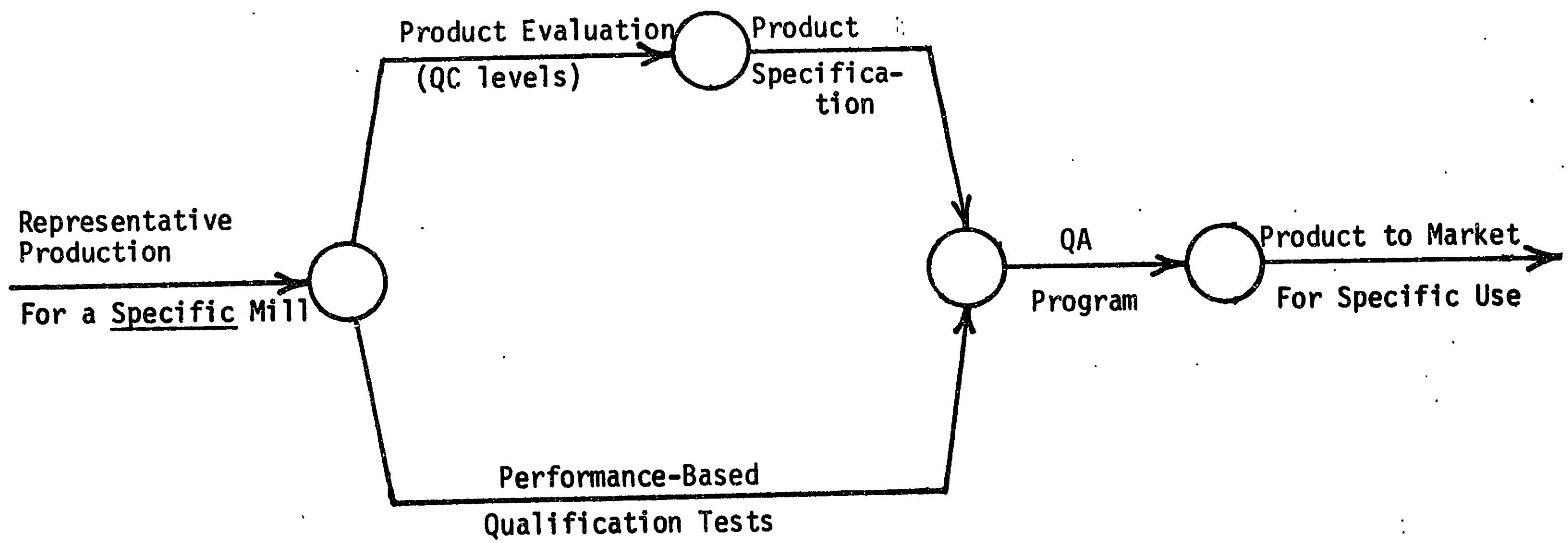


Figure 5-1

Procedures Embodied in Performance Approach

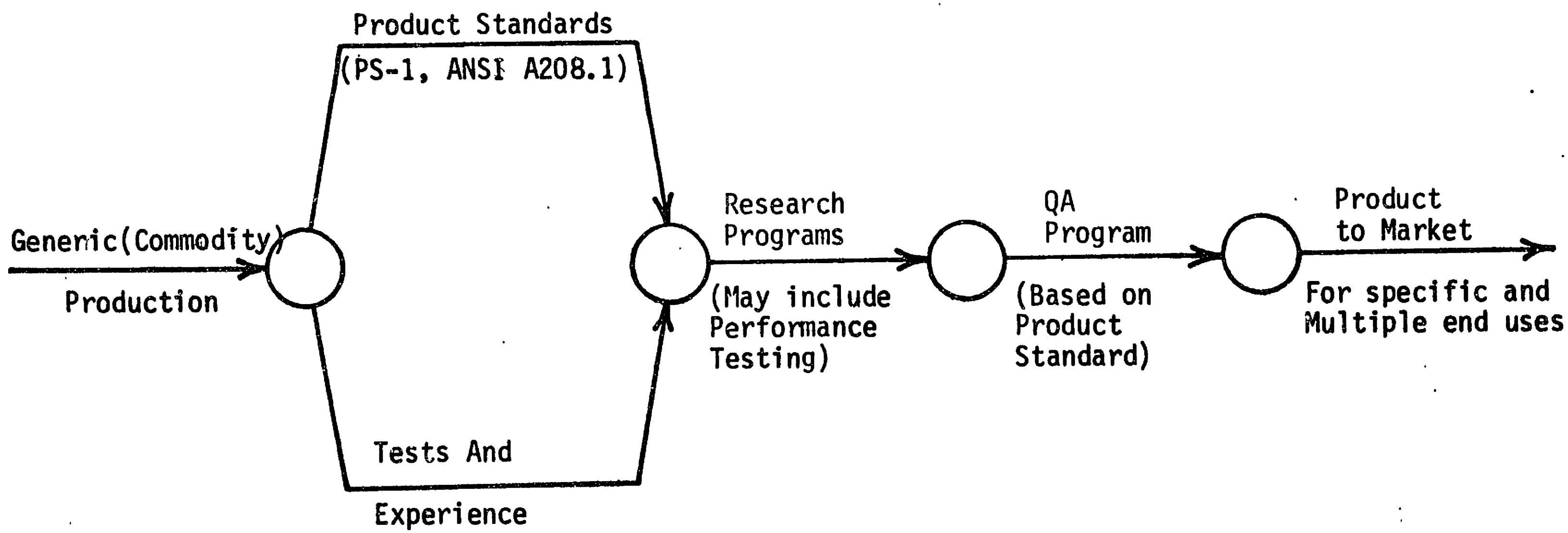


Figure 5-2

Procedures Embodied in Prescription Approach

CHAPTER 6

STATUS OF PRODUCTION OF NEW STRUCTURAL PANELS

It has been possible, using published data from Kidder-Peabody (10) and private communications with the APA (9), the NPA (11), and the Weyerhaeuser Company (12), to compile an up-to-date summary of manufacturing activity in waferboard, COM-PLY^R, and OSB. Arraying this information is useful in pointing out trends in new product introduction preferences, marketing, geographies, etc.

Table 6-1 summarizes the status of North American COM-PLY^R production, all of which occurs in the U.S. In all cases, COM-PLY^R is being manufactured at sites where it complements a pre-existing plywood manufacturing infrastructure. It has already been pointed out that the need for two separate capital-intensive manufacturing facilities to produce COM-PLY^R suggests it is most likely to be used in conjunction with an existing plywood operation where stretching of the existing veneer supply is critical. This assertion is borne out by industry activity to date. In certain sectors of the industry (9, 12), it is felt that the manufacturing costs for COM-PLY^R are only a little less than those for plywood, while manufacturing costs for waferboard and OSB are much lower. These notions will be pursued in detail in a succeeding chapter.

Table 6-2 documents the current status of waferboard production in Canada. All but two of the ten plants are currently in production. Canadian production capacities are included in the scope of this thesis because of the influence Canadian waferboard has had and is having on U.S.

TABLE 6-1

U.S. COM-PLY® PRODUCERS

Company	Location	Annual Capacity (Million Sq. Ft.)
Potlatch	Lewiston, IDA	80
Ellingson	Bend, ORE.	20
Georgia-Pacific	Dudley, N.C.	140

TABLE 6-2

CANADIAN WAFERBOARD PRODUCERS

Company	Location	Annual Capacity (Million Sq. Ft.)
MacMillian-Bloedel	Hudson Bay	120
MacMillian-Bloedel	Thunder Bay	120
Great Lakes	Thunder Bay	120
Weldwood	Longlac	115
Northwood	Chatham	150
Waferboard	Timmins	60
Waferboard	St. Georges	130[1]
Normic	Lasarre	55[1]
Weldwood	Slave Lake	140[2]
Wilson/Grant	Englehard	120[3]

[1]Start-up in 1981

[2]Start-up in 1982

[3]Start-up in 1983

light frame construction markets. It is estimated (11) that approximately half of the waferboard production in Canada is marketed in the U.S., with most of this volume finding itself in light frame construction applications.

A list of U.S. waferboard producers is provided in Table 6-3. As can be seen from the table, more than 70% of the already planned waferboard production in the U.S. is not yet on stream. If all existing manufacturing facilities and plants under construction produce at full capacity, by 1984 there will be in excess of 2.3 billion square feet of waferboard being manufactured in North America.

While the large waferboard expansion is taking place, a sizeable volume of OSB is being introduced or being made ready for introduction to the market. Table 6-4 lists the OSB facilities in production or under construction in the U.S., most of which are scheduled for sizeable production in 1982. It is interesting that two of the three firms which have opted for OSB production (Weyerhaeuser and Potlatch) are companies with sizeable emphasis on Research and Development (R&D) and a past and ongoing involvement in composite panels. The third firm (Elmendorf) has had its production facility constructed on a turnkey contract by Bahre-Bison of West Germany (12), which has conducted significant internal R&D and promotion on OSB as part of an overall processing equipment sales strategy.

As part of a study for investment interests, Kidder-Peabody (10) has compiled a historical record of North American waferboard production since the maturation of waferboard into a significant market force in 1974. Annual figures for North American waferboard production from 1974

TABLE 6-3

U.S. WAFERBOARD PRODUCERS

Company	Location	Annual Capacity (Million Sq. Ft.)
Blandin	Grand Rapids, MICH	80
Louisiana-Pacific	Hayward, WIS	130
Georgia-Pacific	Woodland, Maine	140[1]
Blandin	Grand Rapids, MICH	200[2]
Louisiana-Pacific	Houlton, Maine	130[2]
Northwood	Bemidji, MINN	130[2]
Louisiana-Pacific	Hayward, WIS	130[3]
Diamond	Winn, Maine	160[3]
Huber	Aroostok, Maine	130[3]

[1]Start-up in 1981

[2]Start-up in 1982

[3]Start-up in 1983

TABLE 6-4

U.S. OSB PRODUCERS

Company	Location	Annual Capacity (Million Sq. Ft.)
Potlatch	Bemidji, MI	160[1]
Potlatch	Cook, MI	160[2]
Elmendorf	Claremont, N.H.	140[2]
Weyerhaeuser	Grayling, MI	220[2]

[1]Start-up in 1981

[2]Start-up in 1982

through 1979, as plotted from the Kidder-Peabody data, are displayed in Figure 6-1. Ignoring COM-PLY[R]'s small production volumes (essentially COM-PLY[R] is a product more akin to plywood than to waferboard and OSB), it is possible to combine the waferboard and OSB capacity figures of Tables 6-2, 6-3, and 6-4, along with the historical production data through 1979, to arrive at a projected potential unveneered panel sales curve through 1983. This is shown in Figure 6-2, assuming all plants produce at capacity volumes. Figure 6-3 combines the initial portion of the plywood historical sales curve of Figure 2-1 with the curve of Figure 6-2. Time for both product curves is measured in years from year of achievement of consistent significant commercial volume (chosen as 1943 for plywood, and as 1974 for waferboard/OSB) to allow the two curves to be superimposed.

As is clear from Figure 6-3, waferboards' initial introduction rate was considerably slower than that of plywood. However, as the rapid expansion of the last few years has unfolded and as waferboard is joined on the market by OSB -- a product with which it shares many similarities--the rate of growth of the combined pair has far exceeded that which was exhibited by plywood. Furthermore, these high growth rates of the waferboard/OSB product family have occurred during a deep recession period in the U.S. and Canadian economies. While it is difficult to forecast with a high degree of accuracy future growth rates for new products, the rapid penetration of the new panels compared to plywood and the similarities between the markets of these panels with those of plywood suggest that the future for the waferboard/OSB product family is quite bright.

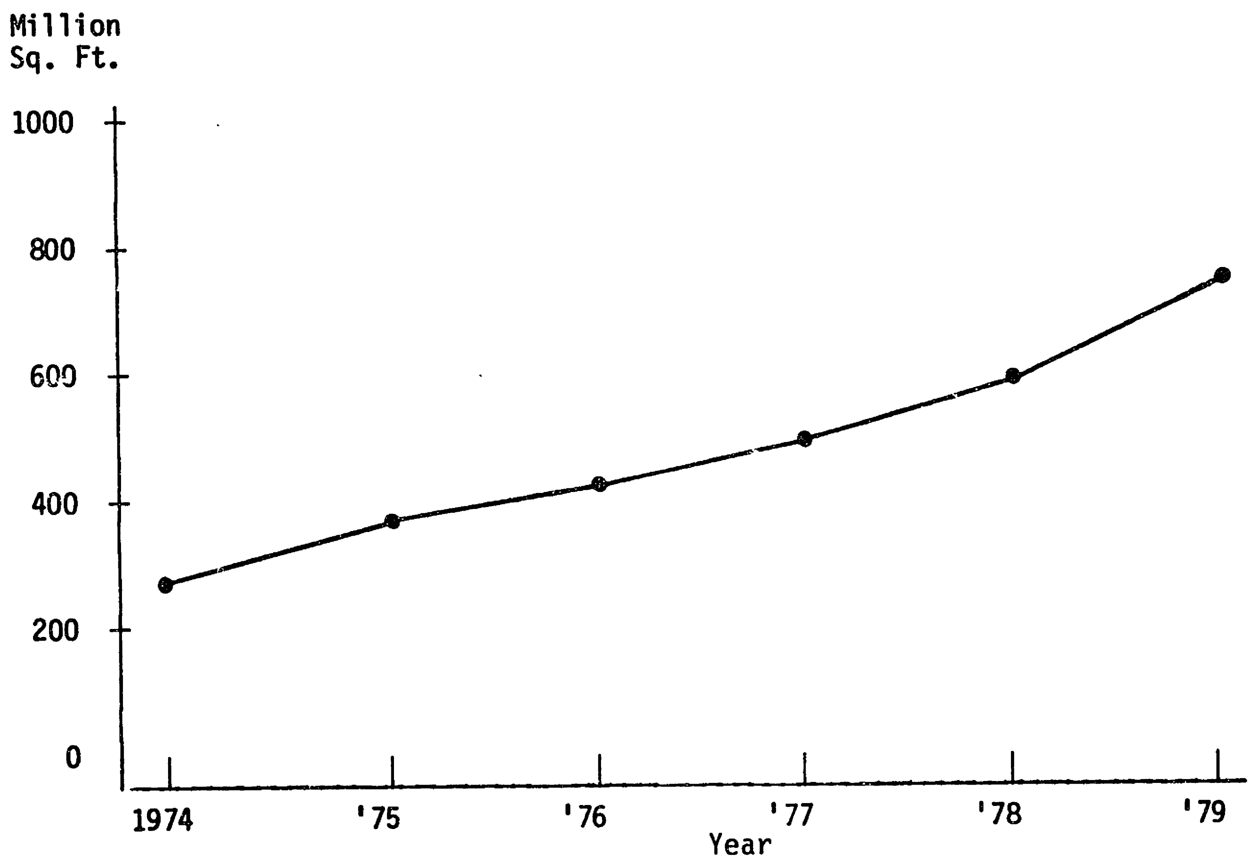


FIGURE 6-1

RECENT WAFERBOARD PRODUCTION

FIGURE 6-2

POTENTIAL WAFERBOARD/OSB VOLUME CURVE

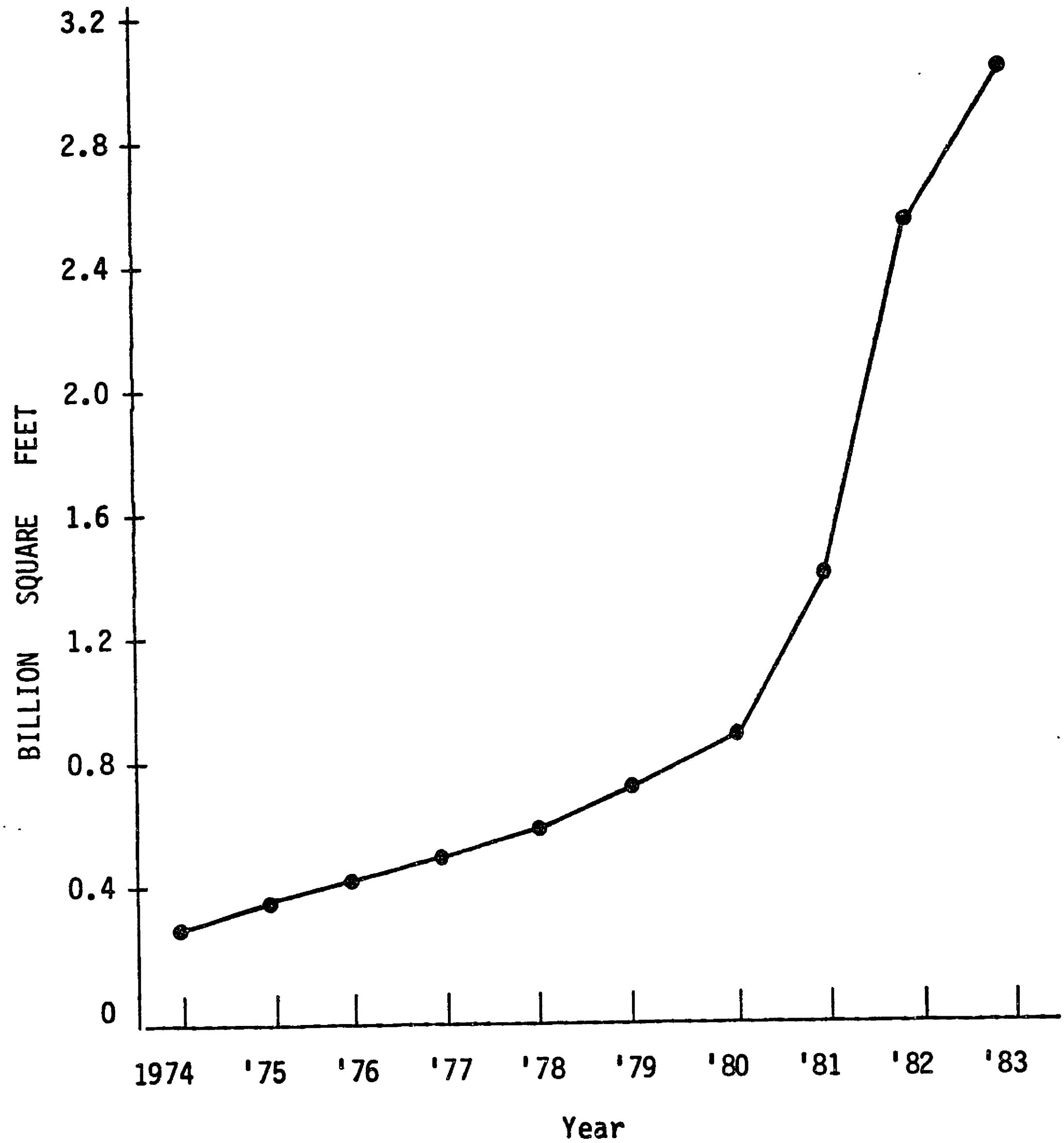
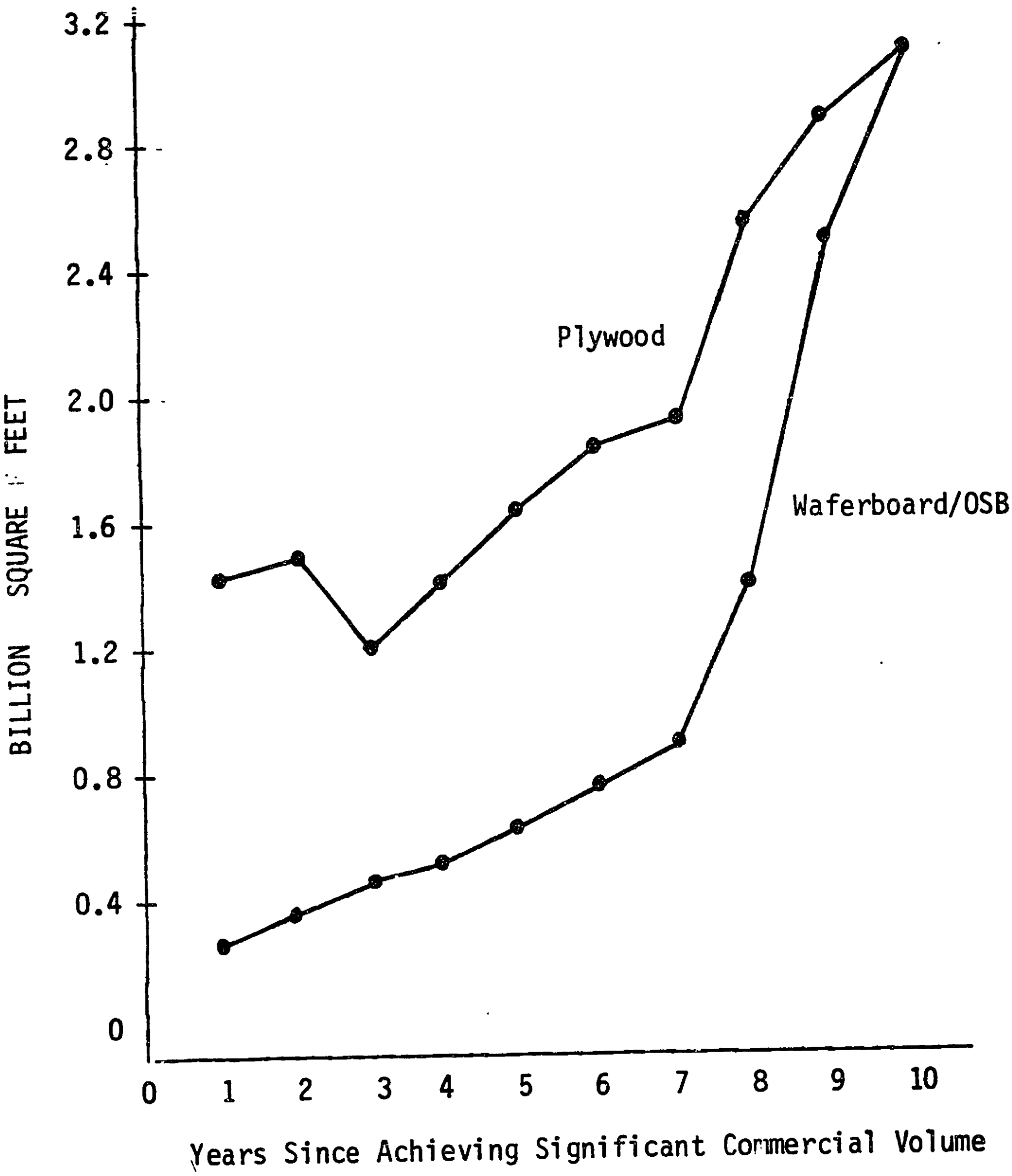


FIGURE 6-3

COMPARISON OF PLYWOOD AND WAFERBOARD/OSB GROWTH RATES



At this point it seems clear that plywood is a product on the defensive. New panels are being introduced -- and accepted -- at a rate which outstrips plywood's own historical experiences. Further, among the three product types, the one least likely, for economic reasons -- and, ironically, the one most similar in characteristics to plywood -- to have a large market impact is COM-PLY[R]. A competition for dominance among the substitutes, then, appears to be unfolding between waferboard and OSB. Clearly, waferboard is the early leader in the race for dominant market share among the plywood substitutes. Its U.S. production capacity through 1983 is projected to exceed 1.1 billion square feet, while announced OSB capacity totals 680 million square feet. When the U.S. waferboard production capacities are combined with a portion of Canadian waferboard production (which is projected to exceed 1.1 billion square feet in total), there will be potential for considerably more waferboard than OSB to appear in U.S. light frame construction.

However, OSB is a very recent market entrant which has been developed to provide a product with properties closer to those of plywood than are waferboard's. It is fair to assume that the relative success of each of these two products should depend on their respective product characteristics. How they compete should also depend on their delivered prices and the returns on investment these delivered prices yield to manufacturers. These returns depend in turn on manufacturing costs the magnitude of which hinge on process configuration and economics. Hence, even though waferboard is the clear early leader in competition with newly introduced OSB, it should not a priori be conceded a long term advantage. It is first necessary to analyze in detail the product performance, process, and manufacturing/market economics issues existing between the two product types. This analysis is begun in the following chapter, which deals with process technology issues related to waferboard and OSB, including raw material implications.

CHAPTER 7

WAFERBOARD/OSB TECHNOLOGY ISSUES

In Chapter 4 waferboard and OSB were portrayed as products which differed in physical appearance in two major ways. First, waferboard is lighter in color than OSB due to use of powdered resins in the former and liquid resins in the latter. Second, waferboard is composed of large, square flake particles, while OSB is made of long, narrow, strand-like flake particles.

Although significantly different in appearance, these two products are produced in manufacturing processes which share numerous common features. A block diagram of a typical waferboard manufacturing process is shown in Figure 7-1. This depiction of a waferboard process has been gathered using information from discussions with equipment manufacturers and personal visits to numerous waferboard plants. While subtle differences exist among the various waferboard plants' processes, Figure 7-1 provides a faithful picture of the overall conceptual nature of all of them.

In this typical waferboard process, de-barked log segments are fed to flaking machines which generate the chiplike wafers required in the product. These wafers are in turn dried in large drum dryers to approximately 2 to 5% moisture content (based on dry wood weight). Dry material then flows over gyratory screens which remove extremely small, undesirable particles (called "fines"). These fines are then used as dry fuel, typically in suspension burners to generate thermal energy for the dryers. Wax (for liquid water resistance in the final product) and

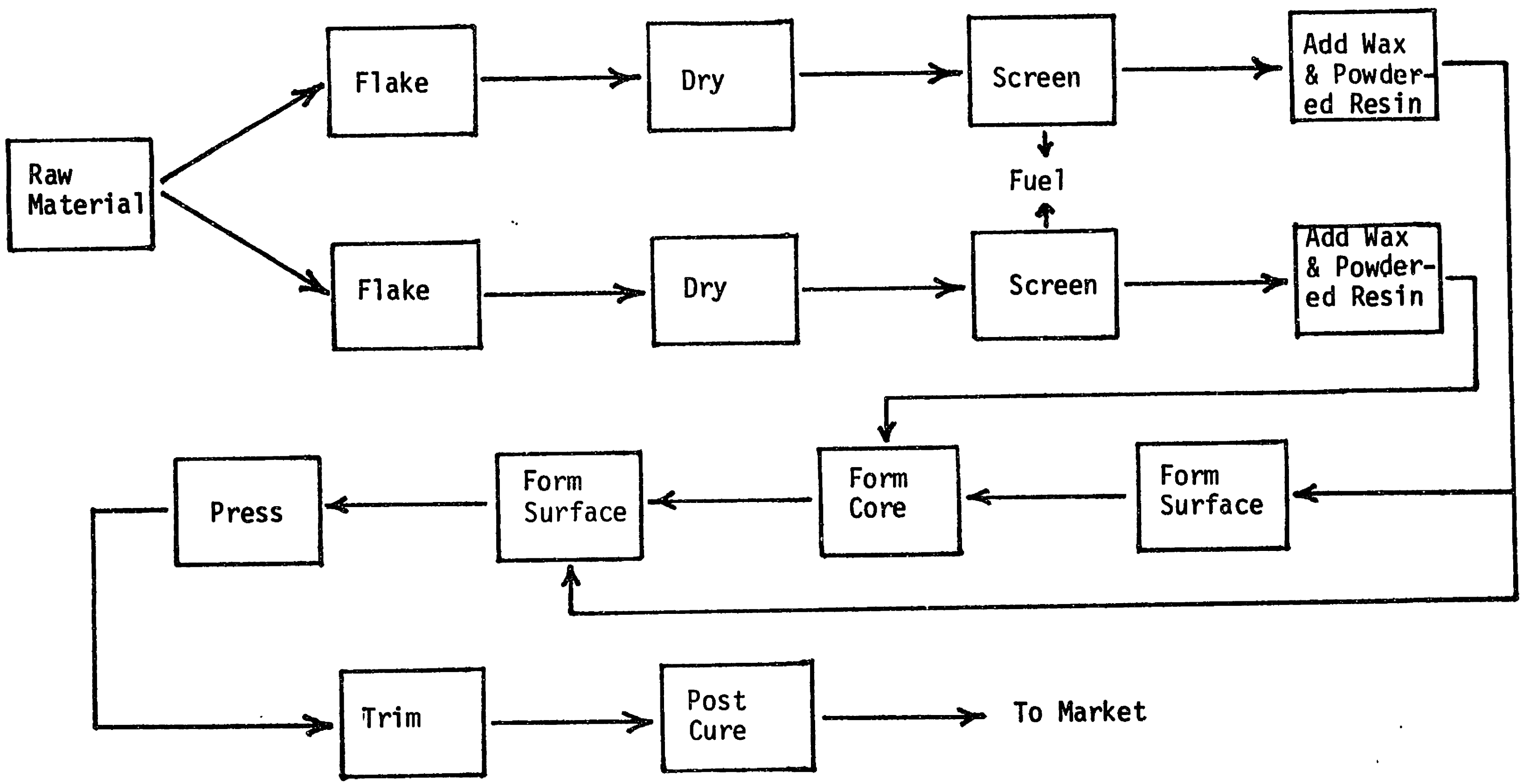


Figure 7-1

Idealized Typical Waferboard Process

powdered resin are added to the dried and screened material in tumble drum blenders. All these processing steps take place in two separate parallel lines, one generating material for the panel surface layers and one generating material for the panel core layer. Core layer material is normally smaller in size than surface layer material for reasons of product performance, leading to the requirement for separate parallel lines. From the blenders material is transported to surface or core forming machines. These pieces of equipment lay down a mat of wafers in three sequential layers -- bottom surface, followed by core, followed by top surface -- which, upon completion of forming, is fed into a hydraulic hot press for consolidation and adhesive curing. Pressed panels are removed from the press, trimmed to size (typically 4-feet by 8-feet for construction sheathing panels), and placed in "hot stacks" for further curing of adhesives, taking advantage of latent out-of-press heat remaining in the panels.

While simple conceptually, a waferboard process is highly capital intensive, embodied in expensive equipment which is kept running within a plant around the clock. The process is continuous, with the particle stream flowing somewhat similarly to the motion of a fluid through the unit operations from flake to final panel.

Figure 7-2 depicts a block diagram of an OSB manufacturing process, assembled, as was the case for Figure 7-1, using information from several equipment manufacturers. Conversations with representatives of OSB-producing companies were resorted to in lieu of the plant visits which aided arriving at a characterization of waferboard processes.

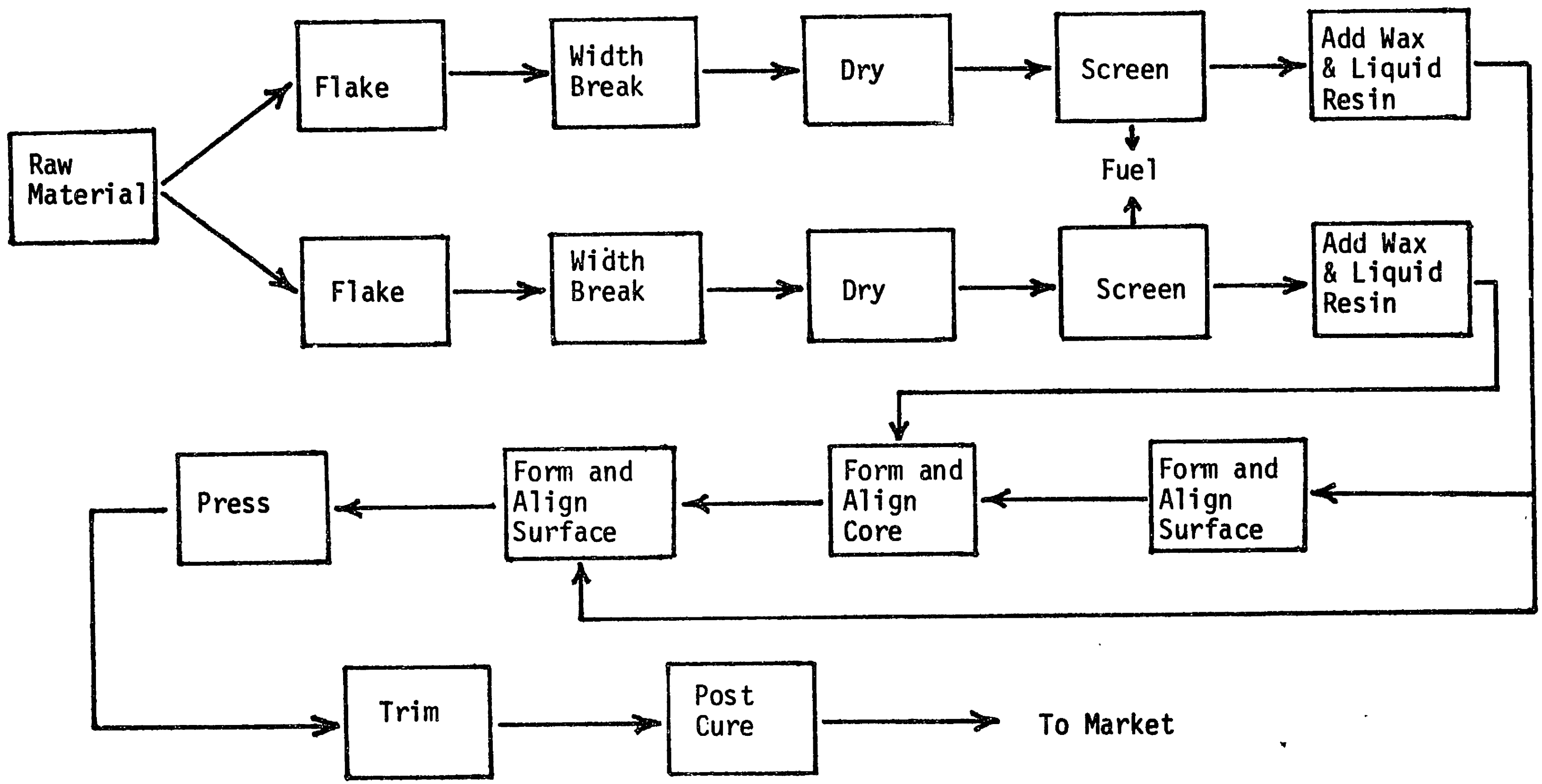


Figure 7-2

Idealized Typical OSB Process

Only a quick glance at Figure 7-2 is required to reveal the interesting fact that there are only a small number of seemingly minor differences between this process and the waferboard process of Figure 7-1. These differences are essentially three in number:

(1) In OSB manufacture, flaked material is split across the wood grain to convert wafers into strands which can be aligned in the forming unit operation;

(2) Flaked and dried material is blended with liquid resin; application of liquid resin to wafers has been a long-standing goal of waferboard producers (11); for technical reasons this has never been achieved with wafers, but has been accomplished with strands; use of liquid resin is desirable because of liquid's higher efficiency which will be seen in comparisons of product properties;

(3) Parallel alignment of the strands in OSB manufacture is accomplished during the forming operation, leading to the three-layered configuration with aligned surface layers and cross-aligned core.

Different engineering approaches for accomplishing these three alterations from what is essentially a waferboard process have been implemented by the three OSB-producing firms (Weyerhaeuser, Potlatch, and Elmendorf). It is interesting to note that the two Potlatch facilities were first announced as waferboard plants. Elmendorf's intentions were not made public until its plant was nearly complete and ready for production. Weyerhaeuser's plant was announced as an OSB facility and was designed from the start to produce OSB. It was after Weyerhaeuser's announcement that Potlatch recanted its waferboard strategy, announced it would become an OSB manufacturer and then went about redesigning its two waferboard processes by retro-fitting them to include OSB capability. Capital estimate studies done in the industry have indicated that incremental capital required for retrofitting an existing waferboard process to OSB capability is less than 10% of the capital required to build the initial waferboard process.

Even though this incremental capital is relatively small, it is foolish to suppose that a firm as well managed as Potlatch would take on the additional investment load to retrofit a facility designed to manufacture waferboard -- a product nearly guaranteed to be well-received by the market -- to enable it to manufacture OSB simply because another well-managed company (Weyerhaeuser) had announced its intentions to market the latter product. Such a decision would logically be made only on the basis of expecting some incremental return which would more than offset the incremental capital which is needed to be invested.

One area of incremental benefit lies in the relative receptivity of the two processes to lower grade raw materials. One of plywood's most serious shortcomings has been its inability to accomodate lower grades of raw material in its process and still produce an acceptable panel. The reconstitution inherent to waferboard's and OSB's processes is much more robust in being able to utilize less desirable raw material and still make a panel which has adequate properties. OSB has a slight advantage over waferboard because of the higher general overall bonding efficiency of the liquid resin it employs.

This flexibility alone, however, would not seem to justify the rush to OSB by this handful of producers. Other, more sizable benefits must be accruable to OSB. Such benefits can be demonstrated, due directly to the improved product performance characteristics of OSB. These are discussed in the following chapter.

CHAPTER 8

COMPARISON OF PRODUCT PERFORMANCE

It is not possible to assess the future acceptability of the new panel products without first comparing their characteristics and expected levels of performance. Since these new products are all intended to substitute directly for plywood in structural applications, their individual properties should be compared with those of plywood as well as with those of each other.

Because sheathing-type applications in light frame construction represent the primary end use market outlets for these panels, the product characteristics critical to performance as sheathing are of primary interest. These important product characteristics include weight, stiffness and strength (particularly in flexure), dimensional stability, and durability. A discussion of the role each of these characteristics plays in the overall acceptability of a structural panel, as well as comparisons involving the new panels and plywood, follow.

Weight

Table 8-1 provides a summary of the weight characteristics of west coast and southern plywood, COM-PLY^R, waferboard, and OSB. These and subsequent comparative data were gathered from Kidder-Peabody (10) and/or private communications with the APA (9), the NPA (11), and the Weyerhaeuser Company (12). Also included in this table are comparisons of overall weights of 4-feet by 8-feet panels at each of five panel thick-

TABLE 8-1

COMPARISON OF AVERAGE PANEL WEIGHTS

Product	Ave. Denisty (lb per cu. ft.)	Ave. Weight (lb) for a 4ft x 8ft panel with thickness of 3/8"	7/16"	1/2"	5/8"	3/4"
Western Plywood	31.5	31.5	36.75	42	52.5	63
Southern Plywood	36	36	42	48	60	72
Southern COM-PLY[R]	39	39	45.5	52	65	78
Midwest Waferboard	42	42	49	56	70	84
Midwest OSB	41	41	47.8	54.7	68.3	82

nesses: 3/8-inch, 7/16-inch, 1/2-inch, 5/8-inch, and 3/4-inch. This comparison is made by listing typical average values of overall panel density and weight for each. In terms of weight per unit volume, west coast plywood is clearly the lightest structural panel produced by the industry. Next lightest is southern plywood, followed by COM-PLY[R], whose weight exceeds that of plywood because of its higher density, particle-based core. Slightly heavier is OSB, and finally waferboard. OSB is a little lighter than waferboard because the strand alignment slightly reduces wood and resin requirements.

While weight has little direct influence on panel performance in service (i.e., on a roof, floor, or wall), it is nevertheless important for two reasons: first, heavier weight dictates increased transportation costs; and second, heavier weight has some effect on user -- particular contractor -- preferences.

Stiffness and Strength

By far the most important properties for structural panels are stiffness and strength. Because these panels are required in end use to be load-bearing members, and because the applied loads are panel-type loads, flexural stiffness and strength are of paramount importance. Of almost equal importance are panel resistance to racking and impact loads, and panel properties in tension, compression, and shear. In order to perform acceptably, panels must meet minimum standards in each of these property categories

Bending stiffness is measured by modulus of elasticity (MOE), and bending strength is measured by modulus of rupture (MOR). Through-the-thickness panel tensile strength is measured by internal bond strength (IB). Comparative values* of these three key properties are provided for western and southern plywood, COM-PLY^{R}, waferboard, and OSB in Table 8-2. Comparison of these data reveal that OSB properties are essentially on a par with those of plywood, while those of waferboard are somewhat lower. It is the aligned strand configuration of OSB which enables it to deliver properties similar to plywood's, as is expected due to the conceptual similarity of their respective constructions. Waferboard, on the other hand, being assembled into a less sophisticated configuration, possesses inferior properties.

Dimensional Stability

Dimensional stability was earlier defined as resistance to expansion and contraction due to changes in moisture content brought on by environmental conditions. The dimensional stability of panels is typically assessed by measuring two parameters: the in-plane expansion of a panel resulting from a large change in atmospheric relative humidity measured between two standard conditions, and the swelling of the panel through-the-thickness brought on by the same change in conditions.

Dimensional stability is an important indicator of panel performance because of the fact that panels used in construction often get wet on the job site (due to rain or humidity), and consequently, do expand.

----

*The values tabulated are typical average values and are not to be used for engineering design purposes.

TABLE 8-2

COMPARISON OF PANEL STIFFNESS AND STRENGTH PROPERTIES*

Product	Typical Values For: Modulus of Elasticity (lb per Sq. in.)	Typical Values For: Modulus of Rupture (lb per Sq. in.)	Typical Values For: Internal Bond Strength (lb per Sq. in.)
Western Plywood	1,250,000	6,500	110
Southern Plywood	1,250,000	6,500	100
Southern COM-PLY^R	1,250,000	6,500	90
Midwest Waferboard	500,000	3,000	70
Midwest OSB	1,250,000	7,000	120

*Values tabulated are not to be used for engineering design purposes

While not all panels necessarily are wetted, many do get saturated during the construction process. This is particularly true for floor panels. As a result of this expansion, panels butting against one another have the potential effect of buckling between framing members or even moving out walls or partitions in the structure. Thickness swell has cosmetic importance, due to the undesirability of having differential expansion of adjacent panels which can cause finish flooring materials (tile and carpeting) to buckle unattractively.

Table 8-3 documents typical linear expansion and thickness swell values for western and southern plywood, COM-PLY^R, waferboard, and OSB. Small, but not significant, differences in linear expansion values among panel types are discernable. COM-PLY^R is slightly more prone to thickness swell than plywood, with OSB somewhat worse than COM-PLY^R, and waferboard the worst of all.

Durability

A final panel performance characteristic of critical importance to sheathing applications is durability, which can be defined as long-term retention of properties. Traditionally, the durability of panel products has been assessed using various accelerated aging tests. These measure the strength of test specimens, then measure the strength of similar samples after they have been subjected to several heat, moisture, cold, and dry cycles meant to simulate the effects of many years of service. Durability is indicated by the ratio of strength after accelerated aging to initial strength, sometimes referred to as "strength

TABLE 8-3

COMPARISON OF PANEL DIMENSIONAL STABILITY PROPERTIES

	Typical Values For	
Product	Linear Expansion (%)	Thickness Swell (%)
Western Plywood	0.25	10
Southern Plywood	0.25	10
Southern COM-PLY[R]	0.30	15
Midwest Waferboard	0.30	30
Midwest OSB	0.20	20

retention." Typical strength retention values for plywood, COM-PLY^R^, waferboard and OSB are tabulated in Table 8-4. The trend of these data is similar to that exhibited in the comparisons for stiffness and strength. Namely, OSB performance is essentially on a par with plywood and COM-PLY^R^ performance, and waferboard's performance is considerably lower. Technically, waferboard's inability to match OSB's strength retnetion is due to the powdered resin system it utilizes, as opposed to OSB's more efficient liquid resin system.

Summary

While these comparisons of structural and engineering characteristics of wood-based structural panels have been brief, two significant conclusions appear to be inescapable:

(1) COM-PLY^R^ and OSB are about comparable to plywood on all important bases except weight (i.e., density);

(2) Waferboard is inferior to the others in nearly all product characteristics, with lower stiffness, strength, and durability, and greater weight.

At this point there seems to be a dilemma in the industry. Waferbaord has been a commercially successful product since its initial introduction, yet all the data in this chapter indicate that it is a markedly inferior product. To date its competition as a substitute for plywood has been with COM-PLY^R^, the latter of which likely will not be a major market force for reasons of economics. Has waferboard succeeded because plywood has been historically an "over-built" product for its

TABLE 8-4

COMPARISON OF PANEL DURABILTY PROPERTIES

Product	Typical Strength Retention Values (%)
Western Plywood	60
Southern Plywood	60
Southern COM-PLY[R]	60
Midwest Waferboard	30
Midwest OSB	65

markets, or has waferboard succeeded solely for reasons of costs and price discounts? Will waferboard continue to succeed? Will the introduction of OSB, with its superior characteristics, complicate waferboard's market picture? Is there some economic justification for additional producers to opt for OSB or for waferboard manufacturers to convert their processes to OSB capability?

These important questions must be addressed and analyzed before a forecast for the future of structural panels can be formulated. Kidder-Peabody (10) states that the key to success of the new panels will depend on their market acceptance. This market acceptance depends, in turn, on building code approvals, panel performance, consumer preference, relative price, and overall demand for structural panels. The most obvious areas of these five categories where product properties can be expected to exert an influence on acceptance are the first two: building code approvals, and panel performance. The latter of these two categories, at least as far as structural performance (life-safety) is concerned, influences the former. Having arrayed comparisons of product performance it is next necessary to compare and contrast code approvals for all product types.

Status of Building Code Approvals

Now residing in the public domain are series of code approvals for all structural panels used in light frame construction. In the hope that pulling this information together would provide insight as to whether improved product properties and performance can lead to market advantages, independently of any cost considerations, the code approval literature of the three major building codes agencies was studied. As a result, a summary of the current code approvals for plywood, COM-PLY[R], OSB, and waferboard was assembled.

As discussed, structural panels are used in light frame construction as wall sheathing, roof sheathing, floor sheathing, and in single-floor systems. A summary of current code approvals for wall sheathing is shown in Table 8-5. From the table it can be seen that plywood is approved for use as wall sheathing at 5/16-inch thickness, whereas the other structural panel products are currently not allowed to be used in thicknesses less than 3/8-inch in this application. While this appears on the surface to be an advantage for plywood, it is a construction reality that typically 3/8-inch plywood is used in this application anyway. In any event, according to the APA, only approximately 2.7% (13) of total plywood sales is marketed into this end use which, in recent years, has constituted market territory which has been grudgingly surrendered to rigid foams which have improved insulation characteristics. In summary, the relative performance characteristics of the four types of structural panels have not been reflected in code approvals for wall sheathing, but this market is so small that any effect would be barely noticeable.

Table 8-6 summarizes the current status of salient building code approvals for roof sheathing. These data are broken down into two categories, to reflect established building practices. With thinner panels, code authorities require the use of edge support in the form of H-shaped clips at the edges of panels to help in load transfer between them and thus make the resulting roof deck stiffer and safer. In order for a

TABLE 8-5

COMPARISON OF PANEL CODE APPROVALS FOR WALL SHEATHING

Product	Minimum Thickness Allowed For 16" Stud Spacing
Plywood	5/16"
COM-PLY[R]	3/8"
Waferboard	3/8"
OSB	3/8"

TABLE 8-6

COMPARISON OF PANEL CODE APPROVALS FOR ROOF SHEATHING

	Mimimum Thickness Allowed for Roof Spacing of 24"	
Product	With Panel Edge Support	Without Panel Edge Support
Plywood	3/8"	1/2"
COM-PLY[R]	3/8"	1/2"
Waferboard	7/16"	9/16"
OSB	3/8"	7/16"

panel type to be used without these troublesome clips, it must of necessity be stiffer and more rigid -- hence, thicker. COM-PLY^R roof sheathing approvals are identical to plywood's. Waferboard can be seen to be at a disadvantage to the other panel types with respect to thickness. However, all is not as it seems at first glance. Historically, although builders are authorized to use 3/8-inch plywood, they generally choose not to do so because of the bending and sag which sometimes occurs when, during construction, workmen step onto the edges of these thin panels between supporting beams. Instead, builders typically choose more expensive 1/2-inch plywood. Into this niche has stepped waferboard in recent years. In spite of its markedly lower stiffness, building workmen have nonetheless found waferboard at 7/16-inch thickness, accompanied with edge supports, to be an acceptable roof sheathing panel. Hence, what emerges is a head-to-head market competition between 7/16-inch waferboard and 1/2-inch plywood in this end use, a competition which for obvious reasons has economic advantages for waferboard. This has been a significant marketing coup for waferboard in its rather brief history.

One nagging drawback keeps this from being a complete success for waferboard; i.e., that at 7/16-inch thickness it is still required to be accompanied in service by the edge support-providing clips. OSB has succeeded in improving on waferboard's position by achieving code approvals at 7/16-inch minimum thickness without the additional requirements for edge support, a quality which OSB producers are confident will give their product incremental attractiveness over waferboard in the eyes of builders.

What emerges from these comparisons of roof sheathing approvals is an impression that the building code agencies have recognized the relative performance characteristics of waferboard and OSB panels in granting their approvals. It could also be argued that, to some degree, the ingenuity of waferboard and OSB producers in recognizing opportunities may have had as large an effect in generating their attractive positions as have their products' characteristics, and that inherent inertia of plywood (and COM-PLY[R]) producers has left them open to these assaults. Nevertheless, in this application -- representing 16.8% of total plywood sales (13) -- waferboard and OSB have achieved advantages over plywood, with OSB's relative position being superior to waferboard's. Because code approvals play a predominant role in the development of marketing strategy and overall sales programs in this industry, these code approval advantages are directly translatable into market advantages.

Table 8-7 summarizes the current status of building code approvals for structural panels used as floor sheathing in light frame construction. In this end use category significant differences exist between minimum approved panel thickness configurations for each panel type. As before, plywood and COM-PLY[R] code approvals coincide. Waferboard, because of its inferior flexural properties, is currently required to be a full 1/8-inch (i.e., 25%) thicker than plywood.** OSB, on the other hand, not only can be significantly thinner than waferboard in this end use (7/16-inch versus 5/8-inch, or 30% thinner), it is also approved for use in this application at a thickness less than plywood. Here, as was the case with roof sheathing, the code authorities have recognized explicitly

----

**One waferboard producer, however, has achieved code approvals for its panel at 1/2-inch thickness for this application; another has approval at 21/32-inch; all other producers are required to be at least 5/8-inch.

TABLE 8-7

COMPARISON OF PANEL CODE APPROVALS FOR FLOOR SHEATHING

Product	Minimum Thickness Allowed For 16" Joist Spacing
Plywood	1/2"
COM-PLY^R	1/2"
Waferboard	5/8" *
OSB	7/16"

*One waferboard producer has achieved code approvals for this end use at 1/2-inch thickness, and another at 21/32-inch.

the improved structural characteristics of OSB over waferboard by granting approvals to OSB which have a large potential advantage in the market over those of waferboard. To date plywood producers have not responded to this new and probably unexpected thickness advantage OSB has achieved over plywood.

Table 8-8 summarizes the status of code approvals for structural panels used in the single-floor system, in which a single panel is required to serve the dual role of sub-floor and underlayment. This type of construction is assembled with the panel used over one or the other of three spans. For the smallest and longest of the three spans (16-inch and 24-inch, respectively), all four panel types are allowed the same minimum thickness (although not all waferboard producers have achieved approvals). For the middle span (19.2-inch), only plywood, COM-PLY^R, and OSB are approved, and their respective minimum thicknesses coincide. As was the case for floor and roof sheathing applications, OSB has a marked thickness advantage over waferboard in single-floor applications, although it has no such advantage over plywood or COM-PLY^R.

For floor applications in general, OSB has more advantageous code approvals than does waferboard, and therefore, has the potential for market economic advantages in this general end use category. Floor sheathing and single-floor construction together have accounted for an estimated 14.5% of total plywood sales, making these thickness advantages potential sources of significant commercial gain.

Conclusions

In this chapter the properties and characteristics of the new struc-

TABLE 8-8

COMPARISON OF PANEL CODE APPROVALS FOR SINGLE-FLOOR APPLICATIONS

Product	Minimum Thickness Allowed for Joist Spacing of 16"	24"
Plywood	5/8" *	3/4"
COM-PLY[R]	5/8" *	3/4"
Waferboard	5/8" **	Not Approved
OSB	5/8"*	3/4"

*Also applicable for joist spacing of 19.2"

**Not applicable to all waferboard producers tural panel products have been compared both with each other and with plywood, the product for which they are marketed as substitutes. From the standpoint of product properties, COM-PLY^{R} and OSB are very nearly equivalent to plywood. Waferboard, on the other hand, is markedly inferior in characteristics. Moreover, a comparison of the status of building code approvals shows that superior product characteristics have been recognized by regulatory groups in the form of panel thickness advantages which can be translated directly into market advantages.

Thorough study of these data suggests that the substitute panel type holding the most advantageous position, independent of any production cost considerations, is OSB. In fact, OSB's relative code approval position at this point is even better than plywood's in two applications, roof sheathing and floor sheathing, which together have comprised a large historical plywood volume outlet.

Having firmly established OSB as a superior product from a performance standpoint, it is next necessary to analyze the competing substitute panel types from the standpoint of manufacturing costs. This is the subject of the following chapter.

CHAPTER 9

MANUFACTURING ECONOMICS

A panel end use thickness advantage is directly translatable into additional monetary return only if not cancelled out by any commensurate increased costs. How do the manufacturing costs of the various panel products compare? Kidder-Peabody (10) has attempted to analyze the variable manufacturing costs associated with each panel type. By appealing to the Kidder-Peabody results together with the results of private discussions with associations (9, 11) and a major producer (12), it was possible to assemble Figure 9-1. This chart graphically compares typical variable manufacturing costs for western and southern plywood, southern COM-PLY^R, and upper midwest waferboard and OSB. The costs displayed are in dollars per thousand square feet of 1/2-inch thickenss. Variable cost line items are wood, adhesive, labor, energy (thermal and electrical), and other.

Several points of interest emerge from inspection of Figure 9-1. First, western plywood is the most expensive structural panel to produce, primarily because of its high wood costs relative to the other panels. Somewhat lower in cost is southern plywood. Slightly lower in cost than southern plywood is COM-PLY^R. It was previously contended that COM-PLY^R economics would not be greatly attractive relative to plywood because manufacture of COM-PLY^R requires two separate capital-intensive processes, each of which adds significant fixed cost components. When fixed costs are added to variable costs (in which southern plywood and southern COM-PLY^R differ only slightly), the higher COM-PLY^R fixed costs will

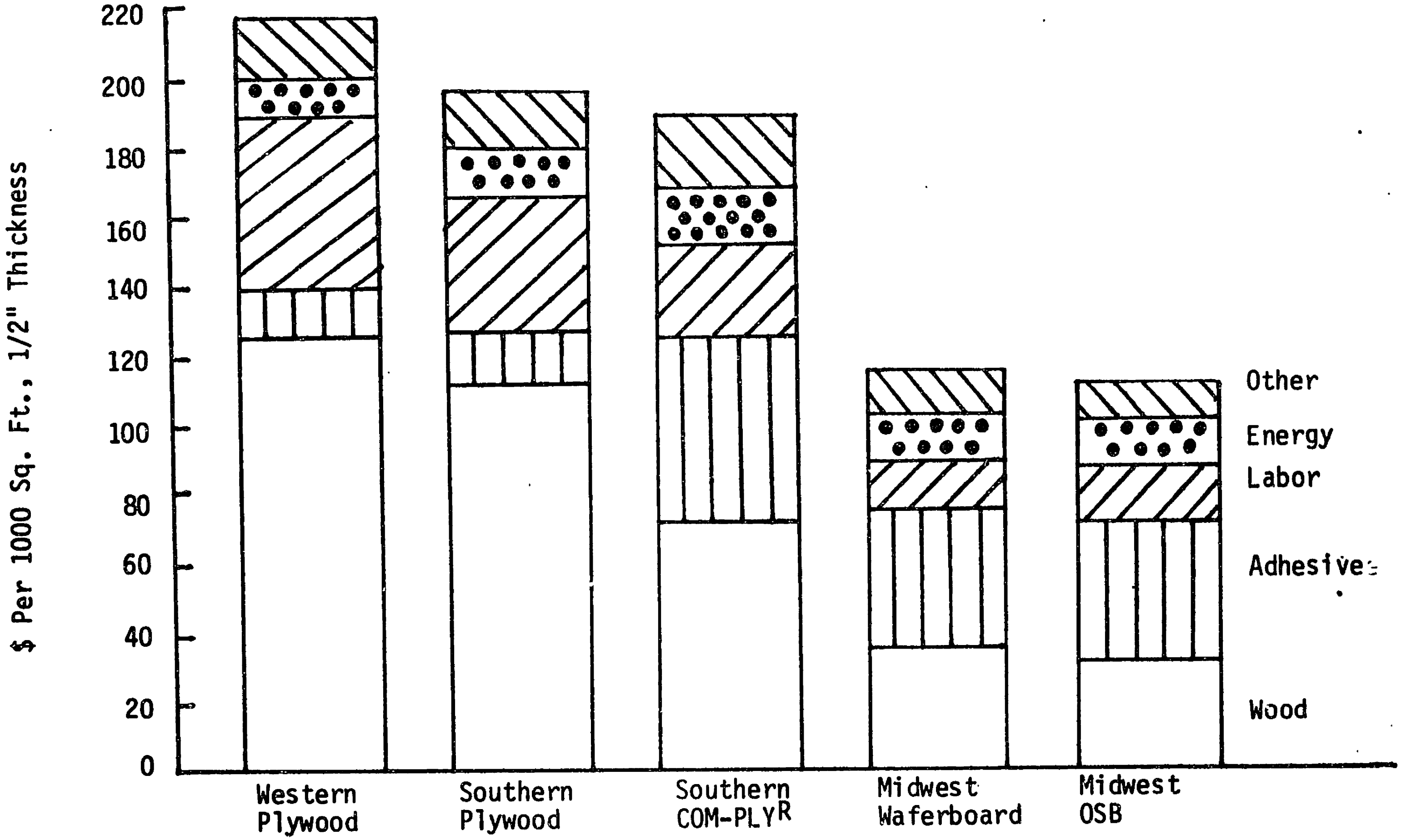


Figure 9-1

Comparison of Panel Variable Manufacturing Costs result in that product's having little if any overall cost advantage relative to plywood.

Waferboard and OSB, on the other hand, have tremendous manufacturing cost advantages over the veneered products. A large part of this advantage is due to drastically lower wood costs, arising from the large difference in stumpage values between midwest aspen and western Douglas fir and Southern pine. Almost equally influential is the difference between labor costs. Plywood processes, by their nature, require much more labor than do waferboard and OSB processes, which are conceptually similar to capital-intensive particleboard processes. The only area where plywood has an advantage in cost is in adhesives where its costs are markedly lower than for COM-PLY^{R}, waferboard, and OSB. This can be considered to be a two-edged sword for the new composite panels. At the current stage of technology, adhesives used are phenolics which are derivatives of petrochemicals. Having a large portion of a product's manufacturing costs tied up in such additives can make that product extremely vulnerable to any future (and inevitable) increases in the price of oil. On the other hand, adhesive technology development is in a neophyte stage for these products, and the high current adhesive costs can be looked upon as an opportunity for new technology to lead to future significant cost reductions.

Because of the importance of present and future cost of wood, it is imperative to study in more detail its current and potential impact. Table 9-1 (10) pulls together a comparison of typical wood costs for western and southern plywood, southern COM-PLY^{R}, waferboard, and OSB. As in Figure 9-1, costs are displayed in dollars per thousand square feet,

TABLE 9-1

COMPARISON OF TYPICAL PANEL WOOD COSTS ($ PER 1000 Sq. Ft.)

	Western Plywood	Southern Plywood	Midwest Waferboard/OSB
Stumpage Price	190	167	3
Harvesting/Transportation	110	55	30
Delivered Cost	300	222	33
Less: Residental Value	36	24	--
Net Wood Cost	264	198	33

1/2-inch basis. Components of total wood costs are stumpage plus transportation and delivery less residual value (plywood peeler cores are either chipped or sold as landscape timbers; all the waferboard/OSB log is consumed in the process). As can be seen, there is a significant difference between plywood log transportation and delivery costs for the west and those for the south, and both plywood figures exceed those for waferboard or OSB. By far the most significant differences, however, surface in comparison of stumpage values. For plywood and waferboard/OSB total wood costs to come to parity, midwest aspen stumpage prices would have to increase many-fold, or western and southern plywood log stumpage prices would have to plummet. Neither of these occurrences is seen in the industry to be at all likely. The most probable scenario is that, as demand on formerly low value, undesirable stands of aspen increases, stumpage prices for waferboard and OSB raw material will increase. However, this increase will not be to such a degree as to make unveneered panel wood costs approach those of plywood.

Here, now, emerges a picture of several competing panel types. The traditional panel -- plywood -- is under severe cost competition from new panel types. One panel type -- COM-PLY[R] -- has only a slight cost advantage over plywood. Waferboard and OSB, however, own significantly better cost pictures. OSB seems to have a very slight cost advantage relative to waferboard. The comparisons are not yet complete, however. Up to this point the products compared were all of the same thickness. From the discussion of code approvals and likely market break-downs, this is <u>not</u> a comparison which accurately and fairly takes into account the relative performance characteristics of the different panel types.

Recall that, in some end uses, the inferior properties of waferboard have resulted in its being marketable only at thicknesses which exceed those of plywood and OSB. In addition, recall that OSB possesses a thickness advantage in some end uses not only over waferboard, but over plywood as well. In order to compare the implications of these end use issues on producers and manufacturing costs, the data of Figure 9-1 have been re-assembled into the format of Figure 9-2. This chart compares variable manufacturing costs for each product for a particular end use category -- floor sheathing -- in terms of dollars per thousand square feet of marketable panel. Thus, for plywood and COM-PLY[R] the costs are in dollars per thousand square feet, 1/2-inch basis. For waferboard they are in dollars per thousand square feet, 5/8-inch basis. For OSB they are in dollars per thousand square feet, 7/16-inch basis.

Figure 9-2 gives a truer comparison of the relative cost advantages of the four panel types in this end use <u>as seen by the producer</u>. Quite clearly, what emerges from this comparison is a picture of OSB as a product with not only performance advantages over waferboard, but also significant cost advantages which are directly traceable to its improved performance characteristics.

In conclusion, a number of points can be summarized:

- Plywood, is, and will continue to be, at a severe cost disadvantage relative to the new panels;
- COM-PLY[R] possesses at most only a slight cost advantage over plywood;
- Waferboard and OSB, primarily due to lower wood and labor costs, have a much better current and projected cost picture than

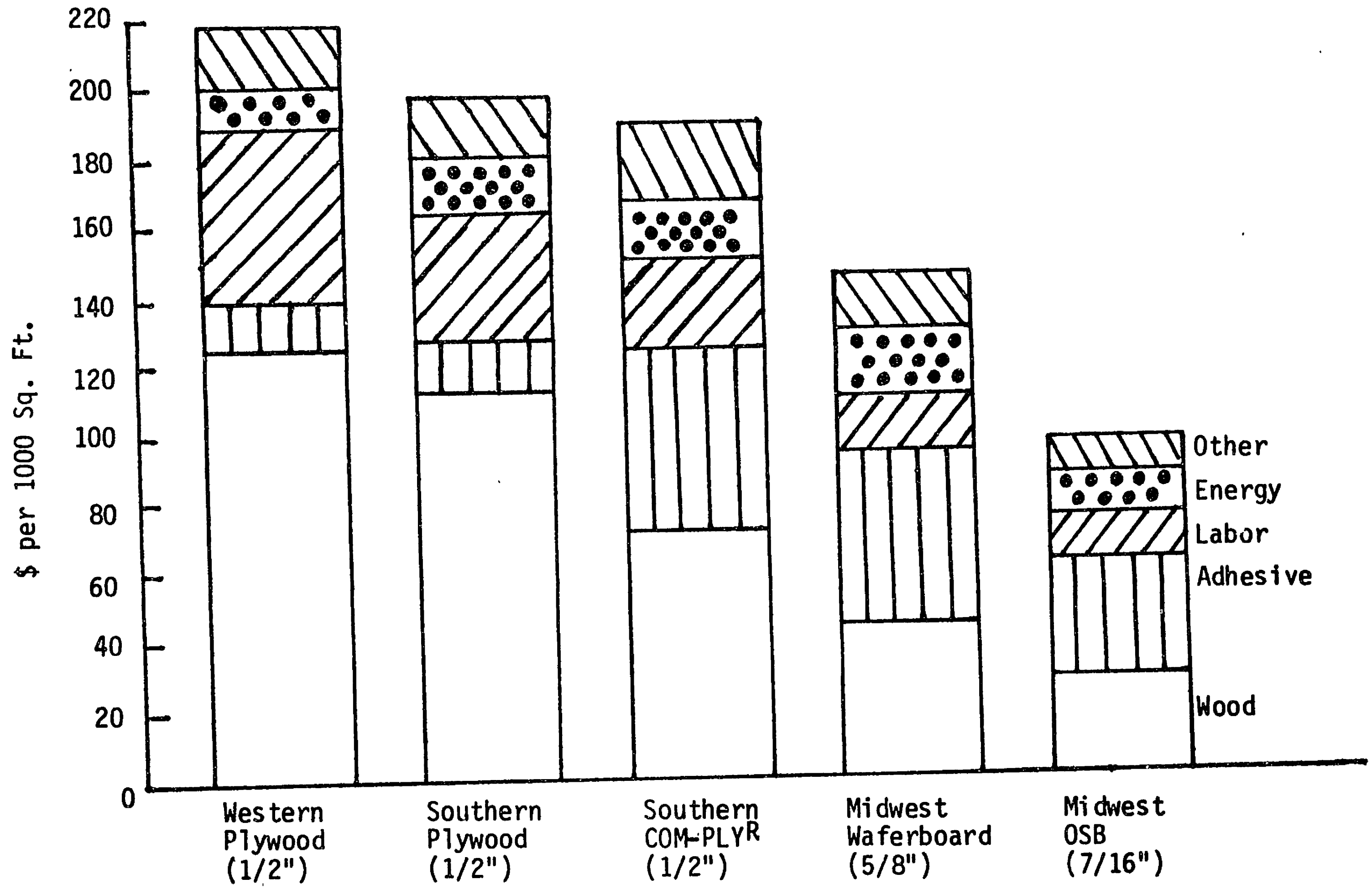


Figure 9-2

Comparison of Variables Manufacturing Costs for Floor Sheathing either plywood or COM-PLY[R];

- In the largest volume end uses -- roof and floor sheathing and single floor systems -- OSB has a significantly better cost posture than does waferboard and, of course, a tremendously better cost posture than does plywood.

Up to this point the entire focus of the analysis has been on light frame construction applications of structural panels which have collectively accounted for a large proportion of plywood's historical production. It is useful to pause for a short while at this juncture and systematically look at plywood's potential vulnerability to invasions of all of its traditional markets. This will help to arrive at an accurate overall picture of the likely progression of this ongoing substitution movement. This will be the subject of the following chapter. Together with a discussion of variables important to success or failure of the new panels it will help toward formulation of possible steps plywood producers can take to respond to this serious threat.

CHAPTER 10

PLYWOOD'S VULNERABILITY AND KEYS TO SUCCESS FOR NEW PANELS

Table 2-1 displayed a summary of plywood's sales volumes in all its end use categories, as compiled by the APA. Kidder-Peabody (10) has superimposed on this end use breakdown a series of subjective judgments as to the vulnerability of plywood to incursion by the new panels into each of its end markets. The Kidder-Peabody approach was to rate end market plywood susceptibility to penetration as high, medium, or low. The results of the Kidder-Peabody analysis are displayed in Table 10-1. Plywood end use markets are divided into five main categories: new residential construction, repair and remodelling, industrial, non-residential construction, and other uses. Each of these categories is further broken down into sub-categories. For each sub-category, the susceptiblity of plywood to penetration is rated.

According to Kidder-Peabody's subjective assessments, nearly half (48.2%) of plywood's 1976 sales categories are highly susceptible to the new panel invasions, and less than one-tenth (7.1%) have low susceptibility. The remainder are in the medium category.

A few of Kidder-Peabody's assessments are arguable. Wall sheathing is certainly a highly susceptible end use, as are concrete forming applications, yet both categories were related as medium by Kidder-Peabody. If these adjustments are made to the Kidder-Peabody summary, 55.3% of plywood's end use markets can be subjectively rated as highly susceptible to new panel penetration. Among these categories are all structural applications in light frame construction and nonresidential and farm

TABLE 10-1

PLYWOOD VULNERABILITY BY END USE MARKET

End Use Category	Per Cent Of Total Plywood Markets	Susceptibility to Penetration By New Panels		
		High	Medium	Low
New Residental Construction				
Roofs	16.8	X		
Floors	14.5	X		
Siding/Trim	5.2		X	
Walls	2.7		X	
Soffits/Overhangs	1.6	X		
Cabinets/Shelves	0.2			X
Garage Doors	0.2			X
Interior Walls	0.1			X
Other	0.6		X	
Total New Residential Construction	41.9	X		
Repair and Remodelling				
Additions/Repairs	12.7		X	
Shelving/Furniture	4.2			X
Small Buildings	1.7	X		
Crafts/Games/Toys	0.6	X		
Transportation	0.2		X	
Other	1.1		X	
Total Repair and Remodelling	20.5		X	

TABLE 10-1 (Cont'd)

End Use Category	Per Cent Of Total Plywood Markets	Susceptibility to Penetration By New Panels		
		High	Medium	Low
Industrial Markets				
Products Made For Sale	9.2		x	
Materials Handling	2.4			x
Plant Repair	2.3	x		
Retail/Wholesale Trade	0.2		x	
Other	2.1		x	
Total Industrial Markets	16.2		x	
Nonresidential Construction				
Nonresidential Building	7.3	x		
Auxiliary Uses	1.5	x		
Concrete Forming	4.4		x	
Farm Building	1.9	x		
Total Nonresidential Construction	15.1	x		
Other Uses	6.3		x	
Total	100.0	48.2	44.7	7.1

building, as well as a variety of other end uses for which the "appearance" of plywood does not play a critical part. Together these categories constitute a significant portion (a majority!) of plywood's end use markets.

On the basis of these subjective ratings, it is fair to hypothesize that, at least theoretically, the new structural panels have the potential to penetrate into most plywood end markets. Much of the penetration is already vigorously underway, in the form of penetration of waferboard and COM-PLY^R into new residential construction.

Having the "potential" to make large scale penetrations does not alone guarantee success for the new panels. It has been shown that these panels have achieved regulatory acceptance, have significant cost advantages, and can be expected to perform in service in at least an acceptable manner. The likelihood of success for these panels, however, rests not only on these factors but also on other economic factors as well. It is useful at this point to summarize and discuss all factors which will affect the overall acceptance of the new panels, given plywood's subsceptibility.

<u>Overall Demand</u>

For obvious reasons, the success of the newly introduced products will depend on the overall demand created in the economy for structural panels. With U.S. housing construction activity in its currently depressed state, demand for structural panels is at conspicuously low levels. If housing starts recover to the level of two million units per year, acceptance of the new panels should be significantly speeded up because overall demand for structural panels will be high. If housing starts remain at or below the level of one million units per year, overall structural panel demand will be low and acceptance of the new panels will be slowed. While it can be argued that in a low demand market the high cost product (plywood) will suffer most, the new panels will also suffer, both in the short term via low demand for structural panels, and in the long term by virtue of a lengthened product acceptance period.

Delivered Costs

The products having the lowest total delivered costs to the customer will, in general, have the most advantageous position. While the analysis of the preceding chapter did not address product transportation costs, it is nevertheless clear that waferboard and OSB will have significant cost advantages over the other product types. Moreover, OSB has an improved cost position relative to waferboard if end use application is taken into account. As long as these cost advantages exist, acceptance of the new panels will be facilitated. Kidder-Peabody (10) has included transportation costs to arrive at estimates of panel delivered costs to various specific market locations, without affecting the ranking of product types relative to cost advantages.

Marketplace Acceptance

The overall key to success of the new panels rests in their actual acceptance in the marketplace. This acceptance depends on building code approvals, panel performance, preference of customers, and overall price. The importance of building code approvals and the status of approvals for all product types have already been discussed. Like-wide, the relative performance characteristics of the different panel types is now well understood. The area of customer preference is worthy of further discussion.

There are several difficult to quantity factors that have had and should continue to have an influence on the acceptability of COM-PLY^{R}, waferboard, and OSB. For example, waferboard and OSB do not possess the "look" of veneer which in a tradition-bound industry is a drawback in some applications. This has not, however, had a detrimental effect on the use of waferboard as sheathing, probably because in these applications the panel is eventually covered and, therefore, not visible in the final structure. For other applications (which in Table 10-1 were generally rated as medium or low in terms of plywood susceptibility), waferboard and OSB are at an appearance disadvantage relative to plywood.

Another area of resistance affecting acceptance of waferboard and OSB relates to roof sheathing applications. In roofing applications the relatively slick surface (especially when the panel is wet) of waferboard has created some traction problems for builders. This problem has, however, been solved by many waferboard producers (11) through the process vehicle of touch sanding the panel surface to "roughten it up". Two OSB producers (12) -- Potlatch and Weyerhaeuser -- are embossing a screen-like textured surface into their panels during pressing so as not to be forced to sand the finished product. This is another, and more efficient, way to address the traction problem. Because it is likely that all waferboard and OSB producers will adopt one of these methods or another method for improving surface traction, the "slippery roof" problem will probably not have too large an effect on overall product acceptability.

As has been discussed, the new panels are at a weight disadvantage relative to plywood. For example, consider roof sheathing. A 1/2-inch thick Douglas fir plywood roof panel weighs approximately 42 pounds, whereas a typical 7/16-inch thick waferboard panel weighs 49 pounds and a typical 7/16-inch thick OSB panel weighs approximately 48 pounds. Since these structural panels are all somewhat bulky and difficult to handle, the increased weight of waferboard and OSB is at least a slight disadvantage relative to plywood.

Producers of waferboard and OSB can be expected to rise above the drawbacks posed by the appearance, traction, and weight problems. To this point, they have not seemed to affect the acceptance of waferboard; the reason is simply one of price. Historically waferboard producers have passed along to consumers some portion of their cost advantage relative to plywood in the form of price discounts, and the product has been accepted in part because of these lower prices. The price issue is and should likely continue to be the single most influential issue affecting the success of the new panels.

Historically waferboard has been discounted at a delivered price roughly 15% lower than the price of southern plywood (12). Kidder-Peabody (10) has compiled detailed price histories for waferboard, as well as some projections for future pricing. At this discounted price level the cost advantage waferboard possesses enables producers to generate high enough returns to stimulate the current explosion in capacity expansion.

OSB has a cost advantage relative to waferboard. Furthermore, its improved product characteristics should enable its lowest likely price to equal or exceed the price of waferboard. Because of its improved properties, it could command a pricing premium relative to waferboard. An argument could be made for OSB pricing to be at or near parity with southern plywood. Such pricing levels, when combined with OSB's cost advantages relative to all the other panel types, would enable it to yield returns more attractive than for the other product alternatives.

In summary, plywood markets are extremely vulnerable to incursion by the new panel types. There are several key factors influencing the success -- current and future -- of these new panels, foremost among them being overall demand for structural panels and price. Whether overall demand for structural panels is high or low, the new panels have advantages in cost and/or performance which give them sufficient price flexibility that they should significantly penetrate plywood markets. High demand will lead to fast penetration, low demand to slower penetration (in volume, but likely not in rate). Among the new panel types, OSB possesses the most advantageous combination of cost and performance.

CHAPTER 11

NEW PRODUCT OPPORTUNITIES AVAILABLE TO THE NEW PANELS

Having clearly established the degree to which plywood is vulnerable to further invasion from the new structural panels and laid out how the emerging substitutes compare in attractiveness to plywood and to each other, another question arises which merits discussion. Neglecting COM-PLY^{R}, which is in actuality essentially a slightly altered plywood product, are there any market end uses open to the new panels which arise as a direct consequence of their properties, characteristics, or manufacturing processes? Frequently, new technologies (e.g., waferboard and OSB) which are developed to replace existing technologies (plywood) possess features which result in the opening up of new, many times unplanned and unforeseen, possibilities and marketplace opportunities. (For example, many technologies developed for defense or space exploration purposes have been applied to industrial or consumer products or processes.) Does this possibility exist in this situation?

To answer this question, it is necessary to first point out essential differences in the processing technologies for plywood and for waferboard/OSB (recall that the waferboard and OSB processes are identical except for a few small differences). Plywood is made from veneers. Waferboard, on the other hand, is made from wafers, and OSB is made from strands, or narrow wafers. Not much imagination is required to think of wafers and strands as, in effect, small veneers, and to think of the waferbaord/OSB process as one which handles many legions of these "mini-veneers" in continuous, automated processes. Because of the relative size of their constituent particles, waferboard and OSB processes, therefore, are considerably more flexible than the plywood process. This flexibility (particularly when coupled with the basic notion of strand alignment) suggests possible panel ingredient configurations which are infinite in number. Like the fiber-reinforced composite materials first developed in the 1960's but only now finding heavy use in the aircraft industry, the process which manufactures OSB has the basic capability to generate panel products which have had desired properties designed and built into them. While such potential end use markets are difficult to specifically identify today, it is not illogical to suppose that such opportunities will emerge in the future. Perhaps future housing construction will modernize and require structural panels having significantly different properties than have plywood or OSB as currently produced (e.g., higher stiffness/weight and strength/weight characteristics). If so, it is the OSB process which offers the most viable route for processing panels which have been manufactured to a set of desired properties, rather than settling for naturally provided wood properties. Exotic possibilities arise when one considers the possibility of molding shapes for structural or other applications by simply replacing the flat platens in the press with shaped dies. Possible examples include molded I-beams or box beams.

Another significant difference in processing technologies exists between plywood and waferboard/OSB which leads directly to potential new market opportunities for the latter product category arising directly from the nature of its process. Plywood is essentially a 4-foot by 8-foot panel, and the press which consolidates it during manufacture is a nominal 4-foot by 8-foot press. Any end use requiring a structural panel which is larger than 4-foot by 8-foot and which utilizes plywood, must result in the presence of panels having edge or end gluing or both. While waferboard and OSB used as sheathing are marketed as 4-foot by 8-foot panels, the hydraulic presses used in manufacturing them are considerably larger. Typical press sizes range from 4-foot by 16-foot to 8-foot by 24-foot in size. Hence, waferboard and OSB can conceivably be made available, depending on individual manufacturers, in finished sizes as large as 8-foot by 24-foot.

Clearly, this opens up a vast new set of product and end use opportunities not available to plywood. Any application which can utilize a large panel becomes a possible end use market. Markets for large panels already exist in mobile home and manufactured housing manufacture. These markets are served by particleboard panels which replaced plywood precisely because of the larger sizes available in particleboard panels. Both waferboard and OSB are superior in performance to particleboard although more expensive to produce, primarily because particleboard is manufactured from urea-formaldehyde, an inexpensive, interior-grade binder.

Another potential new market outlet is in the category of long span structural beams, particularly I-beams. Long span I-beams for use in industrial construction are manufactured with plywood as the web material, with end joints in the web every 8 feet. Either waferboard or OSB would perform adequately in this end use with considerably fewer end joints.

It was already established in Chapter 10 that concrete forming is a traditional plywood market vulnerable to penetration by the new panels. The larger sizes possible with waferboard and OSB will be more attractive to some contractors than 4-foot by 8-foot plywood panels.

Large panels could find attractive market outlets in industrial roof systems, in this case competing with concrete and steel systems. Thus, possibilities arise in non-traditional applications primarily because of features of the new processing technology.

While several other possibilities can be listed, the point is already clear. Waferboard and OSB are manufactured using processing technologies featuring flexibilities which can open up potential opportunities beyond simply 4-foot by 8-foot plywood sheathing substitution. The rticle-based nature of their processes, particularly the OSB process, suggests totally new panel configurations or molded shapes with desired properties and characteristics designed and built into them. The larger panel sizes available from waferboard and OSB open up several promising new market end use possibilities, some of which are currently dominated by non-wood materials.

At this point, a picture of plywood as a product in dire straits has been rather convincingly drawn. However, with the vast capacity in place within the industry devoted solely to plywood production, it is unreasonable to expect plywood manufacturers to "roll over and play dead" in the face of increasing attack. What avenues of response are open to them? Answers to this question comprise the subject of the next chapter.

CHAPTER 12

POTENTIAL PLYWOOD RESPONSES

In spite of the rather disadvantageous position which plywood holds relative to the new panels, particularly the unveneered panels, and especially OSB, a case can be made that all is not lost for plywood producers. As can be seen from the industry capacity summaries of Chapter 6, many waferboard and OSB producers are also major plywood manufacturers. These producers can be expected to formulate overall corporate strategies in structural panels which will best serve the interests of all the panel types which they manufacture.

Aside from this, as a whole, there are several strategic and tactical counter-offensives which plywood can mount against the attack of the new panels. The plywood industry can continue the consolidation trend it has followed -- particularly on the west coast -- the past few years. While this would improve the industry's profitability picture, the lost capacity would likely result in a further loss of market share to the new panels. Hence, this response is far from ideal.

Plywood producers can change their product mixes so as to gradually wean away from the construction sheathing end uses in which they are no longer cost-competitive with waferboard/OSB. As the tremendous expansion of southern plywood production began to take over construction markets from western plywood, west coast producers began to move toward a higher percentage of specialty grade products, such as sanded plywood or plywood siding. Continued responses along this line are possible.

One potential growth area for plywood is in the homeowner repair and remodelling category. Across the U.S. a trend toward "do-it-yourself" projects continues to grow, and many such projects require the use of a structural panel product. It is not unreasonable to expect that the first choice of homeowners for use in such projects will typically be plywood, a product with whose performance they are at least somewhat familar. The APA estimates (14) that about 18% of all households in the U.S. purchase plywood each year for small household projects. By expanding promotional efforts (probably best done through dealer networks) the plywood industry has potential to significantly increase this market. The APA has anticipated that this market could be increased by 33% (14) by 1986.

Another area where plywood has potential for growth is in nonresidential construction, although arguably for the same reasons that would make the new structural panels attractive. One strong societal selling point for wood construction products is that they require much less energy to produce than do other materials which dominate industrial and nonresidential construction. For example, steel requires approximately thirteen times as much process energy as does plywood, and aluminum about twenty times as much. Furthermore, plywood (and waferboard/OSB) is a far better insulating material than other construction materials. It seems reasonable to suppose that increased promotion on the part of the plywood industry could further acceptance of plywood in nonresidential construction applications.

Innovative construction techniques have surfaced during the last few years which make use of plywood's features, and which have as yet not made a large impact on construction practice. One is the "All Weather Wood

Foundation" (AWWF) which has been promoted by the APA and the National Forest Products Association (NFPA) as a substitute for concrete foundation construction. Another is the APA's Plen-Wood system which is an underfloor plenum heating/cooling system for housing construction. Both the AWWF and the Plen-Wood system use significant amounts of plywood. More aggressive promotion by the plywood industry of the merits of these concepts holds promise of expanding outlets for plywood.

In addition to changing and expanding product-oriented emphases, plywood producers can look inward to their process technology for ways of increasing their competitiveness relative to the new panels. Re-inspection of Figures 9-1 and 9-2 shows clearly that plywood is a labor-intensive process, with as much as 23% of its variable manufacturing costs tied up in labor alone. While much work has been done both by plywood producers and equipment manufacturers to improve the efficiency of plywood production, considerable opportunity for automation still exists.

Individual plywood producers whose costs are held high because of the availability of veneer have the option of producing COM-PLY^{R}. This step most likely would not result in a great reduction in overall operating costs and would require capital outlay for core production. Nevertheless, it would allow these producers to extend their available veneer to yield larger total production volumes.

All of these suggested moves have one feature in common -- they are all essentially defensive in nature. Are there any <u>offensive</u> retaliations which plywood can mount? To find the answer to this question, it appears necessary to look no further than to one of the major vehicles taken advantage of by waferboard and OSB manufacturers in their efforts at new product intoduction; i.e., use of the emerging performance standards.

Plywood and the Performance Standards

Recall that the basic underlying concept of the APA performance standards is that it no longer need be necessary for a structural sheathing panel to be made according to accepted, traditional configurations and recipes. Rather, a panel proposed for sheathing end uses need only demonstrate its performance against test criteria correlated to end use performance to be acceptable. Waferboard and OSB have used this approach to introduce panels containing no veneer at all. OSB has been particularly innovative in obtaining (by testing against the performance standards) approvals which are more attractive than plywood's end use approvals (see, for example, Chapter 8).

This would seem to be a large opportunity area for plywood. For example, removing the need to conform to a product standard which stipulates that a plywood panel must be made using only certain veneer combinations opens a door for producers. They need only domonstrate the viability of plywood panels made, at least in part, of veneers of lower grade and, therefore, lower cost wood species. An almost immediate opportunity which surfaces is the possibility of using low grade hardwoods to produce veneer for use in the core of Southern pine plywood in the south. Similar possibilities should exist in the west. A quick look at the cost postures for plywood in Figures 9-1 and 9-2 clearly highlights the size of the wood cost reduction opportunity which such a move would address.

In addition to bringing down costs by veneer species substitution, it is reasonable to propose that plywood has a very good chance of achieving the advantageous thickness advantages which OSB has achieved in floor and roof sheathing applications. For example, a plywood producer who could manufacture a 7/16-inch thick plywood panel which would satisfy the floor sheathing requirements of the performance standard could market that panel in this end use at a one-eighth reduction in variable manufacturing costs from costs of producing 1/2-inch thick plywood. Other, equally innovative, ways in which plywood manufacturers could take advantage of the performance standards which heretofore have been used against them will no doubt come to the minds of entrepreneurial producers.

In summary, although the onslaught of new panels creates a rather negative picture for plywood's long-term outlook, particularly in light frame construction applications, a number of steps are available to plywood to hold back the tide and reduce its impact.

It is common for an industry conforming to an old technology to respond in innovative ways to threats imposed by a new technology. Typically, these responses involve improving and renovating the old technology to make it more versatile, more cost competitive, etc. Plywood has several such options available to it. Some of these options fall into the category of plywood process improvements (e.g., automation) which can lead to reduced manufacturing costs. Others fall into the category of product development (e.g., acceptable-performance thinner panels, panels composed of "new" wood species combinations, etc.) which can lead to a more competitive market position. Others involve simply re-shifting product end use emphases to other, less vulnerable, applications (e.g., specialty plywood grades). All these moves are viable and offer to plywood opportunities to respond constructively to the new panel invasions.

CHAPTER 13

FORECAST

Having presented an overview of plywood history, a discussion of incentives which have arisen to provide motivation for development of new substitute panel products, and descriptions of the members of the new generation of panels, and having presented a sufficient analysis of important technological issues to enable summarizing of plywood's vulnerability and analyzing of potential responses available to plywood to ward off attack, it is useful at this juncture to attempt to summarize the overall status of the structural panel industry.

First, it is apparent (9, 10) that the western plywood industry is undergoing considerable consolidation. Although a number of recent mill closures in the west have been directly motivated by the current severe slump in housing construction, much overall western plywood market share has been gradually lost, first to southern plywood and now to both southern plywood and the new panels. Inland plywood production continues to dominate its geographical area but is losing competitiveness in the midwest. Western plywood product mixes are moving increasingly away from structural grades and into specialty and sanded products.

Southern plywood, after its heyday of expansion in the late 1960s and early 1970s, seems to have plateaued in growth. Because of its lower manufacturing costs and logistics advantages in many major markets (9, 10) relative to western plywood, it has weathered the onslaught of recession and the invasion of the new panels more successfully than has its western counterpart. Southern plywood plants are facing increasing competition from other process outlets for raw material. Although it is not likely to be as severe as has been the case for western plywood, they are facing the likelihood of accelerating cost pressures. Capital requirements for new facilities have escalated rapidly the last several years. The prospect of building a new plywood facility under current cost pressures has ceased to become a financially attractive option to most wood products companies.

While western plywood is declining and southern plywood is plateauing, both panel types are facing increasing competition from the new panels. These panels are extremely cost (and price) competitive in the midwest and northeast. COM-PLY^R, in spite of limited production volumes, has had good market acceptance. Waferboard has had good market acceptance in the end uses where to date it has been marketed. Building code approvals for these products have provided a major impetus to their acceptance. OSB, which can be thought of as essentially an improved version of waferboard, is just now coming on stream. It has improved performance characteristics and has achieved code approvals which would seem to give it significant advantages over waferboard. It also has a large cost advantage over plywood and COM-PLY^R. A tremendous expansion in capacity in waferboard and OSB has been added in the industry during the last few years. Much of the new capacity is not yet on stream.

In 1979 total U.S. plywood production (including COM-PLY^R) was 23.1 billion square feet, while waferboard capacity in Canada and the U.S. together totalled 844 million square feet (10). By 1984, the total North American capacity in waferboard and OSB should exceed 3 billion square feet.

Given this summary of the status of the structural panel industry and all the data and analysis of the preceding twelve chapters, what can be forecast for the future? Sets of predictions follow.

Plywood

West coast plywood producers have borne the brunt of sheathing retrenchment in recent years. This should continue as cost pressures (particularly for raw material) will make it increasingly difficult for western plywood to compete in construction markets. Western plywood will continue to branch out into other markets such as specialty and sanded grades, and will be more aggressive in attempting to expand its off-shore markets.

Southern plywood will cease to expand in total, and will lose overall market share in construction panels to waferboard and OSB. Southern plywood will follow the lead of the west by turning to increased volumes in specialty and sanded products. The net result of this will be to further hurt western plywood. Southern plywood producers will take advantage of product development opportunities available to them by virtue of the new performance standards. Most likely will be the introduction of sheathing grade plywood having conventional Southern pine face plies and inner core plies of lower value hardwoods. Some entrepreneurial plywood manufacturers can be expected to attempt to duplicate OSB's code approved thickness advantages in floor and roof applications. According to the APA (9), a "handful" of plywood producers are "looking into this" currently.

Analogous species substitution will also occur in the west, but not to the same degree as in the south. Southern plywood, like western plywood, will be increasingly aggressive in seeking large volume outlets in offshore applications.

Because inland plywood producers market a large proportion of their volume to the upper midwest, these manufacturing facilities will lose substantial market share to the new panels.

There will be increased activity in the plywood industry aimed at process automation in an attempt to bring down the costs of manufacturing conventional plywood. Defensive development of new technologies will mitigate somewhat plywood's cost disadvantages relative to waferboard and OSB.

Southern plywood will continue to serve as the pricing standard against which the new structural panels will be discounted.

COM-PLY^R

COM-PLY^R, which is essentially a compromise between plywood performance and appearance and waferboard cost, will never become cost competitive against the unveneered panels. Because of its conventional veneer face plies, it has the potential to move into the specialty/sanded outlets being filled by plywood. COM-PLY^R is a transitional product which will be produced in only small volumes. It will be manufactured at plant sites where stretching of current veneer supply is critical, which will amount to a relatively limited number of locations. In summary, COM-PLY^R will not be a key factor in the sheathing business.

Waferboard/OSB

Waferboard, a low cost substitute for plywood sheathing, is inferior in performance to plywood but sufficiently cost competitive to have allowed it to make significant market in-roads in construction applications. Its favorable price relative to plywood has allowed it to fare relatively well throughout the current poor construction market. It will not enjoy wholesale acceptance because of its performance shortcomings which require in some end uses thicker and, therefore, markedly heavier panels. Because of its large volume it has to date established a pricing discount range relative to southern plywood.

OSB is an improved version of waferboard at slightly lower overall manufacturing costs. It is equal to or better than southern plywood in performance. Because of its improved properties, it possesses plywood's versatility (e.g., can be used with confidence in single floor systems). It has the potential for wholesale acceptance.

In the competition between waferboard and OSB the issue of price will be critical. To date the entry of waferboard has been facilitated by the price discounts it has offered relative to plywood. As more waferboard volume comes on stream and as OSB becomes available in larger volume, pricing competition will intensify. Plywood will continue to lose market share. Once available plywood markets are fully penetrated, competition between waferboard and OSB will intensify. The profitability of the new waferboard and OSB manufacturing facilities will depend greatly on the prices they are able to command for their respective products. In the absence of a huge surge in overall demand for structural panels, competition between waferboard and OSB will tend to hold these prices down.

Because of OSB's slightly lower overall manufacturing costs and possible premium in price, and because the difficulty of coverting an existing waferboard facility to OSB capability is relatively minor, there will be a movement among waferboard producers to change to OSB. Being a superior product with cost advantages (and possibly price advantages) OSB will be recognized by alert waferboard producers as the product they should turn to. It is not likely that all waferboard producers will make the transition immediately, but over time OSB has the potential to become the dominant plywood substitute.

Waferboard and OSB will expand and begin to grab increasing market shares in the midwest and northeast. Manufacturers will begin to respond to the seasonality of demand in these regions by penetrating into the south. Eventually, production capacity will be introduced in the south -- the APA reports (9) that several firms are looking there -- as process technology enables the production of waferboard/OSB from low grade mixed southern hardwoods.

The process features (particularly large panel capability) inherent to waferboard and OSB will enable these products to move into new market areas as yet only slightly populated by plywood.

In an effort to estimate the rate at which substitution of unveneered panels for plywood will continue, it is useful to consult the methodology of Fisher and Pry (15). In their classical substitution model, these authors postulated that a technology which begins to replace an existing technology without a major change in function will tend to go to completion. Furthermore, they contended that the time and amount of substitution can be predicted according to a hyperbolic tangent function based on the average annual rate of replacement. In equation form,

$$f = \tfrac{1}{2}\,[1 + \tanh a(t - t_0)]$$

where,

f = fraction of takeover by the new technology in year t;

a = half the initial annual exponential takeover rate;

t_0 = year in which $f = \tfrac{1}{2}$.

Treating waferboard and OSB as one product category (unveneered panels) and using plywood and waferboard production volumes from 1974 through 1979, as displayed in Figures 2-1 and 6-2, respectively, and following the Fisher-Pry procedure, yields,

$$a = 0.0711$$

For 1979, the waferboard per cent takeover rate was 3.60%. From the governing equation,

$$0.036 = 0.5[1 + \tanh 0.0711(1979 - t_0)]$$

Solving yields

$$t_0 = 2002$$

Thus, according to the Fisher-Pry model and the evidence available in

1979, it can be forecast that half the U.S. structural panel market will be made up of unveneered panels by the year 2002.

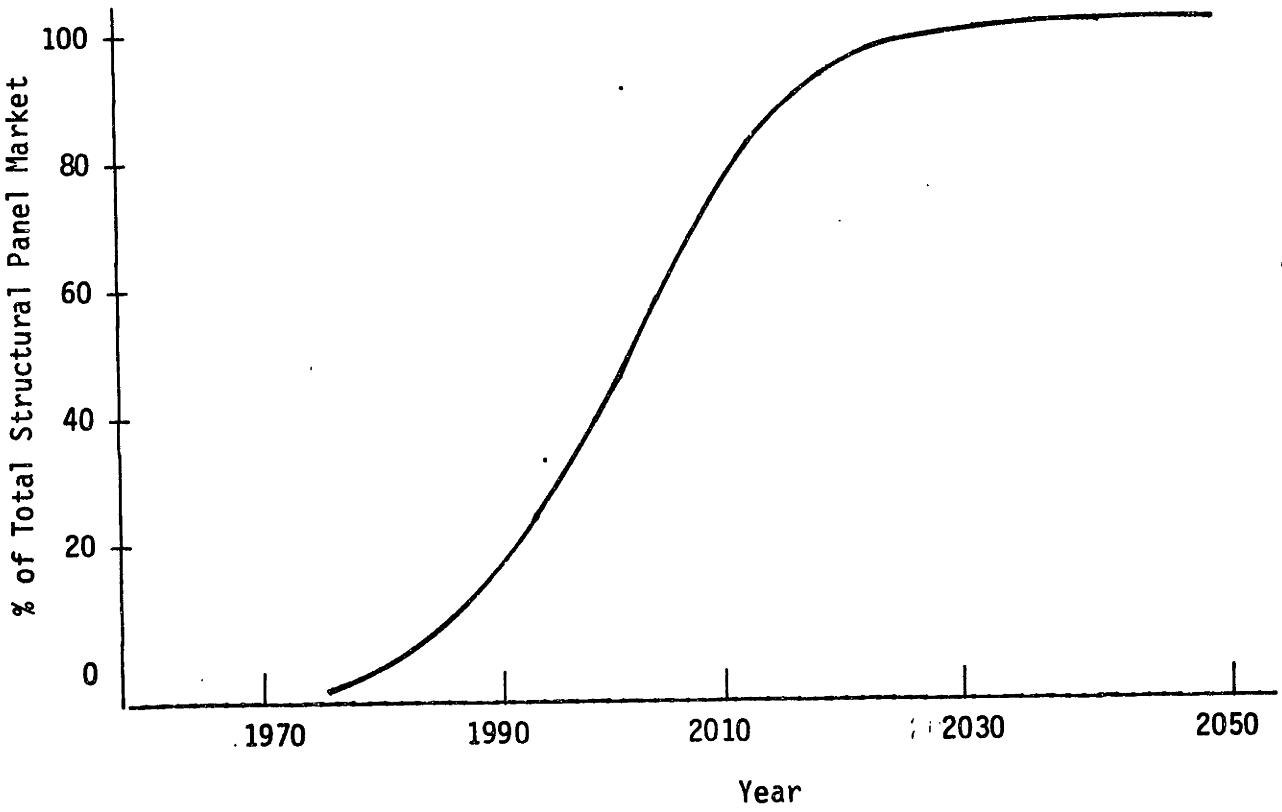
The entire forecasted waferboard/OSB substitution curve, as calculated using this model, is depicted in Figure 13-1 which predicts that substitution for plywood will be essentially complete by 2030.

While the predictions of the Fisher-Pry model need not be taken literally, it is nonetheless clear that the waferboard/OSB product category possesses many advantages which will lead to eventual total substitution of plywood in sheathing markets. However, because of the importance of shipping and transportation costs in the highly regionalized U.S. wood products industry, achievement of this total substitution must await massive installation of production capacity in the west and the south to supplement what is already in place in the midwest and northeast.

The plywood substitutes, particularly the unveneered products, will continue to succeed. Because of its incremental advantages over waferboard in performance, cost, and process flexibility, OSB will emerge as the dominant technology.

FIGURE 13-1

SUBSTITUTION OF UNVENEERED STRUCTURAL PANELS FOR PLYWOOD, AS PER FISHER-PRY MODEL



LIST OF REFERENCES

(1) Arthur D. Little, Inc, "Barriers to Innovation in Industry: Opportunities for Public Policy Changes", prepared for the National Science Foundation, Washington, D.C., September 1973.

(2) American Plywood Association, Regional Production and Distribution Patterns of the Softwood Plywood Industry, Economics Report E31, Tacoma, Washington, June 1981.

(3) American Plywood Association, Plywood End-Use Marketing Profiles 1981-1983, Economics Report E32, Tacoma, Washington, January 1982.

(4) U.S. Department of Commerce, Product Standard PS 1-74, Washington, D.C., 1974.

(5) National Particleboard Association, American National Standard for Mat-Formed Wood Particleboard, ANSI A208.1, Washington, D.C., October 1979.

(6) John J. Zahn, "Wood-BasedComposites", in Wood: Its Structure and Properties, edited by F.F. Wangaard, Educational Modules for Materials Science and Engineering Project, Pennsylvania State University, 1981.

(7) American Plywood Association, Performance Standards and Policies for APA Structural-Use Panels, Tacoma, Washington, 1980.

(8) Council of American Building Officials, National Research Board Report No. NRB-108, January 1982.

(9) Private Communication with the American Plywood Association, Tacoma, WA

(10) Kidder-Peabody and Company, Inc., "Forest Products Industry -- a Critical Issue Report -- COM-PLY^{R}, Waferboard, Oriented Strand

Board: Revolution in the Structural Panel Market?", December 1980.

(11) Private Communication with the National Particleboard Association, Washington, D.C.

(12) Private Communication with the Weyerhaeuser Company, Tacoma, Washington.

(13) American Plywood Association, APA Market Research Reports R38 Through R41, various publication dates.

(14) American Plywood Association, Long Term Plywood Demand 1977-1986, Economics Report E23, Tacoma, Washington, September 1977.

(15) J.C. Fisher and R.H. Pry, "A Simple Substitution Model of Technological Change", Technological Forecasting and Social Change 3, 1971.