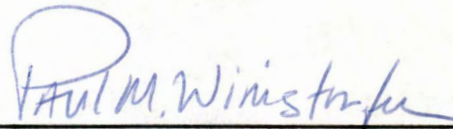


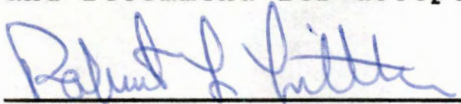
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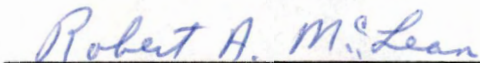
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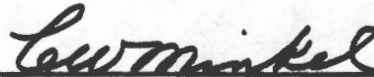
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**THE EFFECT OF FURNISH MOISTURE CONTENT, PRESS CLOSURE RATE,
AND PANEL DENSITY ON THICKNESS SWELL AND THE VERTICAL
DENSITY PROFILE OF A MIXED HARDWOOD FLAKEBOARD**

A Thesis

Presented for the

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Degree

The University of Tennessee, Knoxville

William Cos Treanor Davis

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I am indebted to Paul Winistorfer, Robert Little, and Robert McLean for their aid in my research endeavors. I am also indebted to my parents for their loyal support, to Elaine Hyatt for helping to finish my thesis, and to my grandmother who stirred my interest in wood science.

ABSTRACT

One-half inch non-oriented flakeboard was manufactured using three levels of furnish moisture content (3, 6 and 9 percent); three levels of press closure rate (20, 60 and 100 seconds); and two levels of panel density (41 and 51 lb/ft³). Panels were manufactured with seventy percent dense hardwood species. Panels were tested for thickness swell and accelerated aged internal bond using the American Society for Testing and Materials D-1037 24-hour water soak procedure, and the American Plywood Association-P1 standard oven-dry-vacuum pressure soak procedure. Process variable levels were used to determine a means of decreasing thickness swell and increasing internal bond in panels manufactured with dense hardwood species. Thickness swell decreased with increasing furnish moisture content, decreasing press closure rate, and increasing panel density. Internal bond decreased linearly as furnish moisture content increased, decreased as press closure rate increased, and increased as panel density increased.

Vertical density profiles were developed for all thickness swell and internal bond specimens. The profiles were then divided into five density regions. The response variables were correlated to the five density regions for profiles developed before accelerated aging and for profiles developed by taking the difference of profiles taken before

and after accelerated aging. The strongest correlation was found between the 24-hour water soak internal bond specimens and the core density region of the difference of the before and after accelerated aging vertical density profiles ($R=-0.75$, $p<0.01$).

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I. INTRODUCTION AND OBJECTIVES

Thickness swell, a widely used parameter in determining the dimensional stability of wood composite panels, is an indication of the change in panel thickness usually after exposure to some accelerated aging procedure such as humidity changes or direct exposure to water. Thickness swell is measured as the percent change in thickness from the original panel thickness. Thickness swell can be influenced by combinations of process variables used during manufacture. Problems with panel performance as related to thickness swell are more prevalent today as more commercial wood composites are being manufactured with dense hardwood species (Hse 1975; Winistorfer and DiCarlo 1988).

Thickness swell results from two causes in a wood composite panel. First, wood is a hygroscopic material that adsorbs or desorbs water causing the wood to swell or shrink. Adsorption is the intimate take-up of a gas or liquid from the vapor phase (Stamm 1964). For instance, solid hardwood species change in the radial direction from 8 to 3 percent and in the tangential direction from 12 to 6 percent when dried from green condition to oven-dry (USDA Agriculture Handbook No. 72). Adsorption of water by cellulose is reversible, that is a wood specimen will return to initial equilibrium thickness when excess moisture has dissipated. Second, wood-based composite panels will return

to a prepressed flake thickness when moisture is adsorbed of the springback effect of compressed wood. The springback effect places stress on the wood to resin bond causing bond failure. This component of thickness swell is irreversible (Vital et al. 1980; Hsu et al. 1988).

In measuring the density of a wood composite panel, both a horizontal and vertical density profile should be considered. Panel manufacturing variables related to the forming and pressing operations can affect both thickness swell and formation of the horizontal and vertical density profile (Strickler 1959). However, the vertical density profile which results from a differential transfer of heat and pressure when consolidating the mat in the press is a major concern in this study.

Geimer et al. (1975) explain the formation of the vertical density profile as a progressive densification of individual layers within the mat from the face to the core caused by a temperature, steam and compression graduation process. Densification occurs in the surface layers of the mat because of initial rapid heat transfer and plasticization of the wood mat which expedites resin curing and mat consolidation (Smith 1982). Suchsland and Woodson (1976) illustrated this phenomenon by making fiberboards with uniform vertical density profiles by closing the press and then applying heat after the mat had been consolidated.

The vertical density profile is known to influence

thickness swell (Price and Hse 1982). However, the amount of swell depends upon the test method used. Therefore, a study designed to measure the relationship between thickness swell and the vertical density profile must consider the test method.

The objectives of this study were:

1. To evaluate the effect of furnish moisture content, press closure rate and panel density on thickness swell.
2. To evaluate the effect of furnish moisture content, press closure rate and panel density on the vertical density profile.
3. To verify a relationship between the vertical density profile and thickness swell.

II. LITERATURE REVIEW

Furnish Moisture Content

The level and control of furnish moisture content is fundamental for manufacture of wood composite panels. Excess furnish moisture can contribute to incomplete resin cure, overpenetration of resin solids, and panel delamination during pressing. Inadequate furnish moisture can inhibit heat transfer through the panel, retard resin cure and lead to the condition called dryout. Resin cure efficiency is enhanced by proper furnish moisture content (Albritton et al. 1975).

Thickness swell. Most researchers report that furnish moisture content affects thickness swell. An accepted relationship among scientists is difficult to obtain. Haygreen and Gertjeansen (1972) made a phenolic wafer-type particleboard using poplar flakes at furnish moisture contents of six and nine percent with a target panel density of 49 pounds per cubic foot (lb/ft^3). Thickness swell as determined by an oven-dry-vacuum-pressure-soak procedure (OD-VPS) was 19.8 percent at the nine percent furnish moisture level and 22.9 percent at the six percent level. Thus, an inverse relationship of swell with decreased furnish moisture content was reported. Gatchell et al. (1966) manufactured flakeboard using Douglas-fir furnish at mat moisture levels of eight, twelve and sixteen percent at a

target density of 40 lb/ft³. They reported that in a thirty-day soak test and one year outdoor exposure, the least amount of thickness swell occurred at sixteen percent mat moisture content.

Geimer et al. (1966) produced Douglas-fir flakeboard at mat moisture contents of eight and sixteen percent. Thickness swell from the 24-hour water soak procedure ranged from 15.7 percent at the eight percent mat moisture level to 21.4 percent at the sixteen percent mat moisture level. However, thickness swell from exposure sites of one, two, and five years was more for the eight percent moisture level panels than the sixteen percent moisture level panels.

Strickler (1959), using Douglas-fir furnish, tested mat moisture contents of six, nine and twelve percent. Although a slight decrease in 24-hour water soak thickness swell occurred as mat moisture content increased, no significant difference in thickness swell was found among these levels. Strickler varied the mat surface moisture content from twelve, fifteen, eighteen, and twenty-one percent while leaving the core moisture content at either six or nine percent. High surface moisture and high initial press pressure resulted in panels with less thickness swell.

Internal bond. With the phenomenon of overpenetration or dryout being related to mat moisture content, interflake bonding within the panel, as measured by internal bond, can

be influenced by mat moisture content. Heebink et al. (1972) manufactured panels with mat moisture levels of eight, twelve, and fourteen percent. The twelve percent mat moisture level produced internal bond values of 150 pounds per square inch (psi) while the eight and fourteen percent levels resulted in internal bond values of 100 psi. Panels were also manufactured at five, ten, and fifteen percent mat moisture levels in the core and five, ten, fifteen and twenty-five percent moisture levels in the face layers. A uniform mat moisture content and a four minute press cycle produced internal bond values of 130 psi. Panels produced with a uniform mat moisture content of five percent, with an addition of five percent moisture sprayed on the surface layers, resulted in 130 psi internal bond values with a three minute press cycle. Moisture added to the caul plate surfaces produced lower internal bond values when five percent core moisture was used. Heebink et al. (1972) concluded that a higher mat moisture content requires a longer press time to allow sufficient moisture to escape from the interior of the board so adequate resin polymerization can be obtained for desired levels of internal bond. Geimer et al. (1975) using Douglas-fir phenolic bonded panels also found that excessive surface moisture content decreased internal bond strength due to a lack of steam escape from the core of the panel.

Strickler (1959) using six, nine and twelve percent mat

moisture content levels found that at nine percent furnish moisture content, internal bond had an average value of 108 psi while six and twelve percent levels of furnish moisture content yielded internal bond values that were five to ten psi less. When varying surface moisture and core moisture, the lowest internal bond values were obtained with maximum surface moisture content and minimum core moisture content. Internal bond values of 142 psi occurred at a constant twelve percent mat moisture content. The next largest internal bond value, 132 psi, occurred with a fifteen percent surface moisture and a five percent core moisture. Strickler showed that higher surface mat moisture decreases the amount of time to heat the core, which increased internal bond values. This is opposite the findings of Heebink et al. (1972) and Geimer et al. (1975).

Winistorfer and DiCarlo (1988) found an increasing linear trend between internal bond and decreasing furnish moisture content in the two to eight percent moisture content range. Internal bond values ranged from 74 psi to 119 psi with furnish moisture levels of eight and two percent, respectively.

Most studies indicate that a nine to ten percent uniform mat moisture content will maximize internal bond. The value can vary depending on the press time, particle size and type, and resin used for manufacture.

Vertical density profile. Furnish moisture content

affects the vertical density profile by altering the heat and mass transfer, and subsequent plasticization and densification of the mat during pressing. Suchsland (1962) stated that "the vertical density profile develops due to the time dependent nature of the heat and moisture transfer through the mat affecting the compressibility of the wood substrate and resin cure of the binder." The transfer of heat by convection produces a steam pressure gradient. Particles in the face layers of the mat are heated first and densify before particles in the core layer.

Strickler (1959) studied the developing vertical density profile using six press cycles, three furnish moisture content levels and three panel densities. Greater furnish moisture content lead to a steeper (high face density-low core density) density profile regardless of overall panel density and press closing strategies. Density profile variations are magnified with non-uniform mat moisture content. Many other studies report similar results (Heebink et al. 1972; Geimer et al. 1975; Harless et al. 1986; Winistorfer and DiCarlo 1988).

Press Closure Rate

Press closure rate is defined as the total time from when the press begins to close until final position is reached. Press closure rate is also referred to as time to

stops. Physical board properties can be influenced by varying press closure rate, but seldom without a trade-off among other board properties. Geimer and Price (1978) summarize the physical and mechanical properties of flakeboards when varying press closure rate.

Thickness swell. Strickler (1959) examined the influence of furnish moisture content and press closure rate on thickness swell. Strickler's cycle variations incorporated the time that the maximum press pressure was maintained. The total press time was twelve minutes. Low furnish moisture content and fast press closure rates (less than two minutes) resulted in increased thickness swell from two hour and 24-hour water soak test procedures. A two minute, maximum-pressure press cycle resulted in the greatest reduction of thickness swell.

Rice (1973), using silage sycamore furnish, studied two press closure rates (fifteen and forty-five seconds) and found that thickness swell was independent of press closure rate. Rice et al. (1967) using press closure rates of 1.5 and 3.4 minutes found that a decrease in thickness swell occurred at the 1.5 minute press closure rate.

Internal bond. Strickler (1959) using a press closing strategy of twelve minutes constant pressure (as opposed to maximum pressure), zero minutes constant pressure (equivalent to a fast press closure rate), and six levels of maximum pressure (one, two, three, four, five and six

minutes), found that internal bond values were maximized at the constant twelve minute press cycle and that the lowest internal bond values were recorded at the zero minute maximum press cycle. Internal bond ranged from 91 psi to 117 psi and increased linearly as press closure rate lengthened. However, internal bond strength was not well correlated with density of the core region.

Contrary to Strickler's findings are those findings of Rice et al. (1967) and Smith (1982). Rice et al. (1967) produced 3/4 inch poplar flakeboard using 1.5 and 3.4 minute press closure rates. The 1.5 minute press closure time resulted in increased internal bond. Smith (1982) using an aspen wafer-type furnish reported that a fast press closure rate increased internal bond, although a fast press closure rate decreased core density. Smith used a 30 second and 100 second press closure rate at three different densities. At the 34 lb/ft³ density level, internal bond values increased from 30 psi to 42 psi as press closure rate decreased from 100 seconds to 30 seconds. For the 40 lb/ft³ density level, internal bond values increased from 40 psi to 68 psi as press closure rate decreased from 100 seconds to 30 seconds.

Internal bond is related to core density, which is influenced by the press closure rate. In general, a fast press closure rate will minimize core density and internal bond values, while a slow press closure rate will maximize internal bond values.

Vertical density profile. Heebink et al. (1972) and Geimer et al. (1975) produced panels with steep-sloped vertical density profiles by using rapid press closure rates and also produced panels with a more uniform vertical density profile by using longer press closure rates. The effect of press closure rate and the interaction of other process variables on the vertical density profile are summarized by Kelly (1977). Generally, the closure rate can have a pronounced effect on the development of the vertical density profile.

Panel Density

Thickness swell. In wood composite panels, the general consensus is that greater panel density enhances panel strength properties but increases the amount of thickness swell. These results are not all inclusive for less severe thickness swell test procedures. Suchsland (1973) studied the effect of test procedure on thickness swell using ten commercial particleboards. Samples were maintained in closed containers over saturated salt solutions. Other twelve-by twelve-inch samples were tested using the 24-hour water soak procedure. For the relative humidity tests (40 percent to 93 percent relative humidity), samples with specific gravities ranging from .69 g/cc to .96 g/cc had thickness swell values that ranged from eight to

seventeen percent. Thickness swell of specimens evaluated using the 24-hour water soak ranged from 1.1 to 4 percent, depending on the composition (flake geometry) of the board. Suchsland (1973) found no relationship between specific gravity and thickness swell.

Lehmann (1974) studied thickness swell using panel density levels of 37.5 and 42.5 lbs/ft³. Tests used to evaluate thickness swell were OD-VPS and 24-hour water soak. Thickness swell values ranged from 25.4 to 48.7 percent for the OD-VPS procedure and from 9.7 to 40.6 percent for the 24-hour water soak procedure. Higher panel density resulted in more stable panels in the 24-hour water soak procedure but the opposite was the case in the OD-VPS procedure. Lehmann concurred with Suchsland's results that overall panel density did not have a significant effect on thickness swell.

Hse (1975) found that flakeboard manufactured from a variety of dense hardwoods had greater thickness swell values as panel density increased from 39.5 to 44.5 to 49.5 lbs/ft³ for 50-90 percent relative humidity, 5 hour boil, and OD-VPS tests. Thickness swell ranged from 13.3 to 26.0 percent, 20.0 to 57.0 percent, and 20.0 to 172.0 percent, respectively. In the 50-90 percent relative humidity test, there was no significant difference between the density levels 39.5 and 44.5 lb/ft³. Price (1977) using a thirty day water soak found that thickness swell increased as panel

density decreased. Shorter-cycle dimensional stability tests often result in greater swelling at low panel densities due to less interflake compaction and greater panel porosity, allowing for more water absorption. Greater water absorption will release compression set on the surface of the panel, resulting in increased thickness swell (Larmore 1959; Lehmann and Hefty 1973; and Vital et al. 1980).

In other studies, as panel density increases thickness swell increases proportionally. Geimer (1982) produced Douglas-fir particleboard at 30, 40, 50 and 60 lbs/ft³ and predicted OD-VPS thickness swell using panel density as a single predictor. Most researchers manufacturing panels with dense hardwood species reported increased thickness swell as panel density increased, regardless of the test method used to evaluate thickness swell (Shen 1973; Filho 1981; Rice 1982; Youngquist et al. 1986; Kelly and Price 1985). Other studies that used lower density species or pine furnish also report increased swell with increased panel density (Geimer et al. 1966; Rice 1973; Geimer and Crist 1980; Panning and Gertjeansen 1985). Geimer and Price (1978) stated that density affects the rate of change of thickness swell by controlling the rate of water absorption.

Internal bond. Keeping all other process variables constant, internal bond increases as panel density increases

(Larmore 1959; Heebink and Hann 1959; Hse 1975; Shuler and Kelly 1976; Hill and Wilson 1978; Lehmann and Schaffer 1979; Filho 1981; Rice 1982; Kuklewski et al. 1985; Panning and Gertjejansen 1985; Kelly and Price 1985; and Biblis 1985).

Vertical density profile. Increased panel density will also increase the density of the vertical density profile when all other process parameters are held constant (Heebink et al. 1972). Panels of higher density require longer press times and greater press pressures to compress the mat to a given thickness.

III. MATERIALS AND METHODS

Furnish

The flake type furnish selected for this study was a commercially prepared mixture of approximately seventy percent hardwood species and thirty percent southern yellow pine. The hardwood species, in unknown proportions, were oak, hickory, hackberry, yellow poplar and sweetgum. The furnish was not screened and had a particle geometry consisting of an average three inch length, one and one-half inch average width and a thickness ranging from .015 to .04 inches. The total furnish was divided by weight into three equal portions. One portion was dried to three percent moisture content, the second portion was increased to 6 percent moisture content, and the third portion was increased to 9 percent moisture content. The additional moisture was added to the furnish by atomizing water onto the flakes in a rotary drum blender. The furnish was then placed in air-tight plastic bags until time for panel manufacture. Samples were randomly taken during storage for moisture content determination.

Resin

A commercially prepared liquid phenol-formaldehyde resin (Georgia Pacific Resistran GP-3195) with fifty-three percent non-volatile solid content was used. The resin was atomized onto the furnish in a cascade-type blender at a rate of five

percent resin solids based on oven-dry furnish weight.

Panel Manufacture

To accomplish the selected panel manufacturing combinations (Table 1), enough resin and furnish was blended per batch to make six panels. Each panel represented a randomly selected combination of treatment effects. Resin was applied using a pressurized airless spray system in a cascade-type blender. The time required for resin application was approximately two and one-half minutes per batch. After blending, all furnish was stored in sealed plastic bags. The required amount of furnish for a single panel was removed from the sealed plastic bag and hand-felted in a 15-by 21-inch forming box. Within a six panel batch of furnish, a combination of sub-plot treatments (press closure rate and panel density) were randomly assigned to an individual panel. Panels were pressed to one-half inch thickness in a steam heated hydraulic hot press at 375°F platen temperature. Press time to steel stops (thickness) varied with the press closure rate treatment. The total press time was five minutes including a one minute decompression cycle. Three thermocouple wires, equally spaced through the thickness of the panel were placed in randomly chosen panels to gather temperature data every one-tenth of a second during pressing (Table 2).

Table 1. Summary of panel manufacturing conditions.

Panel dimensions.....	15-by 21-inches
	: (untrimmed)
	: 13-by 19-inches
	: (trimmed)
Nominal thickness.....	.5 inches
Resin type.....	liquid
	: phenol-formaldehyde
Resin content per panel.....	5.5% solids based on
	: oven-dry furnish weight
Resin non-volatile content.....	53%
Furnish species.....	70% mixed hardwood
	: 30% Southern Yellow
	: Pine
Furnish moisture content.....	3, 6 and 9%
Furnish geometry.....	Length: 3 in.
	: Width: 1.5 in.
	: Thickness :.04 to .015
	: inches
Panel density.....	41 and 51 lb/ft ³
Press closure rate.....	20, 60 and 100 seconds
Total press time.....	5 minutes
Press platen temperature.....	375°F
Blender revolutions per minute..	14.5
Pressure on spray system.....	650 psi (airless spray
	system)
Total time of resin spray.....	2.5 minutes
Total time in blender.....	5 minute
Temperature of resin.....	79°F

Table 2. Treatments selected for internal mat temperature collection during pressing.

Furnish Moisture Content (%)	Panel Density (lb/ft ³)	Press Closure Rate (Seconds)
3	41	100
3	51	100
6	41	20
6	41	100
6	51	20
6	51	60
6	51	100
9	41	100
9	51	100

Sample Sectioning and Testing

The experimental design required fifty-four panels to be manufactured, eighteen panels per replication. From each panel, four six-by six-inch thickness swell samples and ten two-by two-inch internal bond samples were obtained. The internal bond samples were cut from strips removed from the center of the panel while the thickness swell specimens were removed from the four corners of each panel.

All test specimens were conditioned to approximately seven percent equilibrium moisture content at 65 percent relative humidity and 75°F. All density calculations were based on weight and volume at these conditions.

From the four six-by six-inch thickness swell specimens, two were randomly selected to be tested using the 24-

hour water soak procedure as outlined by the American Society for Testing and Materials (ASTM D-1037 1985) and two were selected to be tested using the oven-dry-vacuum pressure soak procedure. The oven-dry-vacuum pressure soak is an adaptation of the American Plywood Association standard P-1 (1980) for evaluating thickness swell, linear expansion and water absorption.

Internal bond and 24-hour water soak testing procedures followed ASTM D-1037. Four internal bond specimens were tested in the dry condition to evaluate treatment effects on resin cure, and the remaining six internal bond samples were used to evaluate thickness swell and water absorption. Three internal bond specimens were randomly selected for either the 24-hour water soak or the oven-dry-vacuum pressure soak for accelerated aged internal bond.

A direct-scanning gamma densitometer (Winistorfer et al. 1986) was used to measure the vertical density profile of the internal bond specimens and the accelerated aged internal bond specimens. Radiation counts were taken at twenty incremental steps through the thickness of the specimen and actual density was calculated for each step.

The twenty incremental measurements representing the profile were segmented into five regions. These regions are referred to as regions 1, 2, 3, 4, and 5, and are depicted on the hypothetical density profile shown in Figure 1. Mean density values for each region by treatment are listed in

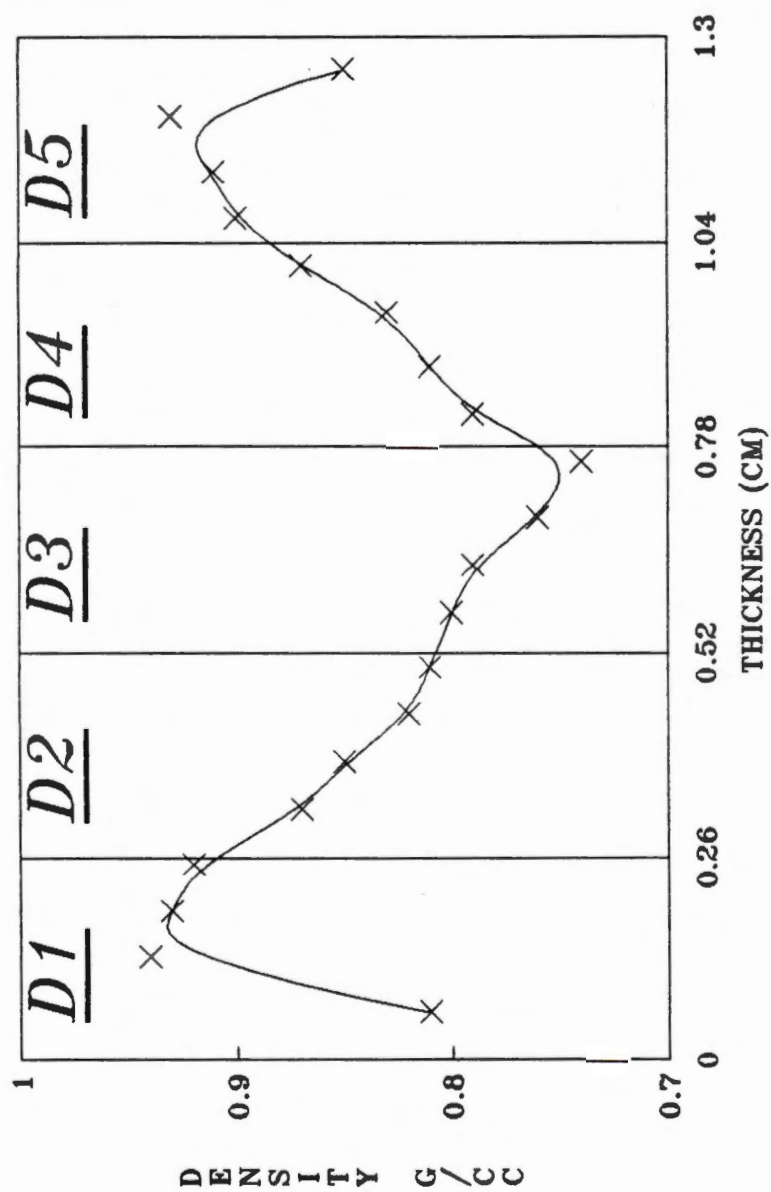


Figure 1. Hypothetical density profile showing density regions 1 to 5.

tables found in Section IV.

The division of the twenty points into five regions was based on a linear regression with the final number of individual points within a region determined by examining the F-value, the coefficient of variation and the coefficient of determination for these regressions. This regression technique was a manual iterative selection procedure (Table 3).

Vertical density profiles were developed for test procedures before and after accelerated aging testing on the accelerated aged internal bond specimens. The difference between the density regions of the vertical density profiles before and after the test procedures was analyzed to identify which regions were most affected by the thickness swell treatments.

TABLE 3. Manual iterative selection process for mean vertical density profile regions.

Probability > F for Process Variables							
Vertical Density Region	Segment of 20 Scanned Points Used	Furnish Moisture Content (%)	Press Closure Rate (Seconds)	Panel Density (lb/ft ³)	Model F-Test P-Value	Coefficient of Determination	Coefficient of Variation
Accelerated Aging Test Procedure (ASTM D-1037) Before 24-Hour Water Soak Procedure)							
D1 a	1-3 b	(P=0.10)	(P=0.32)	(P=0.01)	(P<0.01) c	.66	10.9
D2	4-9	(P=0.67)	(P=0.08)	(P=0.01)	(P<0.01)	.74	8.5
D3	10-12	(P=0.75)	(P=0.01)	(P<0.01)	(P<0.01)	.71	9.2
D4	13-17	(P=0.18)	(P=0.07)	(P<0.01)	(P<0.01)	.73	8.6
D5	18-20	(P=0.52)	(P=0.30)	(P=0.01)	(P<0.01)	.63	13.1
Accelerated Aging Test Procedure (ASTM D-1037) After 24-Hour Water Soak Procedure							
D1	2-3	(P=0.10)	(P=0.21)	(P=0.06)	(P<0.01)	.66	14.3
D2	4-9	(P=0.29)	(P=0.23)	(P=0.02)	(P<0.01)	.74	7.9
D3	10-12	(P=0.34)	(P=0.56)	(P<0.07)	(P<0.01)	.75	11.0
D4	13-17	(P=0.62)	(P=0.34)	(P<0.06)	(P<0.01)	.80	9.5
D5	18-19	(P=0.05)	(P=0.30)	(P=0.01)	(P<0.01)	.71	7.9
Accelerated Aging Test Procedure (APA-P1) Before Ovendry-Vacuum-Pressure-Soak							
D1	1-3	(P=0.42)	(P=0.81)	(P=0.01)	(P<0.01)	.69	10.7
D2	4-7	(P=0.12)	(P=0.05)	(P=0.01)	(P<0.01)	.76	8.7
D3	8-13	(P=0.36)	(P=0.16)	(P<0.01)	(P<0.01)	.78	8.3
D4	14-17	(P=0.70)	(P=0.09)	(P<0.01)	(P<0.01)	.72	9.0
D5	18-20	(P=0.09)	(P=0.29)	(P=0.05)	(P<0.01)	.62	12.9
Accelerated Aging Test Procedure (APA-P1) After Ovendry-Vacuum-Pressure-Soak							
D1	2-3	(P=0.01)	(P=0.44)	(P=0.02)	(P<0.01)	.61	14.1
D2	4-8	(P=0.13)	(P=0.06)	(P=0.01)	(P<0.01)	.72	8.0
D3	9-13	(P=0.37)	(P=0.08)	(P<0.01)	(P<0.01)	.77	9.2
D4	14-17	(P=0.59)	(P=0.16)	(P<0.01)	(P<0.01)	.75	7.9
D5	18-19	(P=0.14)	(P=0.35)	(P=0.01)	(P<0.01)	.62	10.9

^a The before and after profile segments were determined using p-values, the coefficient of determination, and the coefficient of variation. The difference from the before and after segments (D1-D5) is calculated from the before and after and after profile regions listed above.

^b The individual data points used to create the average value of the vertical density profile region.

^c P-values show the probability of finding a greater F-statistic. A smaller p-value denotes a greater chance of significance between the independent and dependent variables.

IV. EXPERIMENTAL DESIGN

The design of this experiment was a complete factorial with three replications, consisting of eighteen panels each, analyzed as a split-split plot design (Anderson and Mclean 1974). The whole plot treatment was furnish moisture content (3, 6, and 9 percent). Replication by furnish moisture content was the whole plot error. Press closure rate (20, 60 and 100 seconds) and panel density (41 and 51 lb/ft³) were the sub-plot treatments. The four-way interaction replication by furnish moisture content by press closure rate by panel density was used as the sub-plot error. Test procedure, ASTM (D-1037) or APA-P1, was the sub-sub-plot treatment. Individual specimen density was used as the covariate in the analysis of covariance of thickness swell and internal bond. The different treatment levels of furnish moisture content and press closure rate were set up as mutual orthogonal contrasts. The treatment sum of squares and the degrees of freedom for furnish moisture content and press closure rate were partitioned into single degree of freedom components to examine a linear effect of the response variable (thickness swell or internal bond) to the treatment or the lack-of-fit (LOF) of a linear relationship between the response variable and the treatment. No attempt was made to fit a mathematical model describing the relationship between the experimental

treatment and the response variable. All data was analyzed using SAS®(1985).

PARCHMENT DEED

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V. RESULTS AND DISCUSSION

Process variables such as furnish moisture content, press closure rate, and panel density are known to influence panel properties. Process variable treatment effects on thickness swell, internal bond, and the vertical density profile were studied and analyzed statistically. Results are discussed by process variable for each response variable. Tables 4, 6, and 8 also list water absorption and springback means which are not discussed in the paper; but, the means are included to aid in understanding thickness swell, accelerated aging internal bond, and internal bond. All treatment means for thickness swell and internal bond were adjusted using panel density as a covariate (Anderson and McLean 1974).

Adjusted and unadjusted means for all treatments are listed in Appendix A. Analysis of Covariance tables are listed in Appendix B. Appendix C is a partial correlation matrix with coefficients and probabilities for response variables. Appendix D contains vertical density profiles for all treatments.

Furnish Moisture Content

Thickness swell. Thickness swell was evaluated for six two-by-two-inch samples cut from the center of each test panel and for four six-by-six-inch samples cut from the four corners of each test panel. Two test procedures, oven-dry-

vacuum pressure soak (OD-VPS) and 24-hour water soak were used to analyze the response variable, thickness swell.

For the two-by two-inch samples subjected to the OD-VPS procedure, thickness swell ranged from 29.0 percent for panels manufactured with 3 percent furnish moisture to 25.6 percent for panels made with 9 percent furnish moisture. Similar specimens subjected to the 24-hour water soak procedure produced thickness swell values from 31.9 percent at 3 percent furnish moisture to 28.9 percent for 9 percent furnish moisture content (Table 4). There was a significant ($p < 0.01$) linear trend of decreasing thickness swell with increasing furnish moisture content for the OD-VPS procedure (Appendix B.4 and Figure 2). A significant difference between the mean thickness swell for the two test procedures was found ($p = 0.01$). Most literature reviewed reported thickness swell values to be greater for the OD-VPS procedure than for the 24-hour water soak procedure (Lehmann 1974; Hse 1975; Geimer 1982). Wax was not applied to the panels in this study, whereas most studies use wax. If wax is not used, less severe test procedures for thickness swell will have a greater effect on thickness swell.

For the six-by six-inch specimens, thickness swell ranged from 24.0 percent at 3 percent furnish moisture content to 19.5 percent at 9 percent furnish moisture content for the OD-VPS test procedure. For the 24-hour water soak procedure, thickness swell ranged from 29.5

TABLE 4. The least squares adjusted treatment mean, the standard error of the least squares adjusted treatment mean, percent retention for accelerated aged internal bond by oven-dry-vacuum pressure soak, and 24-hour water soak for the dependent variables thickness swell, water absorption, springback, internal bond, and accelerated aged internal bond in response to furnish moisture content.

FURNISH MOISTURE CONTENT	SAMPLE SIZE	THICKNESS SWELL (%)	WATER ABSORPTION (%)			SPRINGBACK (%)			INTERNAL BOND	ACCELERATED AGED INTERNAL BOND (PSI)	
(%)	(INCHES)	OVENDRY VACUUM PRESSURE SOAK	24-HOUR WATER PRESSURE SOAK	OVENDRY VACUUM PRESSURE SOAK	24-HOUR WATER PRESSURE SOAK	OVENDRY VACUUM PRESSURE SOAK	24-HOUR WATER PRESSURE SOAK	OVENDRY VACUUM PRESSURE SOAK	(PSI)	OVENDRY VACUUM PRESSURE SOAK	24-HOUR WATER PRESSURE SOAK
3	2X2	29.0 a	31.9	96.6	73.9	23.5	23.6	50.0	17.8	12.4	
		0.5 b	0.6	1.0	0.7	0.7	0.6	2.5	0.8	0.7	
6	6X6	24.0	29.5	83.5	66.1				(35.5) c	(24.7)	
		0.2	0.3	0.5	0.6						
6	2X2	27.9	32.3	91.2	69.9	22.6	25.9	45.8	14.6	8.1	
		0.5	0.7	1.1	0.8	0.7	0.6	2.7	0.8	0.7	
6X6		20.6	27.6	76.0	61.7				(31.9)	(17.8)	
		0.2	0.4	0.6	0.7						
9	2X2	25.6	28.9	89.0	65.9	20.4	23.0	38.7	12.0	9.5	
		0.5	0.7	1.1	0.8	0.7	0.7	2.5	0.9	0.7	
6X6		19.5	26.4	72.7	58.9				(31.0)	(24.5)	
		0.2	0.4	0.6	0.7						

a The least squares adjusted treatment mean.

b The standard error of least squares adjusted treatment mean.

c The retention of internal bond after accelerated aging.

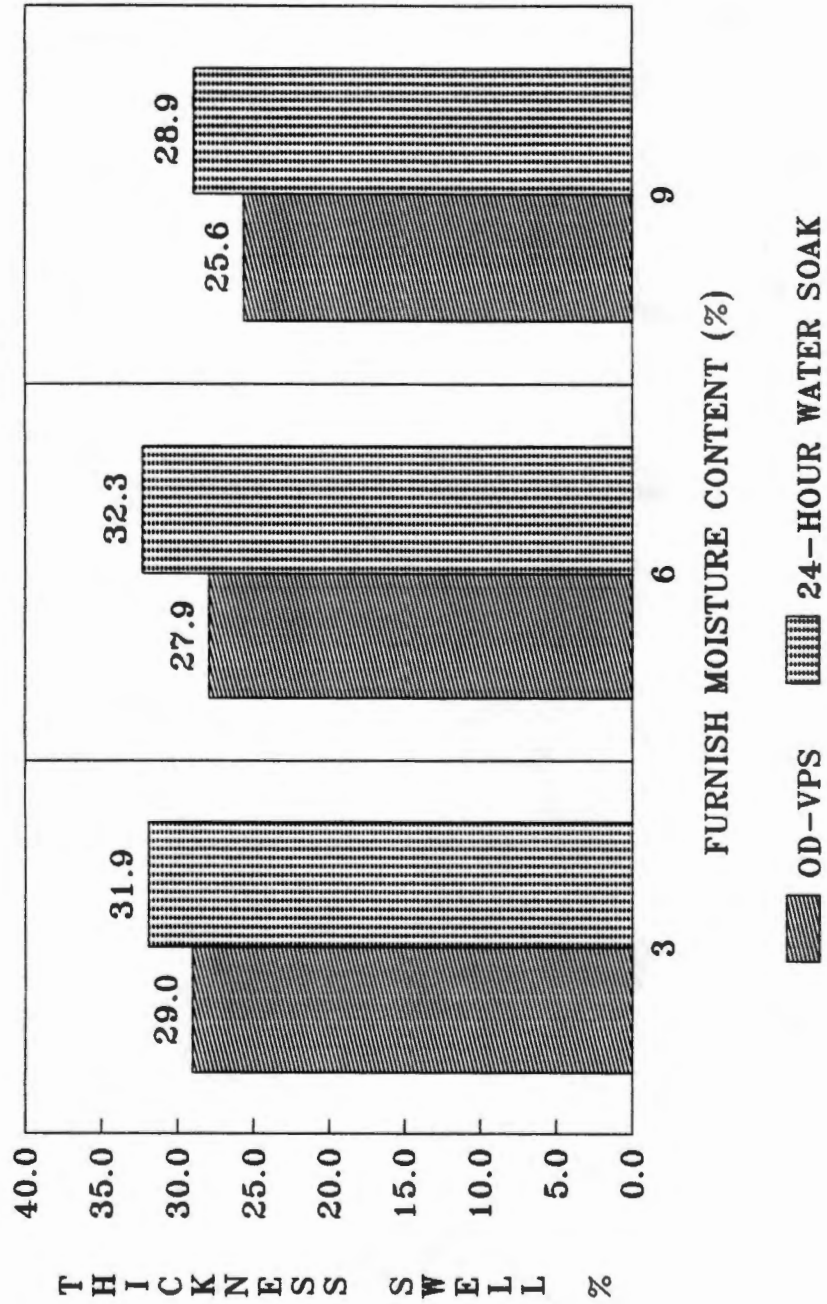


Figure 2. Effect of furnish moisture content on thickness swell of two-by two-inch specimens.

percent at 3 percent furnish moisture content to 26.4 percent at 9 percent furnish moisture content. Furnish moisture content was significant ($p=0.03$) for all treatment levels for both test procedures. A significant difference ($p<0.01$) between test procedures was found (Appendix B.6). A significant linear trend ($p<0.01$) of decreasing thickness swell with increasing furnish moisture content was noted (Figure 3).

Internal bond. Internal bond was tested from four dry specimens and six accelerated aged specimens per panel. Dry internal bond values (ASTM D-1037) ranged from 50.0 pounds per square inch (psi) at 3 percent furnish moisture content to 38.7 psi at 9 percent furnish moisture content. No significant difference between treatment levels ($p=0.09$) was found, but internal bond increased linearly ($p<0.01$) as furnish moisture content decreased (Appendix B.1). Higher furnish moisture content was detrimental to bond formation in the core of the panel. Winistorfer and DiCarlo (1988) reported similar results in a study with dense hardwood furnish.

Furnish moisture content was not a significant factor ($p=0.15$) in explaining variation from accelerated aged internal bond (Appendix B.2). However, internal bond decreased linearly from 17.8 psi at 3 percent furnish moisture content to 12.0 psi at 9 percent furnish moisture content for the OD-VPS treatment and from 12.4 psi at 3

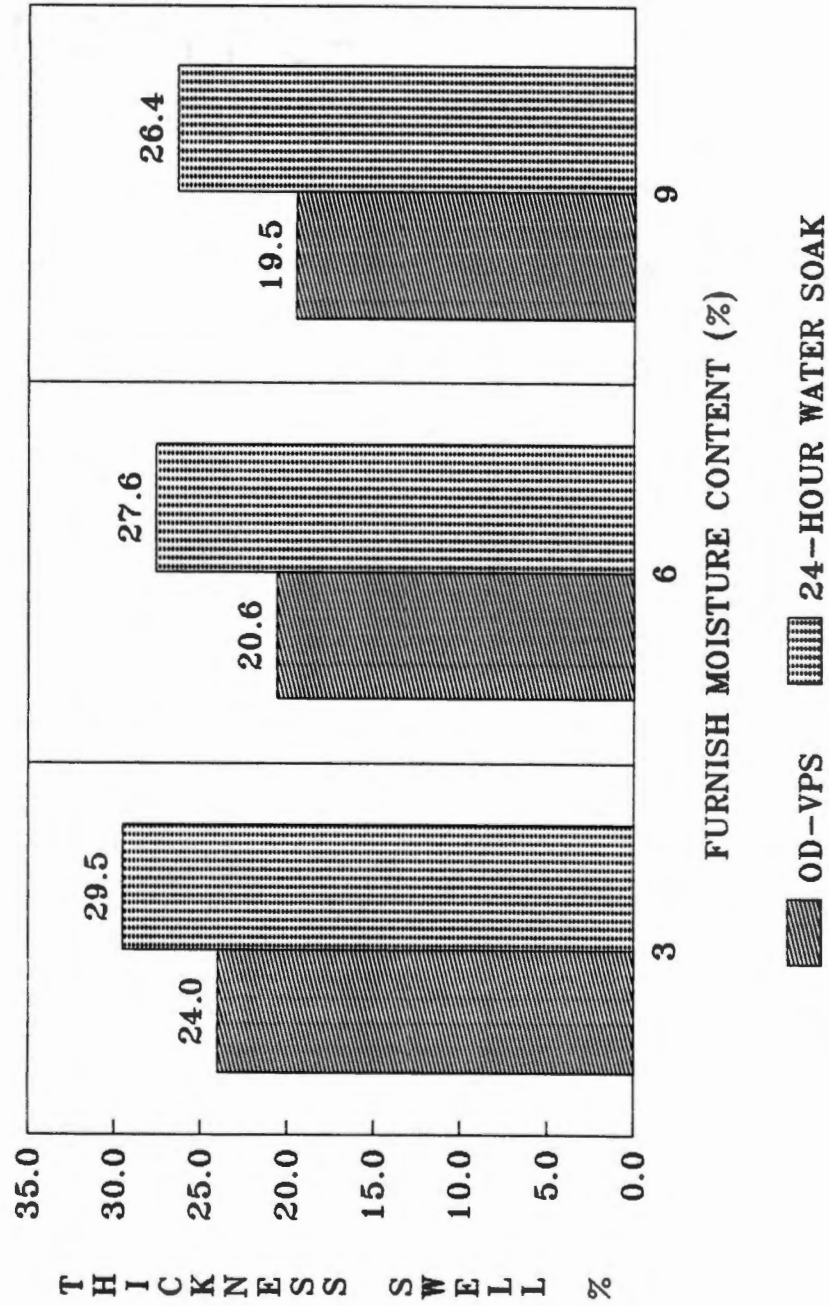


Figure 3. Effect of furnish moisture content on thickness swell of six-by six-inch specimens.

percent furnish moisture content to 9.5 psi at 9 percent furnish moisture content for the 24-hour soak test procedure ($p < 0.01$). There was also a significant difference between the two test procedures ($p = 0.01$) (Appendix B.2). There was less retention of internal bond strength for the 24-hour soak procedure than for the OD-VPS test procedure. No significant difference was found between test procedures.

Vertical density profile. The vertical density profile was measured from all two-by two-inch internal bond and thickness swell specimens. For the OD-VPS procedure, the density of two density regions increased as furnish moisture content increased. The two density regions that showed this statistically significant increasing linear trend were: Region 1 ($p < 0.01$) with density values ranging from .73 g/cc at 3 percent furnish moisture to .77 g/cc at 9 percent furnish moisture, and Region 2 ($p = 0.02$) with density ranging from .76 g/cc at 3 percent furnish moisture to .77 g/cc at 9 percent furnish moisture. For the 24-hour water soak procedure, all density regions showed an increasing linear trend as furnish moisture content increased: Region 1 ($p < 0.01$) with density increasing from .71 g/cc at 3 percent furnish moisture to .79 g/cc at 9 percent furnish moisture, Region 2 ($p = 0.02$) with density increasing from .71 g/cc at 3 percent to .74 g/cc at 9 percent furnish moisture content, Region 3 ($p < 0.01$) with density increasing from .67 g/cc at 3 percent furnish moisture to .68 g/cc at 9 percent furnish

moisture, Region 4 ($p < 0.01$) with density ranging from .71 g/cc at 3 percent furnish moisture to .76 g/cc at 9 percent furnish moisture and Region 5 ($p < 0.01$) with density ranging from .69 at 3 percent furnish moisture to .75 g/cc at 9 percent furnish moisture (Table 5).

To examine the effect of test procedure on the vertical density profile, the density differences of vertical density profiles developed before and after accelerated aging for both test procedures were also analyzed statistically. Furnish moisture content significantly affected Region 1 ($p < 0.01$) and Region 2 ($p = 0.01$) of the difference in before and after density profiles from the OD-VPS procedure. For the 24-hour water soak difference in profile density, Region 3 ($p < 0.01$), Region 4 ($p < 0.01$), and Region 5 ($p < 0.01$) were significantly affected. No linear trend of the five density profile regions with furnish moisture content was noted (Table 5).

Press Closure Rate

Thickness swell. Three press closure rates were studied: 20, 60 and 100 seconds. Press closure rate is expressed in seconds, as the distance to close is always the same. For the two-by-two-inch specimens, evaluated with the OD-VPS procedure, thickness swell ranged from 25.5 percent at 20 seconds to 30.9 percent at 100 seconds. For the 24-hour water soak procedure, thickness swell ranged from 29.9

TABLE 5. Density region means for furnish moisture content from the before vertical density profile and the vertical density profile describing the difference in density from before and after test procedures.

FURNISH MOISTURE CONTENT	OVENDRY-VACUUM PRESSURE SOAK					TEST PROCEDURE					24-HOUR WATER SOAK				
	D1	D2	D3 (G/CC)	D4	D5	DENSITY REGION									
						D1	D2	D3 (G/CC)	D4	D5					
DENSITY REGION MEANS BEFORE VERTICAL DENSITY PROFILES BY TEST PROCEDURE															
3	0.73	0.76	0.71	0.74	0.78	0.71	0.71	0.67	0.71	0.69					
6	0.78	0.77	0.69	0.77	0.79	0.75	0.72	0.67	0.73	0.70					
9	0.77	0.77	0.68	0.76	0.82	0.79	0.74	0.68	0.76	0.75					
P>F	(P<0.01)(P=0.05)(P=0.37)(P=0.56)(P=0.08)					(P<0.01)(P=0.02)(P<0.01)(P<0.01)(P<0.01)									
DENSITY REGION MEANS FOR THE DENSITY DIFFERENCE OF BEFORE AND AFTER VERTICAL DENSITY PROFILES BY TEST PROCEDURE															
3	0.21	0.15	0.16	0.15	0.16	0.23	0.11	0.14	0.15	0.14					
6	0.18	0.14	0.15	0.15	0.13	0.23	0.11	0.16	0.19	0.12					
9	0.15	0.16	0.18	0.18	0.19	0.20	0.10	0.14	0.14	0.12					
P>F	(P<0.01)(P=0.01)(P=0.68)(P=0.89)(P=0.61)					(P=0.64)(P=0.81)(P<0.01)(P<0.01)(P<0.01)									

a The probability >F between treatment density means.

percent at 20 seconds to 32.8 percent at 100 seconds (Table 6). Press closure rate significantly influenced thickness swell in the two-by two-inch specimens ($p=0.02$). A significant increasing linear trend of increased thickness swell with increased press closure rate was found for the two-by two-inch specimens ($P<0.01$) (Figure 4). Rice (1967) also found that thickness swell decreased at faster press closure rates. There was no significant difference in thickness swell between the two accelerated aging test procedures ($p=0.32$).

For the six-by six-inch specimens and the OD-VPS procedure, thickness swell ranged from 20.3 percent at 20 seconds to 23.0 percent at 100 seconds. For the 24-hour water soak, thickness swell ranged from 25.3 percent at 20 seconds to 30.9 percent at 100 seconds (Table 6). Press closure rate had a significant effect on thickness swell ($p<0.01$). A significant linear trend ($p<0.01$) of increasing thickness swell as press closure rate slowed was found (Figure 5). A faster rate of press closure can result in a higher face density which can inhibit water absorption. Less water absorption would decrease the amount of thickness swell. There was no significant difference in thickness swell between the two test procedures ($p=0.54$) for the six-by six-inch specimens. However, the 24-hour water soak procedure showed greater thickness swell values than the OD-VPS procedure for all press closure rate treatment levels.

Internal bond. Press closure rate had a significant

TABLE 6. The least squares adjusted treatment mean, the standard error of the least squares adjusted treatment mean, percent retention for accelerated aged internal bond by oven-dry-vacuum pressure soak, and 24-hour water soak for the dependent variables thickness swell, water absorption, springback, internal bond, and accelerated aged internal bond in response to press closure rate.

PRESS CLOSURE RATE	SAMPLE SIZE	THICKNESS SWELL (%)	WATER ABSORPTION (%)		SPRINGBACK (%)	INTERNAL BOND	ACCELERATED AGED INTERNAL BOND (PSI)
(SECONDS)	(INCHES)	OVENDRY VACUUM PRESSURE SOAK	24-HOUR WATER SOAK	OVENDRY VACUUM PRESSURE SOAK	24-HOUR WATER SOAK	(PSI)	OVENDRY VACUUM PRESSURE SOAK
20	2X2	25.5 a 0.5 b	29.9 0.6	93.2 1.0	69.6 0.7	20.6 0.7	22.6 0.6
	6X6	20.3 0.2	25.3 0.4	76.6 0.5	61.3 0.6		52.8 2.5
	2X2	26.9 0.5	31.0 0.7	92.2 1.1	70.5 0.8	21.4 0.7	43.7 2.8
60	6X6	21.4 0.3	28.1 0.4	79.2 0.6	63.4 0.7		23.9 0.7
	2X2	30.9 0.5	32.8 0.6	91.8 1.0	70.4 0.7	25.4 0.6	37.9 2.4
	6X6	23.0 0.2	30.8 0.6	77.2 0.5	62.7 0.6		12.5 0.8
100	2X2						
	6X6						

^a The least squares adjusted treatment mean.

^b The standard error of least squares adjusted treatment mean.

^c The retention of internal bond after accelerated aging.

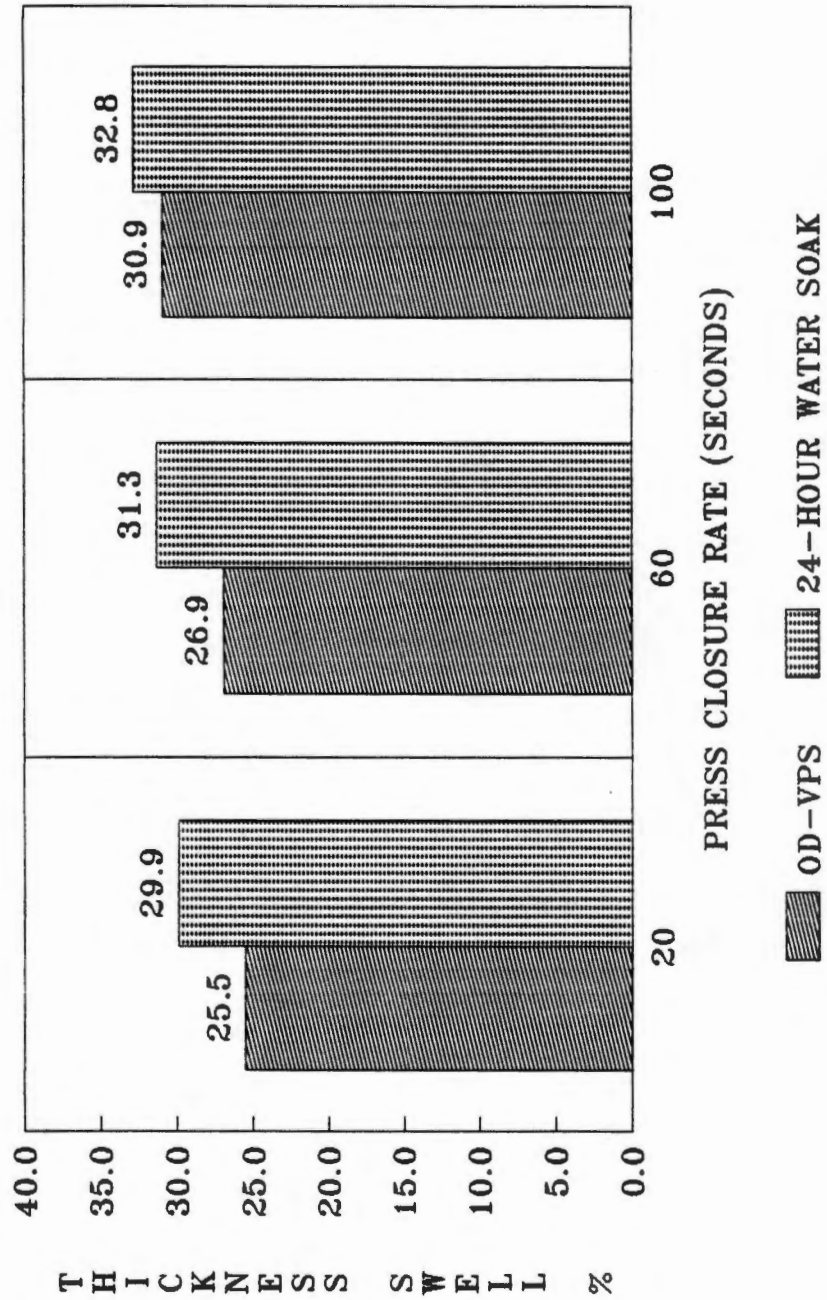


Figure 4. Effect of press closure rate on thickness swell of two-by two-inch specimens.

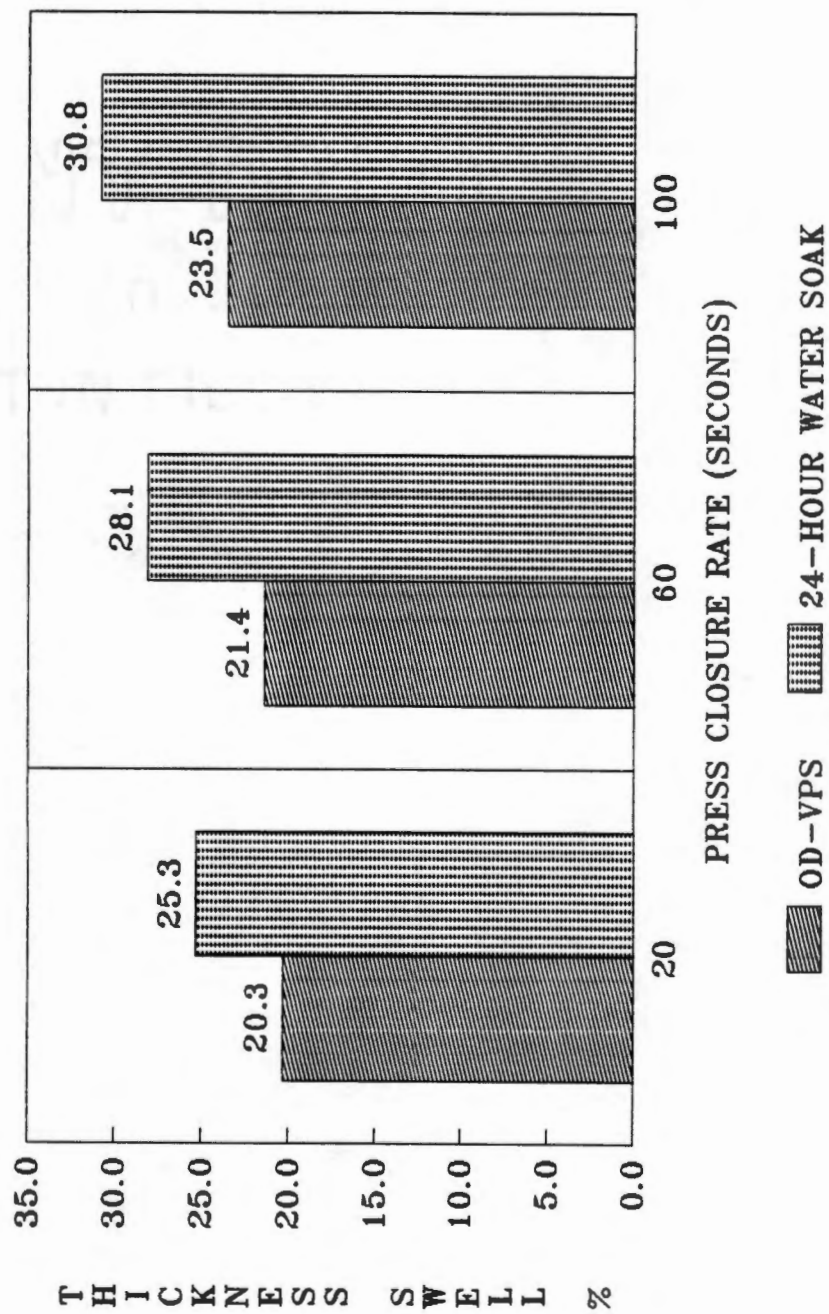


Figure 5. Effect of press closure rate on thickness swell of six-by six-inch specimens.

effect ($p < 0.01$) on internal bond (Appendix B.1). Internal bond ranged from 52.8 psi at 20 seconds to 37.9 psi at 100 seconds. Internal bond showed a significant increasing linear trend as press closure rate decreased ($p < 0.01$).

For internal bond specimens subjected to the OD-VPS procedure, internal bond ranged from 20.6 psi at 20 seconds to 25.4 psi at 100 seconds. For the 24-hour water soak procedure, internal bond ranged from 22.6 psi at 20 seconds to 26.7 psi at 100 seconds. Press closure rate was not significant for either test procedure ($p = 0.10$). Internal bond retention decreased linearly as press closure rate increased and was statistically significant ($p < 0.01$) (Appendix B.2). Internal bond strength retention was less for the 24-hour water soak procedure than the OD-VPS procedure. A faster press closer rate increased the rate of heat transfer to the core influencing the degree of resin polymerization and internal bond strength.

Vertical density profile. For the OD-VPS procedure, press closure rate significantly affected the density change: Region 2 ($p < 0.01$) which ranged from .73 g/cc at 20 seconds to .79 g/cc at 100 seconds, Region 3 ($p < 0.01$) which ranged from .69 g/cc at 20 seconds to .73 g/cc at 100 seconds, Region 4 ($p < 0.01$) which ranged from .73 g/cc at 20 seconds to .77 g/cc at 100 seconds, and Region 5 ($p < 0.01$) which ranged from .77 g/cc at 20 seconds to .84 g/cc at 100 seconds. For the 24-hour water soak procedure, press

closure rate had a significant effect on Region 2 ($p=0.05$) with a density range from .69 g/cc at 20 seconds to .73 g/cc at 100 seconds and Region 5 ($p=0.04$) which had a density range of .70 g/cc at 20 seconds to .75 g/cc at 100 seconds (Table 7). Density regions significantly affected by press closure rate showed increasing density as press closure rate became slower. The change in density from before and after test procedures also increased as the press closure rate the maximum press pressure was reduced. Core density was lower at the faster press closer rate.

For the OD-VPS procedure, press closure rate significantly affected Region 2 ($p<0.01$) which showed a density difference from before and after profiles of .12 g/cc at 20 seconds to a change of .16 g/cc at 100 seconds. Region 3 ($p<0.01$) had a density difference of .13 g/cc at 20 seconds to .16 g/cc at 100 seconds. Region 4 ($p<0.01$) had a density difference of .11 g/cc at 20 seconds to .15 g/cc at 100 seconds, and Region 5 ($p=0.04$) had a density difference ranging from .14 g/cc at 20 seconds to .17 g/cc at 100 seconds.

For the 24-hour water soak procedure, press closure rate affected Region 1 ($p<0.01$) which had a density difference range from .21 g/cc at 20 seconds to .25 g/cc at 100 seconds. For Region 3 ($p=0.03$) there was no density difference between 20 and 100 seconds, and Region 4 ($p<0.01$) had a density difference of .17 g/cc at 20 seconds to .18

TABLE 7. Density region means for press closure rate from the before vertical density profile and the vertical density profile describing the difference in density from before and after test procedures.

PRESS CLOSURE RATE	OVENDRY-VACUUM PRESSURE SOAK					TEST PROCEDURE					24-HOUR WATER SOAK				
	D1	D2	D3 (G/CC)	D4	D5	DENSITY REGION D1					D2	D3 (G/CC)	D4	D5	
DENSITY REGION MEANS BEFORE VERTICAL DENSITY PROFILES BY TEST PROCEDURE															
20	0.76	0.73	0.69	0.73	0.77	0.75	0.69	0.67	0.72	0.70					
60	0.74	0.77	0.70	0.77	0.80	0.75	0.74	0.68	0.74	0.69					
100	0.77	0.79	0.73	0.77	0.84	0.74	0.73	0.66	0.74	0.75					
P>F	(P=0.11)(P<0.01)(P<0.01)(P<0.01)(P<0.01)					(P=0.46)(P=0.05)(P=0.06)(P=0.41)(P=0.04)									
DENSITY REGION MEANS FOR THE DENSITY DIFFERENCE OF BEFORE AND AFTER VERTICAL DENSITY PROFILES BY TEST PROCEDURE															
20	0.15	0.12	0.13	0.11	0.14	0.21	0.10	0.15	0.17	0.07					
60	0.17	0.15	0.16	0.16	0.16	0.22	0.12	0.16	0.17	0.07					
100	0.17	0.16	0.16	0.15	0.17	0.25	0.12	0.15	0.18	0.10					
P>F	(P=0.19)(P<0.01)(P<0.01)(P<0.01)(P=0.04)					(P<0.01)(P=0.24)(P=0.03)(P<0.01)(P=0.16)									

a The probability >F between treatment density means.

g/cc at 100 seconds (Table 7).

Panel Density

Thickness swell. Thickness swell was not effected by panel density for the two-by-two inch specimens: 27.7 percent at 41 lb/ft³ to 27.5 percent at 51 lb/ft³ for the OD-VPS procedure and 33.4 percent at 41 lb/ft³ to 29.2 percent at the 51 lb/ft³ for the 24-hour water soak procedure (Table 8). No practical difference between procedures was detected; however, panel density showed a statistically significant effect on thickness swell ($p=0.01$) and there was a significant difference in thickness swell between the two test procedures ($p=0.03$) (Appendix B.4). One possible explanation for increased thickness swell at the lower density level could be explained by a lack of heat transfer at a lower compaction ratio as opposed to the higher compaction ratio of the higher density level which would decrease resin polymerization. Most studies reviewed have shown that more swell occurs at greater panel densities. This result always occurs when wax was used in the experimentation (Geimer 1982; Hse 1975). Some authors have shown that the effect of density on thickness swell was not significant or that less severe accelerated aging test procedures, such as the 24-hour water soak test, result in less thickness swell than the OD-VPS test procedure (Lehmann 1974; Suchsland 1973). For the six-by six-inch specimens tested by the OD-VPS procedure, thickness swell ranged from

41 lb/ft³ to 21.8 percent at 51 lb/ft³. For the 24-hour water soak procedure, thickness swell ranged from 30.3 percent at 41 lb/ft³ to 25.8 percent at 51 lb/ft³. The effect of density was statistically significant between the two levels ($p < 0.01$) of panel density. A significant difference was found in thickness swell between the two test procedures ($p < 0.01$) (Appendix B.6).

Internal bond. Internal bond values ranged from 23.8 psi at 41 lb/ft³ to 64.3 psi at 51 lb/ft³ (Table 8). Panel density had a significant effect on dry internal bond values ($p < 0.01$) (Appendix B.1). Internal bond increased with panel density, and this trend is generally accepted in other studies (Larmore 1959; Heebink and Hann 1959; Hse 1975; Lyon et al. 1980; Filho 1981; and Biblis 1985).

For both accelerated aging procedures, retention of internal bond strength was much less at the 41 lb/ft³ panel density. Lower panel density affected the degree of furnish consolidation and proximity of interparticle contact, influencing the amount of resin bonding between flakes.

For the OD-VPS procedure, internal bond ranged from 10.6 psi at 41 lb/ft³ to 18.9 psi at 51 lb/ft³. For the 24-hour water soak procedure, internal bond ranged from 5.4 psi at 41 lb/ft³ to 14.2 psi at 51 lb/ft³ (Table 8). There was a significant difference between the two test procedures ($p = 0.01$) but density was not significant in affecting accelerated aging internal bond. Most likely no difference

TABLE 8. The least squares adjusted treatment mean, the standard error of the least squares adjusted treatment mean, percent retention for accelerated aged internal bond by oven-dry-vacuum pressure soak, and 24-hour water soak for the dependent variables thickness swell, water absorption, springback, internal bond, and accelerated aged internal bond in response to panel density.

PANEL DENSITY	SAMPLE SIZE	THICKNESS SWELL (%)	WATER ABSORPTION (%)			SPRINGBACK (%)			INTERNAL BOND	ACCELERATED AGED INTERNAL BOND (PSI)		
(LB/FT)	(INCHES)	OVENDRY VACUUM PRESSURE SOAK	24-HOUR WATER SOAK	OVENDRY VACUUM PRESSURE SOAK	24-HOUR WATER SOAK	OVENDRY VACUUM PRESSURE SOAK	24-HOUR WATER SOAK	24-HOUR WATER SOAK	(PSI)	OVENDRY VACUUM PRESSURE SOAK	24-HOUR WATER SOAK	24-HOUR WATER SOAK
41	2X2	27.7 a	33.4	105.7	81.5	21.4	25.3	23.8	10.6	5.4		
		0.8 b	1.1	1.7	1.2	1.1	1.0	4.2	1.3	1.1		
51	6X6	21.1	30.3	88.6	73.5							
		0.4	0.6	0.9	0.6							
51	2X2	27.5	29.2	80.6	60.1	23.0	23.3	64.3	18.9	14.2		
		0.4	0.5	0.8	0.6	0.5	0.5	2.0	0.6	0.5		
6X6	6X6	21.8	25.8	68.0	52.6							
		0.2	0.3	0.4	0.5							

a The least squares adjusted treatment mean.

b The standard error of least squares adjusted treatment mean.

c The retention of internal bond after accelerated aging.

in internal bond retention occurred between panel densities because of excessive degradation to panel bond strength.

Vertical density profile. For both the OD-VPS and 24-hour water soak procedure, panel density significantly affected all five regions ($p < 0.01$) of the vertical density profile. For the before profile and the OD-VPS procedure, density ranged from .68 g/cc at 41 lb/ft³ to .87 g/cc at 51 lb/ft³ in the face regions and .61 g/cc at 41 lb/ft³ to .77 g/cc at 51 lb/ft³ in the core (Table 9).

Relationship of Vertical Density Profile To Thickness Swell and Internal Bond

Thickness swell. Thickness swell was weakly correlated to the density of Region 2 ($R = -0.23$, $p < 0.01$), Region 3 ($R = -0.28$, $p < 0.01$), Region 4 ($R = -0.18$, $p = 0.04$) and Region 5 ($R = -0.16$, $p = 0.06$) of the vertical density profile scanned from specimens used for the OD-VPS test procedure. OD-VPS Thickness swell was not correlated to profiles developed for the 24-hour water soak procedure (Table 10). As density decreased, OD-VPS thickness swell increased. For the vertical density profile developed by calculating the difference of the before and after vertical density profiles, OD-VPS thickness swell was only weakly correlated to Region 3 ($R = -0.14$, $p < 0.01$) (Table 11). As thickness swell increased, the density difference range also increased.

For the 24-hour water soak, thickness swell was

TABLE 9. Density region means for panel density from the before vertical density profile and the vertical density profile describing the difference in density from before and after test procedures.

PANEL DENSITY	OVENDRY-VACUUM PRESSURE SOAK					TEST PROCEDURE					24-HOUR WATER SOAK				
	D1	D2	D3 (G/CC)	D4	D5	DENSITY REGION D1					D2	D3 (G/CC)	D4	D5	
DENSITY REGION MEANS BEFORE VERTICAL DENSITY PROFILES BY TEST PROCEDURE															
41	0.68	0.69	0.61	0.68	0.73	0.69	0.66	0.60	0.67	0.65					
51	0.83	0.85	0.77	0.83	0.87	0.81	0.79	0.74	0.79	0.78					
P>F	(P<0.01) (P<0.01) (P<0.01) (P<0.01) (P<0.01)					(P<0.01) (P<0.01) (P<0.01) (P<0.01) (P<0.01)									
DENSITY REGION MEANS FOR THE DENSITY DIFFERENCE OF BEFORE AND AFTER VERTICAL DENSITY PROFILES BY TEST PROCEDURE															
41	0.15	0.12	0.14	0.12	0.14	0.21	0.11	0.16	0.18	0.06					
51	0.17	0.16	0.15	0.15	0.17	0.23	0.11	0.14	0.15	0.10					
P>F	(P=0.06) (P<0.01) (P=0.38) (P=0.03) (P=0.02)					(P=0.19) (P=0.91) (P=0.91) (P<0.01) (P<0.01)									

a The probability >F between treatment density means.

TABLE 10. Relationship of response variables thickness swell, water absorption, accelerated aged internal bond, and springback to the density regions of the before vertical density profile using Pearson partial coefficients and corresponding $\text{prob} > F$ values for both accelerated aging testing procedures.

BEFORE VERTICAL DENSITY PROFILE REGIONS BY ACCELERATED AGING TREATMENTS										
RESPONSE VARIABLE	OVENDRY-VACUUM PRESSURE SOAK (APA-P1)					24-HOUR WATER SOAK (ASTM D-1037)				
	D1	D2	D3	D4	D5	D1	D2	D3	D4	D5
THICKNESS SWELL ^a	-0.09	-0.23	-0.28	-0.18	-0.16	-0.02	-0.12	-0.14	-0.12	-0.07
APA-P1	(P=0.29)	(P<0.01)	(P<0.01)	(P=0.04)	(P=0.06)	(P=0.79)	(P=0.15)	(P=0.12)	(P=0.15)	(P=0.44)
THICKNESS SWELL ^b	-0.07	0.04	-0.01	0.03	0.02	0.16	0.23	0.15	0.20	0.11
ASTM D-1037	(P=0.47)	(P=0.65)	(P=0.92)	(P=0.76)	(P=0.78)	(P=0.08)	(P<0.01)	(P=0.09)	(P=0.02)	(P=0.20)
WATER ABSORPTION	0.04	0.04	-0.17	-0.17	-0.18	-0.09	-0.15	-0.16	-0.14	-0.09
APA-P1	(P=0.66)	(P=0.66)	(P=0.05)	(P=0.06)	(P=0.04)	(P=0.32)	(P=0.10)	(P=0.07)	(P=0.11)	(P=0.33)
WATER ABSORPTION	0.04	-0.08	0.08	0.06	0.13	-0.59	-0.59	-0.62	-0.64	-0.36
ASTM D-1037	(P=0.66)	(P=0.36)	(P=0.39)	(P=0.53)	(P=0.16)	(P<0.01)	(P<0.01)	(P<0.01)	(P<0.01)	(P<0.01)
INTERNAL BOND	-0.20	-0.05	-0.09	-0.02	-0.10	0.18	0.31	0.29	0.28	0.05
APA-P1	(P=0.02)	(P=0.59)	(P=0.27)	(P=0.82)	(P=0.26)	(P=0.04)	(P<0.01)	(P<0.01)	(P<0.01)	(P=0.61)
INTERNAL BOND	-0.07	0.04	-0.08	-0.12	-0.19	-0.16	0.22	0.27	0.27	0.09
ASTM D-1037	(P=0.43)	(P=0.65)	(P=0.38)	(P=0.16)	(P=0.03)	(P=0.08)	(P=0.01)	(P<0.01)	(P<0.01)	(P=0.28)
SPRINGBACK	-0.05	-0.07	-0.27	-0.15	-0.16	-0.03	-0.06	-0.08	-0.10	-0.05
APA-P1	(P=0.59)	(P=0.43)	(P<0.01)	(P=0.08)	(P=0.07)	(P=0.77)	(P=0.46)	(P=0.38)	(P=0.24)	(P=0.55)
SPRINGBACK	-0.01	0.12	0.02	0.03	0.05	0.23	0.25	0.24	0.23	0.16
ASTM D-1037	(P=0.88)	(P=0.17)	(P=0.84)	(P=0.75)	(P=0.58)	(P<0.01)	(P<0.01)	(P<0.01)	(P<0.01)	(P=0.07)

^a Pearson partial correlation coefficient - a measure of the strength of the predictor in the presence of other predictors and a measure of multicollinearity.

^b Probability of a greater F-statistic in determining the significance of the predictor on the response variable.

TABLE 11. Relationship of response variables thickness swell, water absorption, accelerated aged internal bond, and springback to the density regions for the difference of the before and after vertical density profile using Pearson partial coefficients and corresponding | prob>F | values for both accelerated aging testing procedures.

DIFFERENCE IN BEFORE AND AFTER VERTICAL DENSITY PROFILE REGIONS BY ACCELERATED AGING TREATMENTS										
RESPONSE VARIABLE	OVENDRY-VACUUM PRESSURE SOAK (APA-P1)					24-HOUR WATER SOAK (ASTH D-1037)				
	D1	D2	D3	D4	D5	D1	D2	D3	D4	D5
THICKNESS SWELL ^a	0.18	0.07	0.14	0.03	-0.08	0.13	0.07	<0.01	-0.14	-0.07
APA-P1 ^b	(P=0.16)	(P=0.41)	(P<0.01)	(P=0.12)	(P=0.44)	(P<0.16)	(P=0.41)	(P=0.92)	(P<0.12)	(P=0.44)
THICKNESS SWELL	0.23	0.19	0.01	-0.01	0.02	0.26	0.23	0.30	0.26	-0.05
ASTH D-1037	(P<0.01)	(P=0.03)	(P=0.96)	(P=0.97)	(P=0.82)	(P<0.01)	(P<0.01)	(P<0.01)	(P<0.01)	(P=0.56)
WATER ABSORPTION	0.13	0.06	0.05	0.01	0.01	0.09	-0.11	-0.12	-0.23	-0.03
APA-P1	(P=0.14)	(P=0.48)	(P=0.57)	(P=0.96)	(P=0.95)	(P=0.29)	(P=0.21)	(P=0.15)	(P<0.01)	(P=0.77)
WATER ABSORPTION	0.15	-0.02	0.13	0.06	0.14	-0.11	-0.16	-0.18	-0.29	-0.07
ASTH D-1037	(P=0.08)	(P=0.80)	(P=0.15)	(P=0.47)	(P=0.11)	(P=0.25)	(P=0.06)	(P=0.04)	(P<0.01)	(P=0.38)
INTERNAL BOND	<0.01	-0.03	-0.18	-0.10	-0.05	0.16	0.01	-0.05	0.28	-0.04
APA-P1	(P=0.99)	(P=0.72)	(P=0.05)	(P=0.25)	(P=0.54)	(P=0.07)	(P=0.89)	(P=0.55)	(P<0.01)	(P=0.71)
INTERNAL BOND	-0.05	-0.14	-0.19	-0.17	-0.04	-0.05	-0.01	-0.75	-0.01	0.14
ASTH D-1037	(P=0.62)	(P=0.12)	(P=0.04)	(P=0.06)	(P=0.67)	(P=0.54)	(P=0.96)	(P<0.01)	(P=0.88)	(P=0.11)
SPRINGBACK	0.17	0.09	0.76	0.05	-0.01	0.07	0.11	0.08	-0.15	-0.01
APA-P1	(P=0.05)	(P=0.30)	(P<0.01)	(P=0.52)	(P=0.93)	(P=0.41)	(P=0.21)	(P=0.37)	(P=0.10)	(P=0.88)
SPRINGBACK	0.16	0.14	0.11	-0.01	0.04	0.32	0.19	0.40	0.18	0.01
ASTH D-1037	(P=0.07)	(P=0.13)	(P=0.22)	(P=0.95)	(P=0.69)	(P<0.01)	(P=0.03)	(P<0.01)	(P=0.04)	(P=0.94)

^a Pearson partial correlation coefficient - a measure of the strength of the predictor in the presence of other predictors and a measure of multicollinearity.

^b Probability of a greater F-statistic in determining the significance of the predictor on the response variable.

correlated to the density of Region 1 ($R=0.16$, $p=0.08$), Region 2 ($R=0.23$, $p<0.01$), Region 3 ($R=0.15$, $p=0.09$), and Region 4 ($R=0.20$, $p=0.02$) (Table 10). For the difference of the before and after profiles, thickness swell was correlated to the density of Region 1 ($R=0.26$, $p<0.01$), Region 2 ($R=0.23$, $p<0.01$), Region 3 ($R=0.30$, $p<0.01$), and Region 4 ($R=0.26$, $p<0.01$) (Table 11 and Appendix C). Twenty-four-hour water soak thickness swell increased as the change in density between the before and after profiles increased. A significant correlation among response variables suggests that different density regions of profiles scanned before accelerated aging tests may be used to predict thickness swell.

Internal bond. For accelerated aged internal bond tested after the OD-VPS procedure, the strongest correlation between internal bond was to density Region 3 ($R=-0.20$, $p=0.02$). OD-VPS internal bond was also inversely correlated to Region 3 ($R=-0.18$, $p=0.05$) of the difference of the profiles taken before and after testing (Table 11). As the density difference increased, internal bond decreased. Although Pearson product moment correlation coefficients show less than moderate strength of relationships, p-values were significant for the coefficients, proving a relationship exists even if the strength was low.

For internal bond tested after the 24-hour water soak procedure, the strongest correlations were between Region 2 ($R=0.22$, $p=0.01$), Region 3 ($R=0.27$, $p=0.01$), and Region 4

($R=0.27$, $p<0.01$) (Table 10). As density increased, internal bond increased.

For 24-hour water soak, the strongest correlation found was to Region 3 ($R=-0.75$, $p<0.01$) for the difference of profiles taken before and after testing. As internal bond retention increased, the density difference of the core (Region 3) decreased. The correlation of internal bond to the core region of the vertical density profile substantiates this assumption.

Density regions of the vertical density profile will be affected according to the severity of accelerated aging test used to measure thickness swell. Both procedures affected the inner and outer core density regions more than the face density regions. The change in core density seemed to contribute the most to thickness swell for both procedures. A mathematical model describing thickness swell from the sum of these components is probable, but was not attempted.

VI. CONCLUSION AND FUTURE STUDY

Summation

The response of the vertical density profile to changes in furnish moisture content, press closure rate, and panel density can be measured. This change in the vertical density profile will affect strength and dimensional stability properties. From this knowledge, a mathematical relationship between strength and dimensional stability, as affected by the vertical density profile, could lead to the use of non-destructive testing as a means of process panel quality control.

Furnish Moisture Content

Thickness swell and internal bond. The three levels of furnish moisture content (3, 6 and 9 percent) had a significant effect on thickness swell in the six-by six-inch specimens ($p < 0.01$) but not for the two-by two-inch specimens ($p = 0.56$). The two thickness swell procedures used produced significantly different results for both the six-by six-inch specimens ($p < 0.01$) and the two-by two-inch specimens ($p = 0.01$). Thickness swell decreased linearly as furnish moisture content increased.

Furnish moisture content did not have a strong influence on internal bond ($p = 0.09$) and had no effect on accelerated aging internal bond ($p = 0.15$). However, internal bond and internal bond retention decreased linearly as

furnish moisture content increased ($p < 0.01$) likely due to "incomplete" resin cure in the core of the panel resulting from a build-up of steam in the core.

Vertical density profile. As furnish moisture content increased, the density of the five profile regions increased. Furnish moisture content had a greater effect on the face densities than the core or outer core regions.

Press Closure

Thickness swell and internal bond. The three rates of press closure (20, 60 and 100 seconds) had a significant effect on the two-by two-inch thickness swell specimens ($p < 0.02$) and on the six-by six-inch thickness swell specimens ($p < 0.01$). The general linear trend for both specimen sizes ($p < 0.01$) was an increase in thickness swell with a decrease in press closure. Increased compaction and a higher density panel face resulted for the faster closure rate. Press closure rate had a significant effect on internal bond ($p < 0.01$); but, had no effect on internal bond retention ($p = 0.10$). Internal bond decreased as the time to position increased. More resin polymerization from higher internal panel temperatures at faster press closure rates enhanced the densification in the core of the panel leading to higher internal bond values.

Vertical density profile. Press closure rate had more of an effect on the core density regions of the vertical

density profile than the face density regions. Overall density averages were more uniform from face to face as press closure rate slowed. Internal bond values should have increased as press closure rate slowed; but, examination of the difference of the before and after scans, indicated a greater density change at the slower press closure rate due to less temperature transfer compounded with a lower compaction ratio.

Panel Density

Thickness swell and internal bond. Panel density had a significant effect on thickness swell for both the two-by-two-inch specimens ($p=0.01$) and the six-by-six inch specimens ($p<0.02$); and also on internal bond ($p<0.01$). However, panel density did not effect the accelerated aged internal bond ($p=0.20$). For the OD-VPS procedure, there was no linear trend but for the 24-hour water soak, thickness swell increased as density decreased. The 41 lb/ft³ density level was too low for adequate flake compaction and heat transfer to polymerize resin in the core. Internal bond increased as panel density increased.

Vertical density profile. The five average density regions of the vertical density profile were significantly different at the two panel density levels. The average density of each profile region increased as panel density increased. After accelerated aging, density reduction within a given region was greatest for more dense regions.

Relationship of Vertical Density Profile to Thickness Swell and Internal Bond

The relationship of all response variables was analyzed using Pearson partial correlation coefficients and probabilities. Relationships of thickness swell to the different density regions of the profile was promising for the 24-hour water soak procedure.

Accelerated aged internal bond (ASTM D-1037) correlated the strongest to the core density region for the 24-hour water soak procedure ($R=0.27$, $p=0.01$). The difference between the core density after the durability treatments for 24-hour water soak also correlated strongly with accelerated aged internal bond for the 24-hour water soak procedure ($R=-0.75$, $p=0.01$). The more density decreased or the change in density increased, the more thickness swell increased. Therefore, the effect of 24-hour water soak treatment on internal bond could be related to the actual core density or the core density difference.

Future Study

It is suggested that future studies quantitatively examine the influence of the density profile on thickness swell. Once identified, the rheological properties of the mat that most influence swell should be altered in an attempt to reduce thickness swell. Studies should be designed to isolate the effect of single process variables.

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APPENDICES

WOMEN'S DEPT.
RUTHERFORD CO. N.J.
100% COTTON FIBER

APPENDIX A. THE LEAST SQUARES ADJUSTED MEAN, THE STANDARD ERROR OF THE LEAST SQUARES ADJUSTED MEAN, THE UNADJUSTED TREATMENT MEAN, STANDARD DEVIATION OF THE UNADJUSTED MEAN, THE COVARIATE (SPECIMEN DENSITY), THE FIVE DENSITY REGIONS (D1-D5), THE DIFFERENCE IN DENSITY (DF1-DF5) TAKEN BEFORE AND AFTER THE OD-VPS AND 24-HOUR WATER SOAK PROCEDURES, THICKNESS SWELL (TS), WATER ABSORPTION (WA), ACCELERATED AGED INTERNAL BOND (AAIB), INTERNAL BOND (IB) AND SPRINGBACK FOR TWO-INCH BY TWO-INCH AND SIX-INCH BY SIX-INCH SAMPLES FOR BOTH ACCELERATED AGING TEST PROCEDURES.

TABLE A.1. Least squares mean and standard errors, the unadjusted treatment mean and standard deviation for all response variables by treatment for oven-dry-vacuum pressure soak test procedure: two-by two-inch specimens.

TRT	PNC	DEN	PCR	TS	WA	MAIB	SPG	DENSITY REGIONS FROM DIFFERENCE OF BEFORE & AFTER PROFILES					DENSITY REGIONS OF BEFORE PROFILES				
								h	i	j	k	l					
a	b	c	d	e	f	g											
1	3	41	20	26.86 1.09 (25.44)(108.28)	96.96 2.38 (15.52)	20.54 1.84 (9.21)	23.72 1.48 (23.60)	0.197 0.017 (0.015)	0.134 0.014 (0.015)	0.153 0.015 (0.015)	0.119 0.015 (0.015)	0.146 0.022 (0.022)	0.679 0.026 (0.021)	0.673 0.021 (0.017)	0.634 0.017 (0.020)	0.676 0.020 (0.025)	0.712
2	3	41	60	30.49 1.11 (27.44)(106.93)	97.20 2.41 (14.17)	19.38 1.87 (6.38)	24.62 1.51 (3.28)	0.180 0.018 (0.017)	0.125 0.015 (0.016)	0.122 0.016 (0.015)	0.137 0.015 (0.015)	0.134 0.022 (0.022)	0.554 0.027 (0.021)	0.598 0.021 (0.018)	0.647 0.021 (0.021)	0.687 0.021 (0.026)	0.719
3	3	41	100	32.67 4.95 (27.86)(106.16)	70.61 2.59 (8.44)	13.59 2.01 (25.30)	27.88 1.62 (4.26)	0.230 0.019 (0.017)	0.118 0.016 (0.015)	0.169 0.017 (0.015)	0.128 0.017 (0.015)	0.164 0.024 (0.024)	0.666 0.029 (0.023)	0.689 0.023 (0.019)	0.611 0.019 (0.022)	0.666 0.022 (0.028)	0.699
4	3	51	20	27.86 1.09 (28.39)(88.66)	92.40 2.38 (21.88)	18.96 1.84 (5.36)	22.50 1.48 (22.65)	0.174 0.018 (0.014)	0.143 0.014 (0.015)	0.165 0.015 (0.015)	0.151 0.015 (0.015)	0.166 0.022 (0.022)	0.818 0.027 (0.021)	0.807 0.021 (0.017)	0.776 0.017 (0.020)	0.791 0.020 (0.025)	0.840
5	3	51	60	28.45 1.10 (29.52)(82.81)	91.55 2.39 (21.88)	21.48 1.84 (5.36)	23.88 1.49 (24.93)	0.184 0.017 (0.015)	0.158 0.014 (0.015)	0.166 0.015 (0.015)	0.172 0.015 (0.015)	0.144 0.022 (0.022)	0.769 0.027 (0.021)	0.826 0.021 (0.017)	0.785 0.017 (0.020)	0.822 0.020 (0.025)	0.842

TABLE A.1. (Continued)

a	b	c	d	e	f	g	DENSITY REGIONS FROM DIFFERENCE OF BEFORE & AFTER PROFILES					DENSITY REGIONS OF BEFORE PROFILES										
							SPG	DP1	DP2	DP3	DP4	DP5	D1	D2	D3	D4	D5					
TRT	PHC	DEN	PCR	TS	WA	AAIB	b	i														
6	3	51	100	30.44	93.81	15.72	25.65	0.278	0.195	0.171	0.162	0.225	0.787	0.871	0.799	0.823	0.879					
				1.10	2.39	1.85	1.49	0.018	0.014	0.015	0.015	0.022	0.027	0.021	0.018	0.020	0.025					
				(29.52)	(90.07)	(17.45)	(26.43)															
				(2.43)	(13.51)	(5.48)	(7.22)															
7	6	41	20	30.44	95.77	16.73	21.93	0.131	0.086	0.092	0.072	0.089	0.671	0.629	0.593	0.627	0.657					
				1.10	2.38	1.84	1.48	0.017	0.015	0.015	0.015	0.022	0.027	0.021	0.018	0.021	0.025					
				(32.50)	(109.67)	(11.67)	(16.90)															
				(4.52)	(7.28)	(3.34)	(3.64)															
8	6	41	60	27.19	94.87	09.08	24.71	0.136	0.107	0.204	0.162	0.145	0.665	0.677	0.589	0.668	0.706					
				1.09	2.46	1.91	1.54	0.018	0.019	0.016	0.016	0.022	0.028	0.022	0.018	0.028	0.026					
				(23.64)	(104.89)	(6.35)	(19.51)															
				(2.40)	(6.94)	(3.67)	(6.97)															
9	6	41	100	29.83	97.92	08.66	31.82	0.166	0.172	0.182	0.222	0.180	0.713	0.735	0.654	0.746	0.785					
				1.14	3.27	2.53	2.04	0.024	0.014	0.021	0.021	0.029	0.037	0.029	0.024	0.020	0.026					
				(25.42)	(104.47)	(5.73)	(29.38)															
				(5.19)	(0.86)	(1.15)	(0.36)															
10	6	51	20	22.28	85.20	23.25	15.56	0.202	0.157	0.121	0.111	0.164	0.879	0.837	0.788	0.844	0.893					
				1.10	2.38	1.85	1.49	0.018	0.014	0.015	0.015	0.022	0.027	0.021	0.018	0.020	0.029					
				(25.04)	(73.89)	(29.69)	(18.72)															
				(2.14)	(7.86)	(10.76)	(3.74)															
11	6	51	60	23.77	86.76	17.20	20.25	0.192	0.112	0.124	0.145	0.147	0.876	0.865	0.802	0.871	0.869					
				1.10	2.39	1.85	1.49	0.018	0.015	0.016	0.015	0.022	0.027	0.021	0.018	0.020	0.048					
				(25.83)	(78.65)	(18.85)	(22.86)															
				(2.51)	(5.60)	(5.16)	(2.83)															

TABLE A.1. (Continued)

DENSITY REGIONS FROM DIFFERENCE OF BEFORE & AFTER PROFILES							DENSITY REGIONS OF BEFORE PROFILES										
a	b	c	d	e	f	g	b i										
TAT	PMC	DEN	PCR	TS	WA	AAIB	SPG	DF1	DF2	DF3	DF4	DF5	D1 j	D2	D3	D4	D5
12	6	51	100	26.11 1.11 (27.42)	89.96 2.42 (84.57)	11.43 1.87 (14.17)	21.59 1.51 (22.07)	0.229 0.017 (0.246)	0.200 0.016 (0.216)	0.185 0.015 (0.199)	0.181 0.015 (0.196)	0.209 0.022 (0.231)	0.843 0.028 (0.871)	0.844 0.021 (0.865)	0.770 0.018 (0.788)	0.842 0.023 (0.865)	0.874 0.027 (0.901)
13	9	41	20	30.33 1.26 (31.59)	95.40 2.74 (98.14)	10.99 2.12 (13.11)	25.08 1.71 (26.79)	0.103 0.020 (0.123)	0.106 0.027 (0.133)	0.155 0.018 (0.173)	0.135 0.018 (0.153)	0.144 0.025 (0.169)	0.565 0.031 (0.596)	0.546 0.024 (0.570)	0.505 0.026 (0.531)	0.648 0.038 (0.686)	0.693 0.029 (0.722)
14	9	41	60	26.26 2.07 (28.33)	94.45 4.49 (98.94)	13.97 3.48 (17.45)	19.08 2.81 (21.89)	0.175 0.033 (0.208)	0.164 0.015 (0.179)	0.246 0.029 (0.275)	0.224 0.028 (0.252)	0.209 0.041 (0.250)	0.565 0.050 (0.615)	0.669 0.039 (0.708)	0.596 0.033 (0.629)	0.678 0.022 (0.700)	0.728 0.048 (0.776)
15	9	41	100	37.91 1.46 (39.37)	93.66 2.59 (96.25)	. . . (35.41)	. . . (96.04)	. . . (0.62)	. . . (1.54)	. . . (0.62)	. . . (1.54)	. . . (0.62)	0.773 0.028 (0.801)	0.751 0.023 (0.774)	0.600 0.018 (0.618)	0.743 0.022 (0.765)	0.823 0.025 (0.848)
16	9	51	20	21.96 1.16 (23.12)	85.21 2.52 (87.73)	13.69 1.95 (15.64)	17.22 1.57 (18.79)	0.162 0.018 (0.180)	0.173 0.015 (0.188)	0.176 0.016 (0.192)	0.147 0.016 (0.163)	0.203 0.023 (0.226)	0.824 0.028 (0.852)	0.800 0.023 (0.823)	0.724 0.018 (0.742)	0.780 0.022 (0.802)	0.837 0.027 (0.864)
17	9	51	60	21.65 1.16 (22.81)	84.23 2.52 (86.75)	13.71 1.95 (15.66)	16.66 1.57 (18.23)	0.178 0.018 (0.196)	0.191 0.015 (0.206)	0.168 0.016 (0.184)	0.212 0.016 (0.228)	0.223 0.023 (0.246)	0.858 0.028 (0.886)	0.900 0.023 (0.923)	0.801 0.018 (0.819)	0.867 0.021 (0.888)	0.909 0.026 (0.935)

TABLE A.1. (Continued)

DENSITY REGIONS FROM DIFFERENCE OF BEFORE & AFTER PROFILES										DENSITY REGIONS OF BEFORE PROFILES							
a	b	c	d	e	f	g	h	1	2	3	4	5					
TRY	PMC	DEM	PCR	YS	WA	AAIB	SPG	DF1	DF2	DF3	DF4	DF5	DI 1	DI 2	DI 3	DI 4	DI 5
18	9	51	100	23.02 (1.15) (24.56) (3.80)	85.55 (2.51) (75.45) (7.54)	11.92 (1.94) (14.43) (6.32)	18.71 (1.57) (21.71) (4.86)	0.147 0.018	0.186 0.015	0.169 0.016	0.182 0.016	0.179 0.023	0.834 0.028	0.862 0.022	0.762 0.018	0.816 0.022	0.906 0.027

Treatment (TRY) boards were manufactured under different combinations of specimen density (two levels), three levels of press closure rate, and three levels of furnish moisture content.

Panels were made of furnish before board manufacture measured in percent.

Panel density (PMC) is the density of furnish before board manufacture measured in percent.

Press density (DEM) is the density of furnish after board manufacture measured in percent.

Press closure rate (PCR) is defined as the ratio of press closure rate to the target treatment density.

For the column labeled (YS) thickness swell, (WA) accelerated aged internal bond and (SPG) springback for the OvenDry-vacuum Pressure Swell, (AAIB) accelerated aged internal bond and (SPG) springback for the OvenDry-vacuum Pressure Swell, (WA) accelerated aged internal bond and (SPG) springback for the OvenDry-vacuum Pressure Swell, (AAIB) accelerated aged internal bond and (SPG) springback for the OvenDry-vacuum Pressure Swell.

Adjusted treatment mean, the second value is the standard error of the least squares adjusted treatment mean. The third value is the unadjusted treatment mean, and the last value is the standard deviation of the unadjusted treatment mean. The third value is the unadjusted treatment mean, and the last value is the standard deviation of the unadjusted treatment mean. The third value is the unadjusted treatment mean, and the last value is the standard deviation of the unadjusted treatment mean.

Thickness swell is defined as the change in thickness after exposure measured as percent change from the original thickness.

Water absorption (WA) is the amount of water absorbed after the exposure test measured as the percent increase in weight from the original weight.

Accelerated aged internal bond (AAIB) is the internal bond of the two inch by two inch specimen after the OD-VPS exposure test.

Springback (SPG) is the response of the panel to the exposure procedure to return to the original thickness and is measured as the percent difference of the dry thickness after the exposure test to the original thickness.

Density regions (DI-1 to DI-5) represent the numerical difference of the five density regions, before and after the exposure test. The reduced density after the exposure test is mostly due to the increased thickness of the specimen. The first value in each column is the unadjusted mean, the second value is the standard deviation of the mean.

Density regions (DI-1 to DI-5) represent five density regions in the vertical plane of the panel, calculated by averaging selected individual density measurements taken during the profile scan. Refer to the Materials and Methods section for details on profile estimation.

a Treatment (TRY) boards were manufactured under different combinations of specimen density (two levels), three levels of press closure rate, and three levels of furnish moisture content.
b Furnish moisture content (PMC) of furnish before board manufacture measured in percent.
c Panel density (DEM) is the target treatment density.
d Press closure rate (PCR) is defined as the time to stops during the press cycle.
e For the columns labeled (YS) thickness swell, (WA) water absorption, (AAIB) accelerated aged internal bond and (SPG) springback for the Oven-dry-vacuum pressure soak (OD-VPS) procedure, the first value in the column is the least squares adjusted treatment mean, the second value is the standard error of the least squares adjusted treatment mean. The third value is the unadjusted treatment mean, and the last value is the standard deviation of the unadjusted treatment mean.
f Thickness swell is defined as the change in thickness after exposure measured as percent change from the original thickness.
g Water absorption (WA) is the amount of water absorbed after the exposure test measured as the percent increase in weight from the original weight.
h Accelerated aged internal bond (AAIB) is the internal bond of the two inch by two inch specimen after the OD-VPS exposure.
i Springback (SPG) is the response of the panel to the exposure procedure to return to the original thickness and is measured as the percent difference of the dry thickness after the exposure test to the original thickness.
j Density regions (DI-1 to DI-5) represent the numerical difference of the five density regions, before and after the exposure test. The reduced density after the exposure test is mostly due to the increased thickness of the specimen. The first value in each column is the unadjusted mean, the second value is the standard deviation of the mean.
k Density regions (DI-1 to DI-5) represent five density regions in the vertical plane of the panel, calculated by averaging select individual density measurements taken during the profile scan. Refer to the Materials and Methods section for details on profile estimation.

TABLE A.2. Least squares mean and standard errors, the unadjusted treatment mean and standard deviation for all response variables by treatment for 24-hour water soak test procedure: two-by two-inch specimens.

a	b	c	d	e	f	g	DENSITY REGIONS FROM DIFFERENCE OF BEFORE & AFTER PROFILES					DENSITY REGIONS OF BEFORE PROFILES													
							SPG	DP1	DP2	DP3	DP4	DP5	D1	j	D2	D3	D4	D5							
TRT	PNC	DEN	PCR	TS	WA	AAIB	b i																		
1	3	41	20	32.25	70.27	14.95	23.87	0.223	0.086	0.114	0.119	0.095	0.668	0.635	0.506	0.647	0.632								
				1.47	1.67	1.51	1.40	0.018	0.028	0.014	0.015	0.023	0.024	0.019	0.017	0.018	0.028								
				(26.30)	(84.40)	(10.47)	(19.31)																		
2	3	41	60	32.11	72.37	13.04	24.57	0.202	0.079	0.112	0.122	0.097	0.599	0.634	0.507	0.647	0.586								
				1.49	1.69	1.54	1.42	0.018	0.028	0.015	0.015	0.023	0.025	0.020	0.018	0.019	0.028								
				(25.53)	(87.61)	(7.55)	(18.53)																		
3	3	41	100	37.71	70.61	10.38	30.98	0.199	0.083	0.168	0.146	0.094	0.598	0.618	0.566	0.602	0.579								
				1.60	1.82	1.66	1.53	0.019	0.031	0.016	0.016	0.025	0.026	0.022	0.019	0.021	0.031								
				(39.06)	(83.16)	(4.77)	(28.20)																		
4	3	51	20	28.55	69.84	14.54	21.09	0.228	0.136	0.168	0.194	0.213	0.802	0.764	0.742	0.778	0.799								
				1.48	1.66	1.51	1.39	0.018	0.028	0.015	0.015	0.023	0.024	0.019	0.017	0.019	0.028								
				(29.83)	(68.39)	(16.09)	(23.58)																		
5	3	51	60	30.59	69.60	13.49	22.90	0.267	0.133	0.168	0.160	0.148	0.797	0.805	0.751	0.796	0.766								
				1.47	1.67	1.52	1.36	0.018	0.028	0.015	0.015	0.023	0.024	0.020	0.017	0.018	0.027								
				(31.93)	(62.30)	(15.47)	(24.25)																		
				(4.20)	(2.90)	(5.95)	(4.08)																		

TABLE A.2. (Continued)

DENSITY REGIONS FROM DIFFERENCE OF BEFORE & AFTER PROFILES								DENSITY REGIONS OF BEFORE PROFILES										
a	b	c	d	e	f	g		SPG	DP1	DP2	DP3	DP4	DP5	D1 j	D2	D3	D4	D5
TRT	PMC	DEN	PCR	TS	WA	AA1B	b		i									
6	3	51	100	31.61	73.20	11.58	25.39	0.272	0.118	0.139	0.151	0.129	0.761	0.783	0.740	0.771	0.811	
				1.48	1.67	1.52	1.40	0.018	0.028	0.015	0.014	0.023	0.024	0.019	0.017	0.019	0.028	
				(34.49)	(66.06)	(12.92)	(29.52)											
				(5.64)	(6.88)	(7.28)	(5.86)											
7	6	41	20	34.95	71.99	07.65	28.66	0.139	0.062	0.152	0.132	0.078	0.668	0.611	0.586	0.625	0.622	
				1.47	1.67	1.51	1.40	0.018	0.028	0.015	0.014	0.023	0.024	0.019	0.017	0.018	0.027	
				(29.93)	(80.34)	(3.75)	(23.92)											
				(5.49)	(3.14)	(1.98)	(3.22)											
8	6	41	60	43.61	71.89	04.92	30.77	0.238	0.118	0.224	0.281	0.189	0.723	0.683	0.606	0.680	0.662	
				1.52	1.73	1.57	1.45	0.019	0.029	0.015	0.016	0.024	0.025	0.021	0.018	0.019	0.029	
				(38.02)	(80.53)	(2.08)	(29.14)											
				(9.70)	(3.93)	(1.79)	(1.75)											
9	6	41	100	36.49	75.10	02.50	31.08	0.254	0.122	0.145	0.272	0.123	0.654	0.683	0.578	0.685	0.669	
				2.02	2.29	2.08	1.92	0.025	0.039	0.020	0.021	0.032	0.033	0.027	0.024	0.026	0.038	
				(35.89)	(81.39)	(2.92)	(30.12)											
				(0.11)	(3.46)	(1.51)	(1.75)											
10	6	51	20	22.38	63.57	16.17	16.45	0.230	0.077	0.145	0.118	0.105	0.875	0.809	0.775	0.834	0.785	
				1.47	1.67	1.52	1.40	0.018	0.028	0.015	0.015	0.023	0.024	0.020	0.017	0.018	0.028	
				(23.44)	(52.18)	(21.61)	(18.69)											
				(5.70)	(4.94)	(8.35)	(4.04)											
11	6	51	60	25.76	65.22	12.23	19.85	0.216	0.099	0.126	0.143	0.105	0.777	0.766	0.718	0.764	0.696	
				1.48	1.68	1.52	1.40	0.018	0.028	0.014	0.015	0.023	0.024	0.019	0.017	0.019	0.028	
				(26.14)	(59.37)	(15.63)	(20.50)											
				(4.02)	(3.78)	(4.59)	(4.64)											
12	6	51	100	29.46	67.48	06.72	23.88	0.275	0.129	0.155	0.174	0.143	0.784	0.788	0.725	0.798	0.787	
				1.49	1.70	1.54	1.42	0.018	0.029	0.015	0.015	0.024	0.025	0.020	0.018	0.019	0.028	
				(29.44)	(64.83)	(9.32)	(24.07)											
				(3.34)	(3.45)	(3.50)	(4.47)											

TABLE A.2. (Continued)

DENSITY REGIONS FROM DIFFERENCE OF BEFORE & AFTER PROFILES										DENSITY REGIONS OF BEFORE PROFILES										
a	b	c	d	e	f	g	b		i	DF1	DF2	DF3	DF4	DF5	D1	j	D2	D3	D4	D5
TRT	PNC	DEN	PCR	TS	WA	AAIB	SPG													
13	9	41	20	35.77	70.29	05.94	30.57	0.181	0.090	0.147	0.160	0.125	0.690	0.621	0.578	0.633	0.631			
				1.69	1.92	1.74	1.61	0.021	0.032	0.017	0.017	0.027	0.028	0.023	0.019	0.022	0.032			
				(31.95)	(79.96)	(3.02)	(27.17)													
				(5.84)	(4.84)	(2.36)	(6.57)													
14	9	41	60	30.15	68.87	09.87	31.76	0.182	0.092	0.151	0.148	0.079	0.753	0.714	0.653	0.708	0.598			
				2.78	3.15	2.86	2.64	0.034	0.053	0.028	0.028	0.044	0.045	0.037	0.033	0.035	0.053			
				(28.00)	(75.30)	(8.13)	(21.55)													
				(7.72)	(2.06)	(1.25)	(3.13)													
15	9	41	100	47.38	74.33	.	.	.	.	.	.	.	0.830	0.760	0.650	0.790	0.840			
				1.56	1.77	.	.	.	.	.	.	.	0.010	0.010	0.020	0.020	0.020			
				(44.49)	(83.42)															
				(4.99)	(1.27)															
16	9	51	20	23.22	63.20	12.69	16.44	0.177	0.086	0.117	0.105	0.115	0.822	0.750	0.715	0.778	0.772			
				1.55	1.77	1.60	1.48	0.019	0.029	0.015	0.016	0.025	0.026	0.021	0.018	0.019	0.030			
				(24.23)	(54.46)	(16.72)	(17.77)													
				(4.16)	(5.27)	(4.26)	(3.64)													
17	9	51	60	23.34	63.54	09.88	18.37	0.238	0.119	0.142	0.139	0.135	0.827	0.807	0.741	0.837	0.834			
				1.56	1.77	1.60	1.48	0.019	0.029	0.015	0.016	0.025	0.026	0.021	0.018	0.020	0.029			
				(25.87)	(54.57)	(13.28)	(21.06)													
				(4.20)	(4.24)	(5.85)	(5.13)													
18	9	51	100	26.55	65.21	07.46	21.24	0.236	0.111	0.135	0.145	0.157	0.831	0.794	0.718	0.788	0.820			
				1.55	1.76	1.60	1.48	0.019	0.030	0.015	0.016	0.025	0.026	0.021	0.018	0.019	0.030			
				(26.92)	(57.84)	(10.10)	(21.71)													
				(6.17)	(4.61)	(6.41)	(5.83)													

TABLE A.2. (Continued)

a Treatment (TRT): boards were manufactured under different combinations of specimen density (two levels), three levels of press closure rate, and three levels of furnish moisture content.
b Furnish moisture content (FMC) of furnish before board manufacture measured in percent.
c Panel density (DEN) is the target treatment density.
d Press closure rate (PCR) is defined as the time to stops during the Press Cycle.
e For the columns labeled (IS) thickness swell, (WA) water absorption, (AAB) accelerated aged internal bond and (SPG) springback for the 24-hour water soak procedure, the first value in the column is the least squares adjusted treatment mean, the second value is the standard error of the least squares adjusted treatment mean. The third value is the unadjusted treatment mean, and the last value is the standard deviation of the unadjusted treatment mean. Thickness swell is defined as the change in thickness after exposure measured as percent change from the original thickness.
f Water absorption (WA) is the amount of water absorbed after the exposure test measured as the percent increase in weight from the original weight.
g Accelerated aged internal bond (AAB) is the internal bond of the two-by two-inch specimens after the 24-hour water soak procedure.
h Springback (SPG) is the response of the panel to the exposure procedure to return to the original thickness and is measured as the percent difference of the dry thickness after the exposure test to the original thickness and is density regions (DI-D5) represent the numerical difference of the five density regions, before and after the exposure test. The reduced density after the exposure test is mostly due to the increased thickness of the specimen. The first value in each column is the unadjusted mean. The second value is the standard deviation of the mean. The first density regions (DI-D5) represent five density regions in the vertical plane of the panel, calculated by averaging select individual density measurements taken during the profile scan. Refer to the Materials and Methods section for details on profile estimation.

TABLE A.3. Least squares mean and standard errors, the unadjusted treatment mean and standard deviation for thickness swell and water absorption by treatment for oven-dry-vacuum pressure soak and 24-hour water soak test procedures: six-by six-inch specimens.

TRT	a	b	c	d	OD-VPS		24-HOUR WATER	
					TS	WA	SOAK	
							TS	WA
e								
1	3	41	20	20.50	92.95	24.99	67.09	
				.52	1.23	.79	1.47	
				(19.51)	(92.51)	(24.47)	(72.60)	
				(2.03)	(2.34)	(2.28)	(3.10)	
2	3	41	60	22.04	85.76	27.94	67.63	
				.53	1.25	.79	1.49	
				(22.07)	(90.38)	(28.05)	(73.39)	
				(2.60)	(3.83)	(2.37)	(2.69)	
3	3	41	100	24.92	85.55	34.49	70.15	
				.57	1.34	.86	1.61	
				(23.95)	(95.02)	(34.05)	(77.24)	
				(3.42)	(4.41)	(3.55)	(1.96)	
4	3	51	20	22.84	77.74	27.09	63.45	
				.52	1.22	.78	1.47	
				(22.76)	(72.03)	(28.17)	(59.67)	
				(2.38)	(3.78)	(2.26)	(2.79)	
5	3	51	60	21.65	78.67	29.65	64.97	
				.53	1.23	.78	1.47	
				(21.92)	(77.55)	(29.33)	(58.06)	
				(4.82)	(3.49)	(1.28)	(3.84)	
6	3	51	100	27.19	79.99	30.94	59.66	
				.53	1.23	.79	1.48	
				(27.91)	(70.17)	(34.90)	(56.34)	
				(1.15)	(3.76)	(1.58)	(10.42)	
7	6	41	20	20.05	81.12	27.13	65.00	
				.52	1.23	.79	1.47	
				(17.89)	(84.64)	(25.57)	(69.67)	
				(2.15)	(3.76)	(1.58)	(1.56)	
8	6	41	60	20.32	80.64	20.33	67.23	
				.54	1.27	.82	1.52	
				(19.20)	(85.42)	(26.95)	(70.22)	
				(1.90)	(1.68)	(6.30)	(4.08)	
9	6	41	100	23.39	79.76	37.32	66.66	
				.72	1.69	1.08	2.02	
				(22.65)	(88.07)	(37.80)	(74.86)	
				(3.77)	(5.43)	(8.70)	(2.97)	

TABLE A.3. (Continued)

TRY	a	b	c	d	OD-VPS		24-HOUR WATER SOAK	
					TS	WA	TS	WA
10	6	51	20		18.69	72.30	20.70	54.12
					.52	1.23	.79	1.47
					(18.14)	(61.69)	(20.96)	(45.45)
					(2.50)	(5.57)	(1.99)	(5.05)
11	6	51	60		19.95	73.93	24.82	55.91
					.53	1.23	.79	1.48
					(20.86)	(63.16)	(19.48)	(42.18)
					(1.67)	(5.79)	(5.67)	(9.94)
12	6	51	100		19.20	73.75	25.21	61.11
					.53	1.25	.80	1.49
					(20.39)	(67.67)	(27.60)	(58.33)
					(2.24)	(2.60)	(1.05)	(4.40)
13	9	41	20		19.59	80.70	29.66	66.12
					.60	1.42	.91	1.69
					(17.31)	(84.66)	(28.96)	(68.12)
					(2.76)	(2.42)	(1.46)	(3.60)
14	9	41	60		21.76	82.79	33.87	75.93
					.99	2.32	1.49	2.78
					(21.54)	(89.71)	(33.15)	(75.91)
					(5.02)	(3.20)	(5.46)	(6.11)
15	9	41	100		25.01	81.33	44.83	67.50
					.81	1.11	1.02	1.53
					(24.12)	(88.91)	(44.67)	(75.51)
					(4.18)	(4.02)	(10.49)	(6.15)
16	9	51	20		18.05	69.13	17.64	52.73
					.53	1.30	.83	1.55
					(18.01)	(59.80)	(20.45)	(46.89)
					(1.89)	(2.67)	(2.86)	(5.20)
17	9	51	60		16.59	73.56	21.25	55.31
					.53	1.38	.83	1.55
					(18.32)	(64.13)	(24.15)	(52.36)
					(1.94)	(8.44)	(2.36)	(5.30)
18	9	51	100		18.38	71.28	22.77	58.24
					.53	1.30	.83	1.55
					(17.05)	(62.67)	(21.51)	(48.21)
					(3.80)	(3.57)	(4.52)	(5.07)

TABLE A.3. (Continued)

- a Treatment (TRT) :boards were manufactured under two levels of specimen density, three levels of press closure rate, and three levels of furnish moisture content.
 - b Furnish moisture content (FMC) is the furnish moisture content before board manufacture measured in percent.
 - c Panel density (DEN),is the value of the covariate, to adjust all means.
 - d Press closure rate (PCR) is defined as time to stops in the press cycle
 - e The first value within a column is the least squares adjusted treatment mean. The second value is the standard error of the least squares adjusted mean. The third value is the unadjusted treatment mean, and the last value is the standard deviation of the unadjusted treatment mean for Thickness swell (TS) and Water absorption values (WA).
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TABLE A.4. Least squares mean and standard errors,
the unadjusted treatment mean and standard
deviation for internal bond specimens
by treatment: two-by two-inch specimens.

TRT	a FMC	b DEN	c PCR	d IB (LBS/IN ²)	e D1	f D2	D3 (G/CC)	D4	D5
1	3	41	20	55.73 5.79 (46.46) (22.92)	.65 .02	.66 .02	.61 .02	.63 .02	.68 .03
2	3	41	60	40.93 5.88 (30.42) (11.80)	.62 .03	.67 .02	.63 .02	.64 .02	.69 .03
3	3	41	100	26.74 6.34 (14.45) (16.02)	.64 .03	.66 .02	.60 .02	.64 .02	.67 .03
4	3	51	20	72.15 5.79 (75.57) (18.65)	.77 .02	.77 .02	.74 .02	.76 .02	.81 .03
5	3	51	60	72.63 5.29 (78.49) (18.99)	.79 .02	.84 .02	.78 .02	.80 .02	.86 .02
6	3	51	100	61.43 5.82 (67.71) (21.03)	.76 .02	.81 .02	.75 .02	.78 .02	.81 .02
7	6	41	20	33.07 5.81 (23.39) (14.71)	.67 .02	.66 .02	.59 .02	.63 .02	.68 .03
8	6	41	60	24.48 6.00 (10.26) (11.08)	.64 .03	.66 .02	.59 .02	.61 .02	.66 .03
9	6	41	100	19.38 7.97 (17.40) (11.25)	.61 .03	.70 .03	.62 .03	.66 .03	.74 .04

TABLE A.4. (Continued)

TRT	a PMC	b DEN	c PCR	d	e IB (LBS/IN ²)	f D1	D2	D3 (G/CC)	D4	D5
10	6	51	20		83.05 5.81 (93.07) (25.07)	.80 .02	.83 .02	.76 .02	.81 .02	.87 .03
11	6	51	60		70.63 5.82 (82.84) (17.29)	.79 .03	.86 .02	.78 .02	.82 .02	.89 .03
12	6	51	100		50.48 5.89 (55.57) (17.99)	.73 .03	.82 .02	.74 .02	.77 .02	.86 .03
13	9	41	20		26.19 6.67 (18.28) (9.55)	.69 .03	.67 .02	.60 .02	.65 .02	.72 .03
14	9	41	60		24.48 10.94 (19.38) (16.84)	.67 .05	.69 .04	.63 .04	.69 .04	.77 .05
15	9	41	100		13.48 5.10 (4.48) (2.66)	.66 .03	.69 .02	.59 .02	.62 .02	.69 .03
16	9	51	20		68.93 6.13 (78.23) (27.46)	.87 .03	.84 .02	.78 .02	.83 .03	.88 .03
17	9	51	60		52.69 6.14 (59.58) (20.53)	.82 .03	.84 .02	.73 .02	.79 .02	.88 .03
18	9	51	100		35.30 6.14 (38.91) (15.79)	.74 .03	.79 .02	.71 .02	.75 .02	.84 .03

TABLE A.4. (Continued)

- a Treatment (TRT) :boards were manufactured under two levels of specimen density, three levels of press closure rate, and three levels of furnish moisture content.
 - b Furnish moisture content(FMC) of furnish before board manufacture measured in percent.
 - c Panel density (DEN) is the value of the covariate to adjust all treatment means.
 - d Press closure rate (PCR) is defined as the time to stop in the press cycle.
 - e Internal Bond (IB) as defined by ASTM D-1037 in pounds per cubic foot.
The first value in this column is the adjusted treatment mean. The second value is the standard error of the least squares adjusted mean. The third value is the unadjusted treatment mean and the last value is the standard deviation of the unadjusted treatment mean.
 - f. The value of the five density regions measured before the internal bond test procedure (D1-D5). The first value in the column is the unadjusted treatment mean and the last value is the standard deviation of the treatment mean.
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**APPENDIX B. ANALYSIS OF COVARIANCE FOR INTERNAL BOND,
RETENTION OF INTERNAL BOND AFTER OD-VPS AND
24-HOUR WATER SOAK PROCEDURES, WATER
ABSORPTION, THICKNESS SWELL, AND SPRINGBACK
IN TWO-BY TWO-INCH SPECIMENS, AND FOR
THICKNESS SWELL AND WATER ABSORPTION IN
SIX-BY SIX-INCH SPECIMENS.**

TABLE B.1. Analysis of covariance for internal bond in response to specimen density (COV), replication (REP), furnish moisture content (FMC), press closure rate (PCR), panel density (DEN), linear (LIN) and lack of fit (LOF) effects partitioned within treatments.

SOURCE	DF	SUM OF	PR>F
COV	1	4096.81	.001
REP	2	5664.04	.217
FMC	2	10753.93	.099
LIN	1	13503.30	.001
LOF	1	225.93	.348
REP*FMC	4	4947.00	.001
PCR	2	16725.78	.001
LIN	1	9034.70	.001
LOF	1	32.74	.721
DEN	1	15648.05	.001
FMC*PCR	4	471.86	.729
FMC*DEN	2	2987.95	.006
DEN*PCR	2	145.33	.734
FMC*DEN*PCR	4	1798.59	.138
REP*MC*DEN*PCR	23	5329.84	.585
ERROR	140	35654.73	.....
TOTAL a	187	198259.72	.....

a Total N=188 samples from 53 boards

TABLE B.2. Analysis of covariance for accelerated aged internal bond for two-by two-inch specimens in response to: specimen density (DEN), replication (REP), furnish moisture content (FMC), press closure rate (PCR), panel density (DEN), procedure (PROC), linear (LIN) and lack of fit (LOF) effects partitioned within treatments.

SOURCE	DF	SUM OF	PR>F
COV	1	832.88	.001
REP	2	78.13	.854
FMC	2	1508.96	.149
LIN	1	1881.66	.001
LOF	1	243.48	.018
PCR	2	1087.65	.100
LIN	1	1115.99	.001
LOF	1	27.55	.059
DEN	1	205.58	.207
FMC*PCR	4	359.58	.440
FMC*DEN	2	425.06	.222
DEN*PCR	2	1.33	.989
FMC*DEN*PCR	4	168.93	.660
PROC	1	1326.51	.012
REP*PROC	2	3.43	.904
FMC*PROC	2	54.08	.375
REP*MC*PROC	4	58.47	.586
PCR*PROC	2	20.54	.612
DEN*PROC	1	3.98	.669
REP*PCR*PROC	4	53.39	.613
FMC*PCR*PROC	4	89.56	.461
REP*FMC*PCR*PROC	8	268.58	.366
REP*DEN*PROC	2	21.88	.597
FMC*DEN*PROC	2	8.00	.793
REP*FMC*DEN*PROC	4	85.77	.474
DEN*PCR*PROC	2	18.52	.636
REP*DEN*PCR*PROC	3	56.12	.495
FMC*DEN*PCR*PROC	4	33.19	.744
MODEL	94	15435.00	.001
ERROR	187	3823.36	.....
TOTAL a	281	19258.51	.....

a Total N=282 samples from 53 boards

TABLE B.3. Analysis of covariance for two-by two-inch water absorption samples in response to specimen density (COV), replication (REP), furnish moisture content (FMC), press closure rate (PCR), panel density (DEN), procedure (PROC), linear (LIN) and lack of fit (LOF) effects partitioned within treatments.

SOURCE	DF	SUM OF	PR>F
COV	1	6416.95	.001
REP	2	129.87	.215
MC	2	566.22	.028
LINEAR	1	979.98	.001
LOF	1	43.98	.018
PCR	2	231.05	.033
LINEAR	1	149.42	.001
LOF	1	27.55	.059
DEN	1	677.74	.006
FMC*PCR	4	79.20	.173
FMC*DEN	2	548.96	.014
DEN*PCR	2	4.33	.645
FMC*DEN*PCR	4	115.01	.124
PROC	1	29564.19	.002
REP*PROC	2	25.02	.371
FMC*PROC	2	17.32	.461
REP*FMC*PROC	4	51.71	.395
PCR*PROC	2	49.67	.295
DEN*PROC	1	77.59	.084
REP*PCR*PROC	4	7.30	.891
FMC*PCR*PROC	4	1.97	.986
REP*FMC*PCR*PROC	8	19.22	.897
REP*DEN*PROC	2	10.35	.588
FMC*DEN*PROC	2	9.34	.613
REP*FMC*DEN*PROC	4	14.40	.756
DEN*PCR*PROC	2	23.29	.388
REP*DEN*PCR*PROC	3	6.23	.838
FMC*DEN*PCR*PROC	4	19.50	.676
MODEL	94	85492.00	.001
ERROR	187	1429.84	....
TOTAL a	281	86922.22	....

a 282 specimens from 53 panels

TABLE B.4. Analysis of covariance for two-by two-inch thickness swell specimens in response to: specimen density (COV), replication (REP), furnish moisture content (FMC), press closure rate (PCR), panel density (DEN), procedure (PROC), linear (LIN) and lack of fit (LOF) effects partitioned within treatments.

SOURCE	DF	SUM OF	PR>F
COV	1	611.53	.001
REP	2	503.04	.153
FMC	2	122.37	.526
LINEAR	1	209.28	.001
LOF	1	0.42	.853
PCR	2	1300.34	.019
LINEAR	1	968.62	.001
LOF	1	30.11	.121
DEN	1	1256.26	.010
FMC*PCR	4	165.56	.250
FMC*DEN	2	1059.68	.024
DEN*PCR	2	281.19	.084
FMC*DEN*PCR	4	102.76	.359
PROC	1	1125.73	.012
REP*PROC	2	379.31	.067
FMC*PROC	2	57.99	.319
REP*FMC*PROC	4	43.34	.623
PCR*PROC	2	59.39	.315
DEN*PROC	1	386.75	.034
REP*PCR*PROC	4	85.08	.426
FMC*PCR*PROC	4	128.82	.319
REP*FMC*PCR*PROC	8	68.57	.738
REP*DEN*PROC	2	106.61	.204
FMC*DEN*PROC	2	39.93	.406
REP*FMC*DEN*PROC	4	8.76	.941
DEN*PCR*PROC	2	4.26	.865
REP*DEN*PCR*PROC	3	12.13	.829
FMC*DEN*PCR*PROC	4	172.86	.254
MODEL	94	9204.00	.001
ERROR	186	2313.61	.....
TOTAL a	280	11518.51	.....

a 281 specimens from 53 boards

TABLE B.5. Analysis of covariance for two-by two-inch springback specimens in response to specimen density (COV), replication (REP), furnish moisture content (FMC), press closure rate (PCR), panel density (DEN), linear (LIN) and lack of fit (LOF) effects partitioned within treatments.

SOURCE	DF	SUM OF SQUARES	PR>F
COV	1	822.38	.001
REP	2	802.51	.183
FMC	2	41.81	.874
LINEAR	1	234.14	.001
LACK OF FIT	1	7.63	.436
PCR	2	842.74	.003
LINEAR	1	608.48	.001
LACK OF FIT	1	41.56	.070
DEN	1	714.58	.008
FMC*PCR	4	133.45	.039
FMC*DEN	2	827.18	.003
DEN*PCR	2	96.44	.027
FMC*DEN*PCR	3	32.08	.116
PROC	1	257.36	.008
REP*PROC	2	114.38	.034
FMC*PROC	2	100.49	.039
REP*FMC*PROC	4	35.33	.196
PCR*PROC	2	11.28	.265
DEN*PROC	1	160.36	.012
REP*PCR*PROC	4	95.78	.079
FMC*PCR*PROC	4	59.66	.123
REP*MC*PCR*PROC	8	54.00	.252
REP*DEN*PROC	2	38.90	.094
FMC*DEN*PROC	2	19.92	.169
REP*FMC*DEN*PROC	4	95.63	.079
DEN*PCR*PROC	2	26.88	.131
REP*DEN*PCR*PROC	3	39.27	.137
FMC*DEN*PCR*PROC	3	48.79	.113
MODEL	92	6955.62	.001
ERROR	176	2204.03	....
TOTAL a	268	9159.65	....

a 269 specimens in 53 panels

TABLE B.6. Analysis of covariance for six-by six-inch thickness swell specimens in response to specimen density (COV), replication (REP), furnish moisture content (FMC), press closure rate (PCR), panel density (DEN), linear (LIN) and lack of fit (LOF) effects partitioned within treatments.

SOURCE	DF	SUM OF SQUARES	PR>F
COV	1	632.85	.001
REP	2	806.43	.004
FMC	2	272.87	.029
LINEAR	1	100.05	.001
LACK OF FIT	1	65.55	.007
PCR	2	971.35	.008
LINEAR	1	964.04	.001
LACK OF FIT	1	88.98	.002
DEN	1	212.94	.015
FMC*PCR	4	66.21	.568
FMC*DEN	2	774.55	.002
DEN*PCR	2	192.76	.053
FMC*DEN*PCR	4	63.94	.582
PROC	1	2651.56	.001
REP*PROC	2	15.99	.467
FMC*PROC	2	50.16	.146
REP*FMC*PROC	4	128.09	.085
PCR*PROC	2	235.90	.007
DEN*PROC	1	433.09	.001
REP*PCR*PROC	4	20.91	.697
FMC*PCR*PROC	4	37.48	.469
REP*FMC*PCR*PROC	8	161.54	.178
REP*DEN*PROC	2	29.91	.274
FMC*DEN*PROC	2	166.95	.015
REP*FMC*DEN*PROC	4	21.61	.685
DEN*PCR*PROC	2	90.51	.055
REP*DEN*PCR*PROC	4	58.99	.289
FMC*DEN*PCR*PROC	4	33.31	.518
MODEL	106	9240.91	.001
ERROR	105	1366.26	....
TOTAL a	211	10607.17	....

a 212 specimens from 53 panels

TABLE B.7. Analysis of covariance for six-by six-inch water absorption specimens in response to specimen density (COV), replication (REP), furnish moisture content (FMC), press closure rate (PCR), panel density (DEN), linear (LIN) and lack of fit (LOF) effects partitioned within treatments.

SOURCE	DF	SUM OF SQUARES	PR>F
COV	1	1663.01	.001
REP	2	220.88	.096
MC	2	920.92	.009
LINEAR	1	657.18	.001
LACK OF FIT	1	174.75	.001
PCR	2	132.41	.171
LINEAR	1	21.76	.165
LACK OF FIT	1	.75	.795
DEN	1	641.51	.002
MC*PCR	4	35.09	.866
MC*DEN	2	239.43	.065
DEN*PCR	2	6.27	.898
MC*DEN*PCR	4	98.15	.536
PROC	1	12746.86	.001
REP*PROC	2	44.84	.409
MC*PROC	2	21.72	.627
REP*MC*PROC	4	101.28	.408
PCR*PROC	2	29.05	.544
DEN*PROC	1	23.31	.338
REP*PCR*PROC	4	53.28	.666
MC*PCR*PROC	4	87.71	.467
REP*MC*PCR*PROC	8	105.17	.747
REP*DEN*PROC	2	28.77	.547
MC*DEN*PROC	2	15.34	.714
REP*MC*DEN*PROC	4	42.45	.743
DEN*PCR*PROC	2	.72	.984
REP*DEN*PCR*PROC	4	3.60	.996
MC*DEN*PCR*PROC	4	92.75	.444
MODEL	106	43742.56	.001
ERROR	105	1528.62	....
TOTAL a	211	45271.19	....

a 212 specimens from 53 panels

APPENDIX C. PARTIAL CORRELATION MATRIX FOR ALL VARIABLES IN THE 24-HOUR WATER SOAK AND OVENDRY-VACUUM-PRESSURE-SOAK, INTERNAL BOND, DENSITY REGIONS TAKEN FROM VERTICAL DENSITY PROFILES SCANNED BEFORE THE ACCELERATED AGING TESTS, AND THE DIFFERENCE OF THE BEFORE AND AFTER PROFILES, AND THE PROFILES SCANNED FROM INTERNAL BOND SPECIMENS.

Data 1. Pearson Partial Correlation Coefficient Matrix for all Variables in the 24-hour water soak,
Ovendry-vacuum-pressure-soak testing procedures and Internal bond specimens.

RESPONSE VARIABLES	TSOD(6X6)	TSOD(2X2)	TS24(6X6)	TS24(2X2)	WAOD(6X6)	WAOD(2X2)	WA24(6X6)	WA24(2X2)	DENOD(6X6)	DENOD(2X2)	DEN24(2X2)
TSOD(6X6) a	1.000	-0.298	0.346	-0.199	0.152	0.191	0.200	0.313	-0.159	0.110	-0.195
	0.000	0.004	0.001	0.020	0.075	0.025	0.019	0.001	0.062	0.202	0.022
TSOD(2X2) b		1.000	-0.109	0.257	-0.129	-0.413	-0.047	-0.018	0.032	0.102	0.257
		0.000	0.205	0.002	0.133	0.001	0.584	0.831	0.711	0.235	0.001
TS24(6X6) c			1.000	-0.116	0.008	0.162	0.507	0.162	0.069	0.046	-0.162
			0.000	0.177	0.927	0.059	0.001	0.059	0.425	0.592	0.581
TS24(2X2) d				1.000	-0.065	-0.170	0.416	0.226	-0.222	-0.046	-0.851
				0.000	0.449	0.418	0.001	0.000	0.009	0.592	0.001
WAOD(6X6) e					1.000	-0.105	0.233	-0.105	0.342	-0.852	-0.022
					0.000	0.288	0.006	0.220	0.001	0.001	0.800
WAOD(2X2) f						1.000	0.159	0.229	-0.060	0.118	-0.935
						0.000	0.062	0.007	0.483	0.169	0.001
WA24(6X6) g							1.000	0.100	-0.753	-0.252	-0.119
							0.000	0.243	0.543	0.003	0.165
WA24(2X2) h								1.000	-0.002	0.075	-0.193
								0.000	0.985	0.383	0.024
DEN24(6X6) i									1.000	0.356	0.061
									0.000	0.001	0.011
DENOD(6X6) j										1.000	0.479
										0.001	0.900
DENOD(2X2) k											1.000
											-0.051
DEN24(2X2) l											0.036
											0.556
											0.672
											1.000
											0.484
											0.562
											1.000
											0.000

RESPONSE VARIABLES	(24-HOUR WATER SOAK)					(OD-TPS)				
	D1	D2	D3	D4	D5	D1	D2	D3	D4	D5
TSOD(616)	-0.318	-0.254	-0.264	-0.239	-0.292	-0.082	-0.071	0.016	-0.005	-0.009
a	0.001	0.003	0.002	0.005	0.001	0.339	0.409	0.855	0.953	0.299
TSOD(212)	0.028	-0.024	0.007	0.003	-0.001	0.228	0.298	0.384	0.305	0.122
b	0.739	0.774	0.934	0.968	0.944	0.007	0.001	0.001	0.003	0.155
TS24(616)	-0.046	-0.009	-0.074	-0.001	-0.164	-0.113	-0.074	-0.011	-0.027	-0.147
c	0.594	0.297	0.191	0.590	0.091	0.118	0.393	0.859	0.751	0.087
TS24(212)	-0.005	-0.011	-0.079	0.010	0.159	0.068	0.246	0.124	0.151	0.186
d	0.959	0.900	0.355	0.906	0.063	0.430	0.004	0.150	0.061	0.029
WROD(616)	-0.076	-0.040	-0.024	-0.052	-0.100	-0.002	0.029	0.072	0.002	0.029
e	0.378	0.600	0.781	0.541	0.035	0.998	0.728	0.401	0.300	0.734
WROD(212)	-0.111	-0.176	-0.215	-0.178	-0.009	-0.614	-0.746	-0.607	-0.746	-0.703
f	0.197	0.039	0.011	0.037	0.915	0.001	0.001	0.001	0.001	0.001
W124(616)	-0.154	-0.175	-0.180	-0.234	-0.077	-0.003	-0.011	-0.018	-0.143	-0.112
g	0.073	0.041	0.035	0.006	0.374	0.338	0.092	0.834	0.095	0.192
W24(212)	-0.502	-0.608	-0.631	-0.638	-0.391	0.061	-0.152	-0.017	-0.069	-0.036
h	0.001	0.001	0.001	0.001	0.001	0.477	0.076	0.045	0.425	0.674
DNR24(616)	0.021	0.025	0.061	0.075	0.153	-0.043	0.052	0.069	-0.012	0.095
i	0.005	0.775	0.402	0.307	0.075	0.621	0.545	0.425	0.894	0.267
DEROD(616)	0.006	0.019	0.035	0.069	0.007	-0.016	-0.054	-0.047	-0.066	-0.001
j	0.931	0.021	0.688	0.418	0.312	0.054	0.529	0.507	0.443	0.308
DEROD(212)	0.097	0.139	0.185	0.144	-0.032	0.684	0.743	0.686	0.749	0.688
k	0.259	0.103	0.030	0.092	0.707	0.001	0.001	0.001	0.001	0.001
DNR24(212)	0.699	0.719	0.725	0.736	0.522	0.003	0.185	0.022	0.185	0.071
l	0.001	0.001	0.001	0.001	0.001	0.333	0.030	0.000	0.221	0.411
D1 24-HOUR WATER SOAK	0.000	0.000	0.000	0.000	0.000	0.007	0.076	-0.041	0.052	0.032
D2	0.000	0.000	0.000	0.000	0.000	0.314	0.377	0.639	0.565	0.713
D3	0.000	0.000	0.000	0.000	0.000	0.037	0.007	0.008	0.076	0.055
D4	0.000	0.000	0.000	0.000	0.000	0.037	0.007	0.025	0.370	0.523
D5	0.000	0.000	0.000	0.000	0.000	0.056	0.169	0.027	0.007	0.094
D1 (OD-TPS)	0.000	0.000	0.000	0.000	0.000	0.518	0.001	0.757	0.311	0.274
a	0.000	0.000	0.000	0.000	0.000	-0.039	0.047	0.002	0.098	0.041
D2	0.000	0.000	0.000	0.000	0.000	0.657	0.588	0.981	0.251	0.636
D3	0.000	0.000	0.000	0.000	0.000	0.912	0.125	-0.091	-0.000	0.093
D4	0.000	0.000	0.000	0.000	0.000	0.902	0.146	0.289	0.351	0.278
D5	0.000	0.000	0.000	0.000	0.000	1.000	0.752	0.701	0.740	0.687
D1 (OD-TPS)	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001
a	0.000	0.000	0.000	0.000	0.000	1.000	0.890	0.830	0.798	0.798
D2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
D3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
D4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
D5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

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- a : Thickness swell partial correlation coefficients and probability $>|R|$ as determined by oven-dry-vacuum-pressure-soak (OD-VPS) for six-by six-inch specimens. Pearson partial correlation coefficients are in the first row and the probability of a linear effect is in the second row.
- b : Thickness swell value from the OD-VPS procedure for two-by two-inch specimens.
- c : Thickness swell value from the 24-hour water soak procedure for two-by-two-inch specimens.
- d : Thickness swell value from the 24-hour water soak procedure for six-by-six-inch specimens.
- e : Water absorption value from the OD-VPS procedure for six-by six-inch specimens
- f : Water absorption value from the OD-VPS procedure for two-by two-inch specimens
- g : Water absorption value from the 24-hour water soak procedure for six-by six-inch specimens
- h : Water absorption value from the 24-hour water soak procedure for two-by two-inch specimens
- i : Density of 24-hour water soak specimen for thickness swell from six-by six-inch specimens
- j : Density of OD-VPS specimen for thickness swell for six-by six-inch specimens
- k : Density of OD-VPS specimen for thickness swell for two-by two-inch specimens
- l : Density of 24-hour water soak specimen for thickness swell for two-by two-inch specimens
- m : Mean density regions from profiles developed before 24-hour water soak tests
- n : Mean density regions from profiles developed before OD-VPS tests
- o : Internal bond (ASTM D-1037)
- p : Springback measured after 24-hour water soak
- q : Springback measured after OD-VPS
- r : Mean density regions taken from the difference of profiles developed before and after 24-hour water soak testing
- s : Mean density regions taken from the difference of profiles developed before and after OD-VPS testing
- t : Accelerated aged internal bond specimens from 24-hour water soak procedure.
- u : Accelerated aged internal bond specimens from OD-VPS procedure.

APPENDIX D. VERTICAL DENSITY PROFILES BEFORE AND AFTER ACCELERATED AGING TESTS FOR ALL TREATMENT COMBINATIONS. THE FIRST NUMBER OF THE TREATMENT DESIGNATION IS FURNISH MOISTURE CONTENT (%), THE SECOND NUMBER IS PRESS CLOSURE RATE (SECONDS), THE LAST NUMBER IS PANEL DENSITY (LB/FT³).

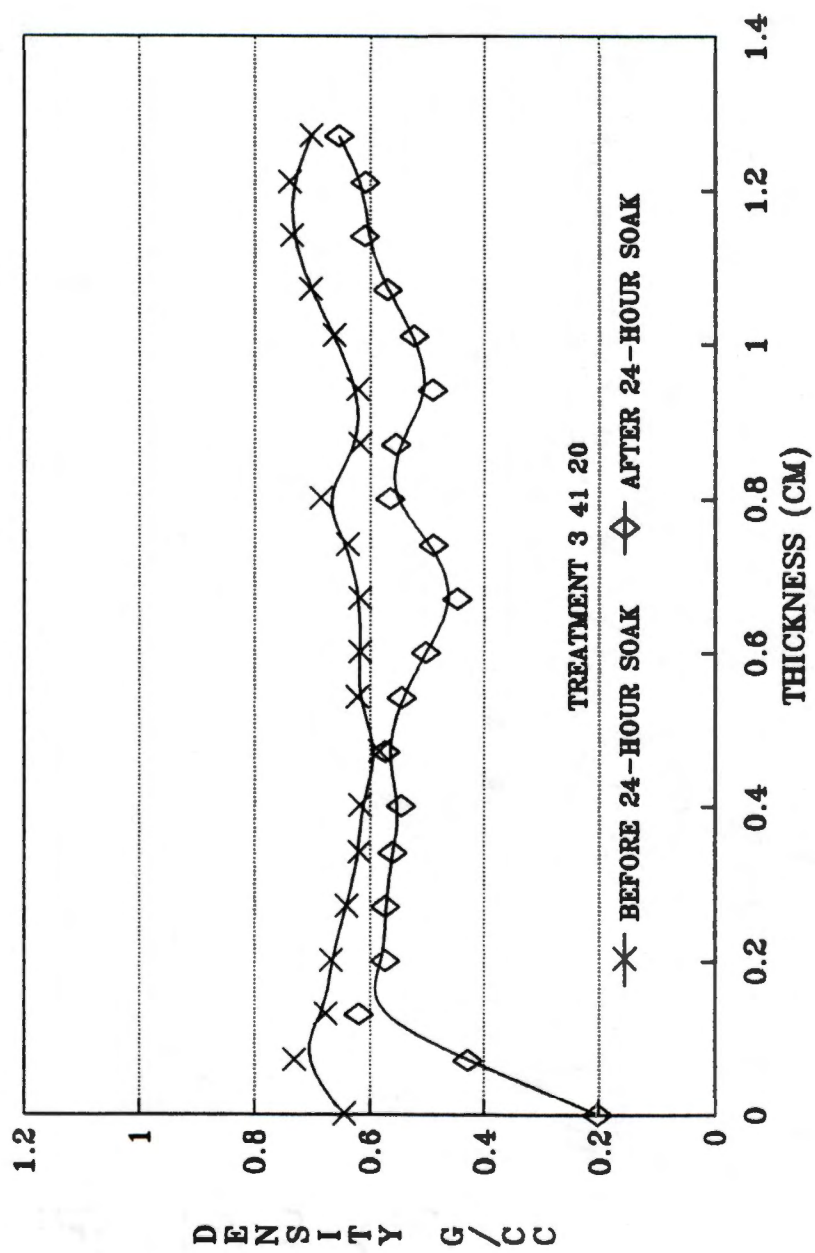


Figure D.1. Vertical Density Profile: 24-hour water soak treatment 3 41 20.

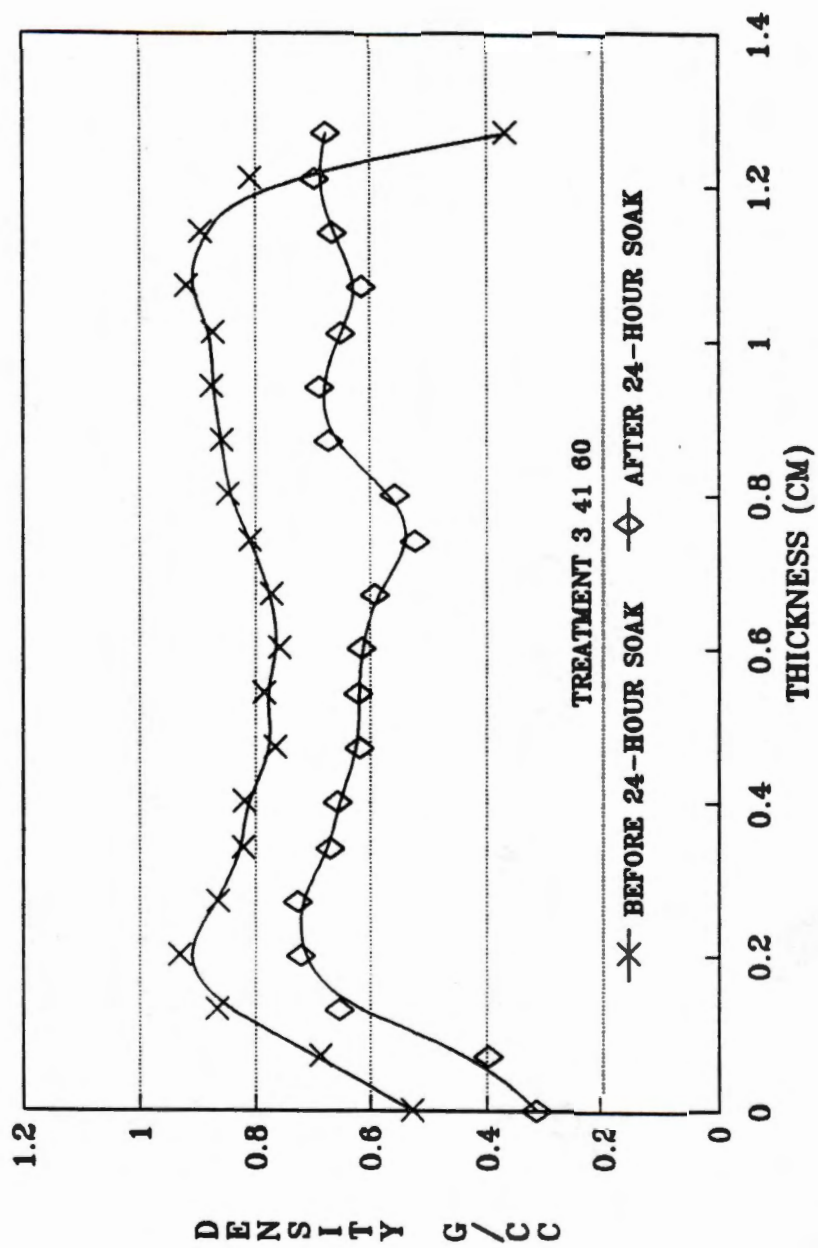


Figure D.2. Vertical Density Profile: 24-hour water soak treatment 3 41 60.

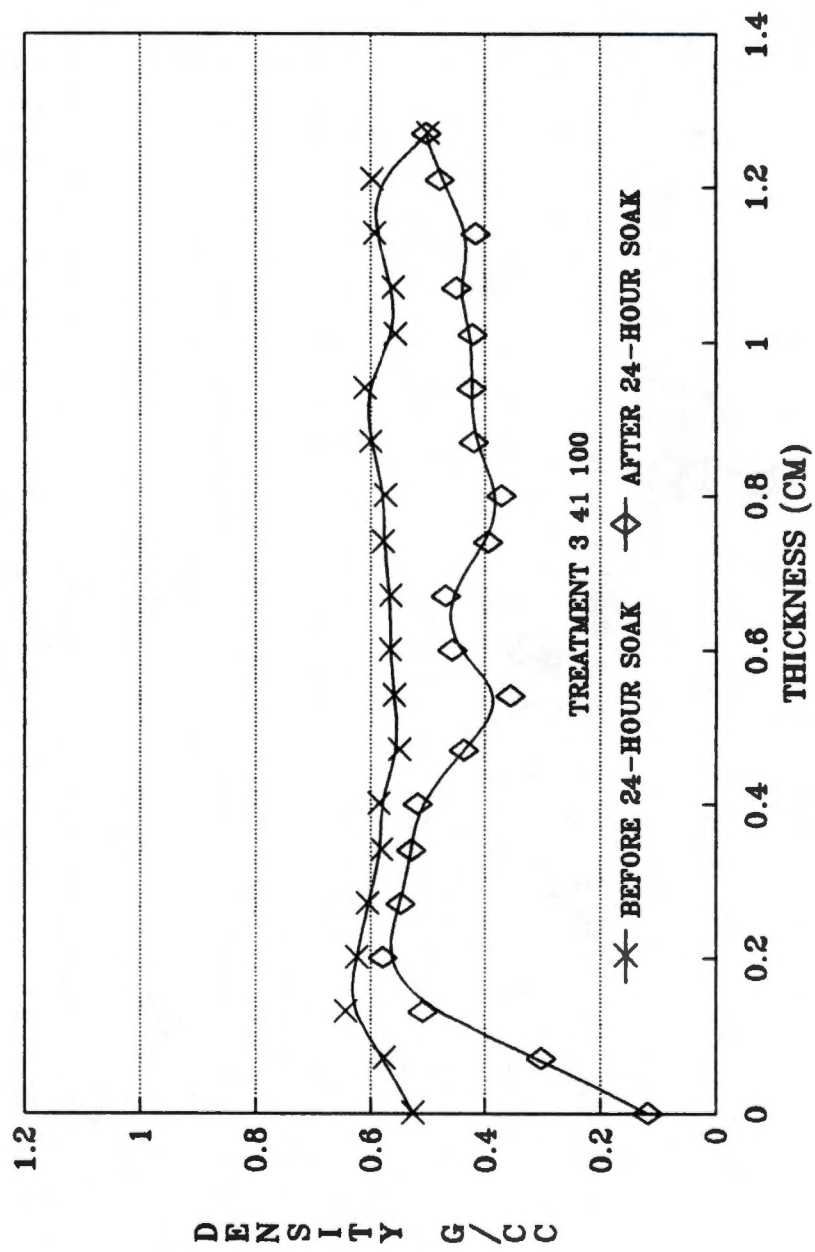


Figure D.3. Vertical Density Profile: 24-hour water soak treatment 3 41 100.

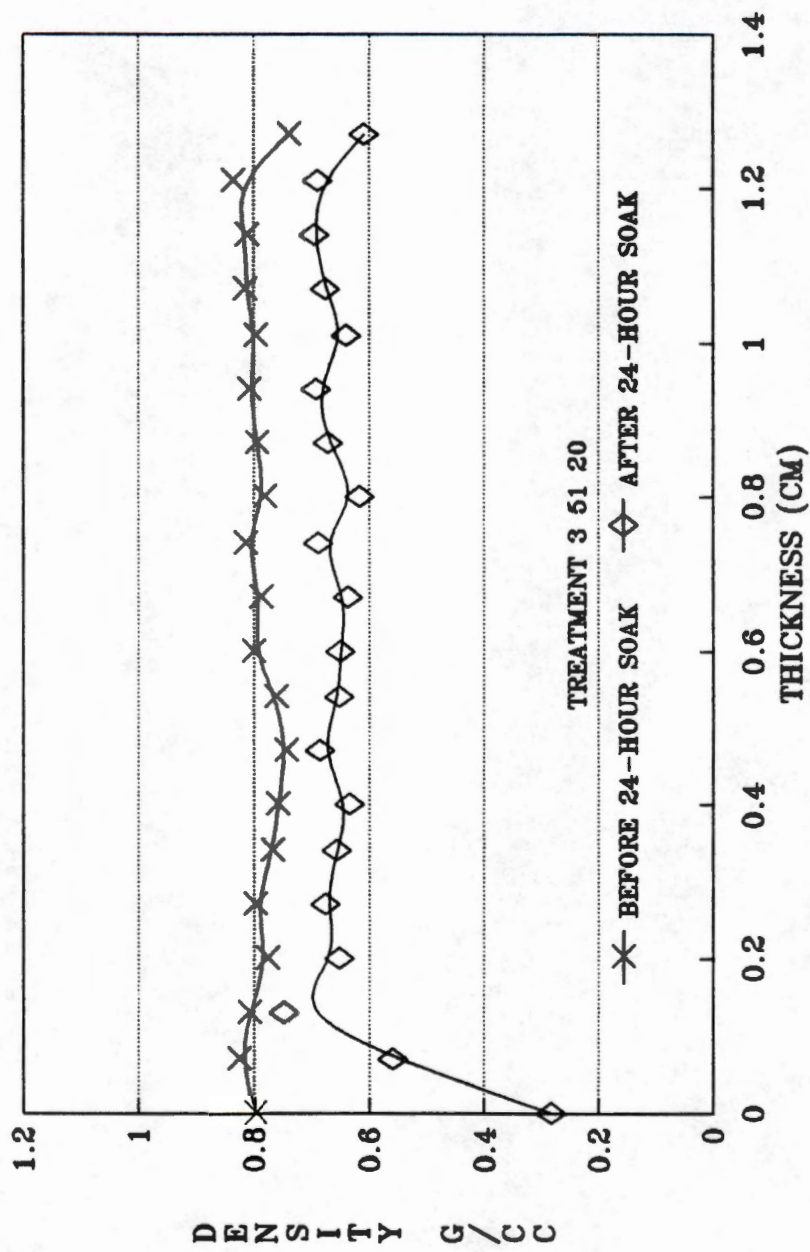


Figure D.4. Vertical Density Profile: 24-hour water soak treatment 3 51 20.

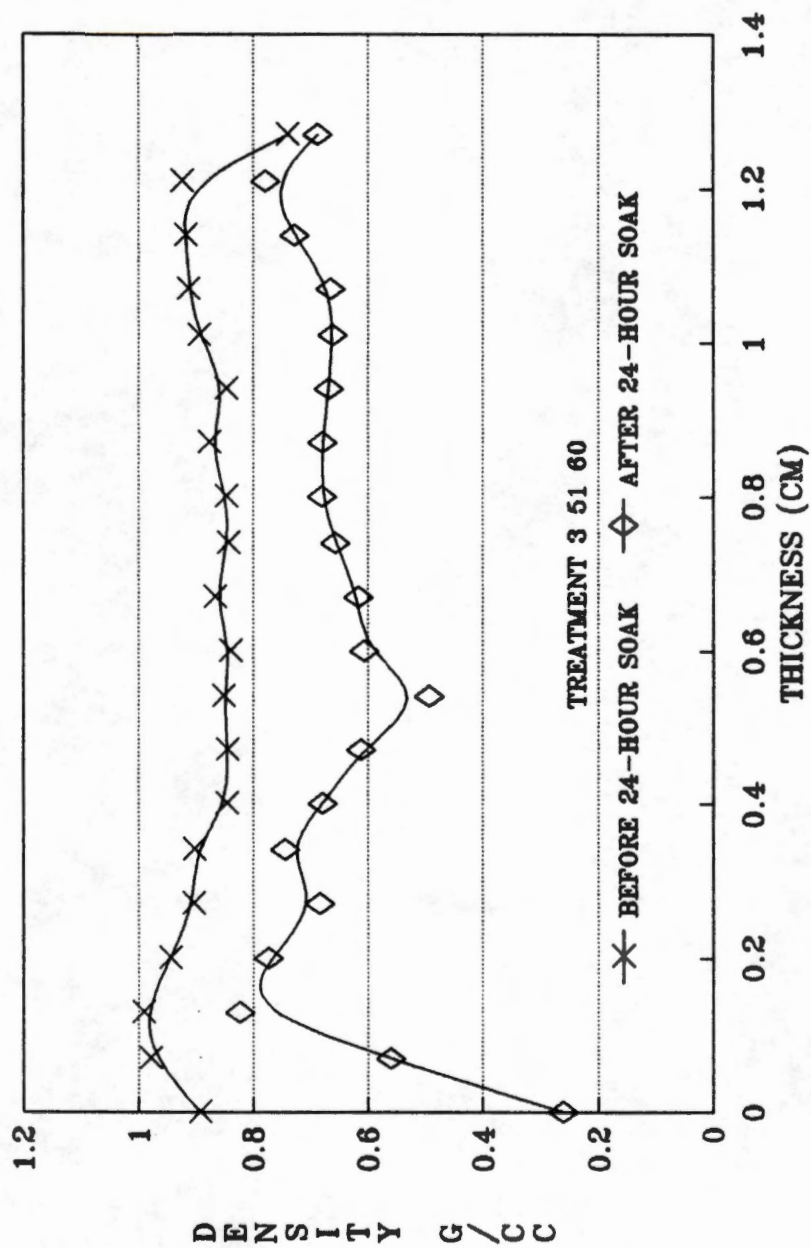


Figure D.5. Vertical Density Profile: 24-hour water soak treatment 3 51 60.

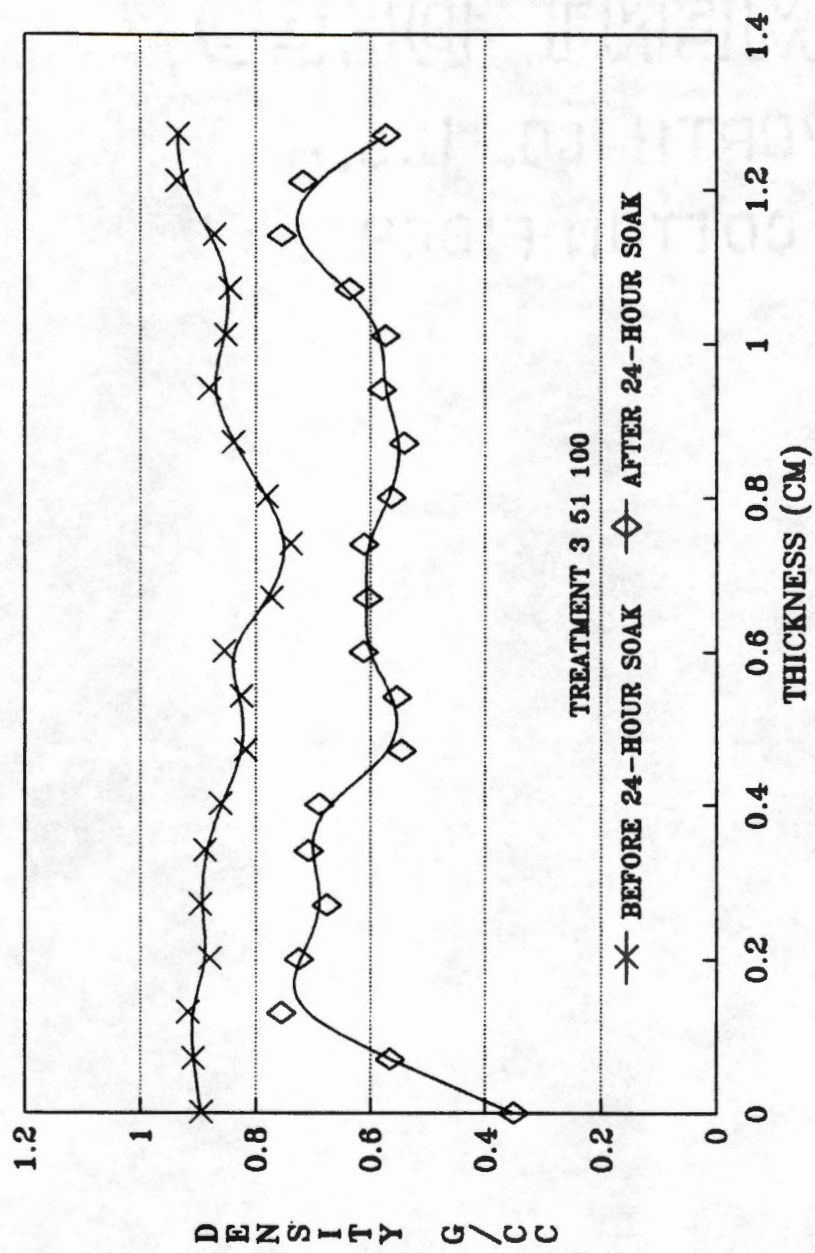


Figure D.6. Vertical Density Profile: 24-hour water soak treatment 3 51 100.

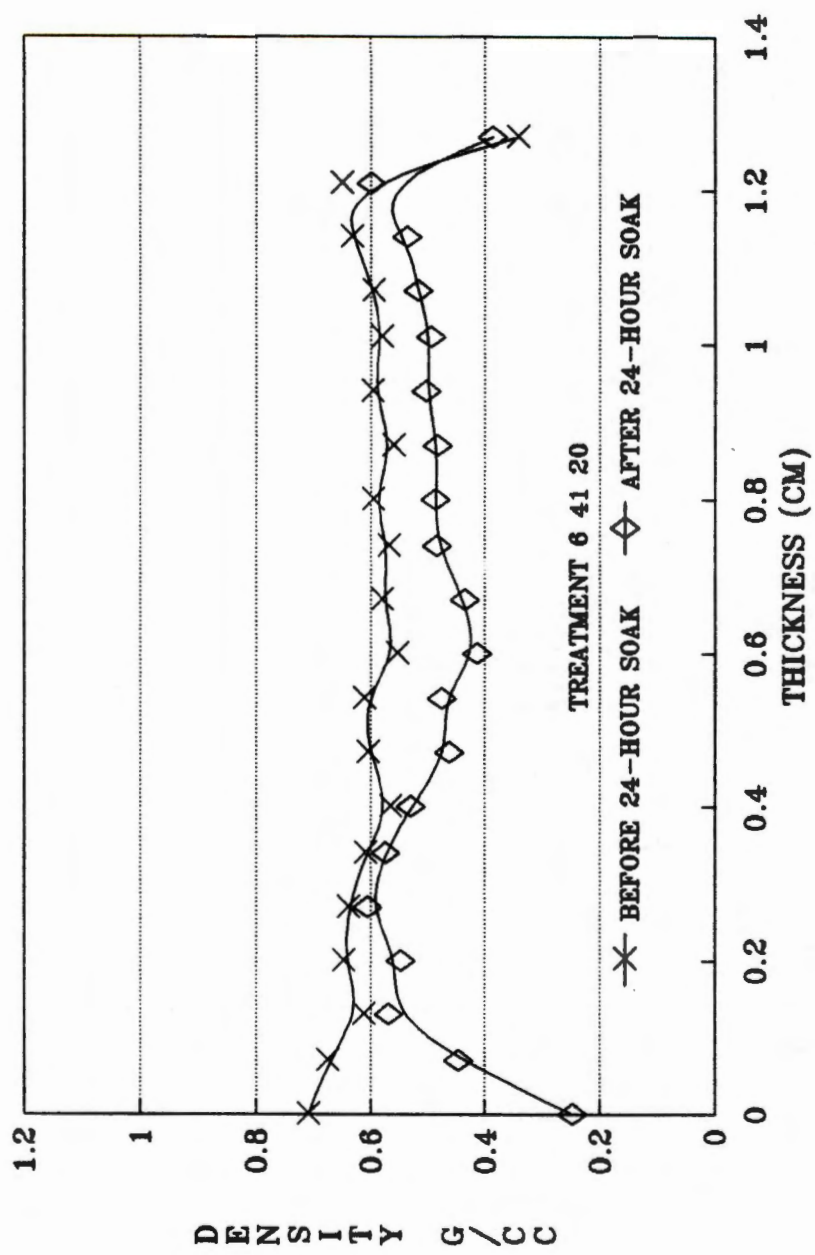


Figure D.7. Vertical Density Profile: 24-hour water soak treatment 6 41 20.

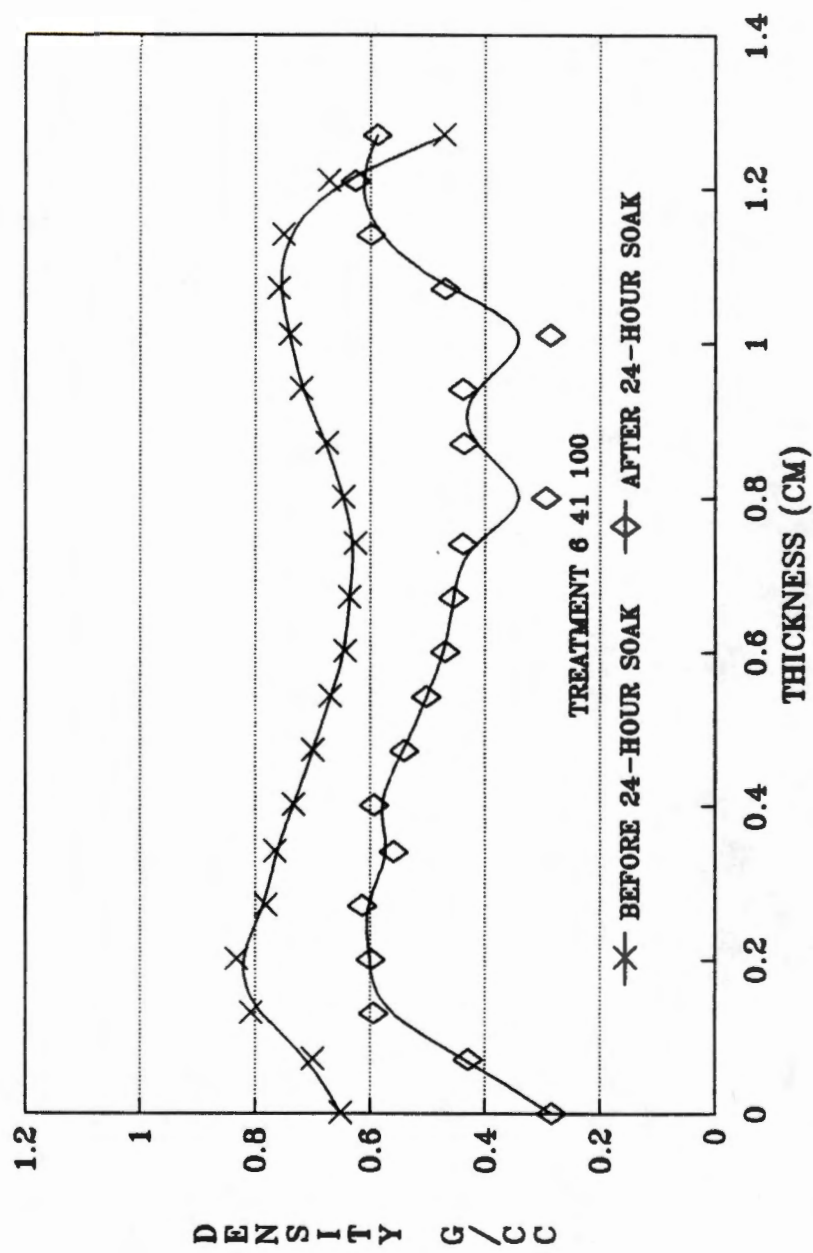


Figure D.8. Vertical Density Profile: 24-hour water soak treatment 6 41 100.

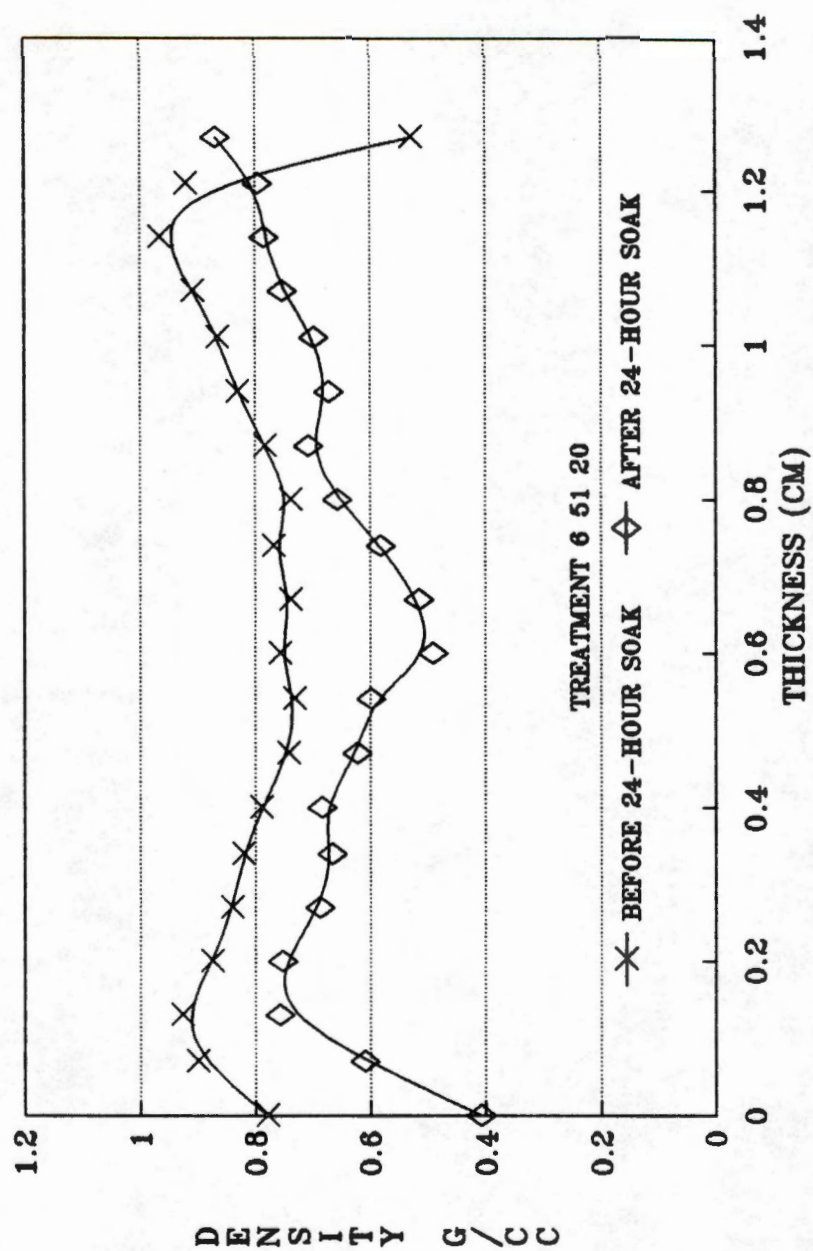


Figure D.9. Vertical Density Profile: 24-hour water soak treatment 6 51 20.

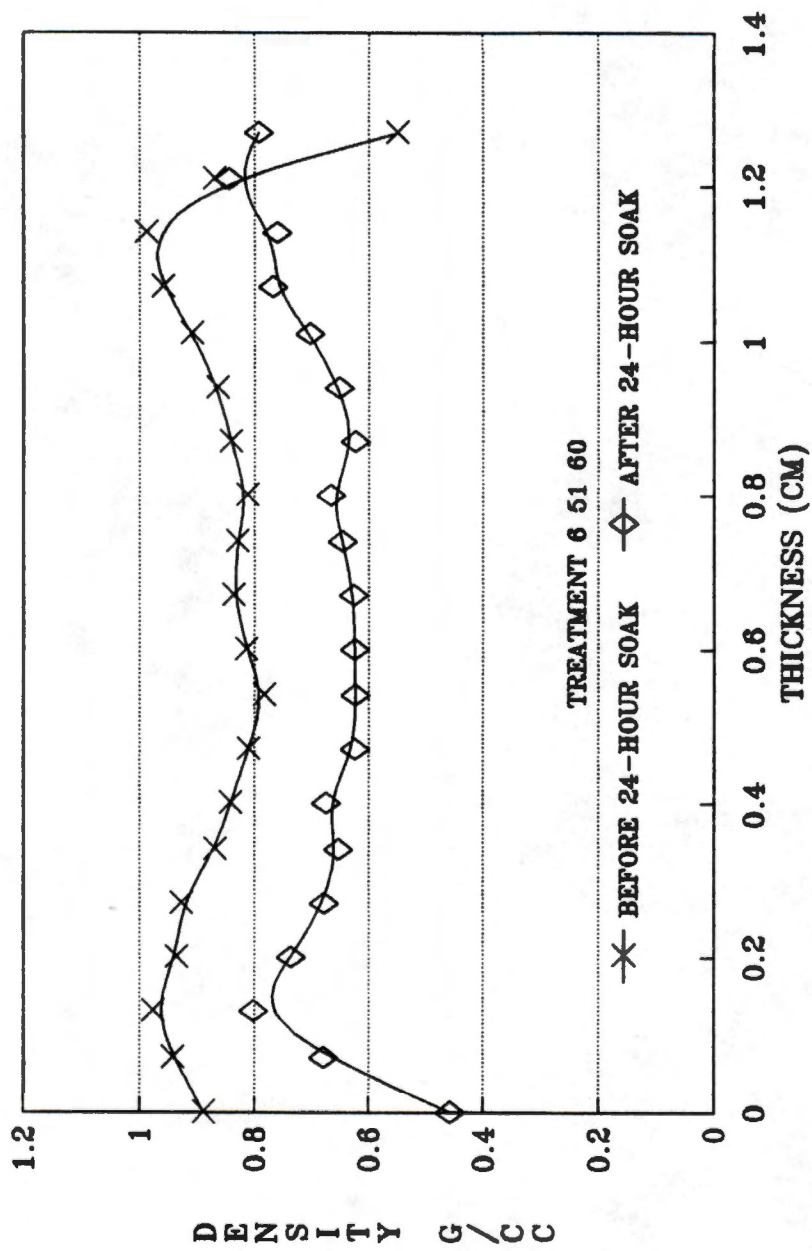


Figure D.10. Vertical Density Profile: 24-hour water soak treatment 6 51 60.

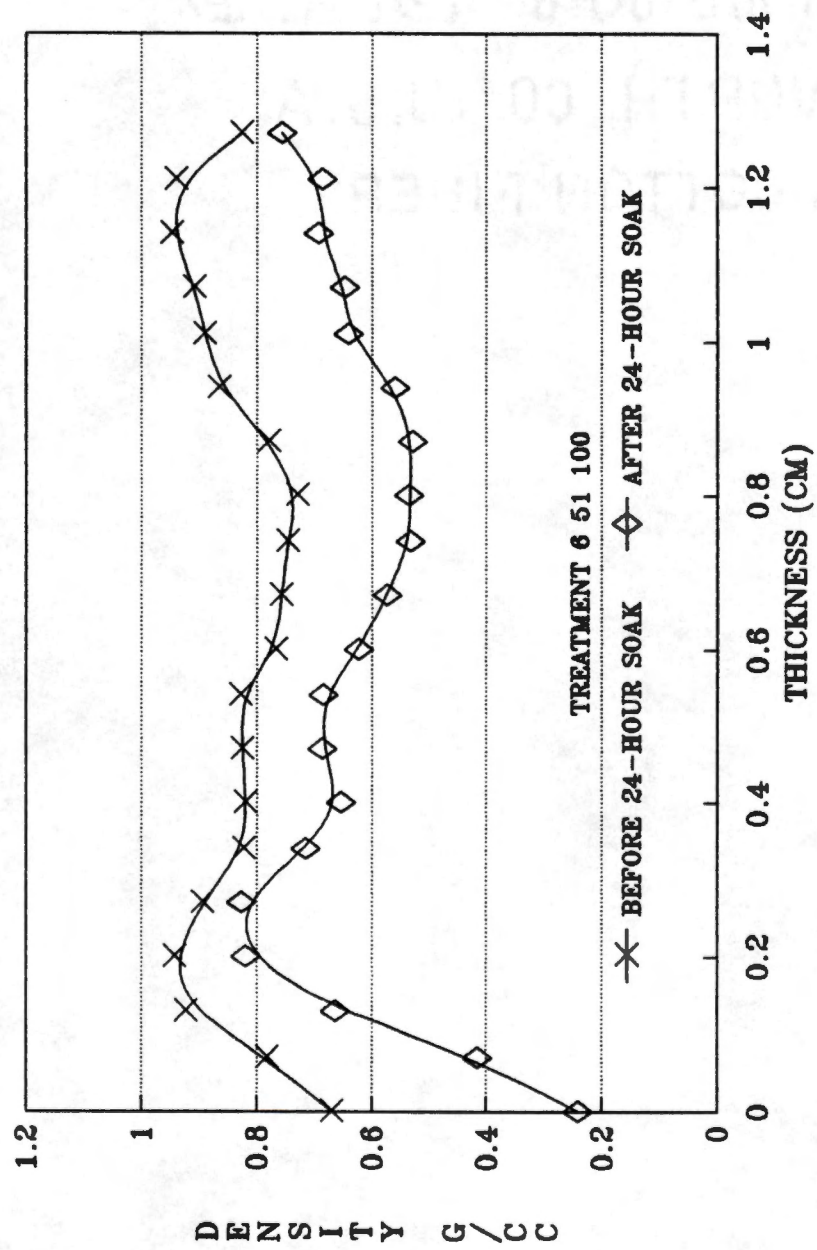


Figure D.11. Vertical Density Profile: 24-hour water soak treatment 6 51 100.

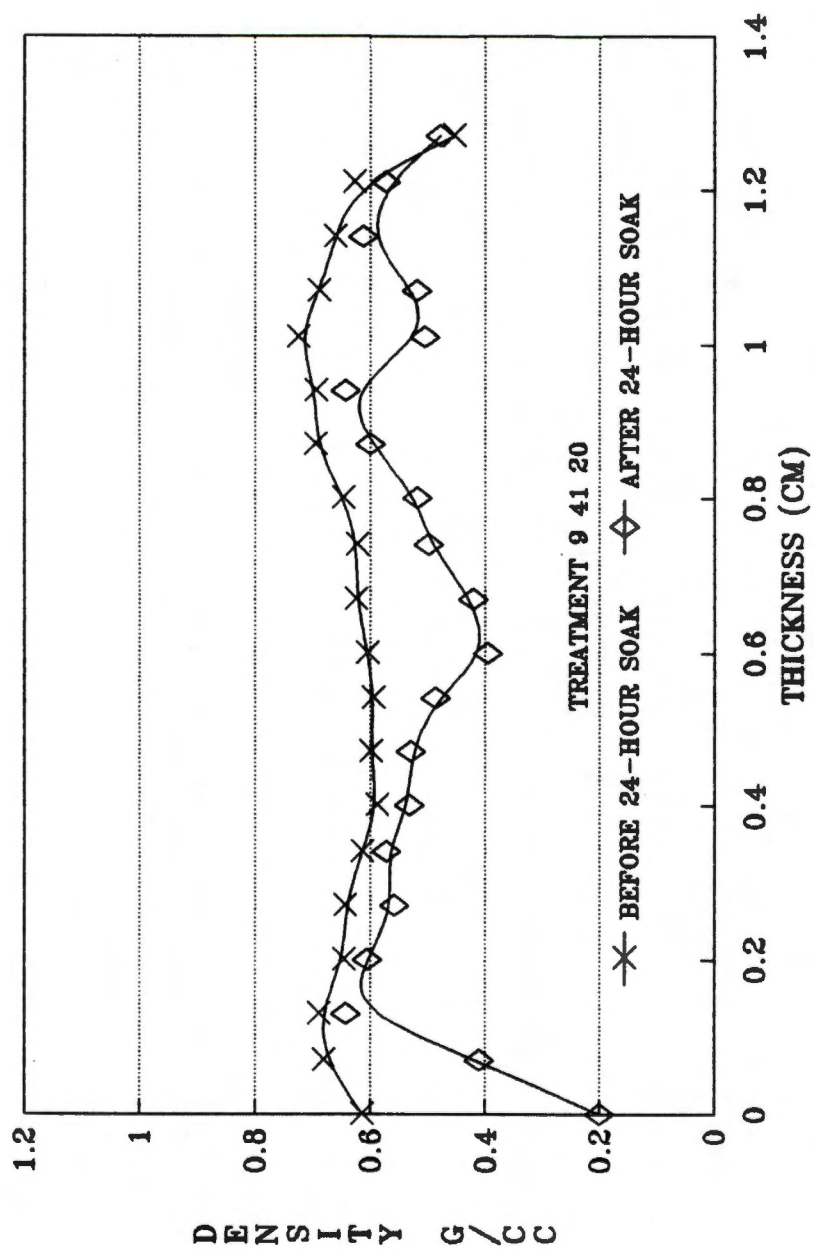


Figure D.12. Vertical Density Profile: 24-hour water soak treatment 9 41 20.

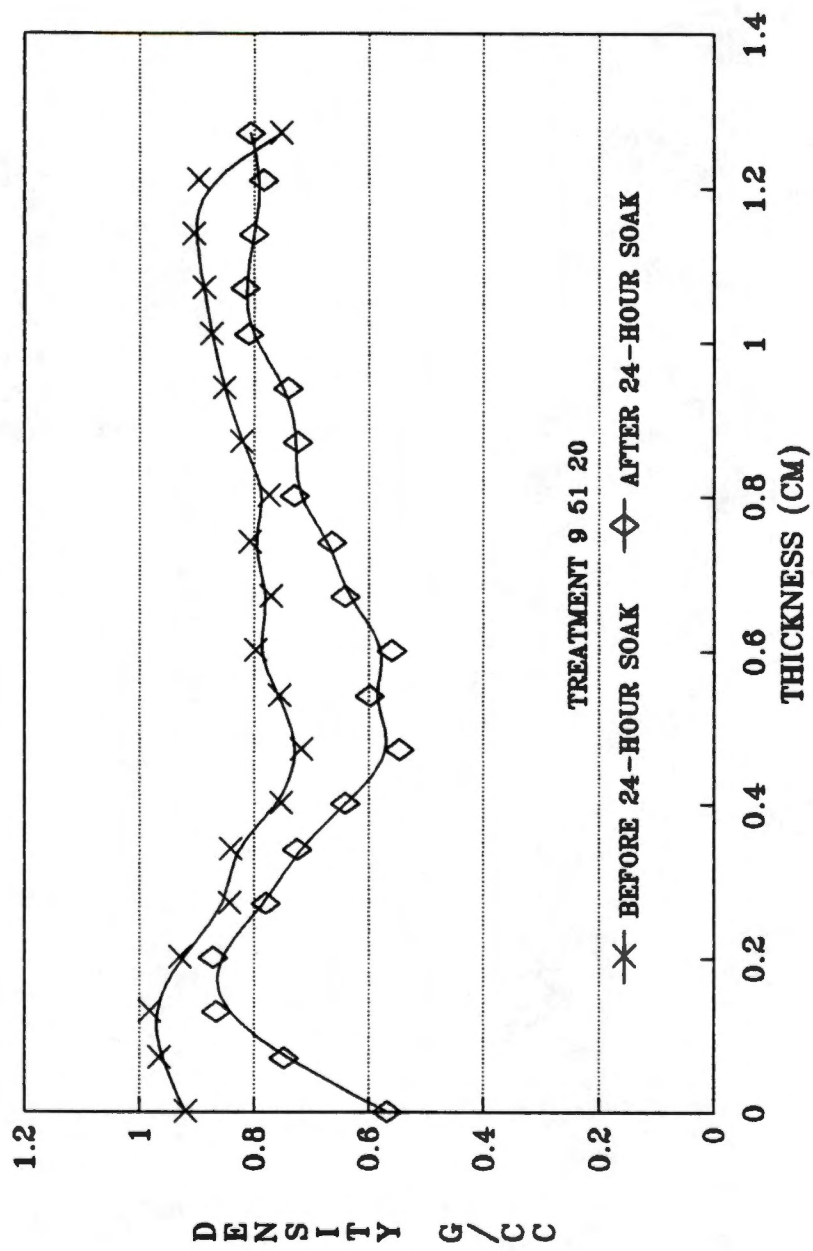


Figure D.13. Vertical Density Profile: 24-hour water soak treatment 9 51 20.

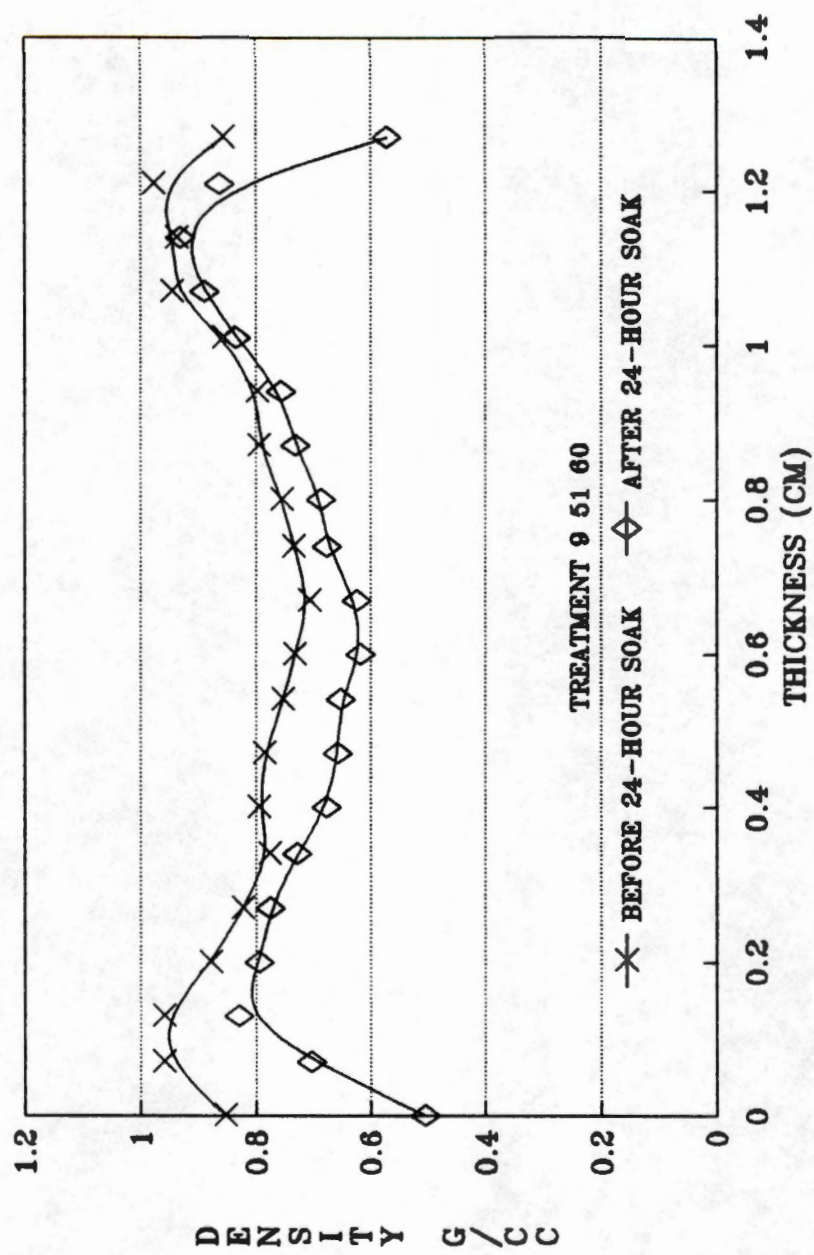


Figure D.14. Vertical Density Profile: 24-hour water soak treatment 9 51 60.

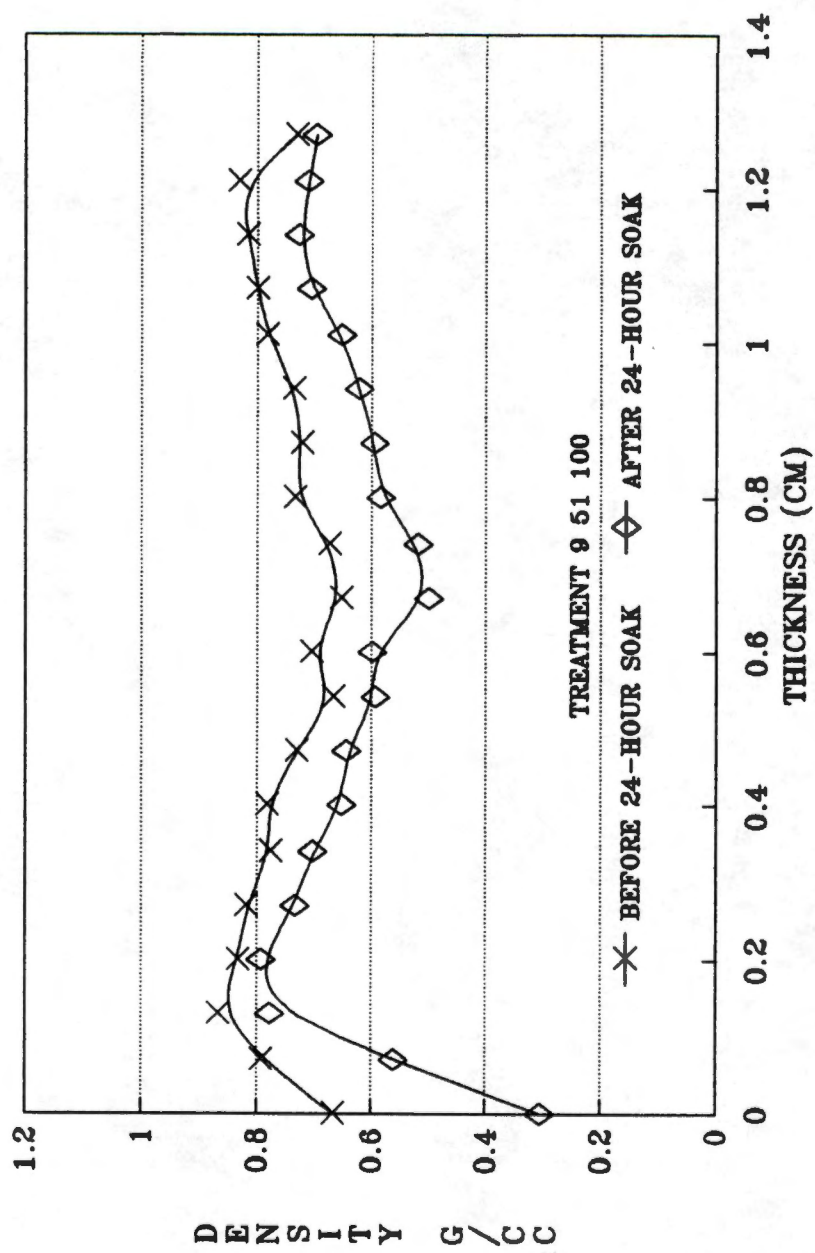


Figure D.15. Vertical Density Profile: 24-hour water soak treatment 9 51 100.

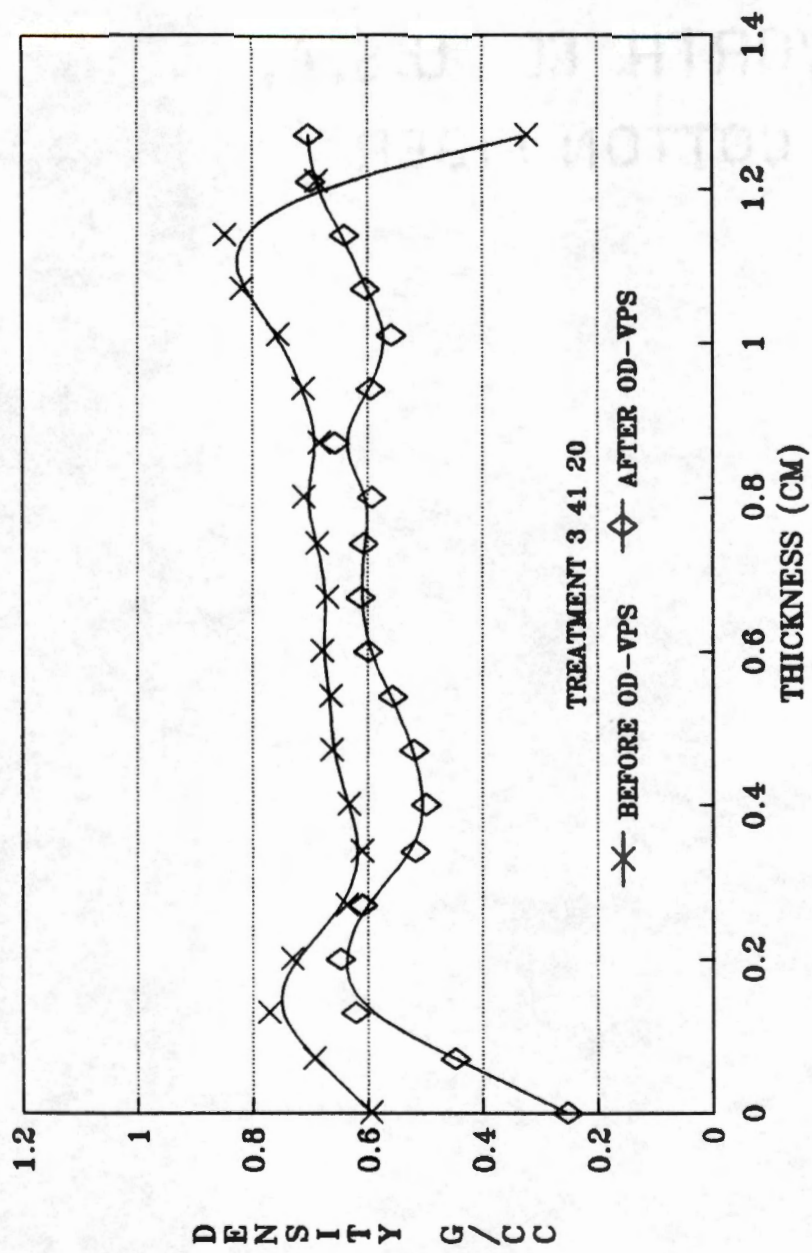


Figure D.16. Vertical Density Profile: Ovendry-vacuum pressure soak treatment 3 41 20.

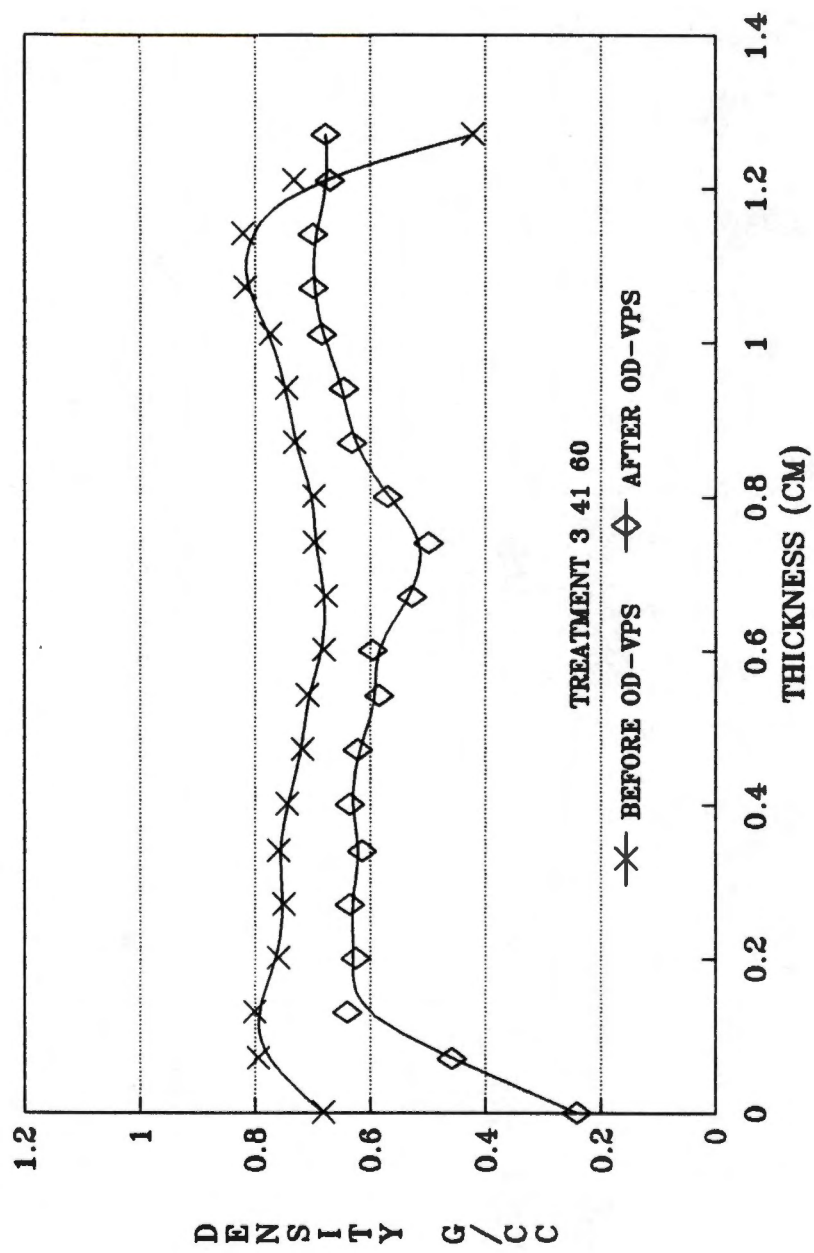


Figure D.17. Vertical Density Profile: Ovendry-vacuum pressure soak treatment 3 41 60.

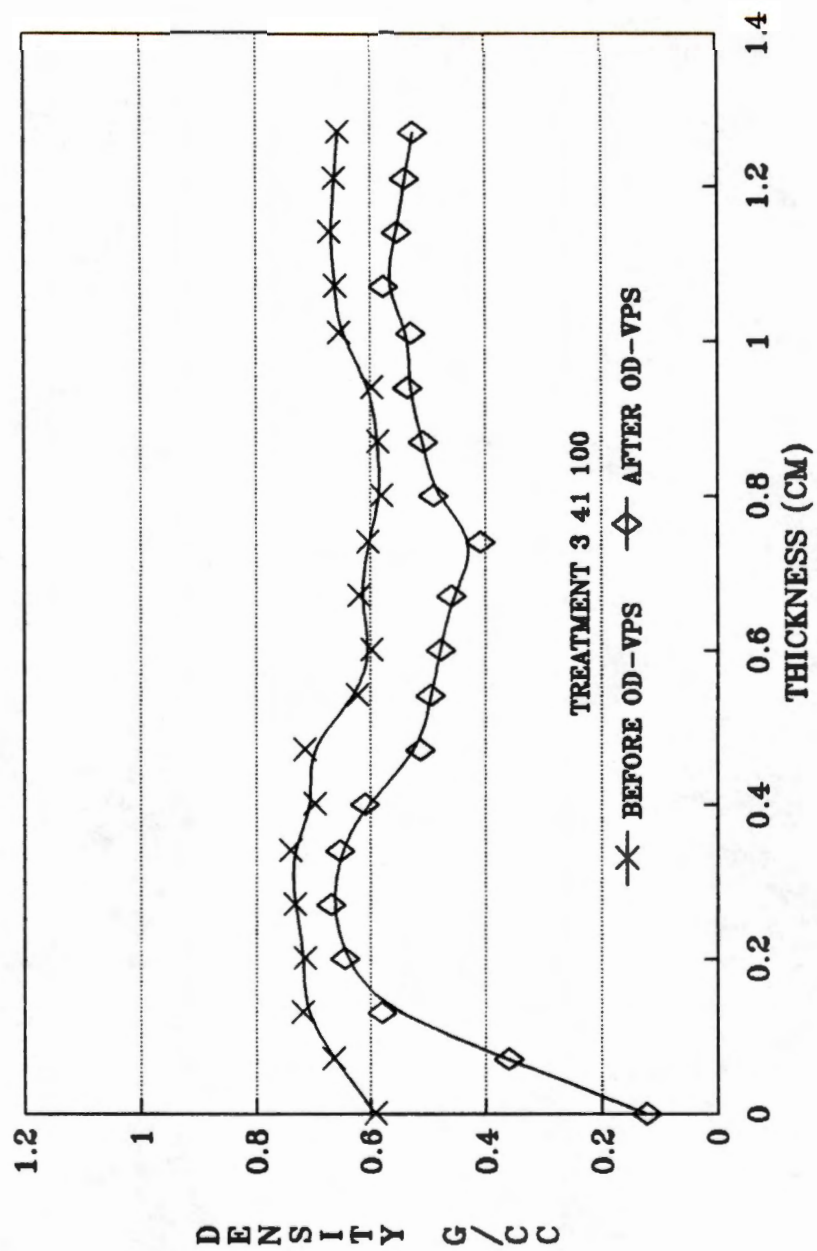


Figure D.18. Vertical Density Profile: Ovendry-vacuum pressure soak treatment 3 41 100.

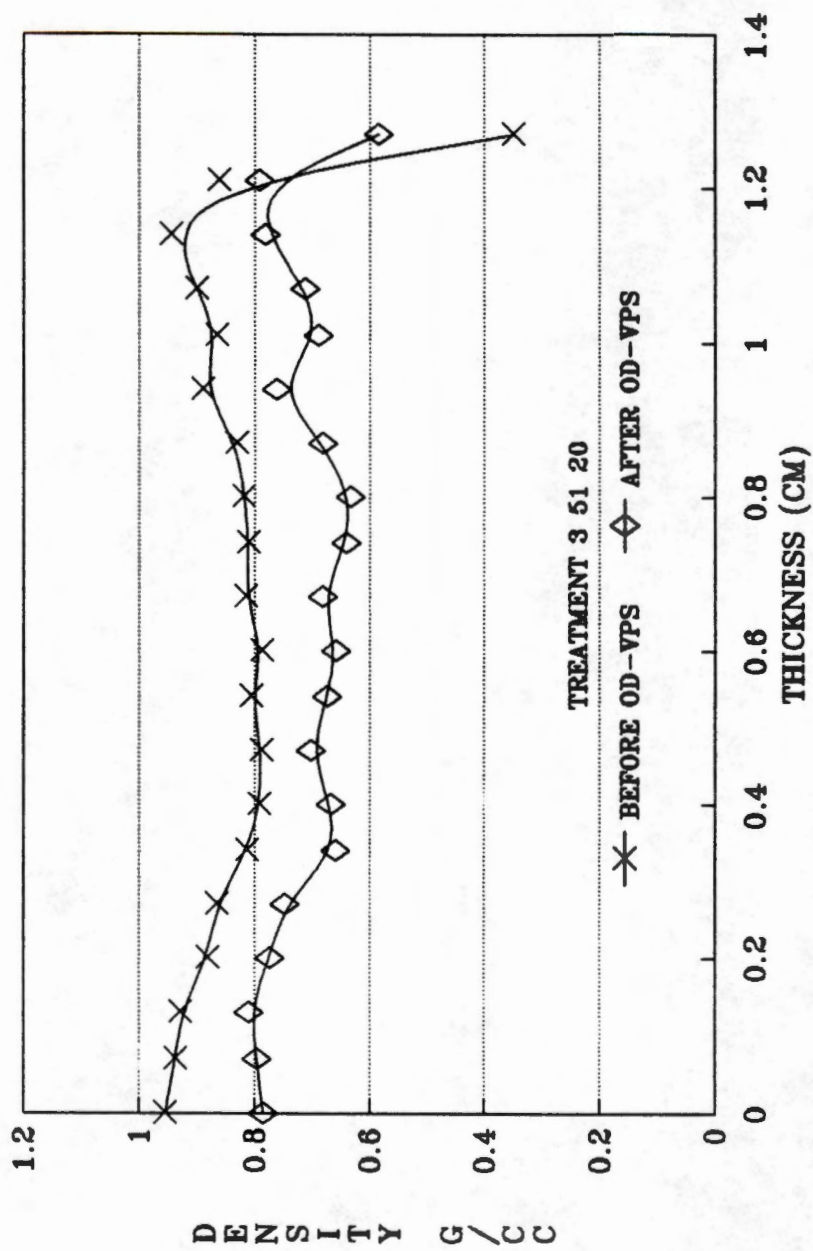


Figure D.19. Vertical Density Profile: Owendry-vacuum pressure soak treatment 3 51 20.

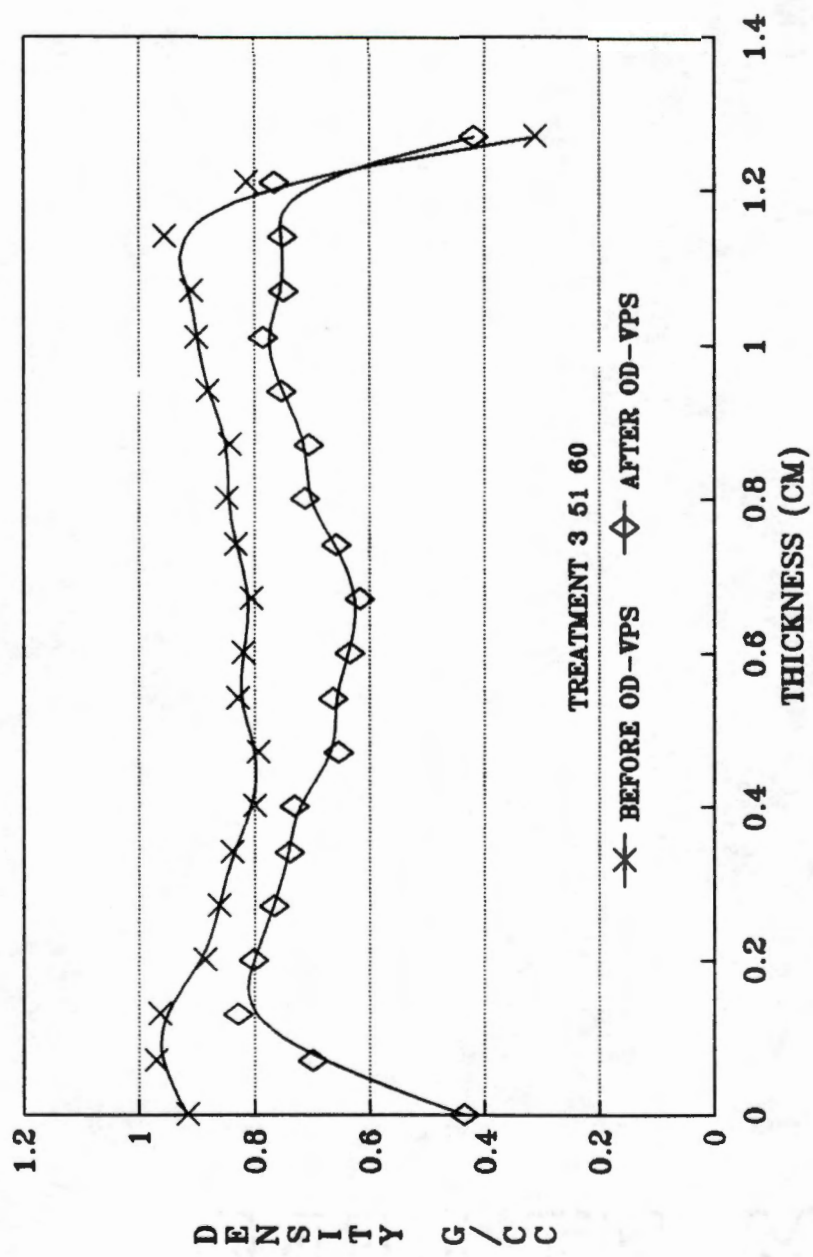


Figure D.20. Vertical Density Profile: Ovendry-vacuum pressure soak treatment 3 51 60.

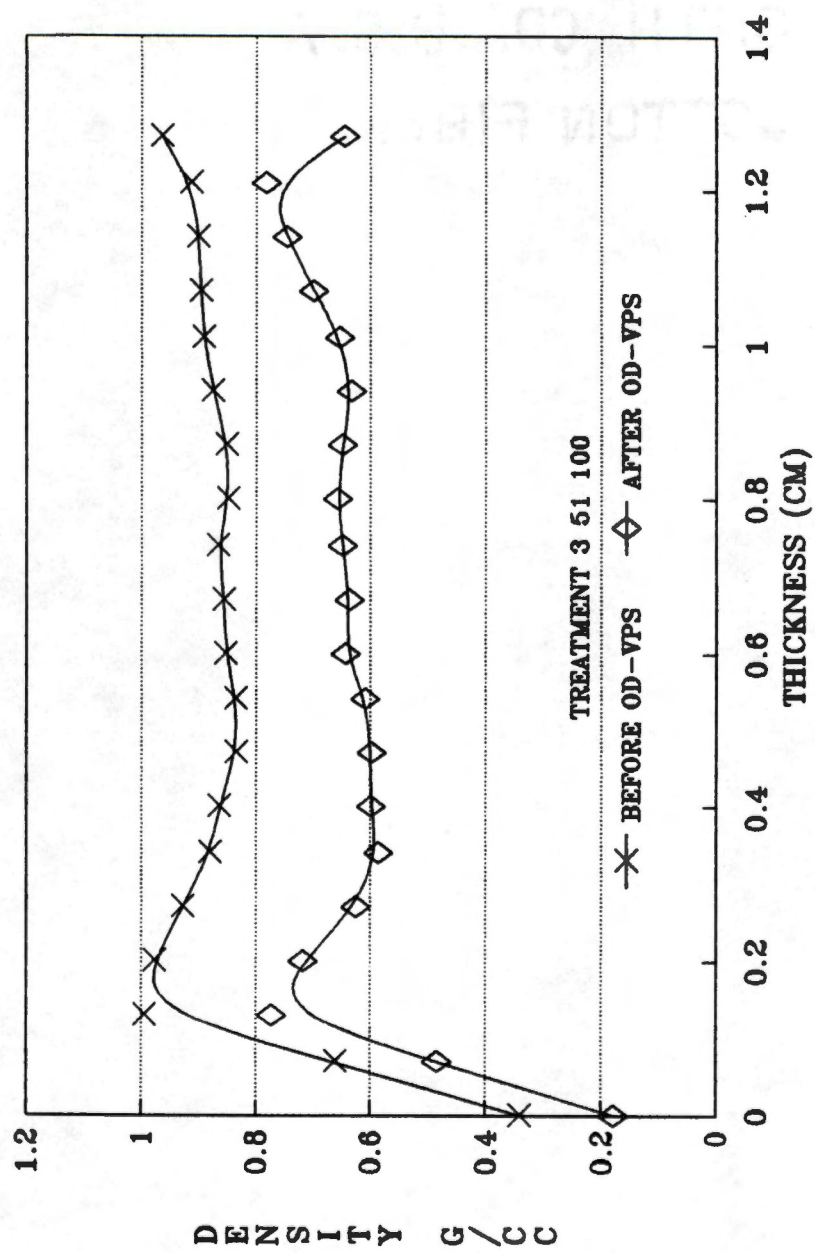


Figure D.21. Vertical Density Profile: Ovendry-vacuum pressure soak treatment 3 51 100.

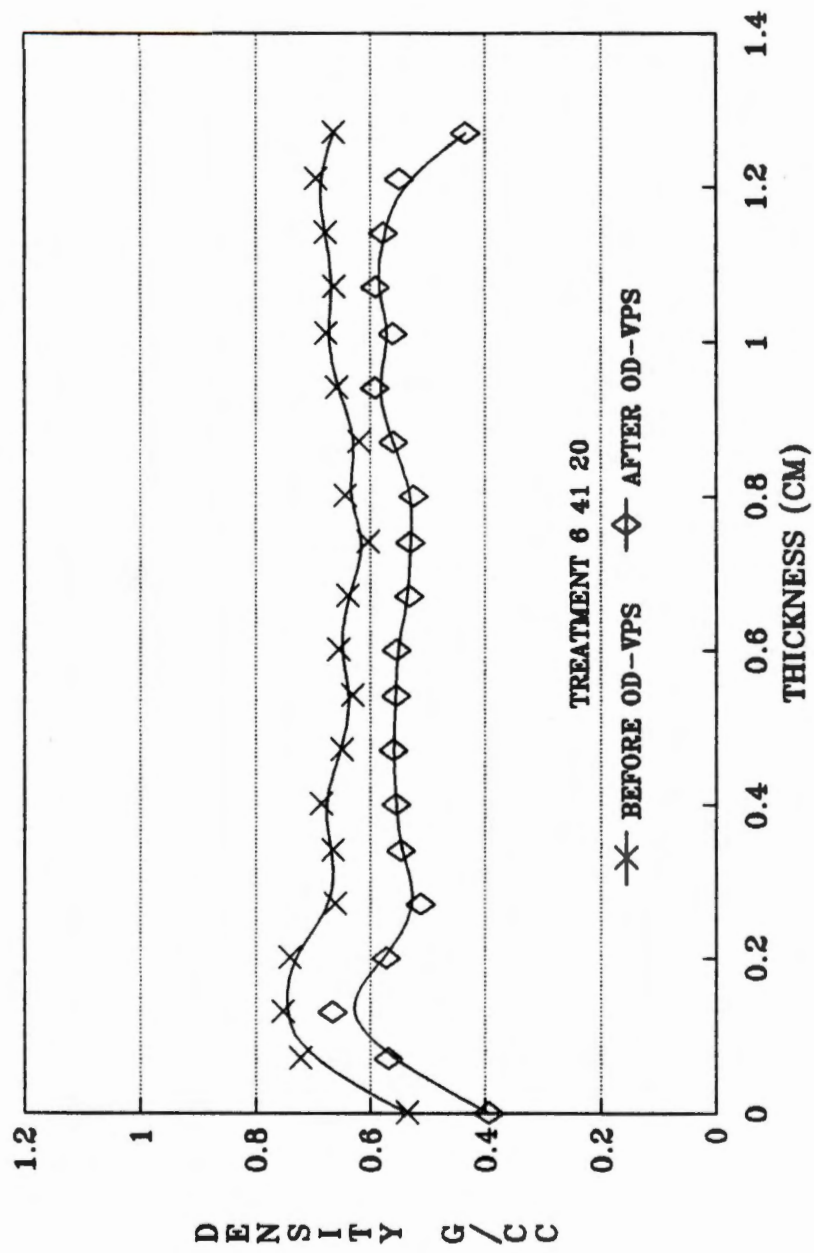


Figure D.22. Vertical Density Profile: Owendry-vacuum pressure soak treatment 6 41 20.

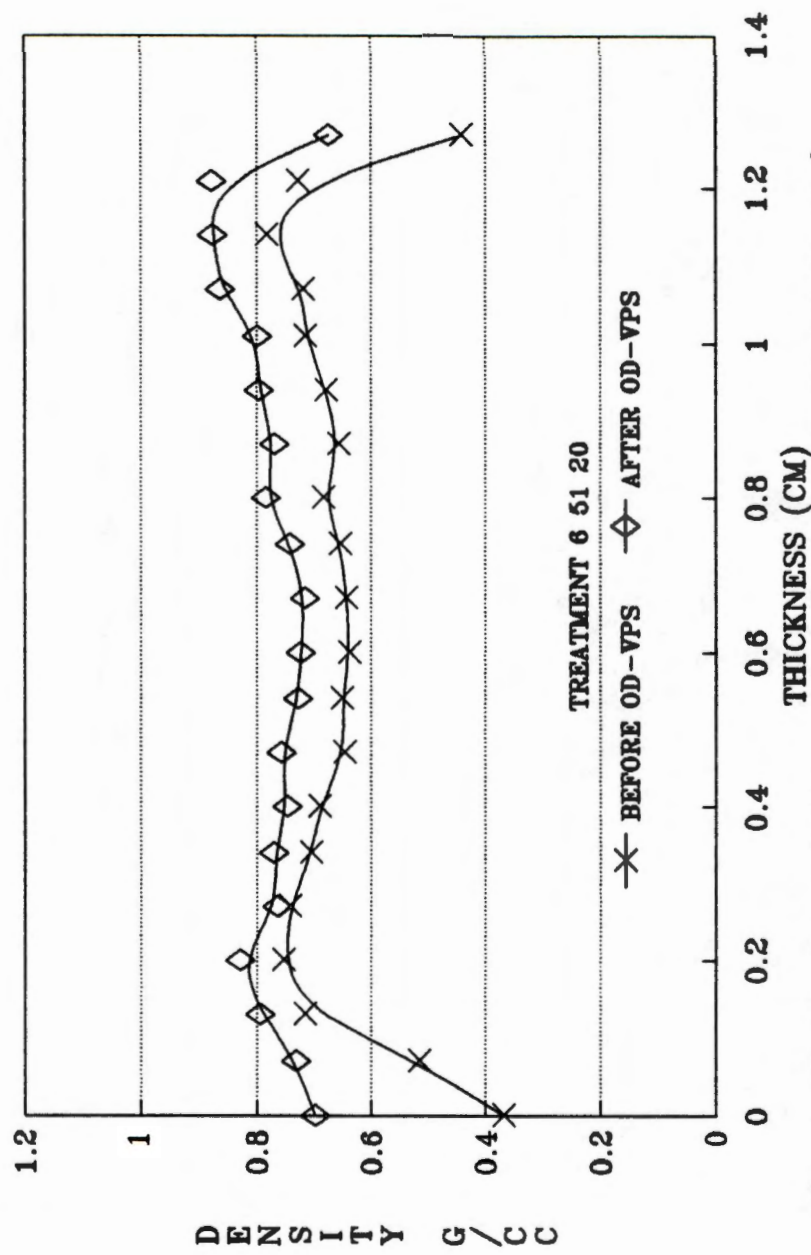


Figure D.23. Vertical Density Profile: Ovendry-vacuum pressure soak treatment 6 51 20.

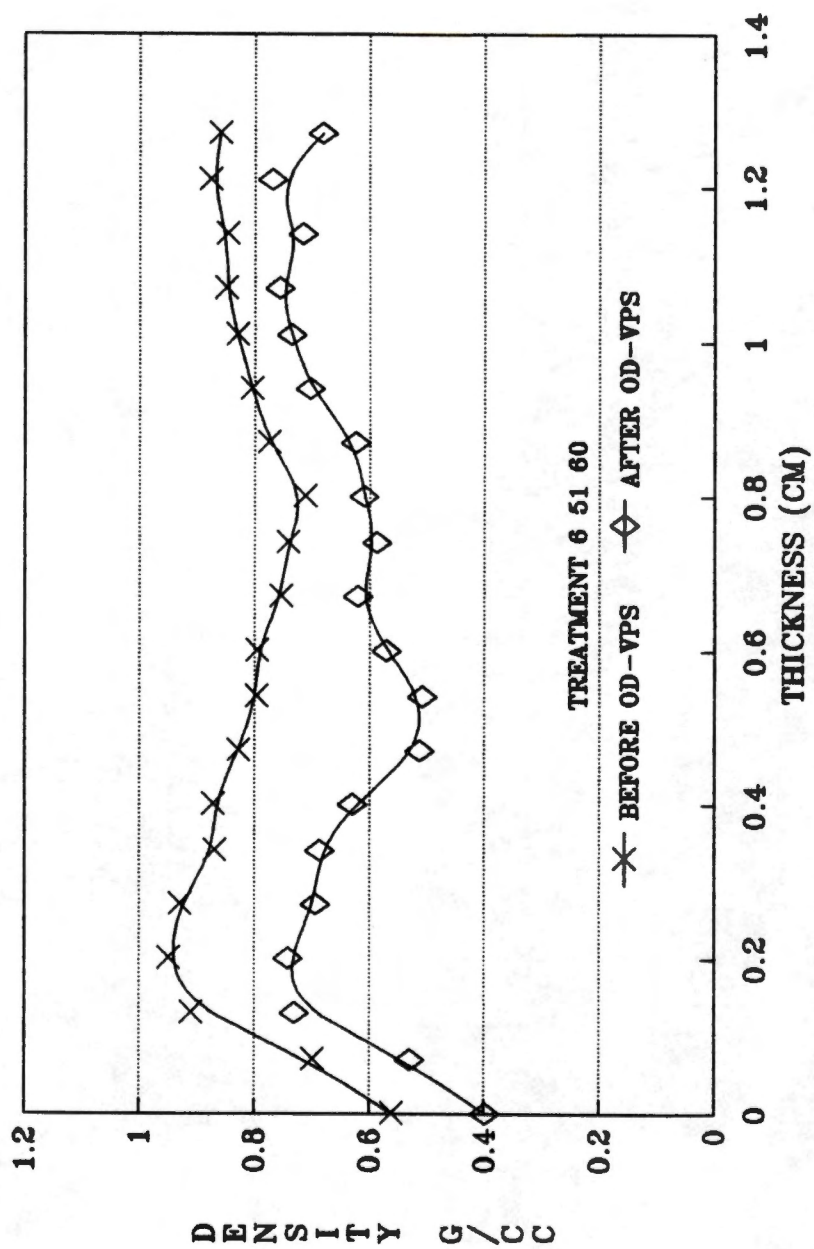


Figure D.24. Vertical Density Profile: Ovendry-vacuum pressure soak treatment 6 51 60.

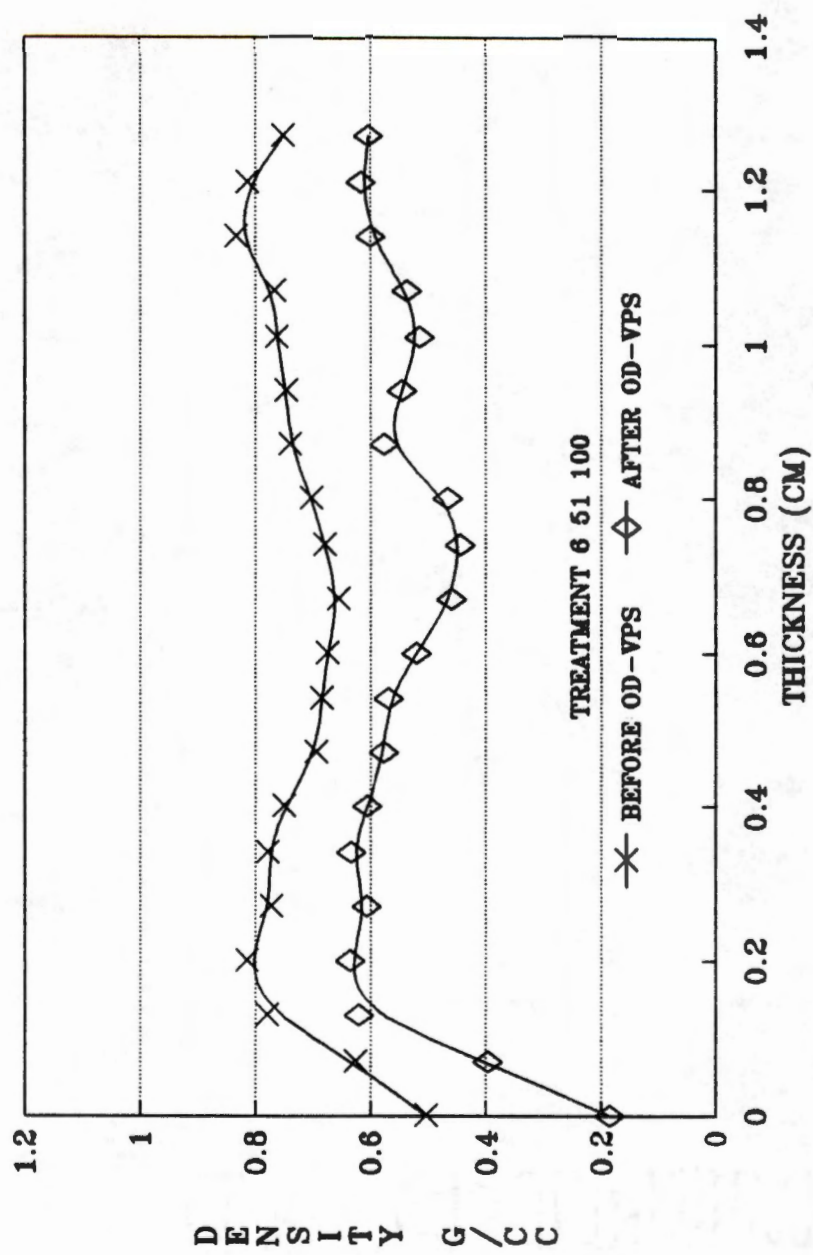


Figure D.25. Vertical Density Profile: Owendry-vacuum pressure soak treatment 6 51 100.

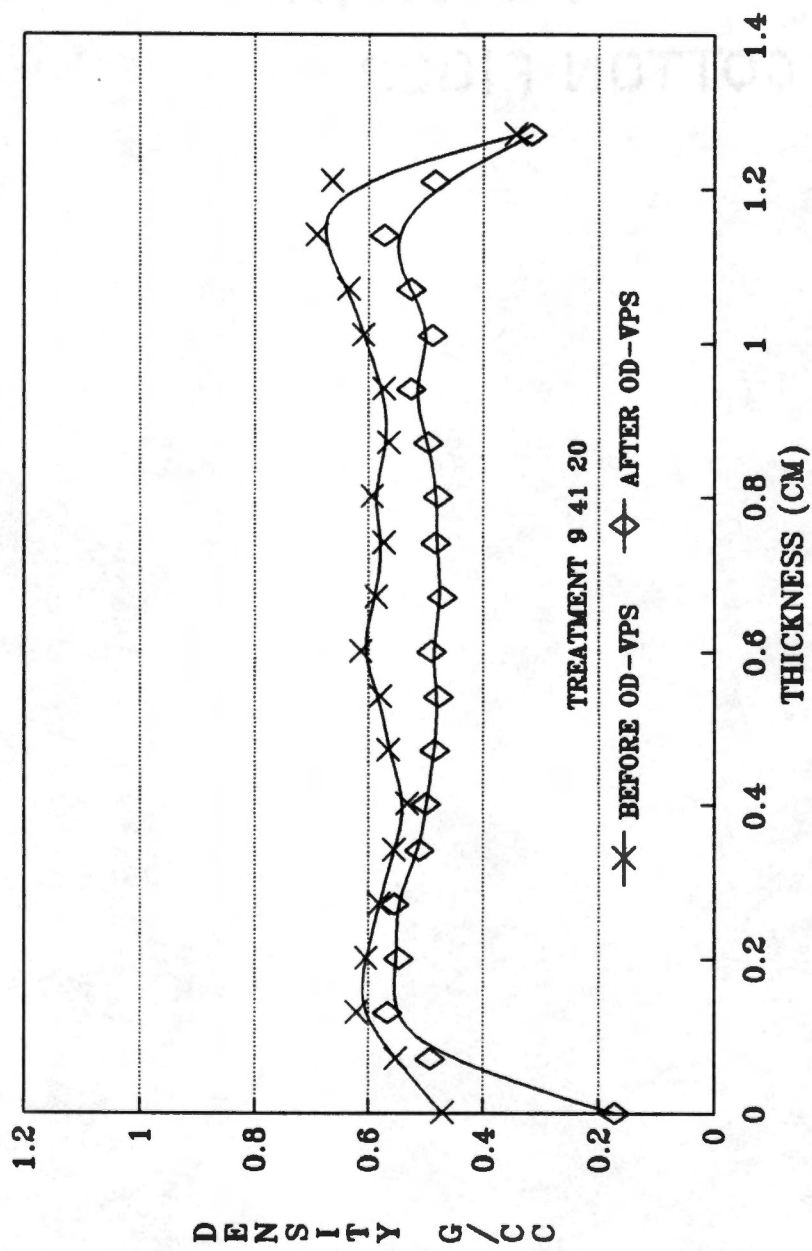


Figure D.26. Vertical Density Profile: Ovendry-vacuum pressure soak treatment 9 41 20.

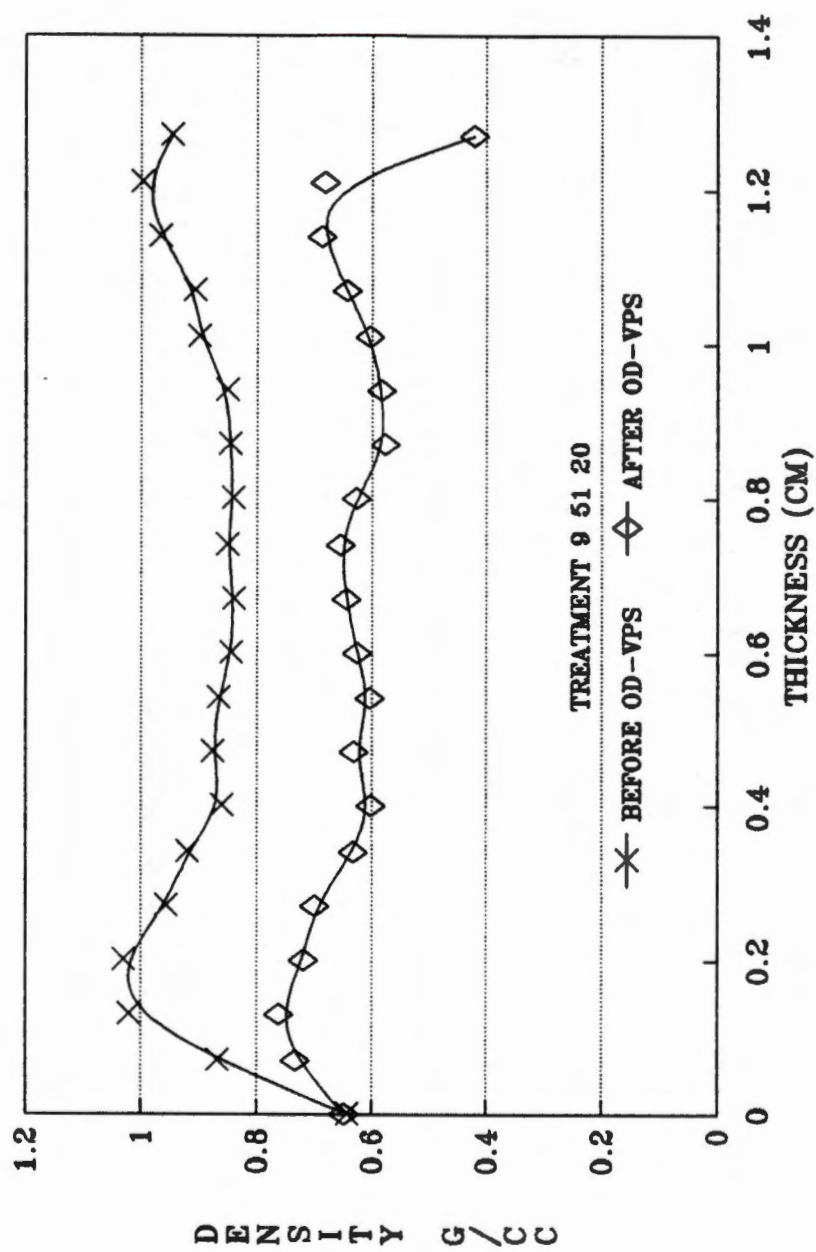


Figure D.27. Vertical Density Profile: Owendry-vacuum pressure soak treatment 9 51 20.

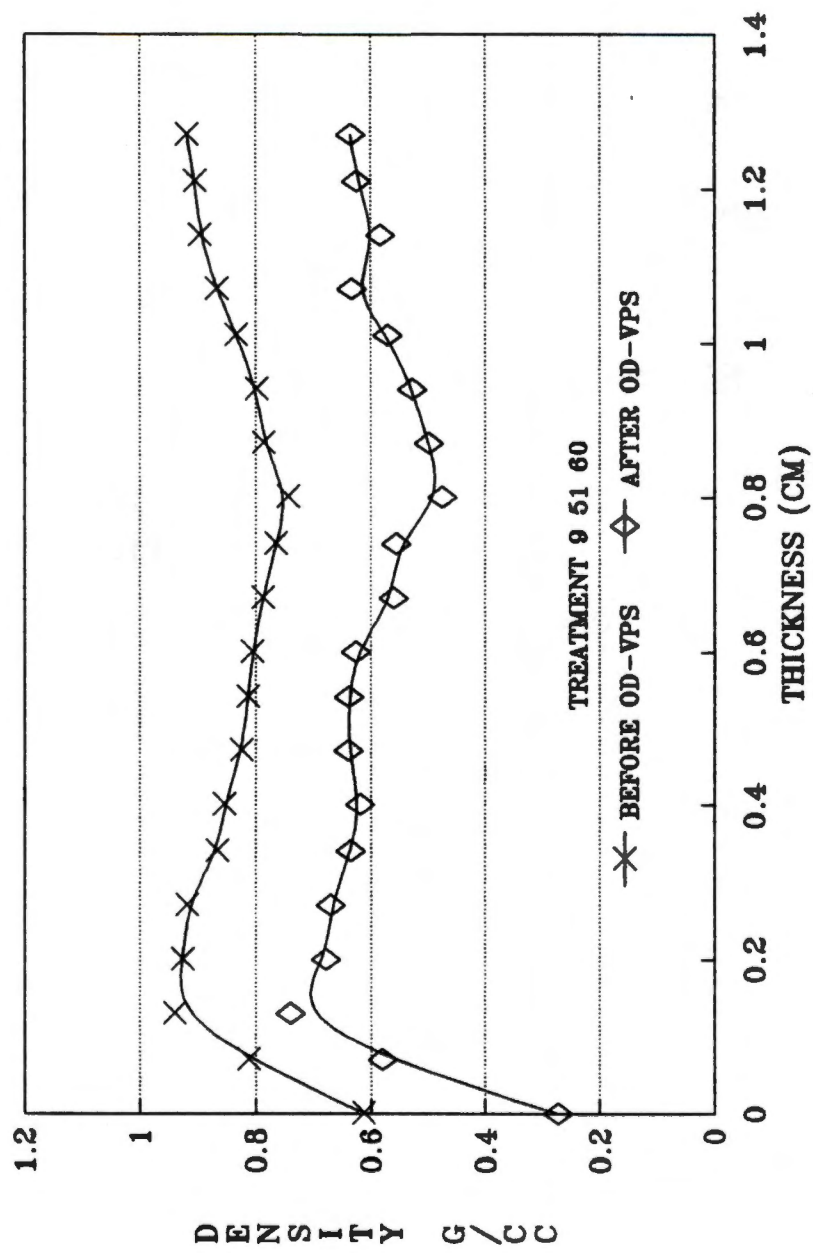


Figure D.28. Vertical Density Profile: Ovendry-vacuum pressure soak treatment 9 51 60.

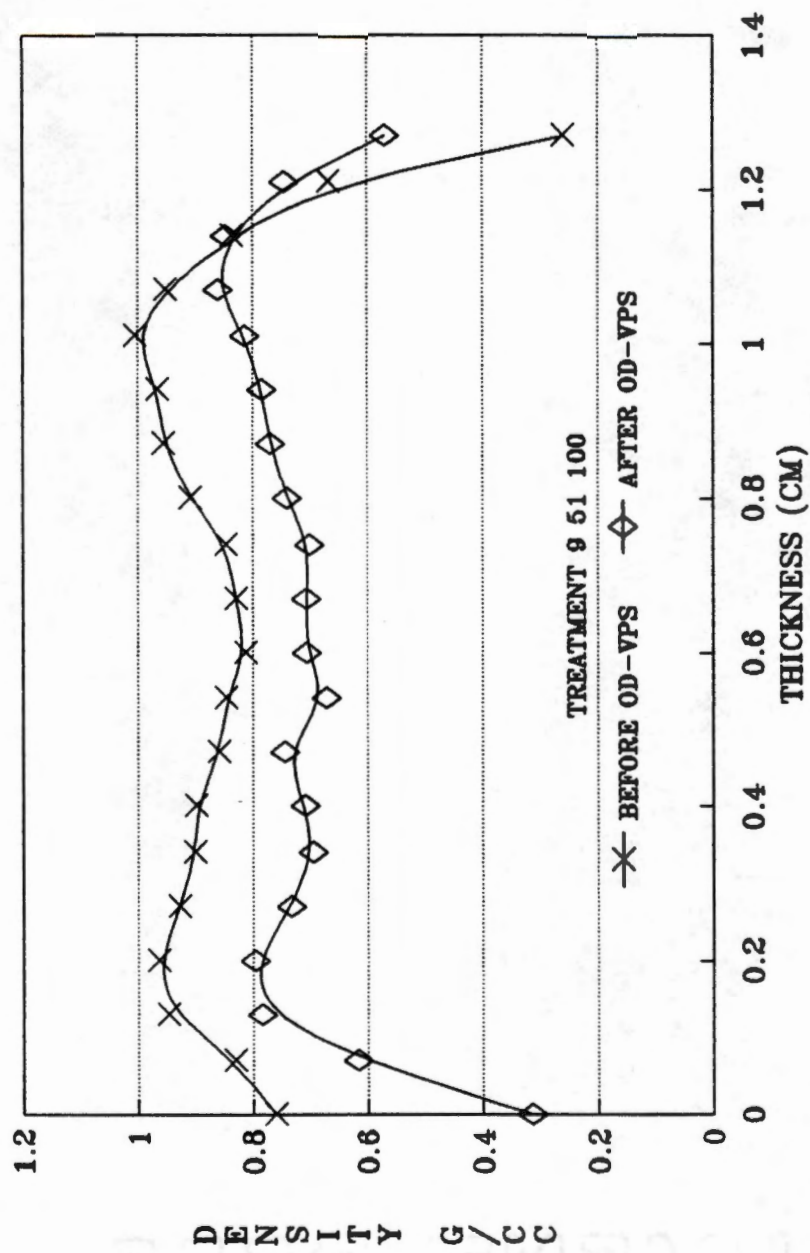


Figure D.29. Vertical Density Profile: Ovendry-vacuum pressure soak treatment 9 51 100.

VITA

William Cos T. Davis was born in Nashville, Tennessee on January 31, 1961. He attended Oak Hill Elementary school and graduated from Montgomery Bell Academy in June 1979. The following September he entered The University of the South, and in June 1983 he received a Bachelor of Science degree in Natural Resources. He started a Master's of Science degree in Wood Technology in January 1984 at the University of Tennessee, Knoxville. This degree was awarded in December 1989.

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