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EFFECT OF MOISTURE CONTENT AND ITS DISTRIBUTION THROUGHOUT THE MAT ON THICK WAFERBOARD

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FOREWORD

This report forms part of the stated goals in CFS/DSS Project 34, Part B "Characterizqtion of the Performance of Waferboard" which was funded by the Canadian Forestry Service.

ABSTRACT

The relationship of press closing time, strength properties and density profile of thick waferboard panels to mat moisture content was demonstrated in this study. Lower mat moisture contents were found to increase press closing time but permit faster binder curing. When the distribution of mat moisture was higher in the face layers, shorter press times were achievable and a significant densification of the panel faces was observed.

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INTRODUCTION

The moisture content (MC) and its distribution in a mat entering hot press is of great importance in pressing composition boards. It is one of the most significant factors in determining the press closing time, which primarily governs the board density profile, and pressing pressure, which influences the design of hot presses. In addition, the MC of a mat can significantly affect the press time, one of the important factors in determining the production rate of a plant.

In view of the above facts, the selection of proper MC and its distribution in the mat is essential to the economic production of high quality waferboards. If the press closing time is kept constant, the properties of waferboard (7/16 in. thick) are almost independent of mat MC within a practical MC range.

Also, thick waferboard is used increasingly for structural members, and its production rate is relatively slower than that of thin waferboard. Thus, the effect of mat MC and its distribution on the production and properties of thick waferboard is considered to be important. The purpose of this study is to investigate the effect of mat MC and its distribution on the press closing time, press time, density profile and the properties of thick waferboard (3/4 in. thick) in detail.

MATERIALS AND PROCEDURE

All wafers used in this study were obtained from a waferboard plant. They were cut from aspen logs by a commercial disk-type waferizer. The wafers had been dried in plant but adsorbed moisture during storage. The MC at the outset of this study was about 8 percent. To remove undersized materials, they were sieved through a four-mesh screen by a gyratory separator.

To achieve the goal of this study, mats were prepared in four different MC and distributions:

A) uniform 3 percent MC distribution in mat;

B) uniform 5 percent MC distribution in mat;

C) the core (50%) of mat at 3 percent MC, with the two faces at 7 percent MC, and

D) the core (70%) of mat at 3 percent MC, with two faces at 9.7 percent MC.

Because it is difficult to dry wafers to the exact target MC, the wafers were always slightly over-dried and then adjusted to the exact target MC by spraying them with water before blending

Corresponding to the above four categories of mat MC and distribution, waferboards were prepared at two density levels. For each specific MC, wafers were blended with 2 percent slack wax and 2.5 percent powdered phenol-formaldehyde resin (based on oven-dry weight of wafers. For each category of waferboard, four mats, each measuring 559 by 571 mm (22 by 22.5 in.) were pressed at 210°C (410°F) to the target thickness 19.05 mm (0.75 in.). The press pressures used were 3.28 MPa (475 psi) and 3.45 MPa (500 psi) for the target density 609 kg/m^3 (38 lb/ft^3) and 673 kg/m^3 (42 lb/ft^3) respectively. During the hot pressing, the press closing time of each board was recorded and the curve of core temperature against press time of each board was automatically plotted. The core temperature was taken at the geometrical centre of the board. The press time of each board was the total time that elapsed to reach core temperature 302°F (150°C) plus one minute for reducing pressure and opening the press.

The boards were tested in terms of the modulus of elasticity in bending (MOE), modulus of rupture (MOR), and internal bond strength (IB). All tests were conducted by standard procedure (2) on conditioned specimens. In addition, the density of about every 1/16-inch-thick layer from top face to bottom face of four specimens for each board category was determined and the density profile for each waferboard category was plotted.

To compare the effect of MC and its distribution on IB, MOE and MOR, the methods of analysis of covariance and least significant difference were used. Whenever the difference between any two means is greater than the value of least significant difference, the difference is significant at the 5 percent significance level. For analysis of covariance, the specific gravity (based on conditioned weight and volume) was used as covariate which was assumed to be linearly correlated with MOR, MOE and IB.

RESULTS AND DISCUSSION

The results of this study are summarized in Figures 1 to 4 and Tables 1 to 4. Each curve in Figures 1 to 4 represents the best fitting curve of four sets of data or curves by a freehand method of curve fitting. Each value in Table 1 represents the average of four replications while each value in Table 2 represents the mean values of 24 tests for MOE, MOR and IB.

The results of analysis of covariance indicated that the mat MC and its distribution had a significant effect on all three properties MOR, MOE and IB.

Curve of Board Temperature Versus Press Time

Figures 1 and 2 illustrate the relationship between the temperature at board geometrical centre and the press time for various mat MC, and distribution. In general, the curve shows three stages of heating -- steam convection, vapour dispersion and heat conduction.

Press Closing Time, Press Time and Density Profile

Tables 1 and 2 show that, as expected, the mat with 5 percent MC had shorter press closing time but longer press time than that with 3 percent MC. This is because high moisture provides more steam and in turn makes wood easier to compress than low moisture but requires a longer time for steam to disperse than low moisture. Tables 1 and 2 also show that at the same average MC (5%), high MC in face layers tended to have a shorter closing time and press time than low MC due to the effect of steam shock. The effect of steam shock can be illustrated by Figures 1 and 2. The graphs show that the core temperature rose to the boiling point of water faster for the faces with high MC than for those with low MC.

Figure 3 indicates that, at specific gravity of 0.603, the specific gravity of core was 16 to 22 percent, lower than the average specific gravity of the board, while that of face layer was 21 to 50 percent higher than the average specific gravity of board. It is clear that the MC and its distribution had less effect on the specific gravity of core than on that of face layer. At the same average MC, high MC in face layers resulted in denser faces and a sharper decrease in specific gravity from face layers to core than low MC in face layers.

Figure 4 illustrates that, at specific gravity of 0.680, the specific gravity of core was approximately 17 to 25 percent lower than the average specific gravity of board and that of face layers was approximately 15 to 45 percent higher than the average specific gravity of the board. Type D had a sharper decrease in specific gravity from face layers to core than other boards.

Internal Bond Strength (IB)

Table 3 shows that the mean values of IB ranged from 296 KPa (43 psi) to 345 KPa (50 psi) for boards at specific gravity of 0.603 while Table 4 shows that the mean values of IB ranged from 365 KPa (53 psi) to 441 KPa (64 psi) for boards at specific gravity of 0.680. The results of analyses of covariance indicated that the mat MC and its distribution had a significant effect on IB for waferboard at the 0.05 significance level.

Table 3 shows that type A boards made with 3 percent MC, had significantly higher IB than type C and D boards because A boards had higher specific gravity in the core than the other two. However, it also indicates that there was no significant difference between type A and B boards, between type C and D boards or between type B and D boards with respect to IB.

Table 4 shows that, for IB, there was no significant differences among type A', B' or C' boards. Examination of Tables 3 and 4 may suggest that the effect of mat MC and its distribution on IB may vary with board density.

Modulus of Elasticity (MOE)

Table 3 indicates that the mean values of MOE ranged from 3.74 GPa (543 ksi) to 4.44 GPa (644 ksi) at specific gravity of 0.603. The MOE tended to increase with an increase in the MC of mat face layers entering the hot press. This can be explained by the specific gravity profiles. Gravity of face layers increased as the MC of mat face layers increased.

Table 4 shows that the mean values of MOE ranged from 4.85 GPa (704 ksi) to 5.72 GPa (830 ksi). Type A' boards had lower MOE than type B', C' and D' boards because the former had lower specific gravity of face layers than the latter. There was no significant difference between type C' and D' boards.

Modulus of Rupture (MOR)

Table 3 shows that at specific gravity 0.603, the mean values of MOR ranged from 19.99 MPa (2900 psi) to 24.46 MPa (3548 psi). Type A board had lowest MOR while type C board had highest MOR among the boards shown in Table 3. Examination of Table 3 indicated that type C board had higher MOR than type D, but there was no significant difference between them in MOE. This result was not surprising because type D had a steeper curve slope for its specific gravity profile from face layer to core than type C (Shown in Figure 3), and the specific gravity of the inner layers next to the extreme face layers had more effect on MOR than MOE.

Table 4 shows that at the specific gravity of 0.680, the mean values of MOR ranged from 24.32 MPa (3527 psi) to 29.40 MPa (4264 psi). Type A' board had lowest MOR while type B' had highest MOR among the boards shown in Table 4. However, there was no significant difference between type C' and D' at the 5 percent significance level.

CONCLUSIONS AND RECOMMENDATIONS

Within the limit of this study, the prinicpal conclusions can be summarized as follows:

1) the lower the MC, the shorter the press time;
2) the higher the MC, the faster the press closing time;
3) at the same average MC, the higher MC in mat face layers the shorter the press time;
4) at the same average MC, the higher MC in mat face layers the faster the press closing time;
5) for thick [(19.05 mm (¾ in)] waferboard, the mat MC and its distribution have a more significant effect on the specific gravity of face layers than that of core;
6) for thick waferboard, the mat MC and its distribution have a statistically significant effect on MOE, MOR and IB, in a descending order;

In short, to reduce press time without impairing the board quality, the MC in the core may be reduced to 3 percent and that in face layers may be increased to 7 percent. It should be noted that a high press pressure would be preferred to maintain a reasonably high specific gravity in face layers when low MC is used.

TABLE 1. Effects of Moisture Content (MC) and Its Distribution on Press Closing Time and Press Time for Waferboard[1] With the Specific Gravity of 0.603

Weight Ratio of Face to Core	MC %		Press Closing Time, sec.	Press Time
	Face	Core		
50 to 50	3	3	190	10'01"
50 to 50	5	3	61	11'54"
50 to 50	7	3	56	11'17"
~~50 to 50~~ 30 to 70	9.7	3	55	10'34"

[1] Press pressure used was 475 psi.

TABLE 2 Effects of Moisture Content (MC) and its Distribution on Press Closing Time, and Press Time for Waferboard[1] With the Specific Gravity of 0.680

Weight Ratio of Face to Core	MC %		Press Closing Time, sec.	Press Time
	Face	Core		
50 to 50	3	3	231	10'04"
50 to 50	5	5	195	12'12"
50 to 50	7	3	107	10'39"
30 to 70	9.7	3	102	10'24"

[1]Press pressure used was 500 psi.

TABLE 3. Effect of MC and its Distribution on the Mechanical Properties of Waferboards at Specific Gravity of 0.603

Board[1]	IB KPa(psi)	MOE GPa(ksi)	MOR MPa(psi)
A	345 (50)	3.74 (543)	19.99 (2900)
B	331 (48)	3.83 (555)	22.10 (3205)
C	296 (43)	4.42 (641)	24.46 (3548)
D	310 (45)	4.44 (644)	22.84 (3312)
Least Significant Difference	28 (4)	0.29 (42)	0.61 (189)

[1]A: Uniform 3% MD distribution in mat.

B: Uniform 5% MD distribution in mat.

C: The core (50%) of mat at 3% MC, with two faces at 7% MC.

D: The core (70%) of mat at 3% MC, with two faces at 9.7% MC.

TABLE 4. Effect of MC and its Distribution on the Mechanical Properties of Waferboard at the Specific Gravity of 0.680

Board[1]	IB KPa(psi)	MOE GPa(ksi)	MOR MPa(psi)
A'	393 (57)	4.85 (704)	24.32 (3527)
B'	441 (64)	5.12 (742)	26.46 (3837)
C'	365 (53)	5.64 (818)	29.40 (4264)
D'	393 (57)	5.72 (830)	28.06 (4070)
Least Significant Difference	34 (5)	0.20 (29)	1.96 (284)

[1]A' Uniform 3% MC distribution in mat.

B' Uniform 5% MC distribution in mat.

C' The core (50%) of mat at 3% MC with two faces at 7% MC.

D' The core (70%) of mat at 3% MC with two faces at 9.7% MC.

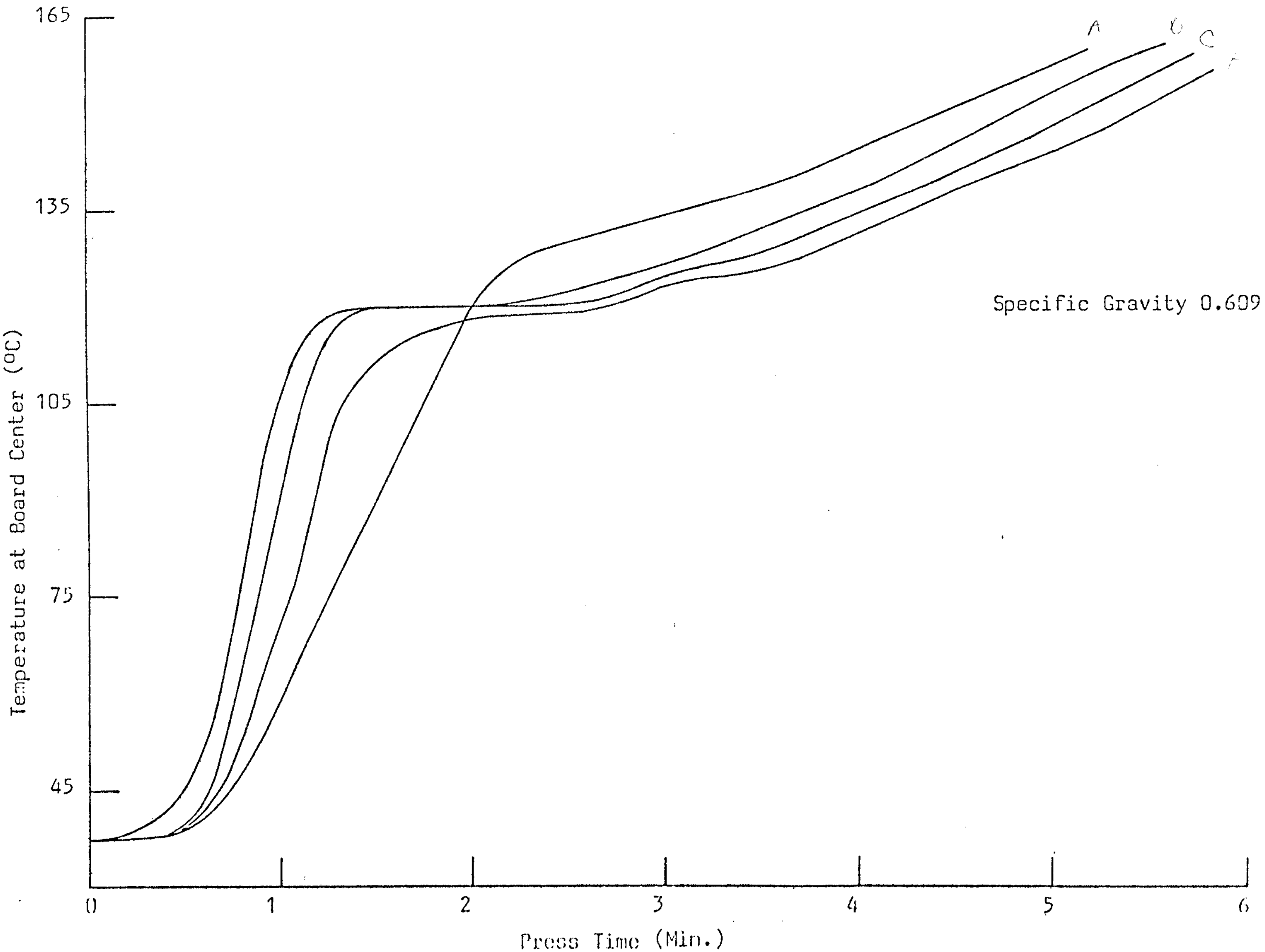

FIGURE 1. Temperature at Board Center versus Press Time.

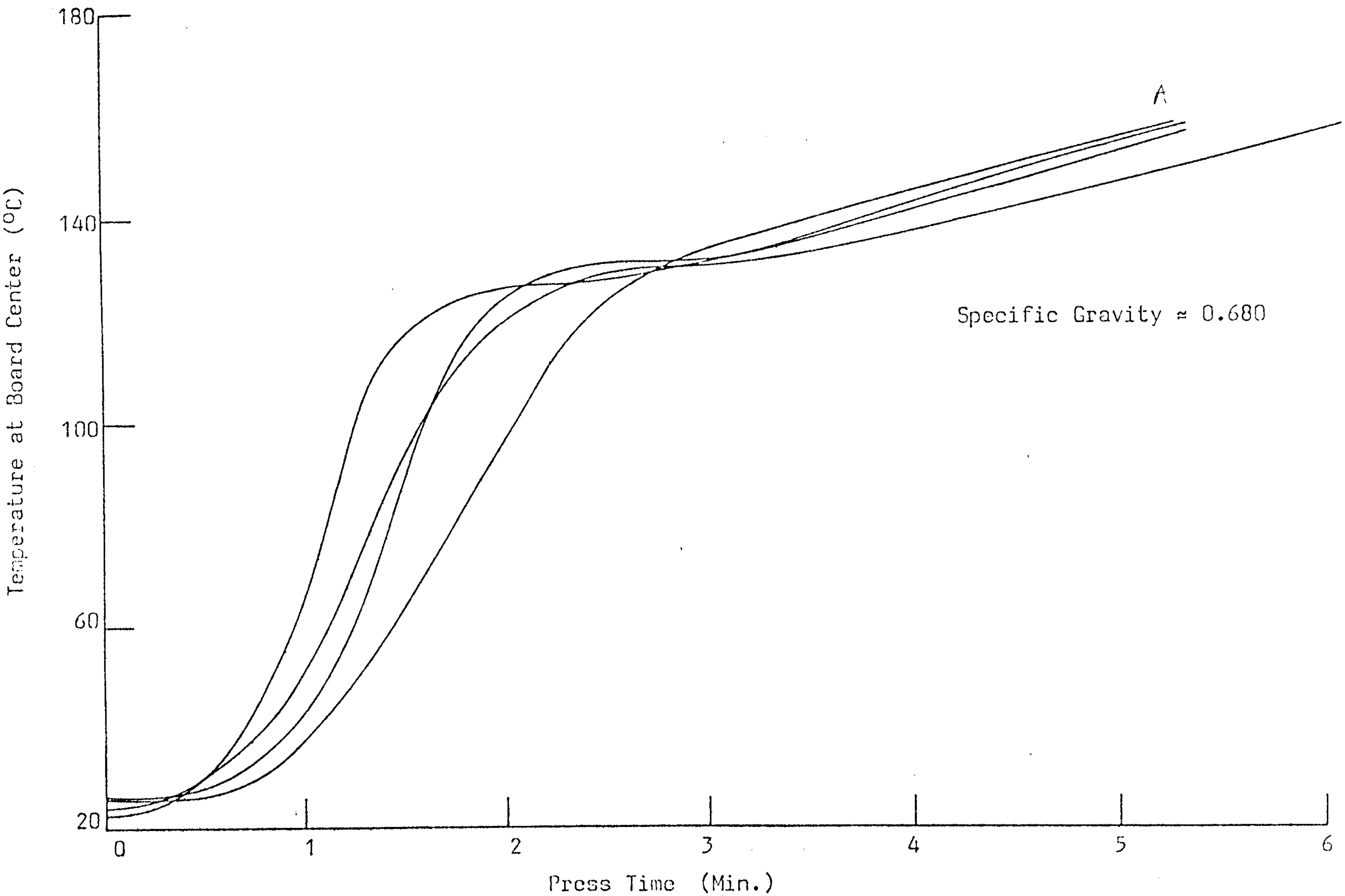

FIGURE 2. Temperature at board center versus press time clapsed.

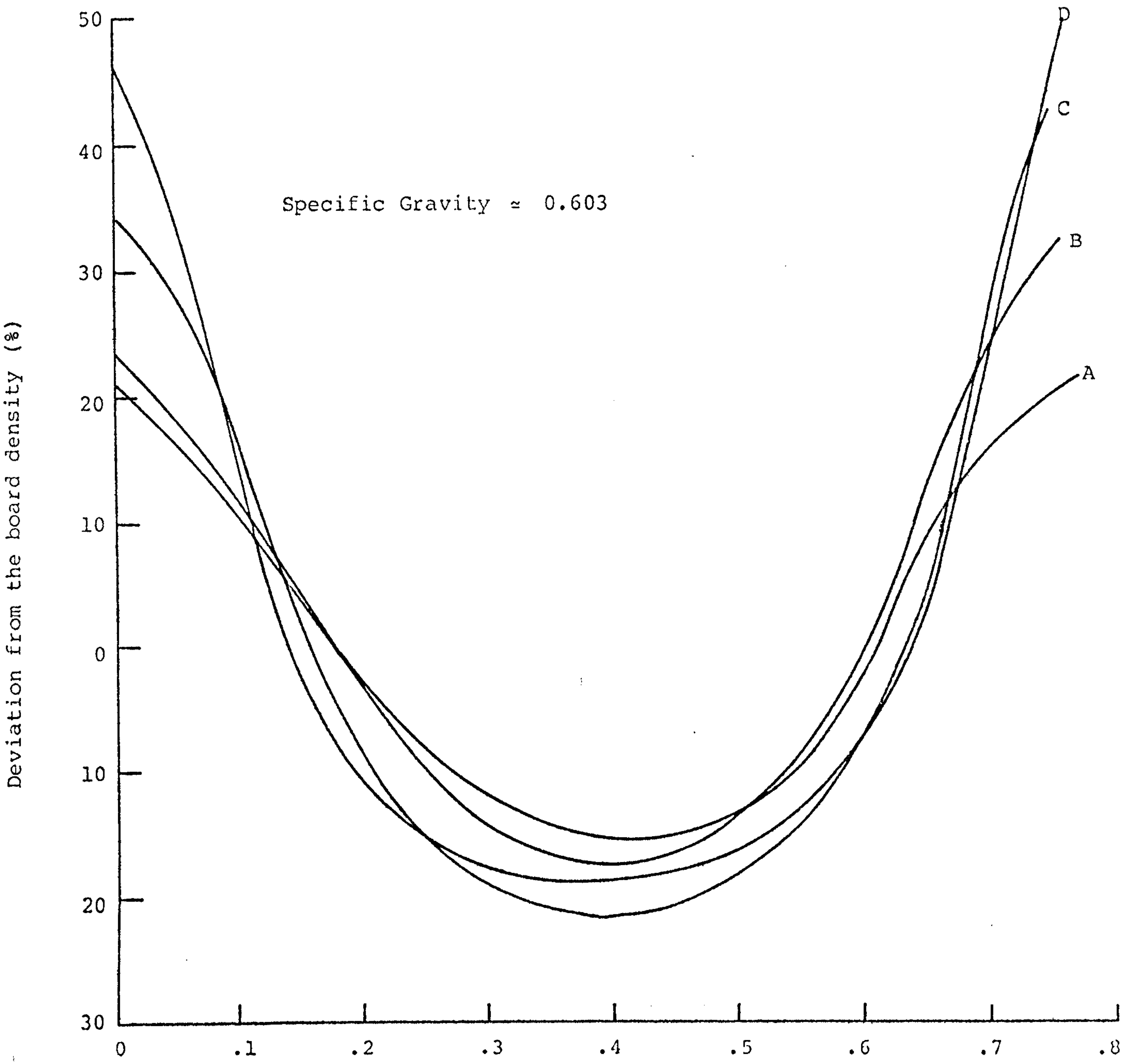

FIGURE 3. Density profile

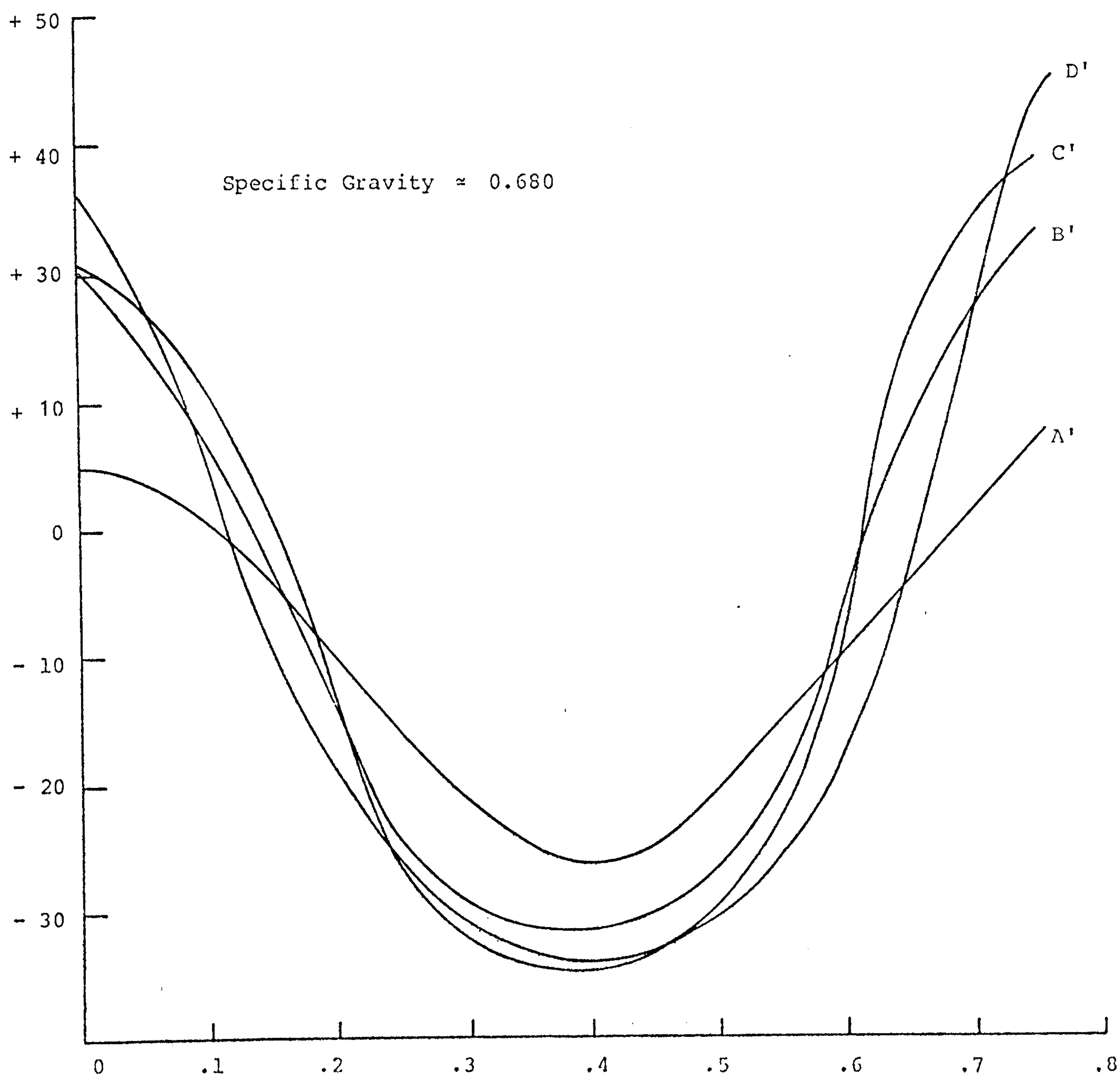

FIGURE 4. Density profile