Studies on the Particle Board

Report 4 ; Temperature and Moisture Distribution in Particle Board during Hot-pressing

Wood Physics, Section II

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This report is concerned with the temperature and moisture distribution in the direction of the thickness of particle board which consists respectively of granular and/or flakey particles.

I Experimental Procedure

1. Board preparation

The particle boards used in this experiment are divided into the following two types (Photo. 1) :

G-type : Made of granular particles (4～10 mm long, 1～5 mm wide and 0.1～2.0 mm thick) of KABA (*Betula Maximowicziana* Regel) and BUNA (*Fagus crenata* Blume), and is comparatively porous.

F-type : Made of flakey particles (8～15 mm long, 3～20 mm wide and 0.1～0.5 mm thick) of KABA and is relatively dense.

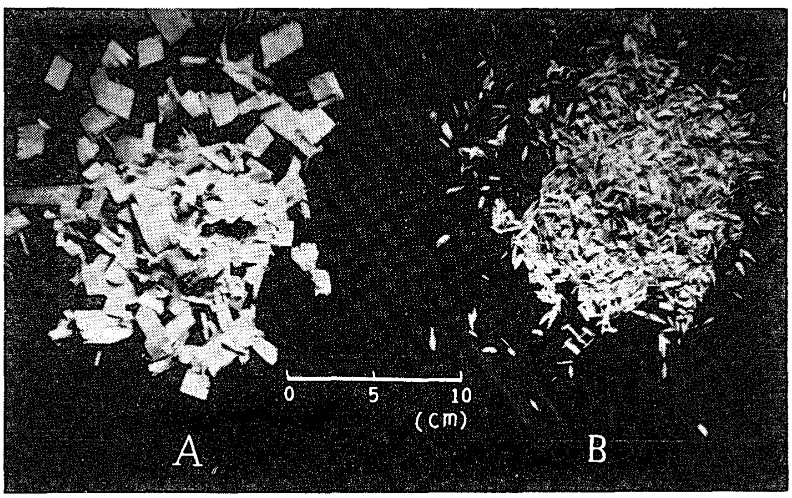

Photo. 1. Particles using in this experiment.
A : Flakey particles for F-type board.
B : Granular particles for G-type board.

The particles mentioned above were conditioned to definite moisture content by water spraying and then formed in a mat and hot-pressed into the board of 17×17×2 (thickness) cm. In these experiments, upper and lower hot-plates were regulated to keep the same temperature 135°C and no binders were applied for the conveniences.

2. Temperature measurement

The temperature was measured by means of Cu-Constantan thermocouples of 0.2 mm diameter, 10 mV-voltmeter and 6 points change-over switches. After soldering the junction the couples were inslated completely with the thin Japanese paper and phenol resin.

Total weight of particles prepared to get the predetermined specific gravity of board was divided into several equal parts. After sprinkling one of them to a mat, a thermo-couple was put on the center of it and then next part of particles was sprinkled and so forth. In a preliminary experiment the thickness of each above mentioned mat (layer) in board was considered to be proportional to its weight.

The measuring points of temperature are as shown in Fig. 1 and the error of the measurement was 2% at about 100°C. The measurement started just at that time when the material was put into hot-press, it, however, took about 20～40 seconds to compress the material to 20 mm thick.

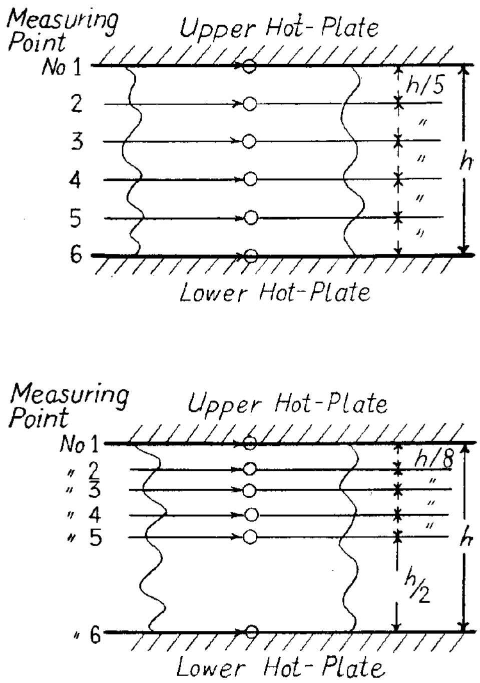

Fig. 1. Measurement of temperature.

3. Moisture measurement

Total weight of particles prepared to have a definite specific gravity, was divided into seven equal parts. They were sprinkled one after another to a mat in 17×17 cm forming-box, and during this process, fine strings were put on each mat as the marks (as shown in Fig. 2).

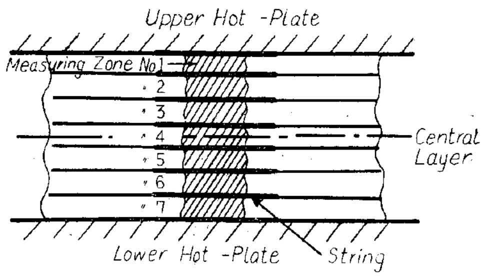

Fig. 2. Masurement of moisture content.

After hot-pressing, the board was taken out, and each layer of its central zone was quickly separated and put into weighing tubes for the moisture content determination.

II Experimental Results

1. Temperature distribution in the board

Generally, the temperature change of board in hot-pressing takes place in three directions, namely in horizontal and vertical directions, but in this experiment, the

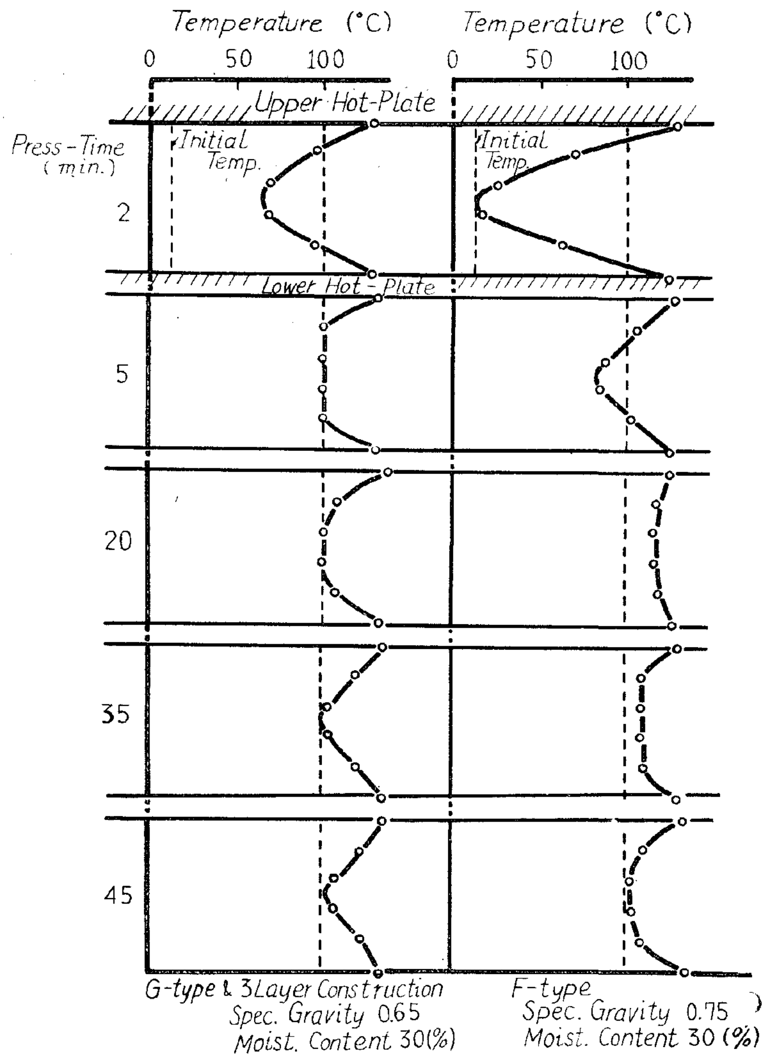

Fig. 3. Temperature distributions in boards.

authors fixed their eyes only upon the latter which is most important in practice.

The results on G-type, F-type and 3 layers construction board are shown in Fig. 3. In this figure, it is clearly shown that if the initial conditions—temperature of hot-plates, moisture distribution and others—are symmetrical about the central layer, the temperature distribution at any time can be considered to be, also, symmetrical about the central layer.

From the view point of the curing of the binder, it may be concluded that the most important layer must be the central layer whose temperature rises most slowly during hot-pressing. Therefore, in this report, the authors discuss mainly on the temperature of the central layer here-after.

2. Relation between the initial moisture content and the temperature behavior.

A) In the case where the initial moisture content is uniform

G-type :

Fig. 4 shows the results on G-type board of specific gravity 0.65 and 20 mm thick.

When the initial moisture content (moisture content of particle mat before hot-pressing) is about absolutely dry, the temperature behavior of central layer shows a characteristic curve of general heat conduction. But, when the initial moisture content is relatively high, the temperature of central layer maintains constant (about 100°C) for a while. And, the heigher the initial moisture content is, the longer the time of constant temperature is.

This can be explained as follows: As the moisture movement in such particle board as G-type is much easier than in wood, almost all of the heat transfered to the central layer are expended for the evaporation of water. Therefore, the material dries at a constant rate up to 10% moisture content. The drying rate then decreases suddenly and the temperature begins to rise again just as the same as in veneer drying.[1] (cf. Fig. 13, 15)

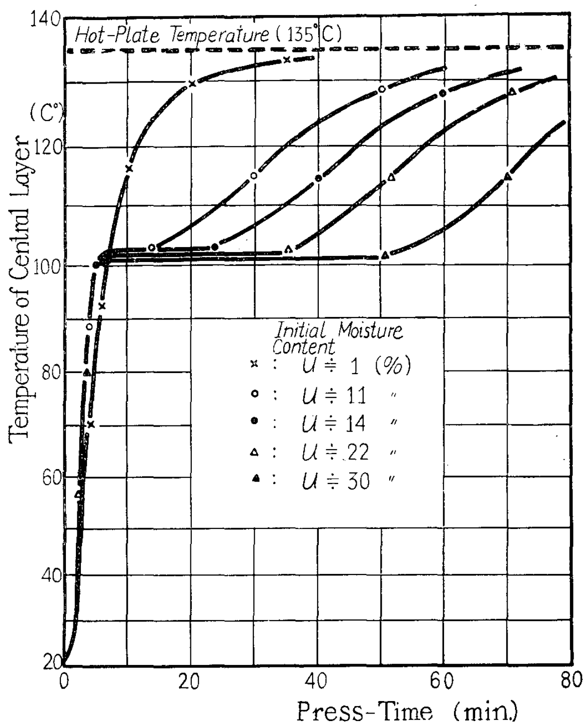

Fig. 4. Relation between initial moisture content and temperature behavior of central layer of board. (G-type, spec. gravity 0.65, board thickness 20 mm)

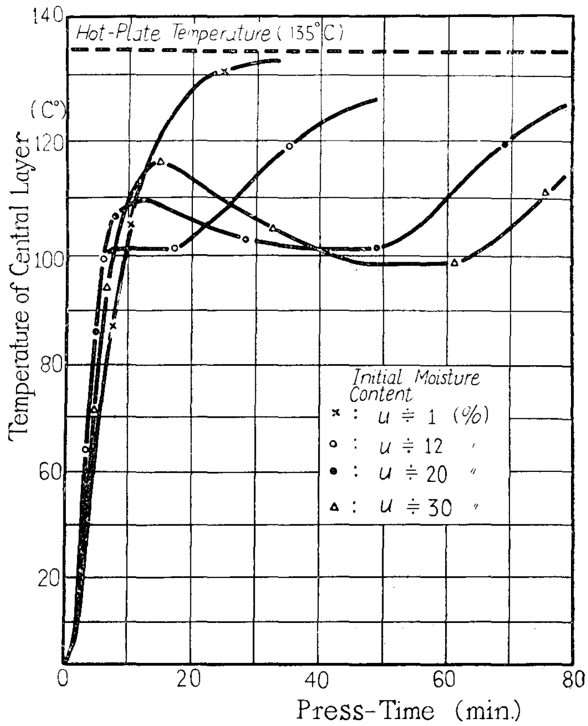

Fig. 5. Relation between initial moisture content and temperature behavior of central layer of board. (F-type, spec. gravity 0.75 board thickness 20 mm)

F-type

Fig. 5 shows the results on F-type board of specific gravity 0.75 and 20 mm thick.

In this figure, when the initial moisture content is nearly zero, the temperature behavior in the central layer shows a normal curve of heat conduction. When the initial moisture content is relatively high, however, the temperature of the central layer reaches a maximum point beyond 100°C at the early stage of hot-pressing, and the higher the initial moisture content is, the higher the value of the maximum temperature is.

These phenomena explain that the moisture movement in this case is not so

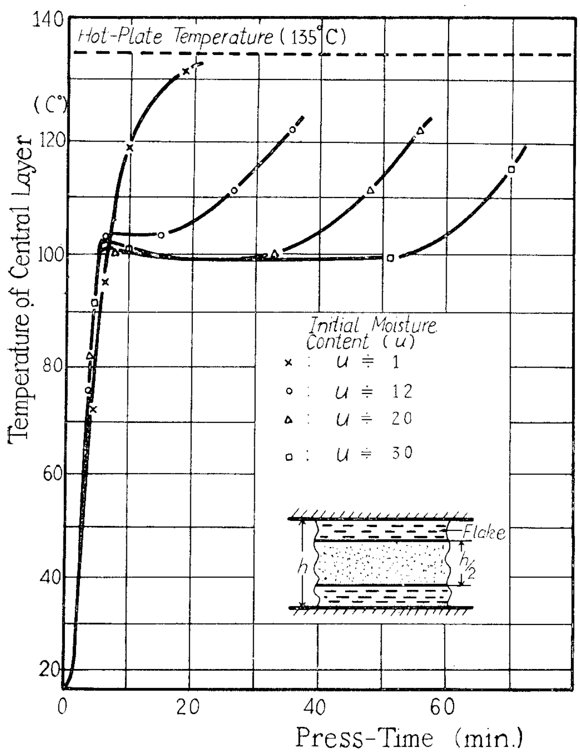

Fig. 6. Relation between initial moisture content and temperature behavior of central layer of board. (3 layer construction, spec. gravity 0.65, board thickness 20mm)

easy as in G-type, thus the evaporation overcomes the moisture movement in board and the boiling point of water rises with the increase of inner vapour pressure. As the moisture content decreases, the rate of drying falls down and the boiling point consequently decreases. In the latter stage of drying, in accordance with decrease of the moisture content, the temperature begins to rise again in the same manner as in the case of G-type.

Three layer construction :

Fig. 6 shows the result on three layer construction's board of specific gravity 0.65, and thickness ratio 1 : 2 : 1 (face and back are F-type and core G-type) This result seems to be similar to that of G-type except a slight rise of boiling point.

B) In the case where the initial moisture content of face and back layer differs from that of core.

In above paragraph, observation has been done on such a case as the initial moisture content of particle mat was uniform. In commercial productions, however, there are often such cases as the initial moisture content of face and back layer differ from that of core layer—the moisture content of face layer is higher than that of core layer, or water is sprayed on the cauls befor mat forming.

These operations increase the apparent thermal diffusivity of face layer and are consequently great aid to shorten the press-cycle.

In the heating of a material in which the diffusion of vapour is comparatively easy and in which there exist a certain amount of moisture (not saturated with water) and tolerable pores for free vapour-movement, it will be considered that the high temperature vapour produced in face layer diffuses into the inner layer of lower temperature because of impossibility of the surface-evaporation, therefore, the heat conduction is accelerated and the apparent thermal diffusivility is considerably increased (for example, in the case of hot-pressing or steaming of wood in the fiber direction[2]). The forming method mentioned above is an application of this phenomenon.

Now, in order to observe this effect, the authors carried out the following experiments ; namely, four kinds of board which have the same mean moisture content of 23% but different moisture distributions before hot-pressing, were hot-pressed and the temperature behaviors of their central layers were measured.

The obtained results are shown in Fig. 7. In this figure it is clear that even if the materials are prepared to the same mean moisture content, their temperature behaviors are greatly influenced by their initial moisture distributions. That is, the higher the moisture content of the face layer is, the more the thermal diffusion is hastened and consequenlty the temperature rising and drying of the central layer are accelerated, thus the press-cycle can be shortened remarkably.

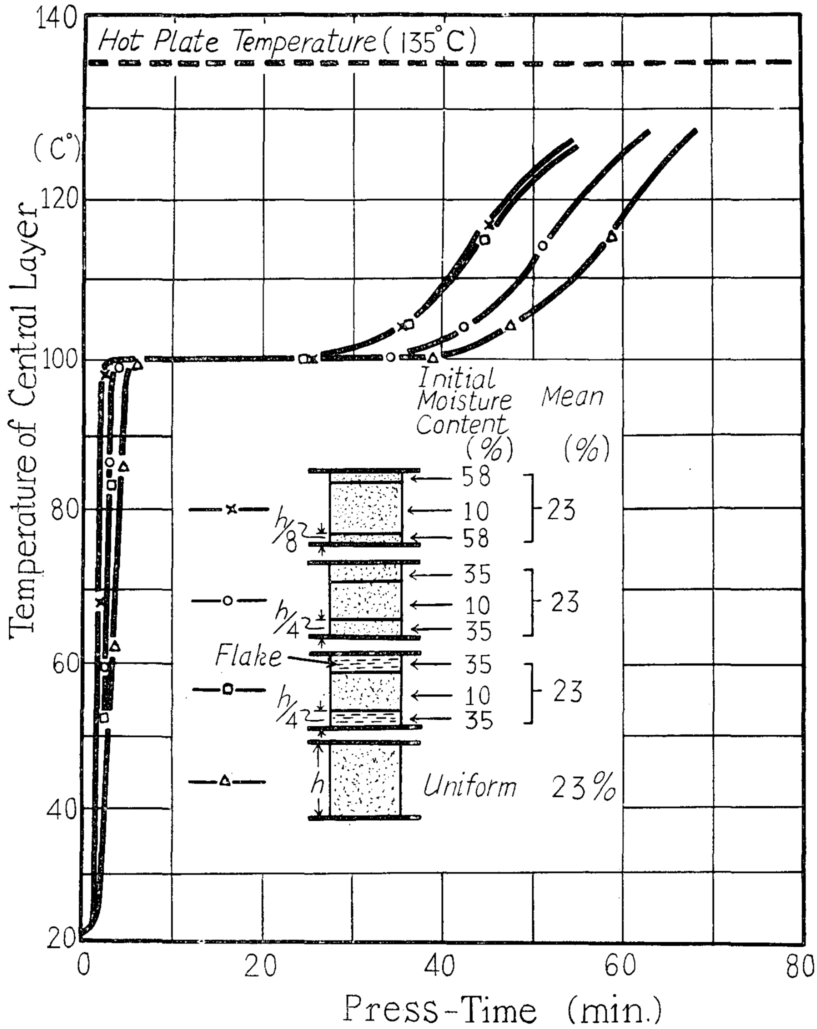

Fig. 7. Relation between initial moisture disturibution and temperature behavior of central layer of board. (G-type and 3 layer constr., spec. grav. 0.65, board thickness 20 mm)

3. Relations between the thickness ratio of three layer construction and the temperature bahavior.

The results on a 3 layer construction board of thickness ratio 1 : 2 : 1 (face : core : back) was previously shown in the article II-2-A. And in this article, the authors discuss on the influence of the thickness ratio on the temperature behavior in their central layer.

As it is clearly shown in Fig. 8, the thicker the core layer is, the more the

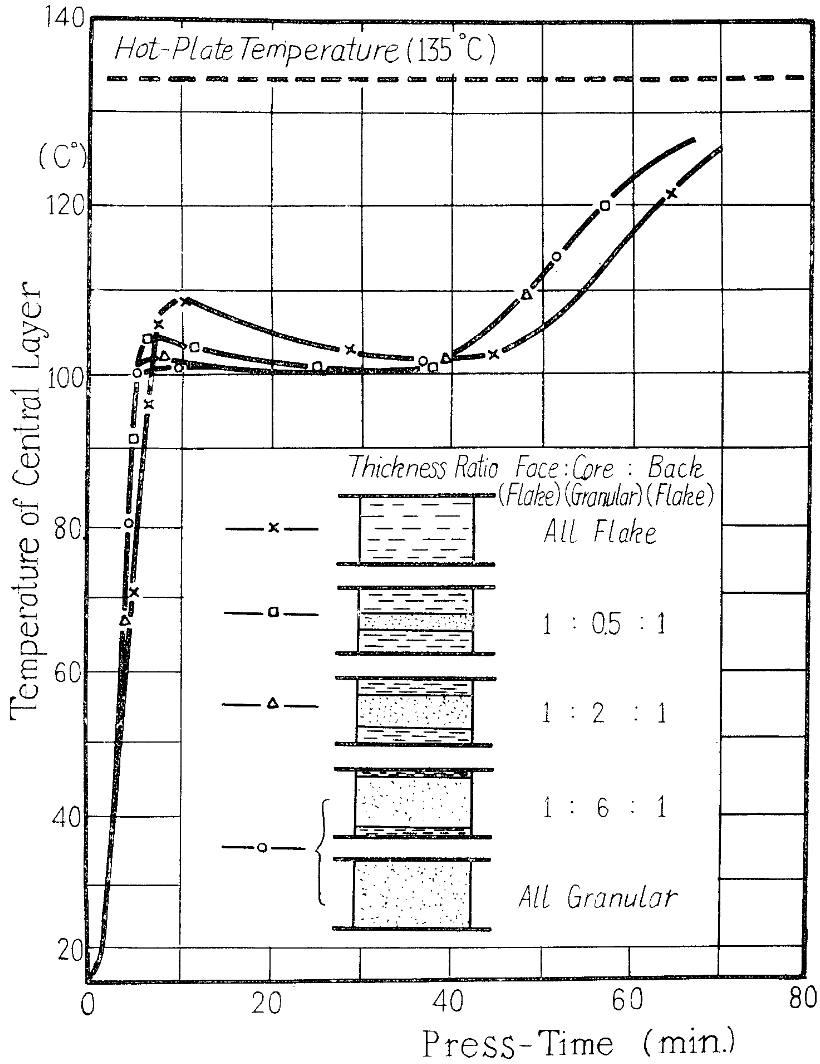

Fig. 8. Relation between thickness ratio and temperature behavior of central layer of 3 layer construction board. (spec. gravity 0.65, board thickness 20 mm, moisture content : face = core = 25%)

maximum point of temperature of the central layer decreases, and for the thickness of the face layer less than h/8 (h = total thickness = 20 mm), the temperature of the central layer becomes to show the same behavior as in G-type.

4. Relation between specific gravity of board and the inner temperature

A) G-type

The relations between specific gravity of G-type and the temperature behavior in the central layer are shown in Fig. 9. The boards were prepared to the same initial moisture content 22% and to the same thickness 20 mm, but their specific gravities were respectively varied to 0.4, 0.65 and 0.85.

It is known from this figure that the temperature behavior is not influenced generally by the difference of specific gravity except a slight rising of boiling point in high density.

This means that, in G-type boards, the drying rates are proportional to their specific gravities and this will be reasonable from the fact that the relation between the ratio w/γ (w : weight of evaporated water, γ : specific gravity) and pressing time is shown as a linear irrespective of their specific gravities (ref. Fig. 12).

B) F-type

The obtained result is shown in Fig. 10. In this figure it is recognized that the result here obtained is fairly similar to that of II-2-A (Fig. 5).

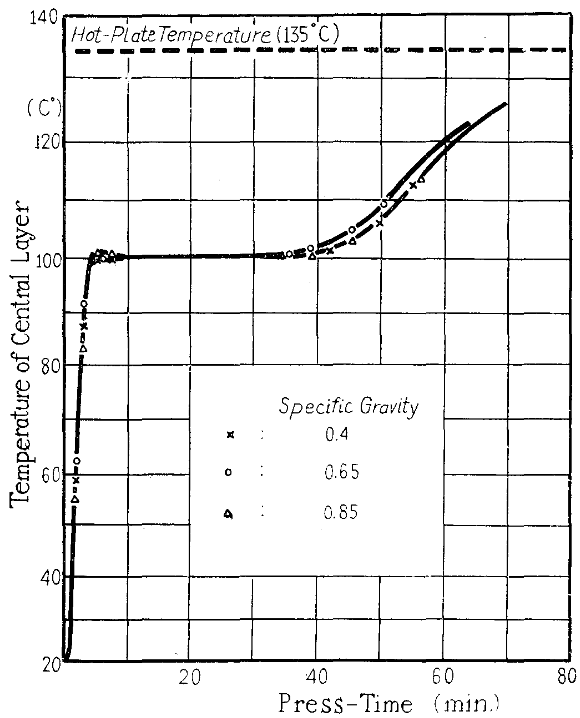

Fig. 9. Relation between specific gravity and temperature behavior of central layer of board. (G-type, moist. content 22 %, board thickness 20 mm).

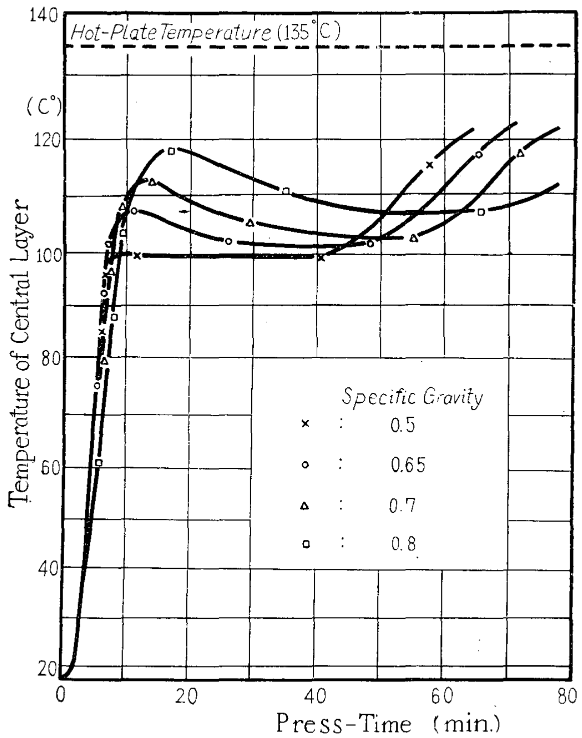

Fig. 10. Relation between specific gravity and temperature behavior of central layer of board. (F-type, moist. content 25 %, board thickness 20 mm).

5. Relation between the hot-plate temperature and the temperature behavior of board

The temperature behaviors in the central layer of G-type board in hot-pressing at 115°, 135°, 160° and 180°C, are shown in Fig. 11.

It is, of course, known that the temperature rising and the drying of the central layer can be accelerated by higher temperature and the press-cycle can consequently be shortened.

6. The characteristics of drying of board

Fig. 12 shows the characteristics of drying, in hot-pressing, of

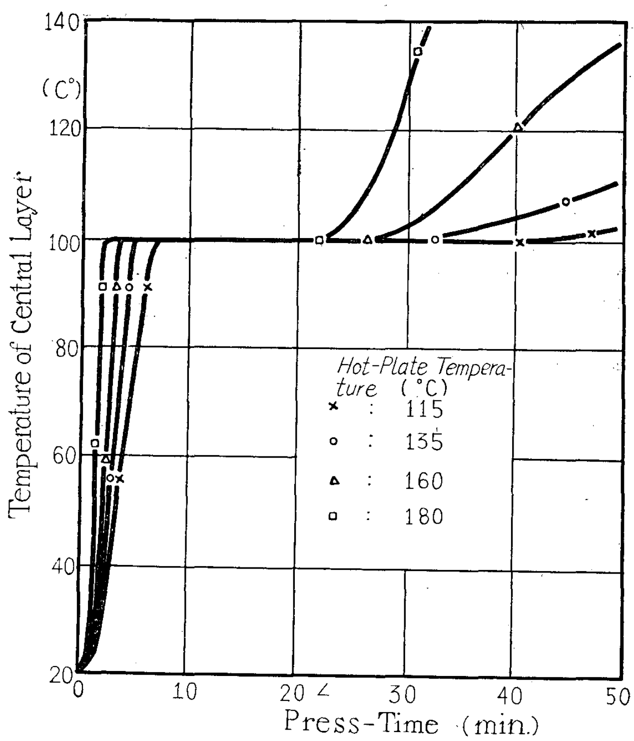

Fig. 11. Relation between hot-plate temperature and temperature behavior of central layer of board. (G-type, spec. gravity 0.65, moist. content 20%, board thickness 20 mm)

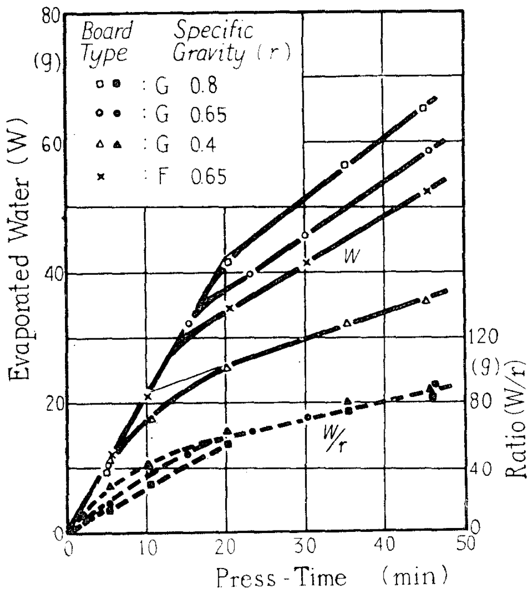

Fig. 12. Characteristics of drying of board. (initial moist. cont. 21∼22%, board thickness 20 mm)

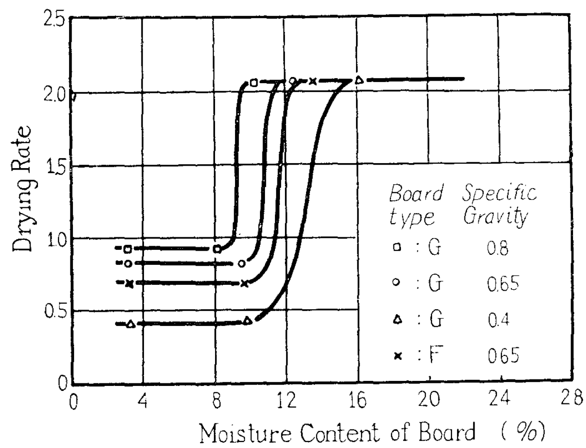

Fig. 13. Moisture content-drying rate diagram. (initial moist. cont. 21∼22%, board thickness 20 mm)

boards of initial moisture content 21∼22 %, and of specific gravity 0.4, 0.65 and 0.8 in G-type and 0.65 in F-type. From this figure it is understood that the drying is represented by two constant rate of drying and the former has no relation to the specific gravity but the latter is greatly affected by the specific gravities and the types of board.

Fig. 13 is the moisture-drying rate diagram obtained from Fig. 12. As obvious from the figure, the lighter the density is, the smaller the drying rate of the second zone and the longer the transition period from first drying rate to second one is, and the critical moisture content is higher in lower density.

The pressing time of 20 mm thick board may be about 20 minutes or so, and the typical specific gravity of the board made of Buna or Kaba particles may be 0.65 or so, therefore, from the view of commercial stand point only the first drying stage takes place of drying in practice.

7. Moisture disfribution in the board

In this article, also, the authors made the investigation only in unidirection which may be more important.

Fig. 14 shows the moisture distribution in drying of G-type (A), F-type (B) and three layer construction board (C). From figures it can be seen that the moisture distribution is always symmetrical about the central layer if the initial conditions are uniform or symmelrical about the mid-plane, and, moreover, from (A), (C), in the first period of hot-pressing there is remarkable moisture movement from face to core, but on the other hand, such kind of movement seems to be very slight in (B).

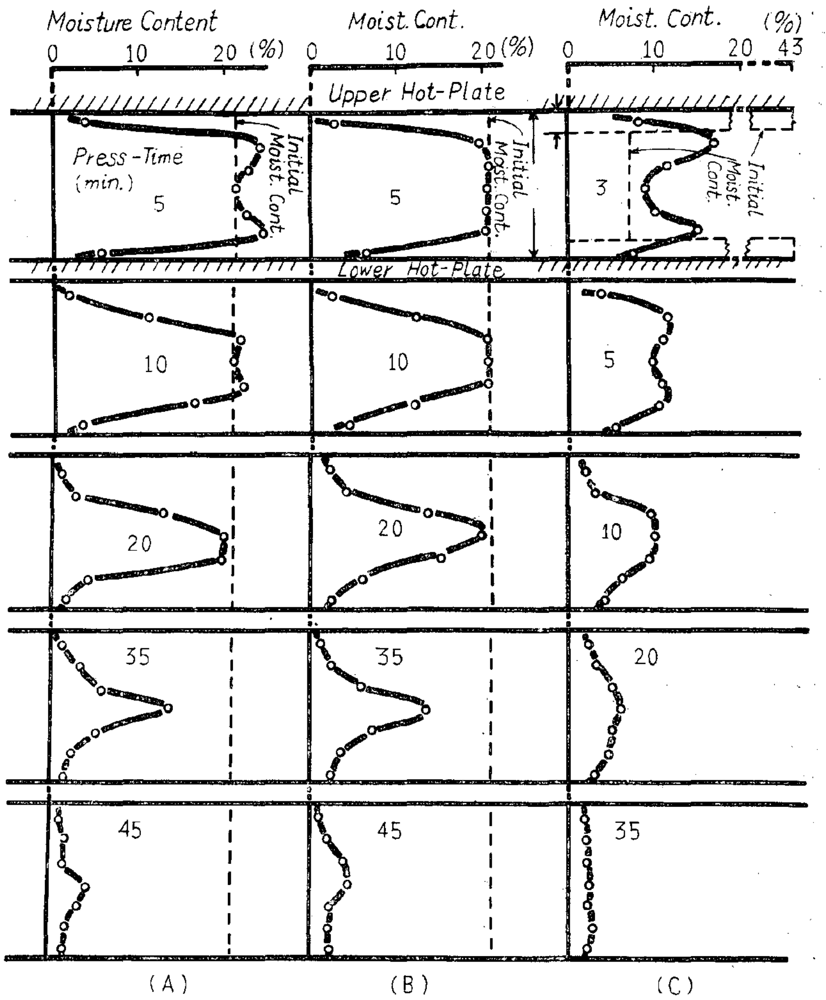

Fig. 14. Moisture distribution in board (20 mm thick)
A : G-type, spec. grav. 0.8, initial moist. cont. 21%.
B : F-type, spec. grav. 0.65, initial moist. cont. 21%.
C : 3 layer construction, spec. grav. 0.65, average moist. cont. 17.3%—face (flake) 43%, core (granular) 7%.

In case of G-type or three layer construction the wave-like moisture movement from face to core first takes place and then, in the central layer, the horizontal movement occurs from the center to edge. In F-type, on the contrary, it seems that the vartical moisture movement is very slight and the horizontal one mainly takes place.

Fig. 15 shows the moisture and the temperature behaviors of G-type together. And Fig. 16 shows, for comparison, the moisture and temperature distributions in several intervals of hot-pressing. From these figures it can be recognized that when the moisture content reaches to about 10%, the temperature of this layer begins to rise again beyond the boiling point and that this grade of moisture content exists in the transition period of first and second drying rate as a critical point.

III Summary

1) The moisture and temperature distributions in cross section of board in hot-pressing are symmetrical about the central layer, if the initial conditions are symmetrical or uniform

2) The temperature of the central layer of G-type (good ventilative) stays for a while at about 100°C, then it begins to rise again at about 10% moisture content.

And the higher the initial moisture content is, the longer the time staying at 100°C is. On the contrary, in F-type (not ventilative) the temperature of the central layer reaches a maximum point beyond 100°C at the early stage of pressing, then it gradually falls down to about 100°C and begins to rise again at about 10% moisture content. And the higher the initial moisture content is, the higher the maximum point of temperature is.

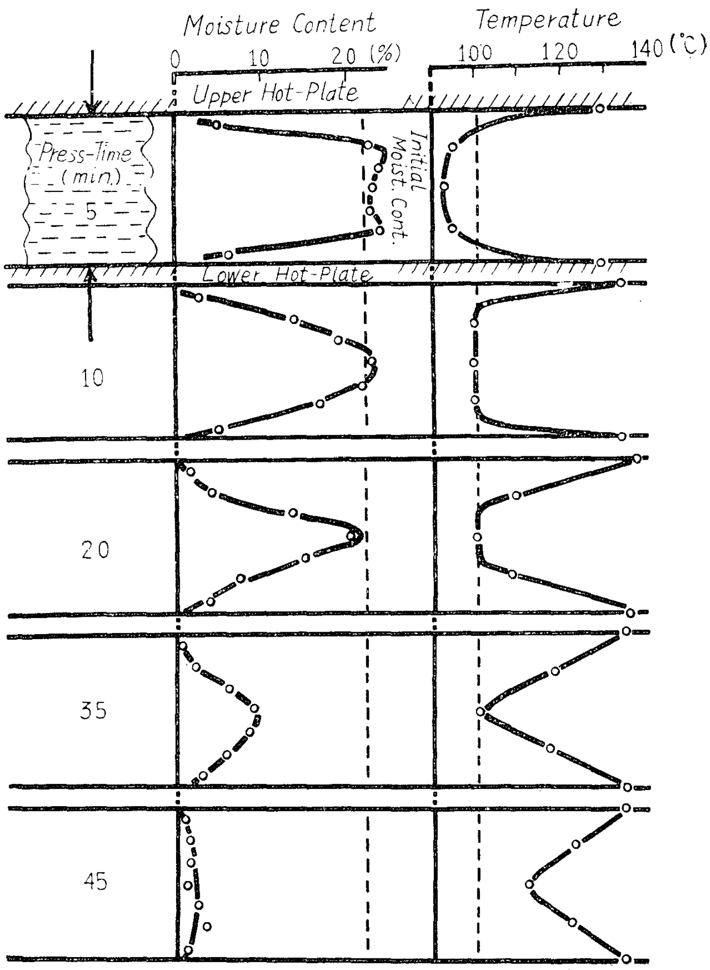

Fig. 16. Moisture and temperature distribution. (G-type, specific gravity 0.65, initial moisture content 22%, board thickness 20 mm)

The relation between the temperature behavior of three layer construction board and its initial moisture content is similar to that of G-type.

3) The temperature of the central layer of the board whose initial moisture distribution is higher in the face, rises faster than that of uniformly distributed one.

4) The temperature behavior of three layer construction (face : F-type, core : G-type) is similar to that of G-type board if the thickness of face is one-eighth or less of thickness of board.

5) The temperature behavior of G-type may not be influenced by density, but in F-type, the temperature of the central layer reaches generally a maximum point beyond 100°C, and the higher the density is, the more the maximum point appears highly and lately.

6) The drying of particle board is represented by two constant drying rates, the first one has no relation with the specific gravity but the second one varies greatly with specific gravity, and at about 10% moisture content there exists the transition period of two drying rate above mentioned.

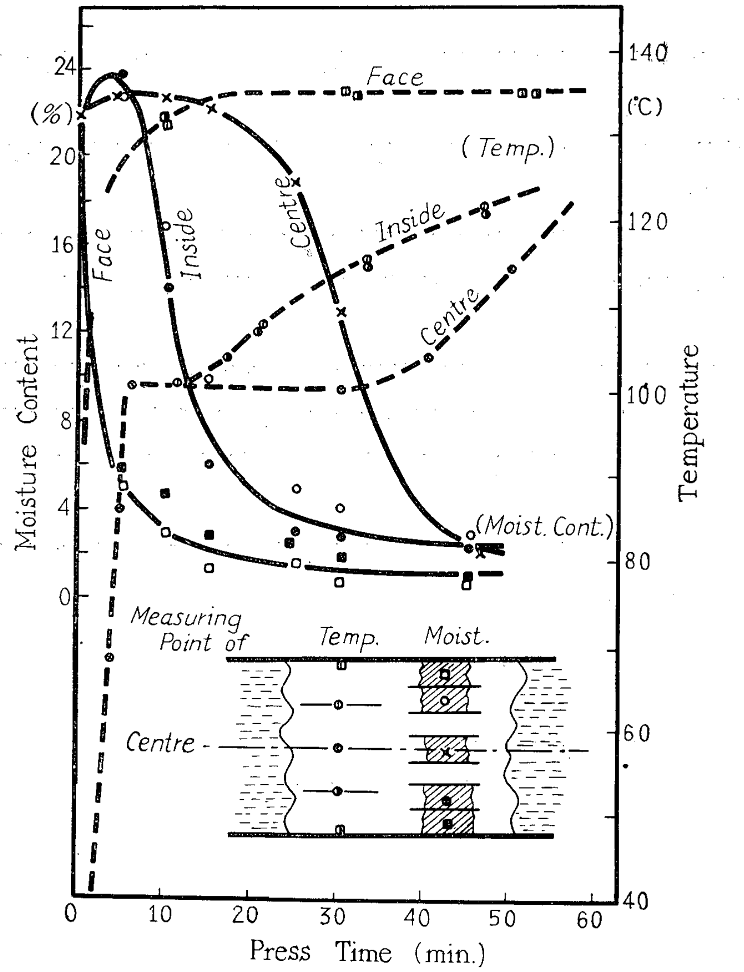

Fig. 15. Moisture and temperature behavior in board. (G-type, spec. grav. 0.65, initial moisture content 22%, board thickness 20 mm)

7) In the first period of hot-pressing of G-type, the remarkable moisture movement from the face to the central layer takes place, but in F-type such a movement is negligiblly slight.

Ⅳ 摘　要

本報告はGタイプ（巾1～5，長さ4～10，厚さ 0.1～2.0 mm のカバ，ブナ混在の粒状パーティクルで作つた板で比較的通気性に富む）Fタイプ（巾3～20，長8～15，厚 0.1～0.5 mm のカバの削片で作つた板で比較的通気が困難である）及び三層構造（表層がFタイプ，芯層がGタイプ）のパーティクル・ボードについて，それ等を熱圧する際の厚さ方向に於ける温度上昇経過並びに水分々布について考察したものである。

温度の測定は Fig. 1 の位置に銅—コンスタンタン熱電対を挿入して行つた，又水分の測定は Fig. 2 の如く各層間に目印をつけておいて熱圧中にとり出して各層の含水率を絶乾法で測定した。

実験結果を要約すると下記の如くである。

1) 熱圧中のパーティクルボードの厚さ方向の水分々布並びに温度分布は，若し他の条件がその中心層に関して対称であればこれ等も亦対称である (Fig. 3, 14, 16)。

2) 通気性のよいGタイプでは熱圧中，中心層の温度が或る期間約 100°C を保ち，含水率10%附近になると次第に上昇し (Fig. 15, 16) 熱板温度へ近づく。この際初期含水率の高いもの程 100°C にとどまる時間が長い (Fig. 14)。

通気性の悪いFタイプでは圧縮初期に 100°C 以上で極大温度に達し，以後漸次 100°C 附近まで降下する，そして含水率が大略10%附近まで乾燥されると温度は再び上昇し始める。

この温度の極大値は含水率の高いもの程高い (Fig. 5) 構成比1：2：1（表層：芯層：裏層の厚さの比）の三層構造に於ける水分と中心温度の関係はGタイプの場合と略々等しい

(Fig. 6)。

3） 表層を高含水率にした場合の中心層の温度上昇は同じ平均含水率をもつた均一な含水率分布をなす場合に比してはるかに早い(Fig. 7)。

4） 三層構造（比重0.65）で構成比が1：6：1或はそれ以上に表層がうすくなると，Gタイプと全く等しい温度経過を示す(Fig. 8)。

5） Gタイプでは比重の如何にかかわらず温度経過はほぼ同様であるが（Fig. 9） Fタイプでは比重の特に低いもの以外は100°C以上に於いて或る極大値をとり，高比重程この極大値が高く且つおそく現われる(Fig. 10)。

6） Gタイプ，Fタイプ共その乾燥速度曲線は2つの恒率乾燥により示され，第1段恒率乾燥速度は比重及びボードのタイプの如何にかかわらず略々同一であるが，第2段恒率乾燥は比重の小さいもの程低い。第1段から第2段への過渡現象は大体含水率10%を中心として急激におこる（Fig. 12, 13)。

7） Gタイプでは熱圧初期に於いて表層から内層へと顕著な水分移動を生ずるが，Fタイプではこの移動はほとんど起らない（Fig. 14)。

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