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METHOD OF FORMING COMPRESSED WOOD STRUCTURES

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This application is made under the act of March 3, 1883, as amended by the act of April 30, 1928, and the invention herein described, if patented, may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment to us of any royalty thereon.

We hereby dedicate the invention herein described to the free use of the people in the territory of the United States to take effect on the granting of a patent to us.

This invention relates to compressed wood, and has among its objects a method of compressing wood in such a manner that the lignin-cementing material between the fibers of the wood will flow sufficiently to relieve the internal stresses created by the compression, thus to stabilize the wood against recovery from compression when it is subjected to moisture; a method of compressing wood without the use of impregnating resins, yet obtaining a finished product equal or superior to most resin-impregnated compressed woods both in strength and low water absorption; and such other objects as will be apparent from the following description and claims.

According to the prior art, one form of so-called densified wood structure is made by compressing a plurality of sheets of veneer or plies having a moisture content normally ranging between 4 percent to 8 percent, and which have been coated with a suitable spreading glue, or interleaved with a suitable film glue, under adequate pressure to obtain the desired compression and adequate temperature to set the glue, but not exceeding 320° F.

Under these conditions, stresses are set up during compressing that persist within the wood without causing instability as long as the wood is kept dry. However, when it is dipped in water or exposed to high relative humidities for appreciable lengths of time, the wood not only swells but the internal stresses are also relieved, whereby the wood recovers to a considerable extent from its state of compression.

Solid wood structures compressed under corresponding conditions act similarly. In some instances solid wood has been compressed at appreciably higher moisture content than in the case of the laminated structure. This has been done to take advantage of the softening action of water on wood, thus making it possible to compress the wood at somewhat lower pressures. However, in this case temperatures over 300° F. have been avoided to prevent excessive drying during the compressing step.

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At temperatures of from 300° F. to 320° F., or lower, even in the presence of considerable moisture, we have found that there is no tendency for the lignin-cementing material between the wood fibers to flow, and, consequently, there is little if any stabilization of the wood against recovery from compression, but that if wood at 6 percent to 15 percent moisture content (on the basis of the oven-dry weight of the wood) is compressed at about 330° F. or higher for a minimum time of from 3 to 50 minutes (the higher the moisture content the lower the required temperature and lower the required minimum time), under conditions to minimize moisture loss, the lignin of the wood flows sufficiently to reduce the internal stresses and continues to act as a binding agent in the absence of impregnating resins, whereby the tendency of the wood to lose its compression when wetted is almost completely eliminated, when wood is compressed to a specific gravity of about from 1.3 to 1.4 (substantially completely compressed).

Pressing at a sufficiently high temperature is the primary consideration. The temperature can, however, be lowered somewhat by increasing either the moisture content or the time the wood is held at the elevated temperature, or by increasing both the moisture and time, stabilization derived from the increased moisture content following from the fact that the water acts as a plasticizer for lignin, and stabilization derived from increased time following from the increased extent of lignin flow.

The maximum safe temperature from the standpoint of the strength properties of the finished product is about 360° F., whereas dropping the temperature appreciably below 330° F. gives inadequate stabilization, even when the moisture content of the wood is high and the time of maintaining the temperature is long. For this reason, the preferable temperature according to this invention is about from 330° F. to 360° F.

Although a high moisture content in the wood aids lignin flow and increases the plasticity of the wood as a whole, to have a moisture content much above 15 percent (on the basis of the dry weight of the wood) is not desirable, since excessive moisture requires excessive heat energy to raise the temperature of the wood to the required point, increases the chances of blistering or checking of a panel upon the release of compressing pressure, increases difficulty in properly bonding plies in case of a laminated structure, and gives a finished product which tends to lose moisture content and shrink with time, because

the moisture content is well above equilibrium values relative to normal atmospheric conditions. Preferably, therefore, the moisture content should not be above 15 per cent, about from 6 percent to 15 per cent being a permissible range, and 9 percent to 12 percent being preferred, as this corresponds to equilibrium values relative to normal atmospheric conditions.

When the temperature of wood is raised to from 340° F. to 360° F., the vapor pressure of water in the wood raises to from 100 pounds to 160 pounds per square inch. Normally this results in excessive drying especially from the end grains of the wood, especially when the ends are exposed as in the case with the usual flat, hot platen press, with consequent lack of stability at the ends of the panels. However, we have also found that by taking proper precautions of sealing the moisture-containing wood, as described below, undue loss of water from the wood at the high temperature we employ in the subsequent heating step is prevented.

Instead of immediately raising the temperature and pressure to optimum values, full compressing pressure is first applied to the structure, either an assembly of plies, preconditioned to the desired moisture content and to which glue has been applied, or a preconditioned solid board, followed by initially raising the temperature to about from 210° F. to 240° F. (resulting in a vapor pressure of from 0 to 10 pounds per square inch, under full mechanical pressure, and this temperature is maintained until the wood is substantially completely compressed. This results in the moisture tending to be sealed in the structure as a result of the compression before the vapor pressure is built up to a high value. When the temperature is subsequently raised while maintaining the pressure, the loss of moisture from the end grains is materially reduced. Consequently, stabilization extends nearer to the ends of the specimen.

A second aid in preventing drying at the ends in case of a laminated structure is obtained by cutting the two face plies about ¼ inch shorter in the fiber direction than the other plies of the assembly and laying up the assembly for pressing with the face plies ½ inch shorter at each end than the other plies. This causes the plies adjacent the face plies to spread over the end-grain ends of the face plies when the assembly is compressed, and as a result seals off the end-grain capillaries of the face plies. Because of the longer interval of heating and higher average temperature of the face plies during the compressing stage of the process, they are more subject to moisture loss than the rest of the assembly. It is desirable, therefore, to follow this procedure in combination with the first-mentioned procedure in making a laminated structure.

A third aid in cutting down moisture loss at the ends of the structure, which is effective both for laminated and solid wood structures, is obtained by applying strips of sealing material, such as thermosetting glue, about ½ inch wide, to the surfaces of the structure along the end-grain ends. When the veneer assembly or solid board structure is compressed, this sealing material rapidly sets sufficiently to seal any capillaries formed between the wood and the flat platens or cauls of the press which are in contact with the structure, thus sealing in water vapor between the platens and the structure.

A fourth aid, which is effective over the entire cross-section of both veneer assemblies and solid

board structures, is obtained by dipping the ends of the veneer sheets or of the boards into a suitable penetrating and sealing material to impregnate the ends therewith. A water-soluble phenol formaldehyde treating resinoid diluted with water to a solid content of 30 percent to 40 percent is satisfactory for this purpose. The end grain of the wood should be dipped about ½ inch deep into the resinoid solution and allowed to soak for from 5 to 30 minutes, depending on the thickness of the ply or board. In the case of a veneer structure, the face take-up of the treating resinoid and the accompanying swelling are excessive. For this reason, it is preferred that first the bonding resin be applied to the surfaces of the plies and that they then be allowed to dry for one-half hour or more prior to dipping in the resinoid solution. The veneer boards so dipped may then be reconditioned to the desired moisture content before pressing. When the veneer assembly or board structure is then compressed, the treating resinoid in the end-grain structure of the wood is sufficiently cured to block the end-grain loss of moisture before the temperature is raised in the second stage of the process.

The fourth aid serves also as a means of sealing the capillaries between the structure and the platens or cauls, in the same manner as is accomplished by the third-mentioned procedure.

It is preferable that either the third or the fourth-mentioned procedure be combined with the first and second in making stabilized compressed wood from veneer, and that either the third or fourth be combined with the first in making stabilized compressed wood from solid boards.

The wood becomes considerably darker in color when compressed according to this process. Any loss of moisture from the end grains tends to reduce the moisture content near the ends of the panel resulting in insufficient stabilization at the ends. This results in light-colored ends that lose their compression, not only when immersed in water, but also when exposed to high relative humidities. For all exacting uses, it is important, therefore, to trim away the unstabilized ends, but with the process herein disclosed, only a very short section need be trimmed away to obtain a fully stabilized, uniformly colored panel.

Following compression, the wood structure should be maintained under pressure and cooled to a temperature of about 200° F. or lower before removal from the press.

Any hot-setting synthetic resin-spreading glue or film glue can be used between the plies in the practice of this invention. Although less water-resistant glues can be used, ordinarily there would be no object in making a product with dimensionally stable plies if the bond between the plies is not water-resistant, since, when used in places subjected to moisture where a stabilized structure is desirable, delamination may occur with non-water-resistant glues.

It has also been shown that in this process the compressed wood can be made up of veneer plies of any thickness and almost any species laid up in either a parallel-laminated or cross-banded manner. Since the glue lines between plies contribute a negligible amount to the stability of the product, it is desirable to use as thick plies as possible, resulting in a substantial saving of glue.

It has also been demonstrated that the process can be applied to non-laminated panels, using solid boards 1 inch to 2 inches in thickness, if desired.

Panels made according to this invention can be glued to each other or to ordinary wood more readily than can resin-treated compressed wood. Good joints can be obtained with all of the hot and cold setting synthetic resin glues thus far tested.

The following examples will further illustrate this invention and the manner in which it may be practiced.

Example I

Plies having a moisture content of substantially 9 percent (on the basis of the dry weight of the wood), so cut that the two face plies were about $\frac{1}{4}$ inch shorter in the fiber direction than the other plies of the assembly, were coated with a hot-setting phenolic glue and air-dried for about $\frac{1}{2}$ hour. The ends of the plies were then immersed for about 5 minutes to 10 minutes in a water-soluble phenol formaldehyde treating resinoid, diluted to a solid content of from 30 percent to 40 percent, to a depth of about $\frac{1}{2}$ inch. The plies were then conditioned to 9 percent moisture and were assembled in a suitable hot press in a parallel laminated or cross-banded fashion, so that the face plies were $\frac{1}{8}$ inch shorter at each end than the rest of the assembly. Full compression necessary finally to compress the wood to a specific gravity of 1.3 to 1.4 (1200 to 2000 pounds per square inch, depending upon the species) was applied and the press platens were heated to raise the temperature at the center of the assembly to about 220° F., this temperature being held until the compression was substantially complete. The temperature was then raised to give 350° F. at the center of the assembly while maintaining the pressure and was held at this point for 15 to 20 minutes for a 0.5 inch thick product. Finally, the assembly was cooled to below 200° F., the pressure released and the product removed from the press.

Example II

A solid board at a moisture content of substantially 9 percent (on the basis of the dry weight of the wood) was face-coated with a $\frac{1}{2}$ inch wide strip of phenolic bonding glue along the end-grain edges, and was conditioned to 9 percent moisture content. The full compression necessary finally to compress the wood to a specific gravity of 1.3 to 1.4 (1200 pounds to 2000 pounds per square inch, depending on the species) was applied in a suitable hot press having flat platens in contact with the board and the platens were heated to raise the temperature at the center of the board to about 220° F., this temperature being held until the compression was substantially complete. The temperature was then raised to give 350° F. at the center of the board while maintaining the pressure, and was held at this point for from 15 to 20 minutes for a 0.5 inch thick product. Finally, the structure was cooled to below 200° F., the pressure released and the product removed from the press.

The following table exhibits relationships of moisture content, temperature and time recommended for obtaining maximum stability in making a 0.5 inch thick stabilized compressed wood structure. Quite satisfactory results can be obtained, however, with reasonable deviation from the ranges stated. The time indicated is exclusive of that required in raising the temperature to the indicated temperature and in cooling the structure before removal from the press.

Moisture content, percent	Final stabilization temperature, degrees F.	Time (minimum), minutes
12	360	3 to 5
12	350	5 to 10
12	340	10 to 20
12	330	15 to 30
9	360	7 to 10
9	350	15 to 20
9	340	25 to 35
9	330	35 to 50
6	360	20 to 25
6	350	30 to 40

In comparative tests with thin cross-section samples of the wood $\frac{1}{8}$ inch long in the fiber direction, it has been shown, using a sample of the 12 percent moisture and 350° F. temperature example of the table above, which had been subjected to a pressure sufficient to compress it to a specific gravity of 1.38, that the increase in thickness in the direction of compression due to soaking in water for one week, followed by drying to the original oven-dry conditions, is only about 4 percent to 6 percent, in contrast to an increase in thickness of about 50 percent to 60 percent for wood compressed at 6 percent moisture content and 300° F. for the same length of time.

As indicated in the above table, the figures are for wood of final thickness of 0.5 inch. If the thickness is doubled, the minimum time is reduced to about one-half. The reason for this is that the thicker panels are subjected to heating of longer intervals during raising of the temperature to the final heating stage and during cooling before removal from the press.

Having thus described the invention, what is claimed is:

1. The method of forming a compressed wood structure comprising subjecting a wood structure having a moisture content from 6 percent to 15 percent, based on the oven-dry weight of the wood, to pressure at an initial temperature from 210° F. to 240° F. until the wood is substantially completely compressed to a specific gravity from 1.3 to 1.4, thereby tending to seal the moisture in the wood in the subsequent heating step, followed by raising the temperature to from 330° F. to 360° F., while maintaining the pressure, and maintaining the temperature so raised for a minimum from 3 to 50 minutes, the higher moisture content requiring the lower temperature and lesser minimum time, the interval of time used being sufficient to cause the lignin-cementing material in the wood to flow, thereby to stabilize the structure against recovery from its compression when wetted.

2. The method of forming a compressed wood structure comprising subjecting a wood structure having a moisture content from 9 percent to 12 percent, based on the oven-dry weight of the wood, to pressure at an initial temperature from 210° F. to 240° F. until the wood is substantially completely compressed to a specific gravity from 1.3 to 1.4, thereby tending to seal the moisture in the wood in the subsequent heating step, followed by raising the temperature to from 330° F. to 360° F., while maintaining the pressure, and maintaining the temperature so raised for a minimum from 3 to 50 minutes, the higher moisture content requiring the lower temperature and lesser minimum time, the interval of time used being sufficient to cause the lignin-cementing material in the wood to flow, thereby to stabilize

the structure against recovery from its compression when wetted.

3. The method of forming a compressed laminated wood structure, comprising laying up plies of wood, having a moisture content from 6 percent to 15 percent, based on the oven-dry weight of the wood, with a suitable bonding material between the plies and with the face plies slightly shorter at each grain end than the other plies, applying pressure to the surfaces of the laid-up plies between flat platens in contact with the face plies, whereby the intermediate plies spread over the end-grain ends of the face plies, thus sealing in water vapor between the platens and the structure, at an initial temperature from 210° F. to 240° F. until the wood is substantially completely compressed to a specific gravity from 1.3 to 1.4, thereby tending to seal the moisture in the wood in the subsequent heating step, followed by raising the temperature to from 330° F. to 360° F., while maintaining the pressure, and maintaining the temperature so raised for a minimum from 3 to 50 minutes, the higher moisture content requiring the lower temperature and lesser minimum time, the interval of time used being sufficient to cause the lignin-cementing material in the wood to flow, thereby to stabilize the structure against recovery from its compression when wetted.

4. The method of forming a compressed laminated wood structure, comprising laying up plies of wood having a moisture content from 6 percent to 15 percent, based on the oven-dry weight of the wood, with a suitable bonding material between the plies and with the face plies slightly shorter at each grain end than the other plies, applying strips of sealing material to the surfaces of the face plies along the end-grain ends, applying pressure to the surfaces of the laid-up plies between flat platens in contact with the face plies, whereby the intermediate plies spread over the end-grain ends of the face plies, thus sealing in water vapor between the platens and the structure, raising the temperature initially to from 210° F. to 240° F. until the wood is substantially completely compressed to a specific gravity from 1.3 to 1.4, thereby tending to seal the moisture in the wood in the subsequent heating step, followed by raising the temperature to from 330° F. to 360° F., while maintaining the pressure, and maintaining the temperature so raised for a minimum from 3 to 50 minutes, the higher moisture content requiring the lower temperature and lesser minimum time, the interval of time used being sufficient to cause the lignin-cementing material in the wood to flow, thereby to stabilize

the structure against recovery from its compression when wetted.

5. The method of forming a compressed laminated wood structure, comprising coating surfaces of plies of moisture-containing wood with a hot-setting water-resistant glue and air drying the glue, impregnating the end-grain ends of the plies with a penetrating and sealing material, conditioning the plies to a moisture content from 6 percent to 15 percent, based on the oven-dry weight of the wood, laying up the thus conditioned plies with the face plies slightly shorter at each grain end than the other plies, applying pressure to the surfaces of the laid up plies between flat platens in contact with the face plies, whereby the intermediate plies spread over the end-grain ends of the face plies, thus sealing in water vapor between the platens and the structure, at an initial temperature from 210° F. to 240° F. until the wood is substantially completely compressed to a specific gravity from 1.3 to 1.4, thereby tending to seal the moisture in the wood in the subsequent heating step, followed by raising the temperature to from 330° F. to 360° F., while maintaining the pressure, and maintaining the temperature so raised for a minimum from 3 to 50 minutes, the higher moisture content requiring the lower temperature and lesser minimum time, the interval of time used being sufficient to cause the lignin-cementing material in the wood to flow, thereby to stabilize the structure against recovery from its compression when wetted.

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