(57) Abstract: A method of forming a composite beam includes cutting an elongated piece of wood to produce strands having cross sections with a substantially symmetrical equilateral polygonal shape. Resin is then applied to the strands, and the strands are formed into a composite beam.
For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.
TITLE

EQUILATERAL STRAND COMPOSITE LUMBER AND METHOD OF MAKING SAME

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Application No. 60/484,068 filed July 1, 2003.


BACKGROUND OF THE INVENTION

[0001] This invention relates in general to composite lumber products and in particular to an improved method of manufacturing equilateral strand composite lumber products.

[0002] In its natural setting a tree is optimally designed to resist the forces of nature. Its composition is a compromise to the various vertical and horizontal forces to which it is subjected. When taken from the forest, sawn and used as a structural building material, however, its composition is no longer optimal. For example, knots and cross-grain can often be found in the areas of greatest bending stress. Density gradients within the wood can lead to zones which are susceptible to shear failures.

[0003] Despite these undesirable characteristics, wood has been the traditional structural building material of choice in North America. Its advantages are many, including high strength-to-weight ratios, workability, renewability, aesthetic value, and cost. However, after a decades-long decline in the quality of solid-sawn
lumber, wood is in danger of losing significant market share to non-wood products.

[0004] The response from the forest products industry was the development of structural composite lumber (SCL). SCL is an attempt to re-engineer the tree to best resist forces subjected to it as a structural member. The tree is broken down into smaller components which are rearranged and reconstituted. The result is a product that possesses design values that are often significantly higher than even the top grades of solid-sawn lumber. Examples of SCL include Laminated Veneer Lumber (LVL), Parallel Strand Lumber (PSL), and Laminated Strand Lumber (LSL).

[0005] The enhanced properties and higher design values are obtained primarily through two techniques: defect randomization and densification of the wood fiber, both largely functions of the size, shape, and composition (species) of the wood element. For reasons to be explained below, certain geometries and species have traditionally been chosen.

[0006] Typically, SCL manufacturers have used thin (defined herein as having a thickness less than about 0.25 inches) elements having a generally rectangular cross section, and produced from either moderate density softwoods or low-density hardwoods. Higher density hardwood species (e.g. maple, birch and beech) have typically not been used, as they require higher pressures to adequately densify and consolidate the wood fiber. These higher required pressures can result in an undesirable increase in manufacturing costs, damage to the wood fiber, problems with dimensional instability, and/or a product that is too dense, and therefore heavy and unreceptive to common mechanical fastening techniques. Additionally, the rectangular strand cross section, as well as method of layup, creates a product with differential properties in the two transverse directions. It
would therefore be advantageous if there could be provided an improved SCL product that possessed isotropic behavior in the transverse directions, while also allowing for use of higher density species.

SUMMARY OF THE INVENTION

[0007] This invention relates to an improved method of forming a composite beam. The method includes cutting an elongated piece of wood to produce strands having cross sections with a substantially symmetrical equilateral polygonal shape. Resin is then applied to the strands, and the strands are formed into a composite beam.

[0008] In another embodiment of the invention, a composite beam includes wood strands having cross sections with a substantially symmetrical equilateral polygonal shape, adhesively bonded together.

[0009] In another embodiment of the invention, a composite beam includes wood strands having cross sections with a substantially triangular shape, adhesively bonded together.

[0010] Other advantages of this invention will become apparent to those skilled in the art from the following detailed description of the invention, when read in light of the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] Fig. 1 is a schematic perspective view of a first portion of composite lumber manufacturing operation capable of making composite beams of the invention.
[0012] Fig. 1A is an enlarged cross-sectional elevational view of a portion of the composite lumber manufacturing operation illustrated in Fig. 1.

[0013] Fig. 2 is a schematic elevational view of a second portion of composite lumber manufacturing operation capable of making composite beams of the invention.

[0014] Fig. 3 is a a schematic perspective view of a first embodiment of a strand manufactured according to the method illustrated in Figs. 1 and 2.

[0015] Fig. 4 is a a schematic perspective view of a second embodiment of a strand manufactured according to the method illustrated in Figs. 1 and 2.

[0016] Fig. 5 is a a schematic perspective view of a third embodiment of a strand manufactured according to the method illustrated in Figs. 1 and 2.

[0017] Fig. 6 is a a schematic perspective view of a fourth embodiment of a strand manufactured according to the method illustrated in Figs. 1 and 2.

[0018] Fig. 7 is a a schematic perspective view of a fifth embodiment of a strand manufactured according to the method illustrated in Figs. 1 and 2.

[0019] Fig. 8 is a schematic elevational view of a second embodiment of a laid-up billet formed in accordance with the method of the invention.

[0020] Fig. 9 is a partial schematic view in elevation showing a strand having one scarfed surface.

[0021] Fig. 10 is a partial schematic view in elevation showing a strand having two scarfed surfaces.

[0022] Fig. 11 is a schematic elevational view of a third embodiment of a laid-up billet formed in accordance with the method of the invention.
[0023] Fig. 12 is a partial schematic cross-sectional view of a beam formed in accordance with the method of the invention illustrated in Figs. 1 and 2. 

[0024] Fig. 13 is a schematic perspective view of a beam having the cross section illustrated in Fig. 12.

[0025] Fig. 14 is a schematic perspective view of a prior art strand.

[0026] Fig. 15 is a schematic perspective view of a prior art beam formed with the strands illustrated in Fig. 14.

[0027] Fig. 16A is a schematic plan view of a first alternate embodiment of the mat illustrated in Fig. 1.

[0028] Fig. 16B is a schematic perspective view of a beam formed with the mat illustrated in Fig. 16A.

[0029] Fig. 17A is a schematic plan view of a second alternate embodiment of the mat illustrated in Fig. 1.

[0030] Fig. 17B is a schematic plan view of a third alternate embodiment of the mat illustrated in Fig. 1.

[0031] Fig. 17C is a schematic perspective view of a beam formed with the mats illustrated in Figs. 17A and 17B.

DETAILED DESCRIPTION OF THE INVENTION

[0032] As shown in Figs. 1 and 2, an apparatus for making composite beams according to the process of the invention is indicated generally at 10. A log 12, preferably a high density hardwood, such as a wood having a specific gravity greater than about 0.55, is placed on a conveyor 14. Examples of suitable high
density hardwood include, but are not limited to, maple, such as red maple and sugar maple, beech, such as American beech, and birch, such as yellow birch. The log 12 moves in the machine direction, indicated by an arrow 15.

[0033] The log 12 is then canted by a canting apparatus 16. The use of a canting apparatus 16 to cant logs 12 is well known in the art. The canted logs or cant 18 is then cut, such as by a plurality of saw blades 20, to produce a flitch or stack 22 of cut boards 24. Preferably, the boards 24 are within the range of from about ¼ inch to about 1 inch thick. More preferably, the boards 24 are within the range of from about 3/8 inch to about 7/16 inch thick. It will be understood however, that the boards 24 can be cut to any desired thickness, such as for example, less than ¼ inch or greater than 1 inch.

[0034] Subsequent to cutting the cant 18 into a stack 22 of cut boards 24, the boards 24 are un-stacked and each board 24 is then separated into strands 26 in a stranding machine 28. Preferably, the stranding machine 28 includes a plurality of saw blades, however any other desired means of separating the boards 24 into strands 26 can be used. Other such means for separating the boards 24 into stands include, for example, clipping, such as with a guillotine, or slicing.

[0035] The strands 26 have a symmetrical and substantially equilateral polygonal cross-sectional shape. As used herein regarding strands 26 separated by the stranding machine 28 and otherwise unmodified, substantially equilateral is defined as all sides of the cross-sectional shape having equal length. Substantially equilateral also includes equilateral cross-sectional shapes and slight deviations therefrom which are due to slight variations caused in the separating process, such as by the stranding machine 28. Such slight variations can include strands having cross-sectional shapes wherein one side length is slightly smaller or slightly larger than a desired side length. For example, a substantially equilateral cross-sectional
shape can include one side length which is within the range of from about 0.7 to about 1.3 times the desired side length. Preferably, the cross-sectional shape of the strands 26 is that of an equilateral triangle, as best shown in Fig. 3. Strands having other symmetrical and equilateral polygonal cross-sectional shapes can also be formed, such as for example, strands having square 26', pentagonal 26'', hexagonal 26''', and diamond 26iv cross-sectional shapes, as shown in Figs. 4 through 7, inclusive.

[0036] Regardless of the symmetrical and equilateral polygonal cross-sectional shape of the strands 26, a side length S1 of the cross section of each strand 26 is preferably within the range of from about \( \frac{1}{4} \) inch to about 1 inch.

[0037] As shown in Fig. 3, the strands 26 have any desired length L1, and therefore the strands 26 can be formed from logs 12 of any desired length. Preferably, the strands 26 have a length within the range of from about 2 feet to about 12 feet. More preferably, the strands 26 have a length of about 4 feet. If desired, one or more boards 24 can be joined together lengthwise to form boards of increased length. The boards 24 can be joined together by any desired method, such as for example, with a finger joint. Once joined together, strands 26 can be formed from the finger jointed boards as described above.

[0038] Preferably, the strands 26 have a slenderness or length-to-depth ratio within the range of from about 100 to about 300. As used in the context of a length to depth ratio, the term depth is defined as the side length S1 of the cross section of the strand 26. For example, a strand 26 having triangular cross-section, a side length S1 of \( \frac{1}{4} \) inch, and a length of 48 inches, has a length to depth ratio of 192. As would be known to one skilled in the art, length-to-depth ratios are positively correlated with bending strength and stiffness, up to a maximum length-to-depth ratio above which little or no increase in bending strength and stiffness
can be observed. For example, in the strand composite product known as waferboard, one study indicated that bending strength and stiffness increase for length-to-depth ratios within the range of from about 120 to about 300. Known strand composite products commonly have length-to-depth ratios within the range of from about 100 to about 400.

[0039] After the strands 26 are formed, they are preferably dried in a dryer 30 to reduce moisture content to a desired level, such as below about 10 percent. The use of a dryer 30 for drying strands 26 of wood is well known in the art.

[0040] After drying, a plurality of strands 26 is then laid-up or arranged to define a mat 32. The strands 26 are arranged substantially parallel to one another, such that each strand 26 is in contact, or near contact with an adjacent strand 26. The number of strands 26 arranged to define the mat 32 depends on the desired final product density, preferably within the range of from about 39 to about 47 lbs/ft^3.

[0041] As best shown in Fig. 1, the method of forming the mat 32 includes arranging a plurality of strands 26 of substantially equal length side-by-side on a surface 34, such as a forming surface or the conveyor 14. The strands 26 are placed side-by-side such that first ends 36 of each strand 26 are substantially linearly aligned with one another, and such that the end surfaces of the first ends 36 of each strand 26 are substantially coplanar.

[0042] Once the plurality of strands 26 are arranged, at least one bead of adhesive 38, such as a hot-melt type adhesive, can be applied transversely across the arranged strands 26, thereby adhering the strands 26 to one another and defining the mat 32. Such a bead of hot-melt type adhesive 38 allows the mat 32 to be easily handled and moved. It will be understood that the hot-melt type
adhesive 38 will melt early in the curing process, as will be described below, thereby allowing the strands 26 to move relative to one another and nest.

[0043] If desired, vibration means 40 can be applied to the surface 34 prior to applying the bead of adhesive 38. Such vibration means 40 will vibrate the strands 26 such that adjacent strands 26 do not overlap, and that each strand 26 is arranged substantially parallel to, and in contact with, an adjacent strand 26. It has been demonstrated through experimentation that strands 26 having substantially equilateral polygonal cross-sectional shapes, such as triangular, respond advantageously to such vibration. The vibration causes the strands 26 to become longitudinally aligned such that each strand 26 is substantially parallel to, and in contact with, an adjacent strand 26.

[0044] Although not illustrated, it will be understood that the strands 26 can be formed into a laid-up billet, such as the laid-up billet 48, without first forming a mat 32. For example, strands of equal or varying length can be randomly dropped (i.e. allowed to drop or fall), to a surface, such as a forming surface or the conveyor 14.

[0045] After applying at least one bead of adhesive 38 to the arranged strands 26, resin 42 is then applied to the mat 32 to define a resin-coated mat 43. Preferably liquid resin, such as phenol-formaldehyde resin is sprayed on a major surface 32A of the mat 32 by a sprayer 44. More preferably, liquid resin is sprayed on both major surfaces 32A of the mat 32 by a plurality of sprayers 44. Although spraying is shown in the exemplary embodiment illustrated in Fig. 1, it will be understood that any other desired method of applying the liquid resin 42 to the mat 32 can also be used. Further, reference is made to using liquid resin 42, although it will be understood that powdered resin can be applied to one or both of the major surfaces 32A of the mat 32. It will be further understood that any other
desired resin can be used, such as for example, diphenylmethane diisocyanate (MDI).

[0046] A plurality of resin-coated mats 43 are then stacked to define a laid-up billet 48. As used herein, laid-up billet is defined as the billet prior to being cured, as described herein below. A first embodiment of a laid-up billet 48 is illustrated in Fig. 1. Preferably, the resin-coated mats 43 are stacked in a stepped arrangement such that a first end 50 of any mat 43 overlaps a second end 52 of the adjacent lower mat 43, thereby defining a lap-joint 54. Preferably, first end 50 overlaps the second end 52 by about two inches. The resin-coated mats 43 are further stacked such that the first end 52 of any mat 43 overlaps the end 50 of the adjacent lower mat 43, thereby defining an overlap region 56. Although 14 mats 43 are shown in the exemplary embodiment of the laid-up billet 48 illustrated in Fig. 1, it will be understood that any other desired number of mats 43 can be stacked to define the laid-up billet 48. The lay-up method, as described above, is well known in the art.

[0047] If desired, a layer of reinforcement material 59 can be disposed between layers of mats 43 adjacent the lap-joint 54, as best shown in Fig. 1A. The layer of reinforcement material 59 can also be disposed adjacent the overlap region 56. Any desired reinforcement material can be used, such as for example a woven fiberglass fabric.

[0048] A second embodiment of laid-up billet 48' is illustrated in Fig. 8. The laid-up billet 48' is substantially identical to the laid up billet 48, and includes a plurality of the mats 43. In the laid-up billet 48' however, the first and second ends 50 and 52, respectively, of the mats 43 do not overlap, but abut one another. This practice is well known in the art.
[0049] If desired at least one surface 33A of at least one end of the mats 32 can be beveled or scarfed, as best shown in Fig. 9. The practice of scarfing is well known in the art. Alternately, two surfaces 33B and 33C, respectively, of at least one end of the mats 32 can be scarfed, as best shown in Fig. 10. Such scarfing minimizes void space which can occur after curing at either or both of the lap joints 54 and the overlap regions 56. The scarfing further minimizes the potential density profile of the cured billet 66 at the lap-joints 54 and the overlap regions 56; i.e. scarfing increases density of the cured billet at the lap-joints 54 and the overlap regions 56. It will be understood that the strands 26 can also be scarfed prior to forming mat 32.

[0050] A third embodiment of laid-up billet 48" is illustrated in Fig. 11. The laid-up billet 48" includes a plurality the mats 43. The mats 43 are preferably stacked such that the first ends 50 of the mats 43 are vertically aligned.

[0051] If desired, a laid-up billet can include stands having a plurality of sizes. For example, strands having equilateral triangle cross-sections and side lengths S1 of about ¼ inch and about 7/16 inch can be used to form a laid-up billet. It is believed that once cured, billets having strands with a plurality of sizes will be stronger than billets made with strands of only one size. It has been shown, for example, that composite beams made from triangular cross-sectional strands having a side length of about ¼ inch have a higher shear strength than composite beams made from strands having a side length of about 7/16 inch. Additionally, composite beams made from strands having a side length of about 7/16 inch have a higher bending strength than composite beams made from strands having a side length of about ¼ inch. Accordingly, for a bending member it would be advantageous to use ¼ inch strands in the core of the beam (where the shear stress
is highest) and 7/16 inch strands on the top and bottom of the beam (where bending stress is highest).

[0052] For example, for a beam intended for use as a bending member, such as a girder, the mats can be formed from strands having at least two different side lengths. As shown in Fig. 16A, a mat 110 can be formed from strands having a larger side length 112 on the sides or outside portion of the mat 110, and strands having a smaller side length 114 centrally disposed in the mat 110 (i.e., the strands having a smaller side length 114 define a central portion of the mat 110). A plurality of mats 110 are then stacked, cured, and cut to a desired width and length as described herein, thereby forming a beam 116. When the beam 116 is rotated 90 degrees such that the strands having a larger side length 112 define the top and bottom layers of the beam 116, as shown in Fig. 16B, the beam 116 thereby defines a bending member believed to have improved bending strength. Although illustrated schematically, it will be understood that the strands 112 and 114 can have any of the substantially symmetrical polygonal cross-sectional shapes described herein, such as triangular.

[0053] For a beam intended for use as a plank, such as in scaffolding, at least two different mats can be formed. A first mat 118 can be formed from the strands having a larger side length 112, as shown in Fig. 17A, and a second mat 120 can be formed from the strands having a smaller side length 114, as shown in Fig. 17B. A plurality of the first and second mats 118 and 120 are then stacked to form a laid-up billet such that the first mats 118 are disposed on the top and bottom of the laid-up billet, and the second mats 120 are disposed intermediate the first mats 118. The laid-up billet comprising the plurality of stacked mats 118 and 120 is then cured, and cut to a desired width and length as described herein, thereby forming a beam 122 having improved strength, as shown in Fig. 17C.
[0054] The laid-up billet, such as the first and second embodiments of the laid-up billets 48 and 48', respectively, is then cured with a combination of pressure and energy. For purposes of illustration, only the laid-up billet 48 is shown in Fig. 2. The method described herein however, also applies to other laid-up billets, such as the laid-up billet 48'. Pressure can be applied to the laid-up billet 48 by any desired means, such as a plurality of rollers 60. Preferably, pressure can be applied to the laid-up billet 48 in a continuous press operation, as best shown at 62 in Fig. 2. In such a continuous press operation 62, the laid-up billets 48 are moved by the conveyor 14, such that the plurality of rollers 60 and/or plates (not shown) exerts a force on at least one surface 48A of the laid-up billet 48, thereby compressing the mats 43.

[0055] Although not illustrated, it will be understood that pressure can be applied to the laid-up billet, such as the third embodiment of the laid-up billet 48', in a batch process, wherein a predetermined length of the laid-up billet 48' is disposed between two platens of a press. The platens are then moved toward one another, thereby compressing the mats.

[0056] Preferably, energy is applied to the laid-up billet 48 during the pressing step to heat, and therefore cure, the laid-up billet 48. Preferably, the energy is applied by an electromagnetic heating operation, such as with radio frequency energy, as schematically illustrated at 64 in Fig. 2. Use of electromagnetic heating in the manufacture of wood composites is well known in the art. Advantageously, electromagnetic heating provides relatively fast and uniform heating throughout the laid-up billet 48. With the application of such uniform heating, plasticization and densification of the wood is substantially constant throughout the laid-up billet 48. The combination of pressure and energy thereby cures the laid-up billet 48 and forms a cured billet 66.
[0057] It will be understood however, that any other desired method of applying energy to the laid-up billet 48 can be used. Examples of such other methods include applying energy by microwave, electrical resistance and/or steam injection techniques.

[0058] As best shown in Fig. 12, even after curing, the strands 26 retain a substantially equilateral cross-sectional shape. It will be understood that as used herein regarding compressed strands 26, substantially equilateral includes equilateral cross-sectional shapes and slight deviations therefrom which are due to distortions caused in the pressing process. Such slight deviations can include strands having cross-sectional wherein one side length is slightly smaller or slightly larger than its original side length S1. For example, a substantially equilateral cross-sectional shape can include one side length which is within the range of from about 0.5 to about 1.5 times the original side length S1.

[0059] Referring again to Fig. 2, once the laid-up billet 48 is cured, a cutter 68 then cuts the cured billet 66 to any desired length, thereby defining a composite beam 70. It will be understood however, that the cured billet 66 can be cut in any desired direction, including longitudinally and transversely, so as to define a beam 70 having any desired length L2, height H, and width W, as best shown in Fig. 13.

[0060] The method of the invention is shown as a continuous process occurring on a continuously moving conveyor 14. It will be understood however, that each step of the method can also be satisfactorily performed at one or more independent workstations.

[0061] As would be understood by one skilled in the art, known strand composite products commonly use thin, generally rectangularly shaped wood pieces, often with a thickness less than 0.25 inches. Although use of such thin
strands often beneficially provides for considerable distribution of defects and can minimize void space, using thin strands reduces the natural strength of the wood in the direction of the grain.

[0062] Further, such known strands 80 are often cut tangentially from a log 82, as shown in prior art Fig. 14. The strands 80 are then stacked to form a beam 84 such that the growth rings 86 of adjacent strands 80 are substantially aligned in the same plane P, as best shown in prior art Fig. 15. Such a beam 84 has anisotropic properties, wherein the mechanical response to a transverse force in the direction of an arrow x₁ is thereby substantially different to the mechanical response to a transverse force in the direction of an arrow y₁. Such a difference in mechanical response or strength provides a beam that is substantially stronger when subjected to a force in the direction of one of the x₁ and the y₁ arrows than when subjected to a force in the direction of the other of the x₁ and the y₁ arrows.

[0063] When strands 26 having symmetrical equilateral polygonal shapes, such as the triangles shown in Figs 3 and 13 are used, the growth rings 90 within each strand 26 become oriented in an orthogonally randomized fashion relative to the growth rings 90 in adjacent strands 26, as best shown in the beam 70 illustrated in Fig. 13. Accordingly, one advantage of the invention is that the use of strands 26 having cross sections with a substantially symmetrical equilateral polygonal shape provides a beam, such as the beam 70, having transverse near-isotropic properties, i.e., a beam wherein its strength or mechanical response is independent of the direction of the force applied. The press-induced density profiles which also cause anisotropic behavior are minimized with the use of electromagnetic curing as described above. It is believed that such orthogonal randomization of the growth rings 90 within a composite beam will produce a beam, such as the beam 70, having transverse near-isotropic properties. Near-isotropic, as used herein, is
defined as the effect wherein the mechanical response to a force in the direction of the arrow x2 is substantially identical to the mechanical response to a force in the direction of the arrow y2.

[0064] Another advantage of the invention is that beams having such transverse isotropic properties, such as the beam 70 shown in Fig. 13, can be manufactured without regard to the orientation of the mats 32 which comprise the beam 70. Further, the beam 70 can be used without regard to the orientation of the mats 32 within the beam 70.

[0065] It is believed that an advantage of the invention is that the stands are relatively thicker, i.e. the strands 26 have a side length S1 within the range of from about ¼ inch to about 1 inch. Such a thicker strand 26 allows each strand 26 to maintain the wood's natural strength in the direction of the grain.

[0066] Another advantage of the invention is that strands 26 having a triangular cross-sectional shape become substantially longitudinally aligned during the arranging step shown in Fig. 1, such that at least one face of each strand 26 is in contact with a face of an adjacent strand 26. After the billet 48 is cured, the strands 26 are nested or arranged such that undesirable void spaces between adjacent strands 26 are minimized, as best shown in Figs. 1 and 13.

[0067] Known strand composite products have generally been produced using either moderate density softwoods (having a specific gravity within the range of from about 0.4 to about 0.55), or low density hardwoods (having a specific gravity less than about 0.4). Higher density hardwood species (having a specific gravity greater than about 0.55) have been avoided, as they require higher pressures to adequately densify and consolidate the wood. As used herein, specific gravity is defined as oven dry weight/volume at 12 percent moisture content. The higher
pressures required to process higher density hardwood can lead to increased manufacturing costs, damage to the wood fiber, problems with dimensional stability and/or a product that is too dense, making it heavy and unreceptive to common mechanical fastening techniques.

[0068] It is further desirable to provide composite beams having a low compaction ratio (as used herein compaction ratio is defined as product density/parent wood species density). Products with higher compaction ratios are often susceptible to undesirable levels of springback, especially upon exposure to moisture, and springback can contribute to undesirable nail pops in drywall and sub-flooring. As used herein, springback refers to the permanent residual thickness swelling which occurs on release of the compressive stress with absorption. Known composite products generally have a compaction ratio greater than about 1.35. Advantageously, composite beams formed according to the present invention have been shown to have a relatively lower compaction ratio. For example, in a beam formed with equilateral triangular stands of red maple, the compaction ratio is 1.26 (wherein the product density is 43 lb/ft$^3$ and the red maple density is 34 lb/ft$^3$).

[0069] Another advantage of the invention is that the strands of the invention can be formed from small to medium diameter trees, which are currently not used in many strand composite products, thereby providing a lower cost source of wood.

[0070] As best shown in Fig. 12, a further advantage of the invention is that in circumstances wherein adjacent strands 26 are not perfectly aligned, the application of pressure causes an edge, such as the edges 26A, 26B, and 26C of the strands 26 to become embedded or wedged into an adjacent strand 26. Such wedging further reduces void spaces between adjacent strands 26, and increases
densification, thereby increasing the strength of the beam relative to a beam having a greater volume of void space. It is believed that the occurrence of such wedging increases when higher density wood is used.

[0071] Another advantage of the invention is that beams manufactured according to the methods of the invention have demonstrated desirable strength and performance values. For example, Table 1 illustrates the strength and performance values for beams formed with strands having equilateral triangle cross-sections and side lengths S1 of about ¼ inch and about 7/16 inch. The performance values shown in Table 1 include modulus of elasticity (MOE), modulus of rupture (MOR), allowable bending stress (Fb), and allowable shear stress (Fs), wherein n is the number of samples. It will be known by those skilled in the art that an increase in product density is known to be positively correlated with most mechanical properties. The values shown in Table 1 are those of the lowest probable product density. A substantial increase in these properties is likely to be achieved with an increase in product density.

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<th>S1 = 1/4 inch</th>
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* Values adjusted to the average density (39.3 lbs/ft³) and a moisture content (9.88%) of all beams.

b Based on the volume adjusted minimum MOR divided by a safety factor of 2.1.

c Based on the minimum shear strength divided by a safety factor of 3.15.

[0072] Although the method of the invention has been described in the context of producing a structural member, it will be understood that the method of the
invention can also be applied to the production of non-structural wood composite products.

[0073] The principle and mode of operation of this invention have been described in its preferred embodiments. However, it should be noted that this invention may be practiced otherwise than as specifically illustrated and described without departing from its scope.
CLAIMS

What is claimed is:

1. A method of forming a composite beam comprising:
   cutting an elongated piece of wood to produce strands having cross sections
   with a substantially symmetrical equilateral polygonal shape;
   applying a resin to the strands;
   forming the strands into a composite beam.

2. The method according to Claim 1, wherein the cross sections have a side length within the range of from about \( \frac{1}{4} \) inch to about 1 inch.

3. The method according to Claim 1, wherein the substantially symmetrical equilateral polygonal shape is one of triangular, square, pentagonal, hexagonal, and diamond shaped.

4. The method according to Claim 1, wherein the elongated piece of wood is a high density hardwood.

5. The method according to Claim 1, wherein the resin is one of a liquid resin and a powered resin.

6. The method according to Claim 1, wherein the step of forming the strands into a composite beam includes vibrating the strands so as to arrange the strands longitudinally.
7. The method according to Claim 1, wherein the composite beam has transverse near-isotropic properties.

8. The method according to Claim 1, wherein the step of forming the strands into a composite beam further includes:
   arranging the strands into a mat;
   stacking a plurality of mats to define a laid-up billet;
   curing the laid-up billet into a cured billet; and
   cutting the cured billet to form a beam.

9. The method according to Claim 8, wherein the step of arranging the strands includes vibrating the strands so as to align the strands longitudinally, thereby minimizing void space between adjacent strands.

10. The method according to Claim 8, wherein the step of arranging the strands includes aligning the strands such that the end surfaces of at least one end of each strand are coplanar.

11. The method according to Claim 8, wherein the step of arranging the strands includes bonding the strands to one another with adhesive.

12. The method according to Claim 8, wherein the stacking step includes disposing a reinforcement material between layers of mats.

13. The method according to Claim 8, wherein the stacking step includes stacking the plurality of mats in a stepped arrangement.
14. The method according to Claim 13, wherein the stacking step includes stacking the plurality of mats in a stepped arrangement such that each mat overlaps an adjacent mat.

15. The method according to Claim 8, wherein the stacking step includes stacking at least a first mat and a second mat, wherein the first mat includes strands having a larger cross-sectional size than the strands of the second mat.

16. The method according to Claim 15, wherein at least one first mat forms a top portion of the beam, at least one first mat forms a bottom portion of the beam, and at least one second mat forms a central portion of the beam intermediate the top and bottom portions.

17. The method according to Claim 8, wherein the arranging step includes arranging a plurality of first strands and a plurality of second strands, wherein the first strands have a larger cross-sectional size than the second strands.

18. The method according to Claim 17, wherein the first and second strands are aligned longitudinally, and arranged such that the first strands define a first outside portion and a second outside portion of the mat, and the second strands define a central portion of the mat intermediate the first and second outside portions.

19. The method according to Claim 8, wherein the curing step includes applying pressure and energy to the laid-up billet.
20. The method according to Claim 19, wherein the energy is provided by a source of radio frequency energy.

21. The method according to Claim 8, wherein the curing step includes applying sufficient pressure to the laid-up billet so as to arrange the strands such that the growth rings of any one of the wood strands are oriented in an orthogonally randomized fashion relative to the growth rings of an adjacent wood strand.

22. A composite beam comprising: wood strands having cross sections with a substantially symmetrical equilateral polygonal shape, adhesively bonded together.

23. The composite beam according to Claim 22, wherein the cross sections have a side length within the range of from about \( \frac{1}{4} \) inch to about 1 inch.

24. The composite beam according to Claim 22, wherein the substantially symmetrical equilateral polygonal shape is one of triangular, square, pentagonal, hexagonal, and diamond shaped.

25. The composite beam according to Claim 22, wherein the wood strands are formed from a high density hardwood.

26. The composite beam according to Claim 22, wherein the composite beam has transverse near-isotropic properties.
27. The composite beam according to Claim 22, wherein the wood strands are arranged such that the growth rings of any one of the wood strands are oriented in an orthogonally randomized fashion relative to the growth rings of an adjacent wood strand.

28. The composite beam according to Claim 22, wherein the beam comprises at least a first mat and a second mat, wherein the first mat includes strands having a larger cross-sectional size than the strands of the second mat.

29. The composite beam according to Claim 28, wherein at least one first mat forms a top portion of the beam, at least one first mat forms a bottom portion of the beam, and at least one second mat forms a central portion of the beam intermediate the top and bottom portions.

30. The composite beam according to Claim 22, wherein the beam comprises a plurality of mats, each mat comprising a plurality of first strands and a plurality of second strands, wherein the first strands have a larger cross-sectional size than the second strands.

31. The composite beam according to Claim 30, wherein the first and second strands are aligned longitudinally, and arranged such that the first strands define a first outside portion and a second outside portion of the mat, and the second strands define a central portion of the mat intermediate the first and second outside portions.
32. A composite beam comprising:
wood strands having cross sections with a substantially triangular shape, adhesively bonded together.

33. The composite beam according to Claim 32, wherein the cross sections have a side length within the range of from about \( \frac{1}{4} \) inch to about 1 inch.

34. The composite beam according to Claim 32, wherein the wood strands are formed from a high density hardwood.

35. The composite beam according to Claim 32, wherein the composite beam has transverse near-isotropic properties.

36. The composite beam according to Claim 32, wherein the wood strands are arranged such that the growth rings of any one of the wood strands are oriented in an orthogonally randomized fashion relative to the growth rings of an adjacent wood strand.

37. The composite beam according to Claim 32, wherein less than about 10 percent of the volume of the beam is void space.

38. The composite beam according to Claim 32, wherein the beam comprises at least a first mat and a second mat, wherein the first mat includes strands having a larger cross-sectional size than the strands of the second mat.
39. The composite beam according to Claim 38, wherein at least one first mat forms a top portion of the beam, at least one first mat forms a bottom portion of the beam, and at least one second mat forms a central portion of the beam intermediate the top and bottom portions.

40. The composite beam according to Claim 32, wherein the beam comprises a plurality of mats, each mat comprising a plurality of first strands and a plurality of second strands, wherein the first strands have a larger cross-sectional size than the second strands.

41. The composite beam according to Claim 40, wherein the first and second strands are aligned longitudinally, and arranged such that the first strands define a first outside portion and a second outside portion of the mat, and the second strands define a central portion of the mat intermediate the first and second outside portions.