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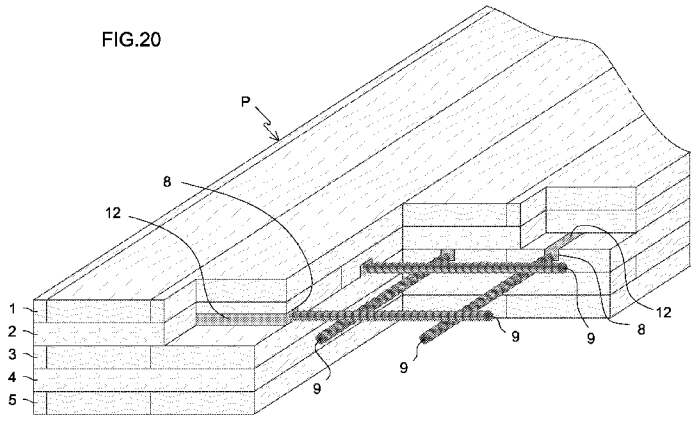
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(54) **Title**: STRUCTURAL PANEL IN REINFORCED WOOD

FIG.20



(57) **Abstract**: The invention includes a method for making a structural panel in wood of the CLT type (P) and a reinforced panel (P) obtained therewith, in turn comprising several superimposed layers (1, 2, 3, 4, 5), each formed by several boards adjacent to each other and arranged in the same direction (X, Y), wherein each layer (L 2, 3, 4, 5) is arranged with the boards laid crosswise to the opposing layer. The method comprises the steps of: making at least one series of specific grooves-recesses (8) on at least one of said layers (2, 3), arranged in the longitudinal direction of said boards of said layer (2, 3) on which they are made; inserting in said recesses (S) reinforcing elements such as rod irons (9) and/or bars and/or section bars having dimensions proportional to the various recesses (8), in addition to the introduction of a specific bonding agent (12) intended to consolidate said layers (2, 3) and of a reinforcing material (9), in order to obtain a grid made up of the reinforcing elements (9) incorporated in the body of the panel (P) so as to be integral with it.

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STRUCTURAL PANEL IN REINFORCED WOOD

DESCRPTION

Scope of the invention

The present invention belongs to the category of wooden prefabricated systems intended for the construction industry and in particular relates to a method for the production of reinforced structural panels made of wood and panels obtained through the implementation of this method.

State of the art

The wooden panels of reference are internationally identified with the abbreviation "CLT", an acronym that stands for "Cross Laminated Timber", that is layers of boards stacked with wood grain orientation alternating 90 degrees at each layer and glued". In Italy this type of panel is also identified with the term XLAM and other countries and/or manufacturers sometimes use their own terminology. In any case, the term CLT used in this document extends its validity to all the names given to this type of panel regardless of location and who assigned them. The term "standard CLT" panel used in this document indicates the state of the art in CLT panel manufacturing based on dedicated CAD/CAM systems and CNC machines, utilizing wooden boards cut to size, planed, sanded and then glued together in layers, with each layer arranged at a right angle with respect to the adjacent boards they are glued to.

The number and thickness of individual board layers used depend on the characteristics the final panel must have, for a total indicative thickness that ranges from 8-9 cm up to more than 40-50 cm. Normally, standard CLT panels are composed of a minimum of three layers up to 5-7 crossed boards (even up to 9-11 and beyond in specific cases). At the end of the various processes the panels obtained, depending on their size, thickness, shape and mechanical characteristics, can be suitable for use for load-bearing and non load-bearing walls, floors and roofs of buildings intended for residential, industrial and commercial use as well as for facilities for general public use (schools, gyms, hospitals, churches, etc.).

Standard CLT panels available on the market are a good solution for the construction of different kinds of buildings, even in seismic zones. However, it must be noted that these panels and the structures made of them have limitations due to the particular characteristics of the base material (wood) used, particularly if the wood is of poor quality and/or has defects not detected during the manufacturing process, and also due to mechanical limitations, for example related to the proper ratios of size-thickness-load capacity-bending capacity or size-thickness-torsion capacity.

The invention in detail

1) The present invention relates to a method for the production of a structural reinforced CLT panel, and panels obtained by the implementation of that method.

2) The main objective of the present invention is to indicate a method for the production of a reinforced CLT structural panel, producible on an industrial scale, using rods with improved

adherence, and/or bars-section bars advantageously made of basalt fibre as reinforcing material, without limitations for the use of other suitable materials, including ferrous and/or alloyed products, in order to obtain a structural wooden panel having characteristics of rigidity and resistance higher than standard CLT panels with equal dimensions. The insertion of the reinforcing material in the reinforced CLT structural panel manufactured in this manner increases its mechanical performance, significantly improving, in proportion to the type, quantity, and arrangement of the reinforcing material used, especially and not only, its behaviour like a rigid plate and/or slab.

3) Another objective of the present invention is to be able to use low quality timber for the manufacturing of reinforced CLT structural panels. This method allows the production of panels comparable or even superior to similar standard CLT panels in terms of general mechanical performance even if those standard panels are manufactured with high quality timbers.

4) A further objective of the present invention is to be able to use a reinforced CLT structural panel also in conjunction with standard CLT panels and/or any type of material used and useable in construction, such as brick, concrete, iron and more, in order to construct buildings of any kind, given the perfect compatibility with respect to dimensions and shapes of both the reinforced CLT structural panels and standard CLT panels.

5) These and other objectives also indicated in the claims, are achieved according to the method described below, without limitations regarding further improvements and/or embodiments which may not be described and/or illustrated in the attached drawings. For simplification purposes, only the manufacturing method of a five layer reinforced CLT structural panel, normally used for the construction of vertical partition walls, will be described together with the instructions for the manufacturing of one having a greater number of layers, normally intended for the construction of horizontal-inclined partition walls, and one with a curved shape. This invention has the objective of constructing reinforced CLT panels having high mechanical performance, and therefore usable mainly in complex structures or in any case where a structural panel engineered with particular characteristics is required. The description of the production of a reinforced CLT structural panel also takes into account only the use of rods made of basalt fibres with improved adherence as the reinforcing material, which for simplification purposes will always be called rod(s), noting however, that the use of rods of any other suitable material involves procedures substantially identical, while for bars or section bars, the procedures are slightly different but not detrimental for the manufacturing process indicated. The production line of reinforced CLT structural panels is essentially entirely similar to a production line for standard CLT panels. More precisely, the lines have: machine tools that prepare the necessary boards, machines and assembly planes, a pressing machine which shall solidly join the different layers of boards as well as cutting, milling, and final finish machines. The only variations foreseen with respect to a production line as described above are the

addition of at least one flat work area equipped with a CNC robotic arm in order to optimize the production time, and a lifting and tipping system for the reasons indicated below.

6) To produce a reinforced CLT structural panel P, like for example the one shown with a partial section in perspective in Figure 20, the method includes the steps below, noting that the reference numbers and letters of the components used and/or the constructional details indicated, are the same in all the attached drawings:

- Preparation of individual boards through the necessary cutting, slabbing, planing, and sanding procedures;
- Positioning of the first layer of boards 1, which have a longitudinal axis of the fibres X, on the working plane of the assembly system;
- Application of the gluing material on the first layer of boards 1 which is of the same type, in the same quantity and with the same method used for the manufacturing of standard CLT panels;
- Positioning of the second layer of boards 2, arranged orthogonally (Y axis) with respect to the underlying layer of boards 1 and conveyance of the assembly to the pressing machine to join these two layers of boards stably;
- After a specific period of time from the moment the first assembly of layers of boards 1 and 2 was conveyed to the press machine, the production of a second assembly of boards is initiated. The assembly sequence is the same as that described above, and more precisely, the arrangement on the assembly system's working plane of the first layer of boards 5 also having a longitudinal axis X, the application of the gluing material, positioning of the second layer of boards 4 arranged orthogonally to the layer underneath, the application of the gluing material and finally, the positioning of the third layer of boards 3 arranged orthogonally to the layer underneath;
- At this point when the second assembly formed by the layers of boards 5, 4, 3 is completed it is immediately conveyed into the pressing machine, subject to the removal of the first assembly consisting of the layers of boards 1 and 2 for which the bonding process is finished. In this way the glue interposed between the layers of boards 5, 4, 3, not yet crystallized, is stabilized through the pressing process as already done for the assembly consisting of the layers of boards 1 and 2;
- After exiting the press machine, the first assembly S1 formed by the layers of boards 1 and 2, is conveyed to an additional work plane where a CNC robotic arm equipped with a cylindrical milling cutter executes the first series of grooves, in a number and size to be determined at the design stage, longitudinally with respect to the direction of the fibres of the layer of boards 2, that is with respect to the Y axis, thus obtaining the grooves 8 of the semi-finished assembly S1 as shown in Figure 1. In this particular case, the grooves 8 are all parallel to each other;

- The same machining carried out on the semi-finished assembly S1 just described, must be carried out on the second assembly formed by the layers of boards 5, 4, 3, and specifically, in the longitudinal direction with respect to the last layer of boards 3, that is with respect to the X axis, obtaining the grooves 8 of the semi-finished assembly S2 as shown in Figure 2. In this particular case, the grooves 8 are all parallel to each other;

- Of particular importance and specificity is the milling cutting operation to create the different grooves 8 necessary in order to obtain the particular shapes of the grooves 8 themselves, as shown in Figures 3, 3a, 3b. The grooves 8 are created in the following way: the milling cutting operation to create a sequence of grooves, for example, 20 mm wide and 17 mm deep, is configured to run with the milling cutter down for about 50-60 cm, then the milling cutter stops, lifts, moves forward in the same direction for a specific distance to create an interruption between grooves, and then lowers again to continue the milling cutting operation, repeating the same actions for the entire length foreseen for a groove 8. Figure 3 shows a partial top view of the boards, 2 or 3, on which milling cutting operations were performed. The left side of the drawing shows the first machining sequence where in the central point there are two grooves 8 that do not intersect or overlap, but leave a small section of the wood at full height. After carrying out all foreseen milling cutting operations, and having made all grooves 8 with the interruptions at the established distances, the milling cutter is replaced with another milling cutter, for example, 16 mm in diameter, which is used to mill cut the aforementioned interruptions as shown in Figure 3, right side, creating the lateral guides 8a. Another fundamental characteristic of this process is based on the fact that this second milling cutter does not penetrate into the layer of boards the entire 17 mm of the first milling cutter, but about 2 mm less, allowing the creation of bumps-spacers 8b in the bottom of the groove 8, as shown in Figure 3a, which shows a longitudinal section of a groove 8, and Figure 3b, which shows a cross section of a groove 8. After completing all the expected milling cutting operations on the semi-finished assembly S1, and subsequently also on the semi-finished assembly S2, the surfaces are cleaned to eliminate sawdust and shavings by means of aspiration, in order to allow the insertion of the reinforcing material, that is, a rod 9 as shown in Figure 7, and the gluing material 12 foreseen for the now perfectly clean grooves 8. The rods 9 of each semi-finished assembly S1 and S2 are therefore all mutually parallel, having been inserted in the grooves 8 which are parallel to each other;

- Figures 4, 5, 6, show and highlight some distinctive characteristics related to the distance 11 of a groove 8 from the edges of the semi-finished assemblies S1 and S2, in addition to the distance 11a from any holes or niches 10 (also shown in Figures 1 and 2). This arrangement allows the insertion of the reinforcing material 9 in a precise manner, in addition, it allows the final machining of the panel P to be carried out in the same way as that carried out for standard CLT panels. It should be noted, however, that all grooves 8 do not necessarily end

at the same distance 11 from the edges of the semi-finished assemblies S1 and S2, and this also applies to the distances 11a due to the possible presence of holes and/or niches 10, and also because of the fact that the reinforcing material 9 calculated to obtain a reinforced CLT structural panel P, can also be non-uniformly distributed inside it;

- Figures 8 (top view of a groove 8), 8a (longitudinal section of a groove 8) and 8b (cross section of a groove 8), show how the rods 9 are inserted in different grooves 8 and, precisely, how they are kept at the centre of the grooves 8 by the guides 8a and raised from the bottom by the bump-spacers 8b. The fact that the contact points 8a and 8b with the rods 9 are extremely limited is very important because when the gluing material 12 is injected it completely encompasses the rods 9, ensuring a perfect union between the rods 9 and the layers of boards 2 and 3 where the grooves 8 are. The ratio between the size of the grooves 8 and the rods 9 to be housed in them is critical, and this is determined by the quantity of rods 9 involved, their diameter and positioning, which may also be diagonal, totally and/or partially, based on the specific structural calculations depending on the specific intended use of the reinforced CLT structural panel P. The grooves 8 have a depth a little greater than the diameter of the rods 9 and preferably, for structural reasons, especially if not arranged in line with the wood fibres, never greater than half the thickness of the layers of boards 2 and 3 on which they are mill cut, as shown in Figures 8a and 8b. In the same way, the width of the grooves 8 must not be greater than a few tenths of the diameter of the rods 9, as shown in Figures 8 and 8b, to simultaneously allow the gluing material to penetrate into the grooves 8 completely encompassing the rods 9, see Figure 10, and to ensure the right bond between the reinforcing material and the wood, according to the gluing material specifications. To ensure the desired mechanical performance of the reinforced CLT structural panel P to be produced, the reinforcing material, if foreseen, should be placed with a centre distance between pieces of about 20-25 cm, but may vary in relation to the diameter of the suitable rods 9 used and/or for other particular structural needs. The reinforcement rods 9 used in a given panel P may also have different diameters and/or lengths from each other, and consequently also the respective grooves 8 will be sized accordingly. The reinforcing materials used may also be made of different materials which means that a single reinforced CLT structural panel P may contain rods 9 made of basalt fibre or other fibres, ferro-alloys and/or derivatives, as well as bars and/or section bars of any suitable material;

- Figure 9, from left to right, shows and highlights the insertion of rods 9 and gluing material 12 in the different grooves 8 mill cut in the semi-finished assembly S1. This is done in two stages: 1) insertion of the reinforcement rods 9 into the grooves 8; 2) injection of the gluing material 12 into the grooves 8. After the insertion of the reinforcement rods 9 into the different grooves 8, which can be carried out either mechanically or manually, with the aid of the aforementioned CNC robotic arm, and replacing the milling cutter with a special container-

dispenser for the injection of the specific epoxy gluing material 12 or other suitable gluing material into the different grooves 8, in a predetermined amount established given the volume of the grooves 8 net of the volume of the rods 9, so that the gluing material 12 completely surrounds each rod 9 and reaches, without overflowing, the level of the plane formed by the layer of boards 2. The use of basalt fibre rods 9, thanks to their particular shape and almost perfect linearity, as shown in Figure 7, is preferable to other possible round section reinforcing materials, particularly and above all for the characteristics of the basalt fibre hereinafter described, since different products, having different shapes, would require more complex machining of the grooves 8, or the prior injection of gluing material 12, and/or the need for additional components. In particular, by making the grooves 8 without the specific shapes 8a and 8b, it would be absolutely necessary to equip any reinforcing material used with special spacers from the edges and the bottom of the grooves 8, with a consequent increase in costs. In addition, the insertion time would be longer and would need to be performed by hand to prevent problems of any kind related also to the use of the aforementioned spacers, and/or to limit the leakage of gluing material with the subsequent need for top-ups of the glue and cleaning of the boards involved, even complex, given that the gluing material may smear.

- Figure 11 shows and highlights the sequence of machining operations for the semi-finished assembly S2, identical to those carried out on the semi-finish assembly S1 and more precisely: 1) insertion of the reinforcement rods 9 into the grooves 8; 2) injection of the epoxy gluing material 12 or other suitable gluing material into the grooves 8 in a predetermined amount until the rods 9 are completely surrounded by the gluing material 12 which reaches the level of the layer of boards 3;

- After all the aforementioned operations have been performed on the two semi-finished assemblies S1 and S2, that is, the milling cutting, the aspiration of sawdust and shavings, the insertion of the rods 9, the injection of the gluing material 12, and having waited out the curing time of the gluing material to solidly bond the rods 9 and the corresponding semi-finished assemblies S1 and S2, the subsequent operation is to join the semi-finished assemblies S1 and S2 themselves. This happens after the application of the gluing material on the semi-finished assembly S2, as shown in Figures 12 and 13, by lifting and turning the semi-finished assembly S1 over 180° in such a way that it overlies the semi-finished assembly S2. This operation also allows the precise lining-up of the areas for holes-niches 10 also shown in Figures 1 and 2. When the panels are placed together the final pressing takes place, exactly the same as the pressing necessary to achieve a standard CLT panel, obtaining the reinforced CLT structural panel P arranged in the right stratigraphy of boards expected, 1-2-3-4-5, as summarized and shown in Figure 14;

- In a longitudinal section of the reinforced CLT structural panel P just completed as shown in Figure 15, there is a noticeable formation of a reinforcing grid, constituted by the

series of rods 9 having an X axis with the series of rods 9 preferably arranged orthogonally and therefore having a Y axis. In this view note the presence of the reinforcing material on the entire body of the panel ensuring its structural homogeneity; the absence of those reinforcements 9 corresponding to the holes 10, and the termination at a certain distance 11 near the edges of the finished panel P. In Figure 15a, one of the possible embodiments of the panel P in Figure 15, note that in the upper part of the panel, corresponding to the hole 10 foreseen, there is an additional reinforcing element 9a, or even more elements if necessary. This solution can be adopted, for example, when large openings are foreseen in panel P, in order to create greater strength in certain areas and to guarantee the mechanical behaviour of the reinforced CLT structural panel P as homogeneous as possible;

- Figure 16, a partial cross section of the reinforced CLT structural panel P, shows the stratigraphy of boards 1-2-3-4-5 placed correctly; in addition it is possible to see the rods 9, those with a Y axis, embedded in the grooves 8 flush with the layer of boards 2 and the rods 9, with an X axis, therefore preferably orthogonal to the prior rods, embedded in the grooves 8 flush with the layer of boards 3. Figure 16a, an extrapolation of Figure 16, summarizes and highlights an X-Y crossover point between rods 9 where it is possible to see the epoxy glue 12 or other suitable glue, injected into the grooves 8, which fully incorporates the rods 9 and especially, the extreme closeness of the rods 9 to each other which in fact, thanks to the glue that joins the layers of boards 2 and 3, cooperate with each other structurally and consequently with the whole panel P. Figure 16b, another extrapolation of Figure 16, summarizes and highlights the distance 11 from the edge of the finished panel P of a groove 8, the free space 11b between the end of the groove 8 and the rod 9, in addition to the epoxy glue 12 or other suitable glue, which makes each rod 9 integral with the layer of boards 3; exactly the same applies also to the rods 9 inserted in the layer of boards 2. Keeping the rods 9 shorter than the respective grooves 8 and consequently at a certain distance 11+11b from the edges of the reinforced CLT structural panel P is motivated by the fact of facilitating the insertion but also so that the panel P may be machined, in its final stages, such as cutting-trimming edges and the like, in the same way as a standard CLT panel, creating perfect compatibility between the two processes;

- Alternatively or also in combination with the method indicated above, in a panel P composed of multiple layers of boards 1, 2, 3, 4, 5 it can be expected that at least one generically crossed reinforcing grid normally consisting of two series of rods 9 inserted solidly in the respective grooves 8, may be placed in any one of those layers 2, 3, 4. In practice, any one of those layers 2, 3, 4 may comprise two series of those grooves 8 generically transverse to each other to create a network of grooves 8 suitable for the complete insertion-housing of that double series of rods 9, or a generic previously prepared grid. In this type of processing, the assembly process of a reinforced CLT panel P is the same as that of a standard CLT panel, that is, the various layers of boards 1, 2, 3, 4, 5, that comprise it, and on at least one layer 2, 3, 4 of which

two series of reinforcing material 9 are inserted to form a reinforcing grid, are stacked in sequence with each other, without the need to form distinct semi-finished assemblies;

- The end result is in any case a reinforced CLT structural panel P, Figures 17 and 17a, where aesthetic differences in shape and/or size are not noted in its front and side views, as compared to any standard CLT panel;

- A reinforced CLT structural panel may be also composed of multiple layers of reinforcing grids created from the reinforcing material 9 used. This is possible, in a reinforced CLT structural panel P1 as shown in Figure 18, when the layers of boards necessary and expected, for example, are seven in number, or even higher. To obtain a second reinforcing grid constituted by the rods 9, in addition to performing the above machining at the level of the layers of boards 2 and 3 two additional series of milling (X-Y) are carried out at the level of the layers of boards 5 and 6 with the same modalities already mentioned. In this case there are three semi-finished assemblies on which to perform the expected machining, but the joining process to each other is substantially the same as the process where there are only two semi-finished assemblies. The following operations are performed in sequence: 1) assembly, joining by pressing, milling, cleaning by aspiration, insertion of reinforcements, injection of glue, relative to the first semi-finished assembly; 2) assembly, joining by pressing, milling, cleaning by aspiration, insertion of reinforcements, injection of glue, relative to the second semi-finished assembly; 3) joining by pressing of the first and second semi-finished assemblies after turning one 180° on top of the other; 4) milling, cleaning by aspiration, insertion of reinforcements, injection of glue flush with the level of the layer of board 5; 5) assembly, joining by pressing, milling, cleaning by aspiration, insertion of reinforcements, injection of glue, relative to a third semi-finished assembly; 6) joining by pressing of the first set of semi-finished assemblies (first and second) and the third semi-finished assemblies after turning the latter over 180°. Even in a reinforced CLT panel P1, just like a reinforced CLT panel P, it is possible that at least one of the reinforcing grids, formed by two series of reinforcing material 9 or by a previously prepared grid, may be incorporated in a single layer of boards; operating as previously indicated;

- Given the possibility of bending the rods 9 and/or reinforcing bars/section bars it is also possible to construct curved reinforced CLT structural panels P2, as shown in Figure 19, fully compatible, except for the greater mechanical performance which in these cases is even more useful, with standard CLT panels in that shape. The machining procedures, in the case of curved panels, are modelled substantially after the same machining that is carried out for flat panels, excepting the specifications resulting from the fact that the assembly of such a standard curved panel is not always done on horizontal planes, and therefore, just like for a standard curved panel, appropriate assembly methodologies will be adopted;

- Figure 20 shows a perspective view of what was already indicated in Figure 16 where there is a noticeable formation of a reinforcing grid consisting of two series of rods 9

incorporated in two distinct layers of boards 2, 3 which are mutually orthogonal and directly adjacent and where the reinforcing elements 9 are fully inserted in the respective grooves 8 and securely fixed therein with a specific gluing material 12;

- The methods described so far suited to construct a reinforced CLT structural panel P, P1, P2 can, as specified in point 5) of this document, be subject to new embodiments without requiring modifications and/or extensions of the limits of protection also included in the claims which, essentially, are intended to safeguard the fundamental principle of the invention therefore, a panel P, P1, P2 is always reinforced by at least one reinforcing grid and wherein that reinforcing grid is understood to be at least one reinforcing element 9 incorporated and placed along the X axis of a panel P, P1, P2 which is crossed by at least one reinforcing element 9 incorporated and placed along the Y axis of the same panel. In practice, a generically crossed reinforcing grid formed by two series of reinforcing bars 9 can be formed by placing the two series of rods 9 in the respective grooves 8 formed in the longitudinal direction into two separate and individual layers of normally and advantageously adjacent boards. Purely by way of non-limiting example, a reinforcing grid may be formed by two series of rods 9 arranged in the X and Y axes of a panel P, P1, P2 and where those rods 9, inserted into the respective grooves 8, although having directions generically crossed with each other, may not be directly facing each other as in Figures 16, 18, 19, but be inserted, as shown in a partial cross section of a panel P in Figure 21, a first set of rods 9 longitudinal to the layer of boards 2 facing the layer of boards 1 and a second series of rods 9 inserted longitudinally to the layer 3 facing the layer of boards 2;

- The same principle also applies to panels P1 and P2, regardless of the number of layers of boards and of reinforcing grids with which they are made, and this is shown in the solutions in Figures 22a, 22b, 22c, 22d, 22e, 22f, 22g, and 22h, examples of partial cross sections of reinforced CLT structural panels. In these cases they are reinforced CLT panels with seven layers of boards, where it appears that at least two series of these reinforcing elements 9 are variously inserted in any two distinct pairs of adjacent layers of boards 1-2, 2-3, 5-6, 6-7. Consequently, at least two series of these reinforcing elements 9 are therefore directly facing or not facing each other, notwithstanding the fact that in a panel P, P1, P2 composed in this manner there is, however, at least one generally crossed reinforcing grid that forms consisting of the reinforcing elements 9 themselves. When, for structural reasons, reinforced CLT structural panels having the arrangement of at least one series of reinforcement elements 9 included in the first 1 and/or last layer 7 of the same must be constructed, as in the cases of Figures 22c, 22d, 22g, and 22h, operating methodologies that facilitate these operations can be used, such as, by way of a non-limiting example, pre-assemble the layers of boards 1 and 7 fixing them solidly or not solidly to at least one additional thin layer of boards variously arranged and placed in their most external façade, or to thin panels of wood such as plywood, LVL, OSB and/or the like,

forming in reality semi-finished assemblies which are then machined and assembled in the same manner to that already described.

Description of the drawings

- Figure 1 is the perspective view of the semi-finished assembly S1, composed of two layers of boards arranged orthogonally to each other and joined together with glue, with a series of milling performed in order to obtain grooves-recesses suitable to house the reinforcing material foreseen;
- Figure 2 is the perspective view of the semi-finished assembly S2, consisting of three layers of boards arranged orthogonally to each other and joined together with glue, with a series of milling performed in order to obtain grooves-recesses suitable to house the reinforcing material foreseen;
- Figure 3 is the top view of a part of the flat surface of a semi-finished assembly where the specific lateral shaping of a groove is highlighted, formed by a first and second machining sequence;
- Figure 3a is the longitudinal section view of a groove, with the particular shape of its bottom highlighted in which specific bumps-spacers were machined;
- Figure 3b is the cross-sectional view of a groove, with the lateral guides relating to Figure 3 and the bottom bumps-spacers relative to Figure 3a indicated;
- Figure 4 shows and highlights a single groove that ends at a specific distance from the edge of the board where it is made;
- Figure 5 shows and highlights a single groove that ends at a specific distance from any niches-holes foreseen in the finished panel;
- Figure 6 shows and highlights a single groove that ends at a specific distance from the edge of the board where it is made;
- Figure 7 shows a specific usable type of reinforcing material;
- Figure 8 is the top view of a groove with the expected reinforcing material inserted, maintained in a central position of the groove by the particular lateral shapes of the grooves;
- Figure 8a is the longitudinal section view of a groove with the expected reinforcing material inserted, maintained in a raised position from the bottom of the groove by the particular bumps;
- Figure 8b is a cross-sectional view of a groove with the expected reinforcing material inserted, maintained in the correct position by the particular shapes shown in Figures 8 and 8a;
- Figure 9 shows and highlights the insertion sequence of the reinforcing material in a groove and the subsequent injection of the gluing material in order to firmly join the reinforcing material and a specific layer of boards to each other;

- Figure 10 is a longitudinal section of Figure 9 (this also applies to Figure 11) and in particular of a groove where the reinforcing material is inserted after the introduction of the gluing material;
- Figure 11 shows and highlights the sequence of insertion of the reinforcing material in a groove and the subsequent introduction of the gluing material in order to firmly join the reinforcing material and a specific layer of boards to each other;
- Figure 12 shows and highlights the first semi-finished assembly inverted by 180° with respect to its processing position ready to be joined to the second semi-finished assembly;
- Figure 13 summarizes and highlights the second semi-finished assembly prior to the operation to join it to the first semi-finished assembly;
- Figure 14 summarizes and highlights a portion of the reinforced CLT structural panel assembled;
- Figure 15 is a longitudinal section of the reinforced CLT structural panel, where the successful formation of a reinforcing grid constituted by the reinforcing material inserted, and the absence of the same in the presence of niches-holes at the edges is clearly shown;
- Figure 15a is a variant of Figure 15 in which there is an additional reinforcing element (there can be more than one and in multiple areas) in correspondence with the upper part of a panel where there is a hole;
- Figure 16 is a partial cross section of the reinforced CLT structural panel, with two series of reinforcing material inserted, arranged orthogonally to each other, to form a reinforcing grid;
- Figure 16a, an extrapolation of Figure 16, illustrates an intersection between two reinforcement elements arranged orthogonally to each other;
- Figure 16b, an extrapolation of Figure 16, shows a groove and the reinforcing material inserted in it and their distance from the edge of the finished panel;
- Figure 17 is the front view of a finished reinforced CLT structural panel;
- Figure 17a is a view of the narrow edge of a finished reinforced CLT structural panel;
- Figure 18 is a partial cross section of a reinforced CLT structural panel, with four series of reinforcing material inserted, arranged in pairs perpendicular to each other, to form two reinforcing mesh grids;
- Figure 19 is the partial cross section of a curved reinforced CLT structural panel, with two series of reinforcing material inserted, arranged orthogonally to each other, to form a reinforcing grid;
- Figure 20 is a partial section, in perspective, of Figure 16 which highlights the reinforcing material arranged cross-axially to form a reinforcing grid and incorporated solidly in two distinct layers (2, 3) of boards;

- Figure 21 is a partial cross section of a reinforced CLT structural panel with two series of reinforcing material inserted, arranged orthogonally to each other, to form a reinforcing grid and where those two series of reinforcing material are not directly facing each other, as shown in Figure 16, even if inserted in two layers (2, 3) of adjacent boards.
- Figures 22a-h show some partial cross sections of reinforced CLT structural panels with four series of reinforcing material inserted, arranged in pairs perpendicular to each other, to form two reinforcing grids and where each of those two pairs of reinforcing material are shown with different configurations in individual layers of boards (1, 2, 3, 5, 6, 7) being directly or not directly facing each other.

Implementation of the invention

A reinforced CLT structural panel thus conceived, being perfectly compatible as regards shape and size with any standard CLT panel, can be used interchangeably in combination with panels of the same type, in conjunction with standard panels, and also with other materials used in construction. Given the specific mechanical characteristics of a reinforced CLT panel, especially in the version with two or more grids of crossed rods, it is particularly indicated when, for example, floors, flat or curved roofing must be constructed, where given the same thickness a greater capacity and/or spans are necessary and/or where, regardless of its use, better behaviour as a rigid plate and/or slab is structurally advantageous. The use of such a panel is also indicated, for example, in the construction of buildings where cantilevered structures are foreseen and this allows, given the better mechanical properties of a reinforced CLT structural panel compared to a standard CLT equivalent panel, greater or improved volumes and/or shapes to be attained. Another advantage of the use of the present invention is to be able to use low quality timber, which, given its great availability around the world, enables the attainment of reinforced CLT structural panels which are advantageous also from the economic point of view, in addition to helping to safeguard ever more precious and rare tree species. An important element of this invention, in addition to what has already been explained, is the type of reinforcing material indicated to achieve it, and specifically the use of rods with improved adherence, and/or rods and/or section bars made of basalt fibre. This absolutely does not compromise the use of other reinforcing materials, such as carbon fibre or other suitable fibres, iron, steels and/or alloys of any type, but the use of basalt fibre as a reinforcing material is one that responds best to the ratio between mechanical performance - thermal performance - environmental impact - chemical/physical performance - price. The preference for the use of rods with improved adherence, and/or rods and/or section bars made of basalt fibre, results from a series of precise reasons which briefly and concisely can be summarized as follows:

- basalt fibre is a product derived from basalt rock, a raw material present in large quantities in nature, given that it is a stone of volcanic origin and therefore available, with huge deposits difficult to estimate in terms of volumes, in many areas of planet earth;

- basalt fibre can take on any shape and size so much so as to have been used for a long time, especially in the eastern countries (China - Russia - Japan - Korea - others) in various sectors such as automotive, mechanical, aerospace, marine, textiles, construction, infrastructure, as well as others where it is already used, and those countless sectors where they are experimenting with its benefits;

- basalt fibre has very low thermal transmittance, so much so as not to affect in any way the performance of this type of reinforced CLT structural panel where it is used;

- the basalt fibre rods with improved adherence considered here, and/or bars and/or section bars, which can be produced at the desired lengths, have no need for joints when used in reinforced CLT structural panels even if they are long, and this benefits the mechanical performance of the panel, which is homogeneous;

- basalt fibre has a resistance to high temperature and this ensures good fire behaviour in the case of fire, maintaining at length the structural characteristics of the reinforced CLT panel in which it is used;

- the basalt fibre rods with improved adherence, and/or bars and/or section bars, have high resistance to alkali and radiation and are not prone to rust, therefore ensure the same characteristics and initial performance for the lifetime of the reinforced CLT structural panel;

- the basalt fibre rods with improved adherence considered here, and/or the bars and/or section bars, have mechanical characteristics very similar, with some parameters even higher, with respect to corresponding elements in iron, as well as those made of carbon fibre and/or other fibres and/or alloys;

- basalt fibre, made in the form of rods and/or bars and/or section bars, to remain in the construction industry, can be used in traditional building in substitution of and/or addition to the normal iron rod, as per consolidated experiences in highly seismic zones such as Japan, and this provides reliable data on the mechanical performance of this material;

- basalt fibre rods with improved adherence, and/or bars and/or section bars, thanks to their approximately 75% lower specific weight compared to corresponding elements made of iron and their even higher general mechanical performance, enable the construction, for example, given the same thicknesses, of products made of reinforced concrete with much higher structural characteristics and, in the case of its use as in the invention, in the construction of reinforced CLT structural panels also give the advantage compared to iron of not adversely affecting the overall weight of the same, except for a few kilograms per square meter of panel;

- the basalt fibre rods with improved adherence considered here, and/or the bars and/or section bars, given their low specific weight compared to iron, are extremely easy to handle; in addition, the particular shape and linearity permits their use in the invention herein in a simple, precise, and fast manner;

- the basalt fibre rods with improved adherence, and/or the bars and/or section bars, have very low magnetic susceptibility and therefore, unlike iron, do not form "magnetic cages" inside buildings made with reinforced CLT structural panels, to the benefit of the health of the environment and the quality of life of the people in the building itself;
- the cost of basalt fibre rods with improved adherence, and/or bars and/or section bars, is almost one tenth that of those made of carbon fibre, making the use of basalt fibre economical compared to carbon fibre but slightly higher than iron. However, in comparison with the latter, much less energy is used for their production, therefore the entire production cycle has advantageous conditions for the environment.

In summary, the use of a reinforced CLT structural panel presents numerous performance benefits, especially and not only where particular mechanical characteristics are required, but also to make shapes still not realized and/or feasible with the technique practiced to date.

Therefore, with reference to the preceding description and the attached diagrams the following claims are made.

CLAIMS

1. Method for making a structural panel in wood of the CLT type (P), that is, comprising several superimposed layers (1, 2, 3, 4, 5), each formed by several boards adjacent to each other and arranged in the same direction (X, Y), wherein each layer (1, 2, 3, 4, 5) is arranged with the boards laid crosswise with respect to the boards of the opposing layer, **characterized in that** it comprises the following steps:

- making at least one series of grooves-recesses (8) on at least one of said layers (2, 3), wherein said recesses (8) are arranged in the longitudinal direction of said boards of said layer (2, 3) on which they are made;
- inserting completely in said recesses (8), resulting from a milling operation, reinforcing elements such as rod irons (9) and/or bars and/or section bars having dimensions proportional to those of the various recesses (8), that is, always smaller than those of the corresponding recesses (8) obtained in each single layer (2, 3), so that said rod irons (9) and/or bars and/or section bars never project beyond the level formed by said layer of boards (2, 3) in which said recesses (8) are made.

2. Method according to claim 1, **characterized in that** it also comprises the step of cleaning said layers (2, 3) where said recesses (8) are made, said step being performed by means of a suction system.

3. Method according to the preceding claims, **characterized in that** it also comprises the step of introducing in said recesses (8) a specific bonding agent (12) of the epoxy type or in any case suitable for the intended purpose, in such a quantity as to completely incorporate said reinforcing elements (9) until reaching the level of the corresponding layer of boards (2, 3), making said reinforcing elements (9) integral with said layer (2, 3).

4. Method according to claim 3, **characterized in that** said introduction of the intended bonding agent (12) in said recesses (8) takes place after the insertion of said reinforcing elements (9), thus allowing the bonding agent to be correctly measured out and avoiding dirtying the surfaces of said layers (2, 3) where there are the recesses (8) in which said reinforcing elements are inserted (9).

5. Method for making a panel (P) according to the preceding claims, **characterized in that** it comprises the following steps:

- making at least two semi finished panels (S1, S2), each formed by two or more of said layers (1, 2, 3, 4, 5), with at least one series of said recesses (8) made in one of said outermost layers (2, 3) of each semi finished panel (S1, S2);
- joining said at least two semi-finished panels (S1, S2) so that the respective layers (2, 3) in which said recesses (8) are obtained directly face each other, and wherein said reinforcing elements (9) are completely inserted in said recesses (8) arranged crosswise with respect to each other so as to obtain a reinforcement grid with crossed meshes.

6. Method for making a panel (P1) according to the preceding claims, **characterized in that** it comprises the following steps:

- making a first semi-finished panel (S1) with at least one series of said recesses (8) in an external layer of boards (2) and with the respective reinforcing elements (9) inserted therein;
- making a second semi-finished panel (S2) with at least one series of said recesses (8) in an external layer of boards (3) and with the respective reinforcing elements (9) inserted therein;
- joining said first and said second semi-finished panels (S1, S2) so that said layers (2, 3) with said recesses (8) directly face each other, and wherein said reinforcing elements (9) are completely inserted in said recesses (8) arranged crosswise with respect to each other so as to obtain a first reinforcement grid with crossed meshes.
- making at least one further series of said recesses (8) created longitudinally in the external layer (5) of one of said semi-finished panels (S2) already joined to said first semi-finished panel (S1) and inserting the corresponding reinforcing elements (9) completely in said recesses (8);
- making at least one third semi-finished panel with at least one series of said recesses (8) created longitudinally in an external layer of boards (6) and inserting the corresponding reinforcing elements (9) completely in said recesses (8);
- joining said third semi-finished panel to said pair of already joined semi-finished panels (S1, S2), so that said layers of boards (5, 6) with said recesses (8) face each other, and wherein said corresponding reinforcing elements (9) are completely inserted in said recesses (8) arranged crosswise with respect to each other so as to obtain a second reinforcement grid with crossed meshes.

7. Method for making a panel (P, P1) according to the preceding claims, **characterized in that** it comprises, alternatively, the steps of

- providing, on at least one of said layers, two or more series of said recesses (8) arranged crosswise to each other;
- inserting two series of iron rods (9) arranged crosswise to each other, or a pre-formed mesh grid, in said recesses (8) completely, so as to form at least one reinforcement grid with crossed mesh.

8. Method according to the preceding claims, **characterized in that** it comprises further final processing steps for said structural panels (P, P1), carried out with the same methodologies applied to any other non-reinforced CLT panel.

9. Structural panel in reinforced CLT (P), that is, comprising several superimposed layers (1, 2, 3, 4, 5), each formed by several boards adjacent to each other and arranged in the same direction (X, Y), wherein each layer (1, 2, 3, 4, 5) is arranged with the boards laid crosswise to

the boards of the opposite layer, **characterized in that** it comprises:

- at least one series of grooves-recesses (8) in both of said layers (2, 3), and wherein said recesses (8) are arranged in the longitudinal direction of said boards of said layer (2, 3) on which they are made;
- reinforcing elements, like iron rods (9) with improved adhesion and/or bars and/or section bars, completely and integrally inserted in the corresponding recesses (8) in each single layer (2, 3), and wherein said rod irons (9) and/or bars and/or section bars are made of any suitable reinforcing material.

10. Panel (P, P1) according to claim 9, **characterized in that** said reinforcing elements (9) are advantageously made of basalt fibre.

11. Panel (P1) according to claims 9 and 10, **characterized in that** it comprises at least two semi-finished panels (S1, S2) joined to each other, each one formed by two or more of said layers (1, 2, 3, 4, 5), with at least one series of said recesses (8) made in both of said outermost layers (2, 3) of each semi-finished panel (S1, S2), and wherein the corresponding reinforcing elements (9) arranged crosswise to each other so as to form a reinforcement grid with crossed mesh are completely inserted in said recesses (8).

12. Panel (P1) according to claims 9 and 10, **characterized in that** it comprises at least three semi-finished panels joined to each other, each one formed by two or more of said layers (1, 2, 3, 4, 5, 6, 7) and even further ones, if provided, with at least one series of said recesses (8) made in all of said outermost layers (2, 3, 5, 6), and even further ones, if provided, of each semi-finished panel, and wherein the corresponding reinforcing elements (9) arranged crosswise to each other so as to form at least two reinforcement grids with crossed mesh are completely inserted in said recesses (8).

13. Panel (P, P1) according to the preceding claims, **characterized in that** it comprises two series of said recesses (8) generically arranged crosswise to each other, both made in the same layer of boards of said panel (P, P1), and two series of said reinforcing elements (9), or a pre-formed mesh grid, completely inserted in said recesses (8) so as to form at least one reinforcement grid with generically crossed mesh.

14. Panel (P, P1) according to the preceding claims, **characterized in that** at least two series of said recesses (8), created longitudinally on any two distinct single layers of boards directly opposing each other orthogonally, with the corresponding reinforcing elements (9) inserted in said recesses (8), do not always necessarily face each other like said reinforcing elements (9) inserted therein, without prejudice to the fact that at least one reinforcement grid with generically crossed mesh made up by the reinforcing elements (9) in any case is formed in said panel (P, P1).

15. Panel (P, P1) according to the preceding claims, **characterized in that** said recesses (8) made in all the concerned layers of boards, and the corresponding reinforcing elements (9) are

equal to or different from each other in number, distance between axes, length, size, shape, in addition to directions that are even non linear with respect to the fibre of the respective boards.

16. Panel (P, P1) according to the preceding claims, **characterized in that** said recesses (8), and the corresponding reinforcing elements (9), are present on the entire area of the respective layers of boards, or only on one portion or more portions of the same, due both to structural reasons and/or to the need to make holes (10), niches, cuts and/or to carry out other types of processing on the panel (P, P1).

17. Panel (P, P1) according to the preceding claims, **characterized in that** each one of said recesses (8) comprises in its cross section one or more narrowed portions (8a, 8b) serving as spacer guides with the function of maintaining said reinforcing elements (9) inserted in a defined position.

18. Panel (P, P1) according to the preceding claims, **characterized in that** the depth of each one of said recesses (8) does not exceed half of the thickness of the respective layer of boards on which the recess is provided and its length and width slightly exceed the diameter and/or size of the respective reinforcing elements (9) and/or bars and/or section bars.

19. Panel (P, P1) according to the preceding claims, **characterized in that** it comprises one or more additional reinforcing elements (9a) inserted in corresponding recesses (8) made in proximity to holes (10) and/or openings and/or niches and/or where said reinforcing elements (9a) are structurally useful.

20. Structural CLT panel (P2) according to all of the preceding claims, **characterized in that** it is curved.

FIG.1

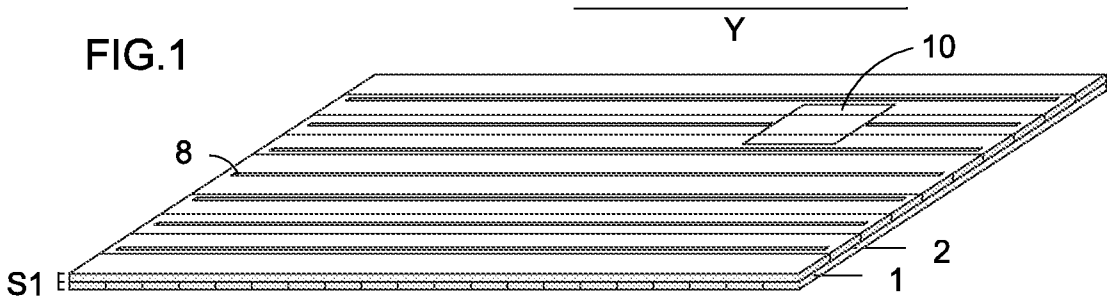


FIG.2

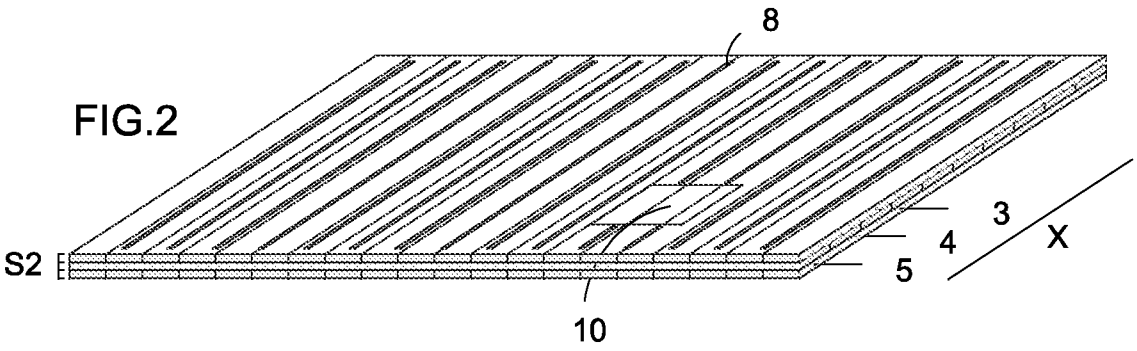


FIG.3

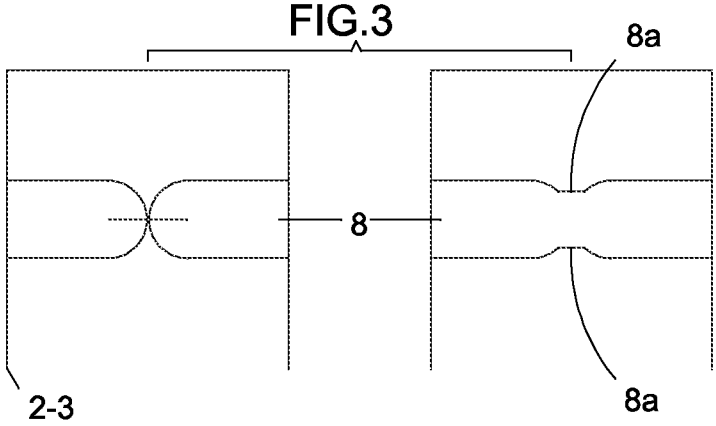


FIG.3a

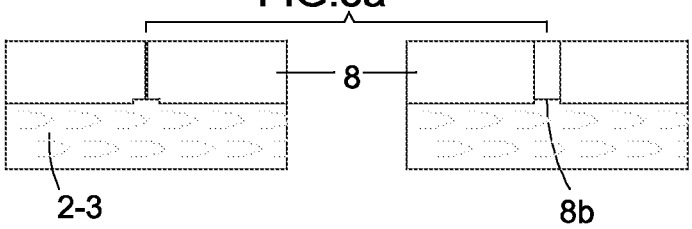


FIG.3b

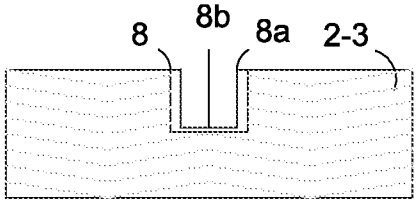


FIG.4

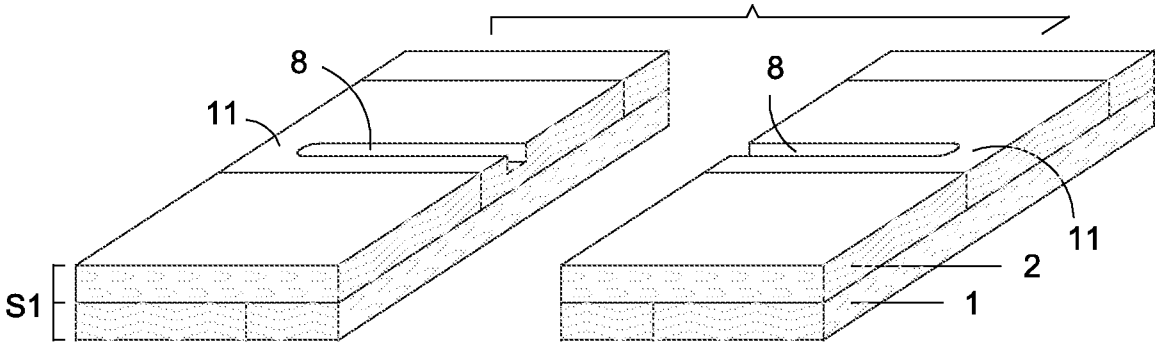


FIG.5

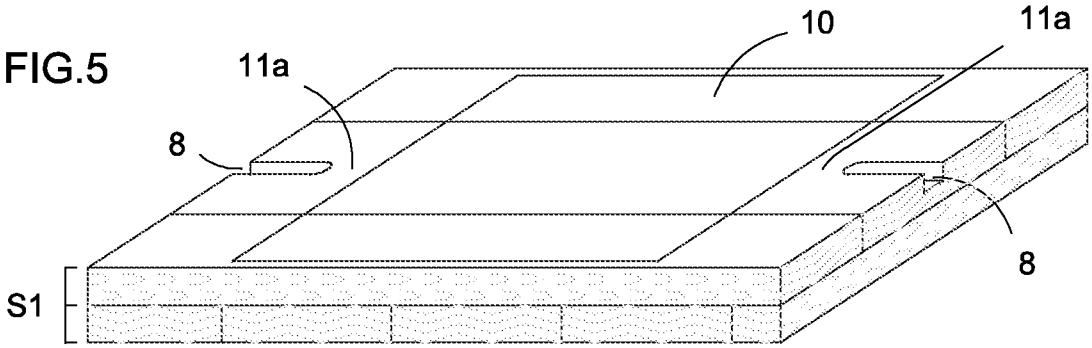


FIG.6

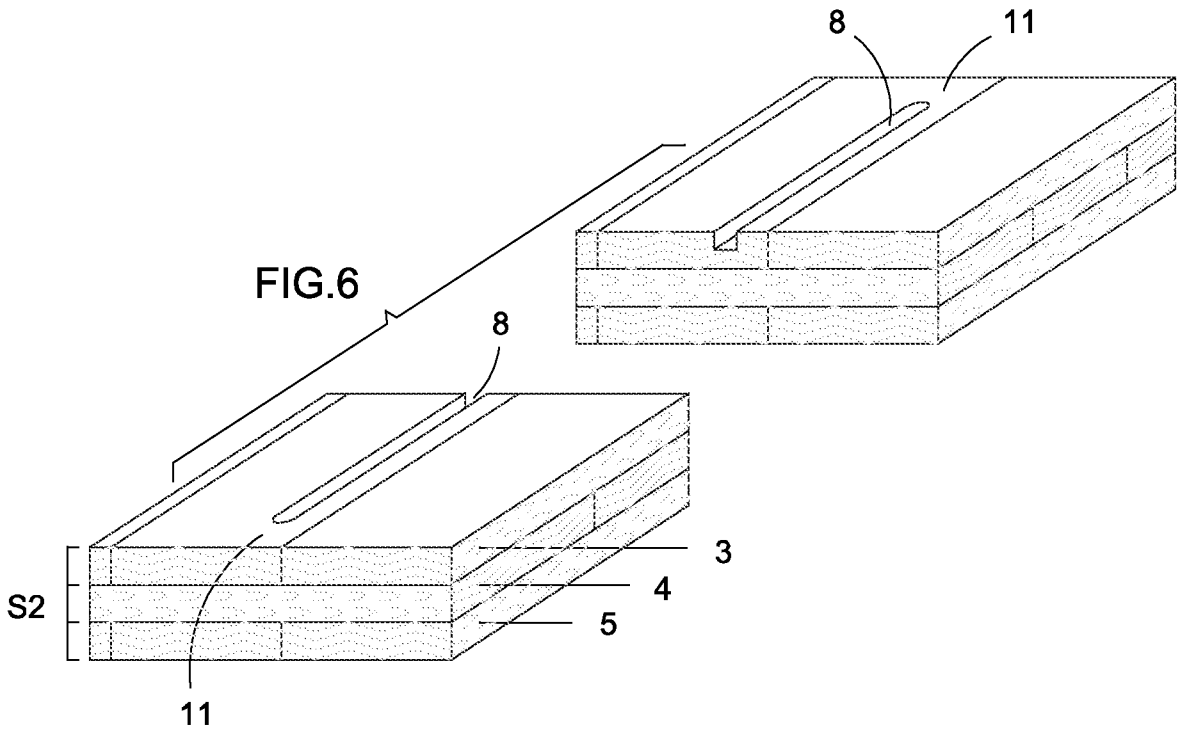


FIG.7



FIG.8

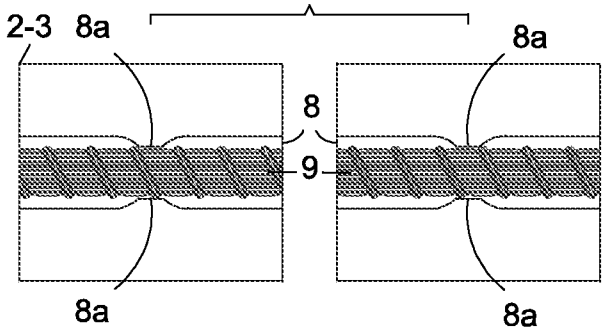
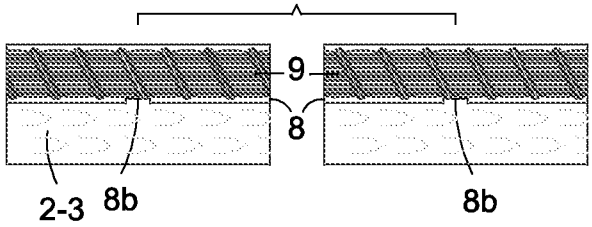


FIG.8a



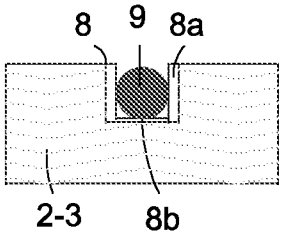


FIG.8b

FIG.9

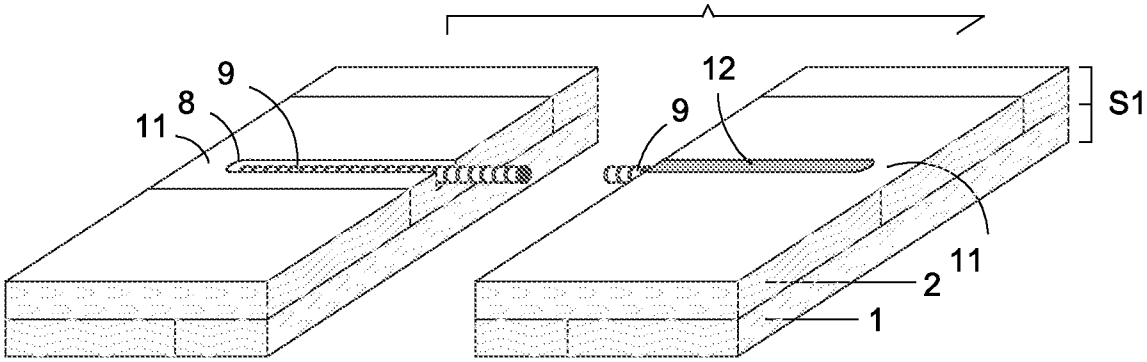


FIG.10

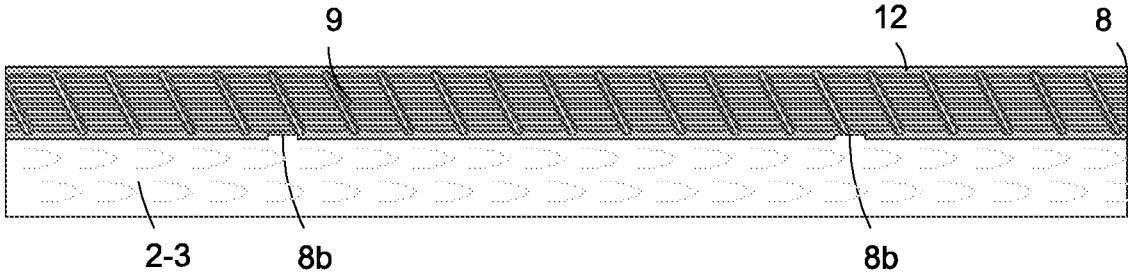


FIG.11

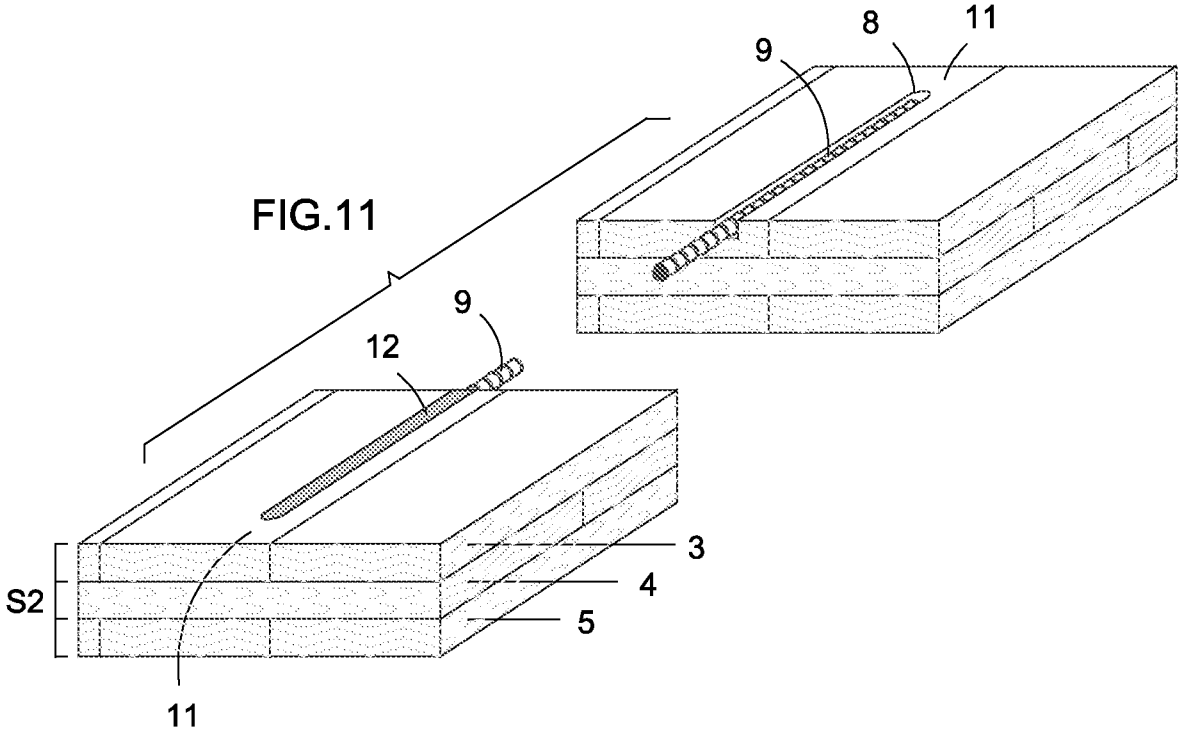


FIG.12

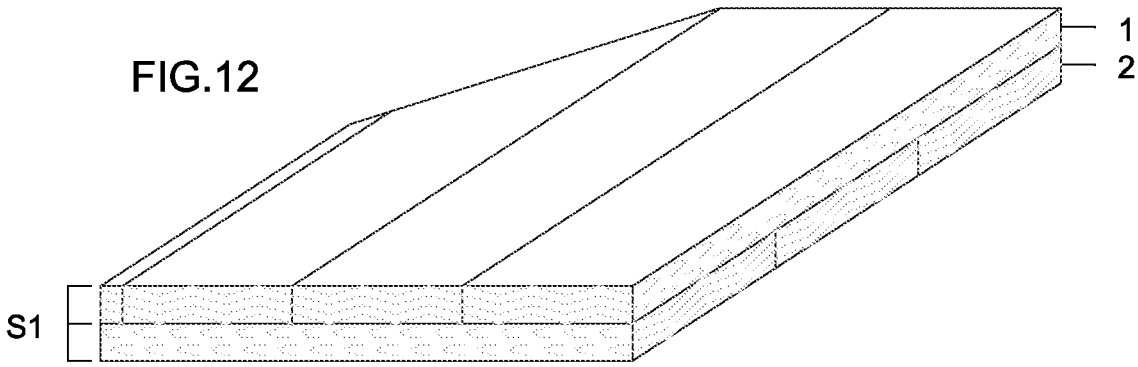


FIG.13

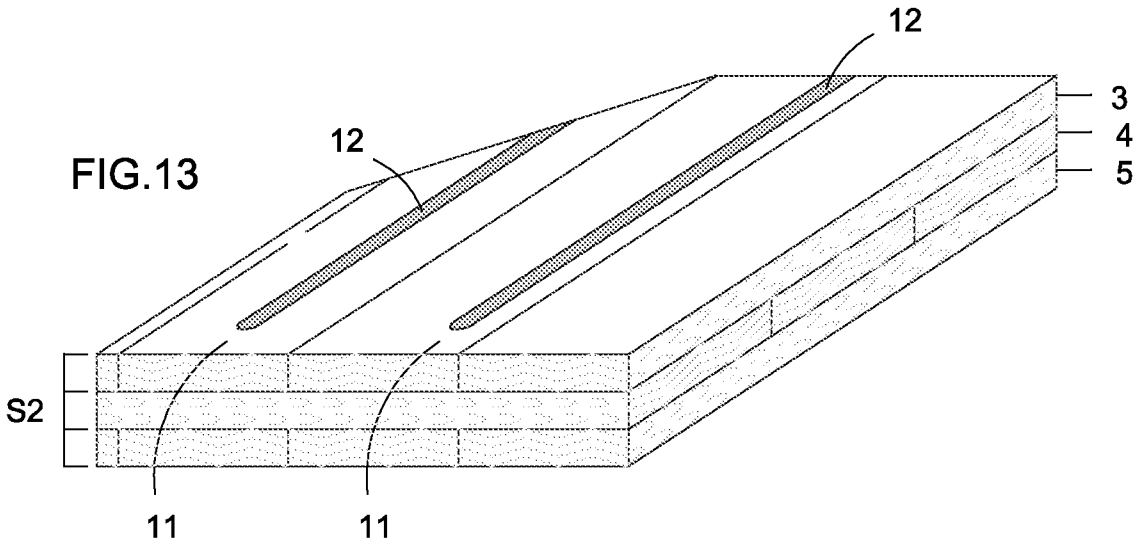
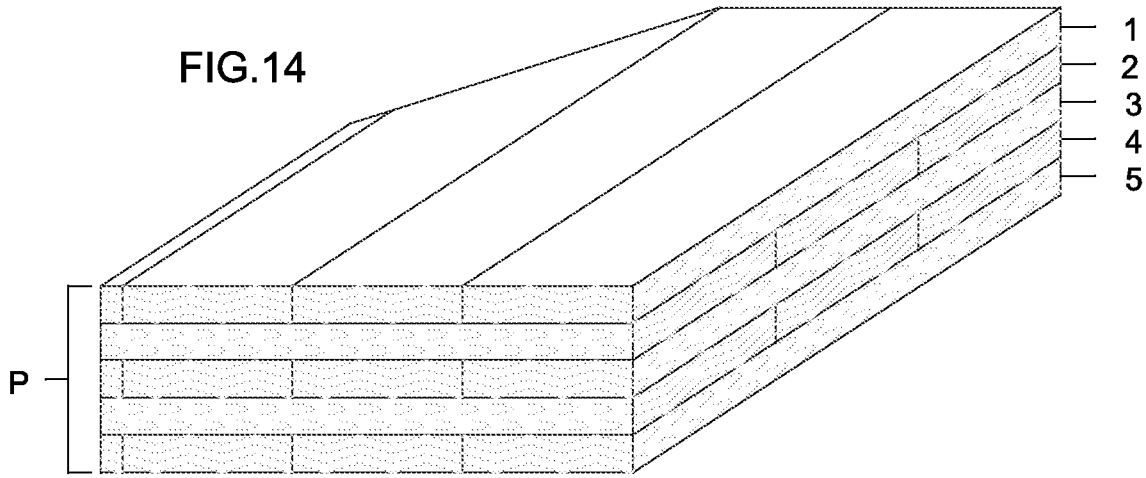


FIG.14



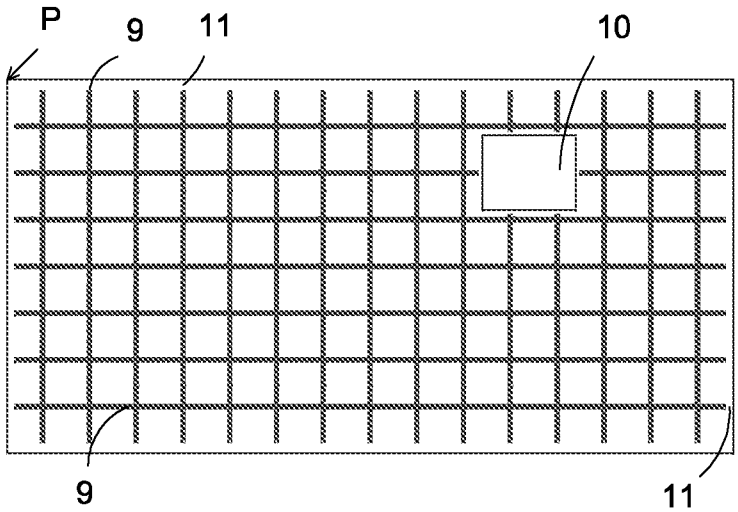


FIG.15

FIG.15a

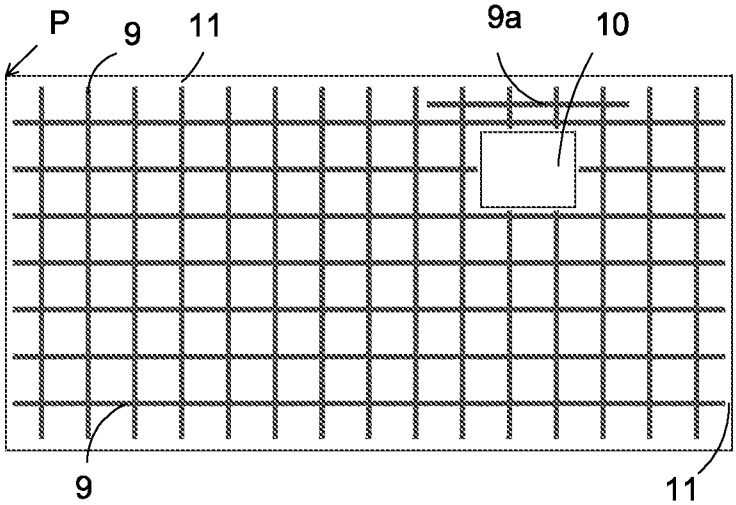


FIG.16

FIG.16a

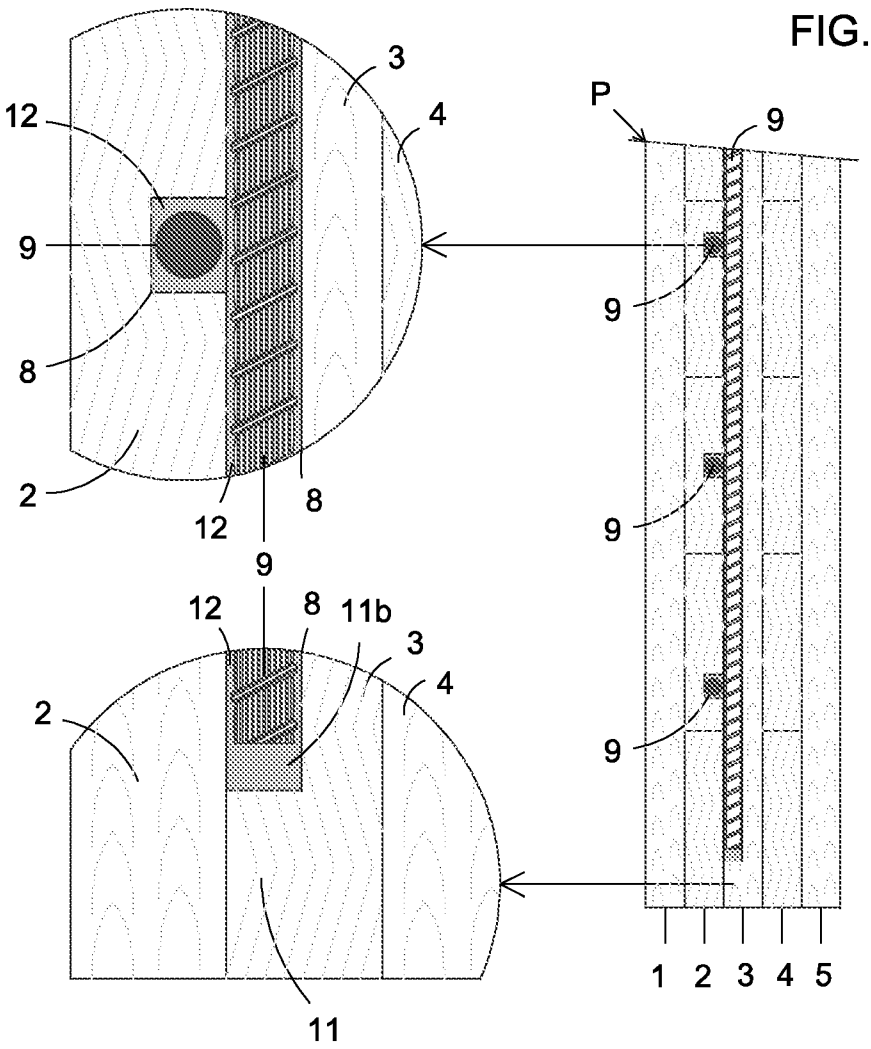


FIG.16b

FIG.17

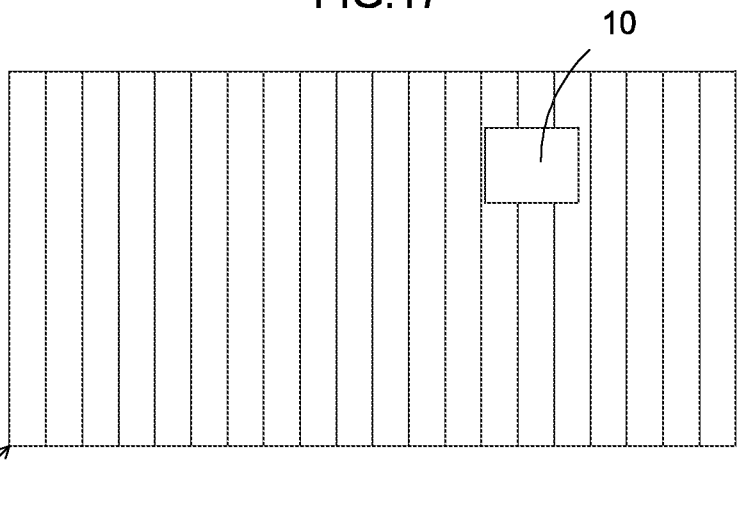
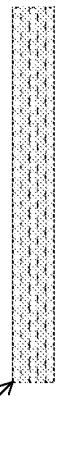


FIG.17a



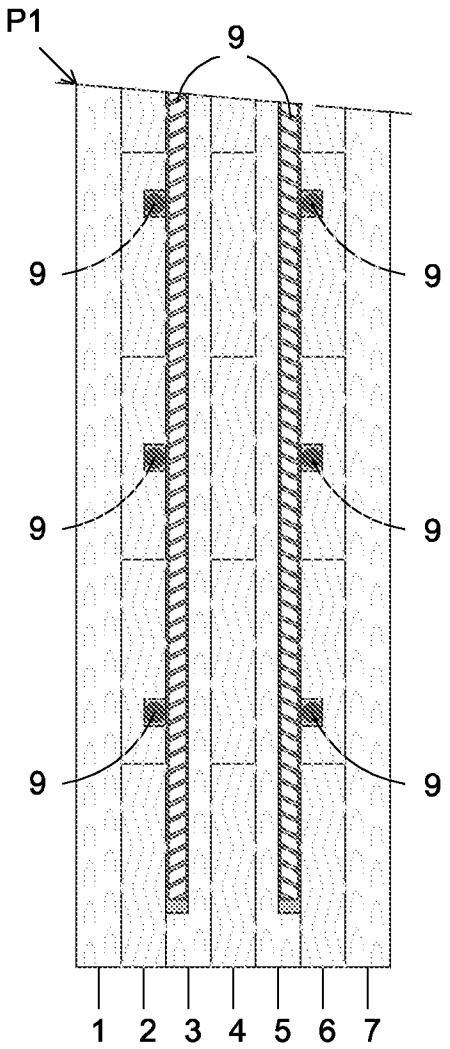


FIG.18

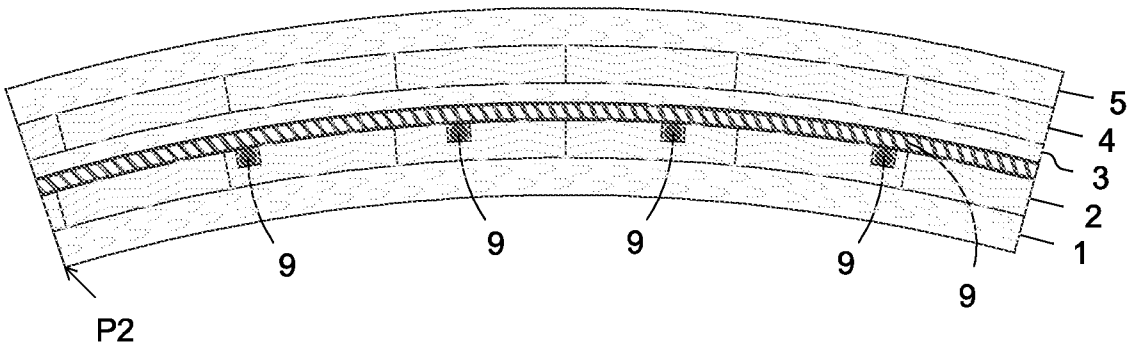


FIG.19

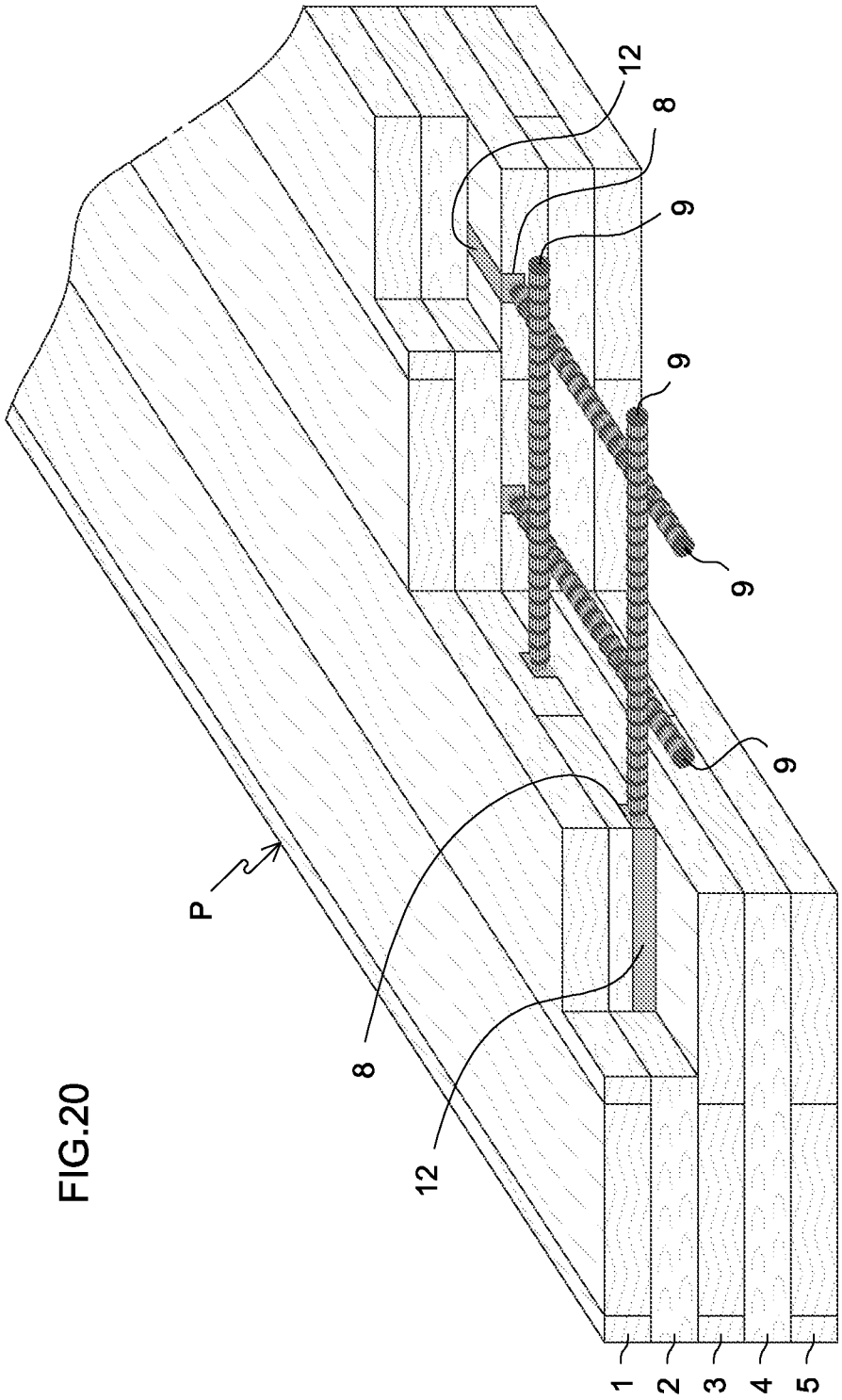
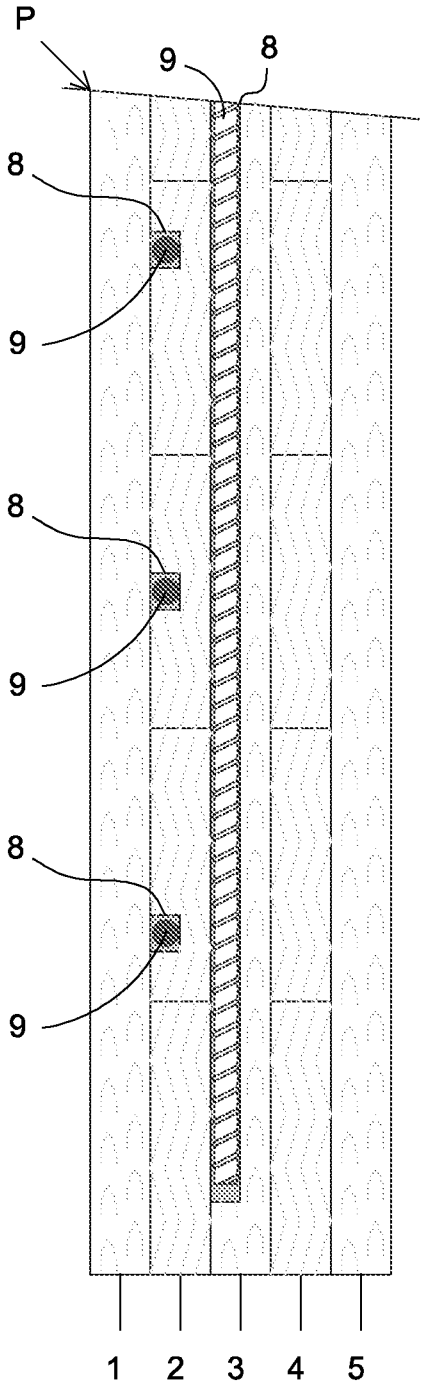


FIG.20

FIG.21



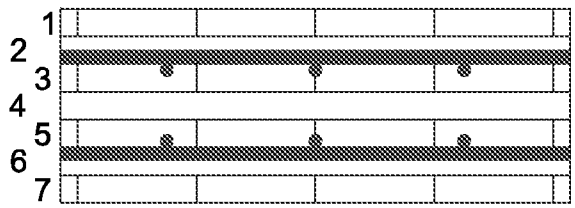


Fig. 22a

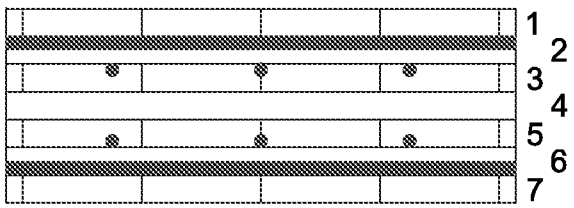


Fig. 22b

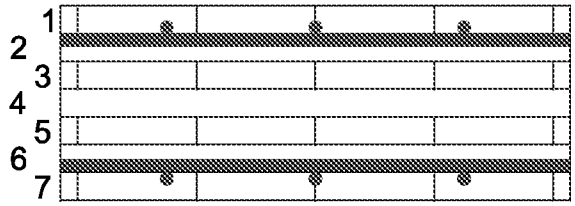


Fig. 22c

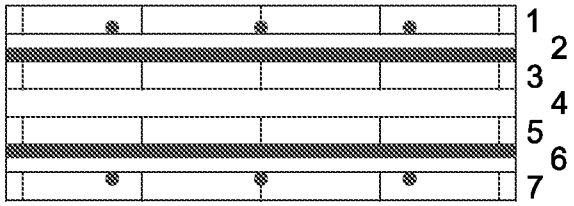


Fig. 22d

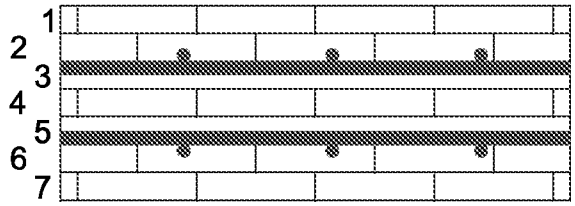


Fig. 22e

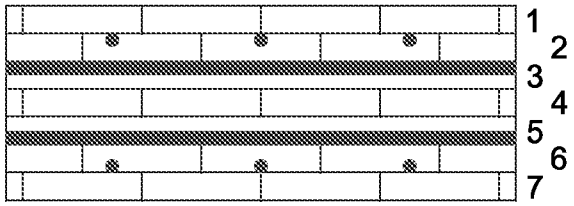


Fig. 22f

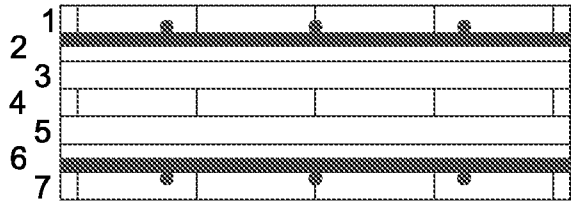


Fig. 22g

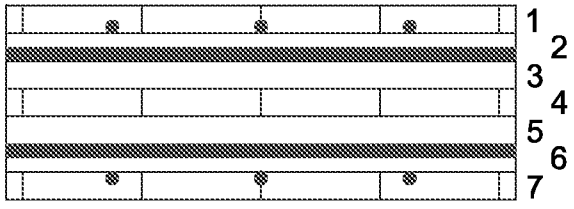


Fig. 22h

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2013/055074

A. CLASSIFICATION OF SUBJECT MATTER
INV. E04C2/14 B32B21/13 B27M3/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
E04C B32B B27M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
6 November 2013	14/11/2013

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Huggins, Jonathan

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2013/055074

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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