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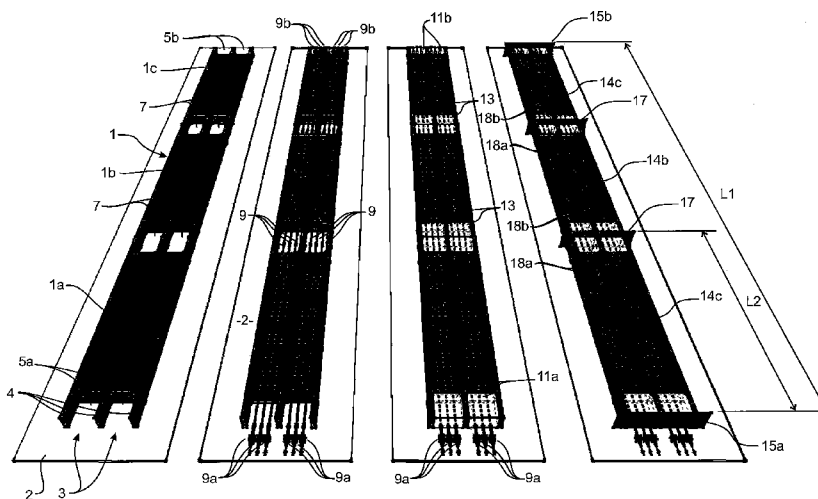


FIGURE 1

(57) Abstract: A method of manufacturing a pre-stressed beam or panel and the resulting beam or panel are described. The method includes providing a timber-based component (1); providing a pre-stressing member (9) arranged along the timber-based component; applying a tensile force to the pre-stressing member (9); providing concrete anchors (11a, 11b) at locations that are spaced apart along the timber-based component (1); coupling the pre-stressing member (9) to the concrete anchors (11a, 11b); and releasing the tensile force on the pre-stressing member (9) to transfer a compressive force to the timber-based component (1) through the concrete anchors (11a, 11b) to form a pre-stressed beam or panel.

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## PRE-STRESSED BEAMS OR PANELS

### FIELD OF THE INVENTION

This invention relates to a pre-stressed beam or panel and to a method of manufacturing a pre-stressed beam or panel.

### 5 BACKGROUND

Traditional pre-stressed concrete hollow-core planks are used in the construction of buildings and bridges. While concrete-based construction members are strong and low cost, they are also heavy, expensive to transport and have a high associated environmental cost.

10 Timber has many advantages over concrete; it has higher strength to weight, is a renewable resource, and wood-based members generally perform better during seismic events due to their reduced mass. Timber is often considered more aesthetically pleasing than concrete and therefore is less likely to necessitate painting or cladding. Despite these advantages, engineered timber structural members are used less often  
15 than concrete in large commercial building. This is due to the higher cost of timber and because the on-site construction process is often more complex than for concrete members.

Concrete construction members are available as pre-fabricated and pre-stressed lengths, whereas timber members normally require post-tensioning on site. That requires special  
20 skills and equipment and slows construction time.

In this specification where reference has been made to patent specifications, other external documents, or other sources of information, this is generally for the purpose of providing a context for discussing the features of the invention. Unless specifically stated otherwise, reference to such external documents or such sources of information is not to  
25 be construed as an admission that such documents or such sources of information, in any jurisdiction, are prior art or form part of the common general knowledge in the art.

It is an object of at least preferred embodiments of the present invention to provide a pre-stressed beam or panel, and a method for manufacturing a pre-stressed beam or panel that addresses the above mentioned problems and/or that at least provides the  
30 public with a useful alternative.

## SUMMARY OF THE INVENTION

In a first aspect, the invention provides a method of manufacturing a pre-stressed beam or panel. The method comprises: providing a timber-based component; providing a pre-stressing member arranged along the timber-based component; applying a tensile force to the pre-stressing member; providing concrete anchors at locations that are spaced apart along the timber-based component; coupling the pre-stressing member to the concrete anchors; and releasing the tensile force on the pre-stressing member to transfer a compressive force to the timber-based component through the concrete anchors to form a pre-stressed beam or panel.

10 In a preferred embodiment, the concrete anchors are provided by pouring concrete at locations that are spaced apart along the timber-based component, embedding respective portions of the pre-stressing member. Coupling the pre-stressing member to the anchors comprises allowing the concrete to substantially cure, before the tensile force on the pre-stressing member is released.

15 Preferably, the concrete is poured at two spaced apart locations positioned at or adjacent the ends of the timber-based component to form end anchors.

In an alternative embodiment, the concrete anchors are pre-cast. The pre-stressing members may be coupled to the pre-cast anchors by grouting, concrete, or mechanical fasteners, for example.

20 In a preferred embodiment, the method comprises providing and tensioning a plurality of pre-stressing members.

In one embodiment the method comprises pouring concrete at one or more locations between the two end anchors to form one or more intermediate concrete anchors embedding a respective intermediate portion of the pre-stressing member;

25 allowing the or each intermediate concrete anchor to substantially cure; and cutting the beam or panel through the or each intermediate anchor and through the respective anchored intermediate portion of the pre-stressing member to form two or more shorter pre-stressed beams or panels. Alternatively, the method may comprise placing at least three discrete pre-cast anchors at spaced apart locations and coupling the pre-stressing member to each of the at least three pre-cast anchors using concrete or grouting. Preferably these three anchors comprise two end anchors and an intermediate anchor positioned between the two end anchors. Once the concrete or grouting has substantially cured, the pre-stressed beam or panel may be cut through

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the intermediate anchor and through the respective anchored portion of the pre-stressing member, to form two shorter pre-stressed beams or panels.

Using this method, a plurality of shorter pre-fabricated pre-stressed beams or panels, suitable for transport to a construction site, may be pre-stressed at one time.

- 5 Some embodiments may comprise pouring or placing two or more intermediate anchors between the end anchors, and cutting the pre-stressed beam or panel through each intermediate anchor.

Preferred forms of the method may be carried out in existing yards currently used for producing precast concrete, with only minor modifications to the yards and equipment.

- 10 Equipment such as pre-stressing jacks may be used to apply tensile force to the pre-stressing member(s). The tension may be maintained in the pre-stressing member(s) while the concrete cures using any known suitable method.

- The pre-stressing member(s) may consist of one or more tendons, which may be rods, bars or cables, for example, or alternatively may consist of one or more plate or sheet  
15 members, and could for example be laminates. Preferably the pre-stressing member(s) comprise high tensile steel, but alternatively they may comprise an alloy, carbon composite, glass-aramid, or other composite material.

- The timber-based component is preferably an elongate member with one or more elongate hollow portion(s) or channel(s) to receive at least a portion of the pre-stressing  
20 member(s). The pre-stressing member(s) may be inserted in a respective hollow portion(s) or channel(s) of the completed timber-based component, for example by being placed in channel(s) extending along an outer surface of the timber-based component. Alternatively the pre-stressing member(s) may be inserted in a respective hollow portion(s) or channel(s) during assembly of the timber-based component, for  
25 example by being placed in a channel that is subsequently covered by a timber member such that at least a part of the pre-stressing member(s) is enclosed by the timber-based component.

- In one embodiment, the concrete for the anchors is poured into hollows or boxed regions defined by the timber-based component. In an embodiment having three or more  
30 anchors, in which the initial beam or panel is cut into a plurality of shorter beams or panels, the timber-based component is preferably sufficiently elongate that the plurality of shorter beams or panels are also elongate.

The timber-based component may be a single integrally formed member or may comprise a plurality of members or sub-components assembled or arranged together.

The timber sub-components may be arranged, for example, end-to-end, but not connected. Alternatively, the sub-components may be connected. In that embodiment, the pre-stressing member is arranged to extend along all of the individual sub-components, and the or each intermediate concrete anchor is poured between the ends  
5 of two adjacent individual sub-components to join the sub-components. The intermediate concrete anchor(s) may then be cut to separate the beam or panel into shorter beams or panels.

The timber-based component may further comprise a transverse channel or hollow portion for receiving a transverse pre-stressing member for pre-stressing the beam or  
10 panel in a second transverse direction. The transverse pre-stressing member may be one of the type described above, and may be the same or different from the longitudinal pre-stressing member(s).

In one such embodiment, the method further comprises inserting a transverse pre-stressing member into the transverse channel or hollow portion, applying a tensile force  
15 to the transverse pre-stressing member, pouring concrete at spaced apart locations along the transverse pre-stressing member, allowing the concrete to substantially cure to anchor respective portions of the transverse pre-stressing member, and releasing the tension from the transverse pre-stressing member to pre-stress the beam or panel in the transverse direction. These steps to pre-stress the beam or panel in the second  
20 direction may be carried out on the pre-fabricated beam or panel, after the beam or panel has been pre-stressed in the first direction, and optionally after the initial beam or panel is cut into shorter lengths. Alternatively, the beam or panel may be pre-stressed in the second direction at the same time it is pre-stressed in the first direction.

In an alternative embodiment pre-stressed in a transverse direction, the method may  
25 further comprise coupling pre-cast anchors at spaced apart locations along the transverse pre-stressing member, inserting transverse pre-stressing member into the transverse channel or hollow portion, applying a tensile force to the transverse pre-stressing member, coupling the tensioned pre-stressing members to the pre-cast anchors, and releasing the tension from the transverse pre-stressing member to pre-  
30 stress the beam or panel in the transverse direction. The pre-stressing member may be coupled to the pre-cast anchors by grouting, concrete, or by mechanical fasteners.

In an embodiment, the timber-based component comprises an engineered timber laminate such as LVL (laminated veneer lumber), glulam (glued laminated timber), or Cross-lam/CLT (cross laminated timber). Alternatively or additionally, the timber-based  
35 component may comprise a wood-based composite, for example manufactured by

binding strands, particles or veneers of wood together with adhesive to form a composite, and/or sawn hard wood. The timber-based component may also comprise one or more other structural materials such as steel, composite carbon fibre reinforcement, or glass reinforcing members. As one example, a timber-based component having one or more webs may comprise composite CFRP (carbon fibre reinforced polymers), GFRP (glass fibre reinforced polymers), or steel reinforcing in the webs.

The timber-based component may also comprise a concrete topping layer on a top side of the timber-based component, for fire, seismic, acoustic and/or vibration performance, for example. The concrete topping layer may be reinforced, for example with steel or mesh reinforcing and may be prefabricated or poured in-situ or at the same time as the concrete anchors. The topping layer may be bonded to the timber-based components, so to contribute to the strength of the beam or panel. In one embodiment, the concrete topping layer is bonded to the timber-based component by way of fasteners protruding from a top side of the timber-based component. The fasteners become at least partly embedded in the concrete when the topping layer is poured. Alternatively the topping layer may be unbonded from the timber-based component.

The timber-based component may further comprise a transverse channel or hollow portion for receiving a transverse pre-stressing member. In such an embodiment, the timber-based component may comprise cross laminated timber. In such embodiments, the method may comprise inserting a transverse pre-stressing member into the transverse channel or hollow portion; applying a tensile force to the transverse pre-stressing member; pouring concrete at spaced apart locations along the transverse pre-stressing member; allowing the concrete to substantially cure to anchor respective portions of the transverse pre-stressing member; and releasing the tension from the transverse pre-stressing member to pre-stress the beam or panel in the transverse direction.

Alternatively the method may comprise attaching pre-cast anchors to the timber-based component at spaced apart locations along the transverse channel or hollow portion; inserting a transverse pre-stressing member into the transverse channel or hollow portion; applying a tensile force to the transverse pre-stressing member; coupling the tensioned transverse pre-stressing member to the respective pre-cast anchor; and releasing the tension from the transverse pre-stressing member to pre-stress the beam or panel in the transverse direction.

A plurality of pre-fabricated beams that have been pre-stressed in the first longitudinal direction may be placed side-by-side and pre-stressed in the second direction together to form a panel member. This step may be carried out on a construction site. For example, a plurality of pre-fabricated pre-stressed beams each comprising a transverse channel or hollow portion may be placed side-by-side so the channels or hollow portions on the beams are aligned, and the transverse pre-stressing member arranged to extend through the transverse channels or hollow portions in the plurality of side-by-side beams.

In one embodiment, two side members each comprising a transverse opening aligned with the transverse channels or hollows may be placed one on either side of the plurality of side-by-side beams. Concrete is poured into the transverse opening in each side member to form the anchors for the transverse pre-stressing member. Alternatively, pre-cast anchors may be attached to opposite sides of the timber component and the transverse pre-stressing member tensioned and coupled to those pre-fabricated anchors. The pre-stressing member may be coupled to the pre-cast anchors by grouting, concrete, or mechanical fasteners.

The concrete anchors may be made from light weight concrete, or may comprise hollow regions or timber cores to reduce weight. The method may comprise placing timber, polystyrene or other filler material at the location for each anchor, before pouring the concrete, to create a lightweight core, region, or void in the anchors.

The concrete anchors may comprise steel reinforcing, for example stirrups and bars. For example, the method may comprise placing one or more steel reinforcing members at the location for each anchor, before pouring the concrete, to reinforce the concrete anchors.

In embodiments in which the concrete anchors are poured, shear or axial connectors may protrude from part of the timber-based component into one or more of the anchor locations, such that the connectors become at least partly embedded in the concrete anchors when the anchors are poured. The concrete then cures around the connectors, strengthening the connection between the anchors and the timber-based component.

In a second aspect, the invention provides a pre-stressed beam or panel manufactured according to the method outlined in relation to the first aspect above.

In a third aspect, the invention provides a pre-fabricated pre-stressed beam or panel comprising: a timber-based component; spaced apart concrete anchors operatively connected to the timber-based component; and at least one pre-stressing member

extending between the spaced apart concrete anchors. The pre-stressing member comprises portions coupled to the concrete anchors to apply a compressive force to the timber-based component to pre-stress the beam or panel.

5 The concrete anchors are preferably discrete anchors and preferably comprise two end anchors recessed in opposite ends of the timber-based component. The beam or panel may comprise one or more intermediate anchors positioned between the two end anchors. The intermediate anchors preferably have a length about twice the length of the end anchors.

10 The beam or panel may comprise one or a plurality of pre-stressing members. The pre-stressing member(s) may consist of one or more tendons, which may be rods, bars or cables, for example, or alternatively may consist of one or more plate or sheet member(s), and could for example be laminates. Preferably the pre-stressing members comprise high tensile steel, but alternatively may comprise an alloy, carbon composite, or glass-aramid or other composite material, for example.

15 The pre-stressing member(s) preferably comprise portions embedded in the discrete anchors.

20 The timber-based component is preferably an elongate member with one or more elongate hollow portion(s) or channel(s) to receive the pre-stressing member(s). The pre-stressing member(s) may be positioned in the hollow portion(s) or channel(s) of the timber-based component, for example they may be positioned in channel(s) extending along an outer surface of the component or within internal hollow portion(s) in the timber-based component such that at least a portion of the pre-stressing member(s) are enclosed by the component. The timber component may comprise a transverse wall adjacent each anchor, the wall comprising one or more apertures through which the pre-stressing member(s) extend. Preferably, the cross sectional area of each concrete anchors is much larger than the cross sectional area of the channel, hollow or wall aperture(s) immediately adjacent the anchor. For example, the cross sectional area of each concrete anchors may be at least twice or at least three times the cross sectional area of the channel, hollow or wall aperture(s) immediately adjacent the anchor.

30 In an embodiment having three or more anchors, the timber-based component is preferably sufficiently elongate that a plurality of shorter beams or panels that are also elongate may be formed by cutting through the intermediate anchor(s). The timber-based component may comprise a plurality of individual timber-based sub-components arranged end-to-end. In such an embodiment, the pre-stressing member(s) may extend  
35 along all of the individual sub-components, and the intermediate concrete anchor(s) are

positioned between the ends of two adjacent individual sub-components connecting the sub-components.

In one embodiment, the timber-based component comprises an engineered timber laminate, a wood-based composite and/or sawn hard wood, and may comprise other structural materials or topping layers, as described with above with respect to the first aspect.

For example, one embodiment comprises a concrete topping layer on a top side of the timber-based component. The beam or panel may further comprise fasteners attached to the top side of the timber-based component and at least partly embedded in the concrete topping layer. The topping layer may comprise steel or mesh reinforcing.

The timber-based component may further comprise a transverse channel or hollow portion for receipt of a transverse pre-stressing member. Spaced apart transverse concrete anchors may be operatively connected to the timber-based component. In one such embodiment, the beam or panel further comprises spaced apart transverse concrete anchors and a transverse pre-stressing member arranged in the transverse channel or hollow portion and extending between the transverse concrete anchors, applying a compressive force to the timber-based component to pre-stress the beam or panel in the transverse direction. The transverse pre-stressing member may be one of the type described above, and may be the same or different from the longitudinal pre-stressing member(s).

The beam or panel may comprise a plurality of the above beams each comprising a transverse channel or hollow portion arranged side-by-side with the channels or hollow portions aligned and further comprising two side members, one on either side of the plurality of side-by-side beams. In such an embodiment, the side members each comprise a concrete anchor aligned with the transverse channels or hollows, and a transverse pre-stressing member arranged in the transverse channels or hollow portions and extending between the transverse concrete anchors, such that the transverse pre-stressing member pre-stresses the beam or panel in the transverse direction.

The concrete anchors may be made from a light weight concrete, or may comprise hollow regions or timber cores to reduce weight.

In some embodiments, the beam or panel comprises shear and/or axial connectors that protrude from the timber-based component into one or more of the anchor regions, such that the shear connectors are at least partly embedded in the concrete anchors. This strengthens the connection between the anchors and the timber-based component. The

shear and/or axial connectors may comprise timber-based protrusions on the or each timber-based component. Alternatively, the timber-based component may comprise recesses in the anchor regions, such that the concrete anchors protrude into the recesses to strengthen the connection between the anchors and the timber-based component.

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One embodiment beam or panel comprises: a plurality of side-by-side timber-based components; spaced apart transverse concrete anchors; and a transverse pre-stressing member extending between the transverse concrete anchors and coupled to the transverse concrete anchors, the transverse pre-stressing member applying a compressive force to the timber-based component to pre-stress the beam or panel in the transverse direction.

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In one embodiment, the anchors are at least partly pre-cast. The pre-cast anchors may comprise attachment features and the timber-based component may comprise a series of complementary attachment features for attaching the anchors to the timber-based component. In one embodiment the attachment features on the anchors comprise a plurality of protruding rods, bars, or screws, and the attachment features on the timber-based component comprise a plurality of complementary holes for receiving the rods, bars, or screws. Alternatively the timber-based component may comprise protruding rods, bars, or screws, and the anchors may comprise a plurality of complementary holes. The holes may contain epoxy, grouting, concrete, or an adhesive to improve the connection between the anchors and the timber-based component.

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In one embodiment the anchors are partly pre-cast and each comprise a duct that receives the pre-stressing member. The duct comprises concrete or grouting, coupling the pre-stressing member to the anchors. In an alternative embodiment, the anchors are pre-cast and the pre-stressed beam or panel comprises mechanical fasteners that mechanically couple the pre-stressing member to the anchors.

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In a fourth aspect, the invention provides a method of manufacturing a panel. The method comprises placing a plurality of pre-fabricated beams or panels as outlined in relation to the second or third aspects of the invention, side-by-side. The method further comprises providing a transverse pre-stressing member arranged transversely across the side-by-side timber-based components, applying a tensile force to the transverse pre-stressing member, providing transversely spaced concrete anchors, coupling the transverse pre-stressing member to the transversely spaced concrete anchors, and releasing the tensile force on the transverse pre-stressing member to

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transfer a transverse compressive force to the timber-based components through the transverse concrete anchors to pre-stress the panel in the transverse direction.

Each pre-fabricated beam or panel may comprise a transverse channel or hollow portion, the pre-fabricated beams or panels being arranged side-by-side so the channels or  
5 hollow portions of the beams are aligned. In such an embodiment, the transverse pre-stressing member is preferably arranged to extend through the aligned transverse channels or hollow portions.

The term 'comprising' as used in this specification and claims means 'consisting at least in part of. When interpreting statements in this specification and claims which include  
10 the term 'comprising', other features besides the features prefaced by this term in each statement can also be present. Related terms such as 'comprise' and 'comprised' are to be interpreted in a similar manner.

It is intended that reference to a range of numbers disclosed herein (for example, 1 to 10) also incorporates reference to all rational numbers within that range (for example, 1,  
15 1.1, 2, 3, 3.9, 4, 5, 6, 6.5, 7, 8, 9 and 10) and also any range of rational numbers within that range (for example, 2 to 8, 1.5 to 5.5 and 3.1 to 4.7) and, therefore, all sub-ranges of all ranges expressly disclosed herein are hereby expressly disclosed. These are only examples of what is specifically intended and all possible combinations of numerical values between the lowest value and the highest value enumerated are to be considered  
20 to be expressly stated in this application in a similar manner.

To those skilled in the art to which the invention relates, many changes in construction and widely differing embodiments and applications of the invention will suggest themselves without departing from the scope of the invention as defined in the appended claims. The disclosures and the descriptions herein are purely illustrative and  
25 are not intended to be in any sense limiting. Where specific integers are mentioned herein which have known equivalents in the art to which this invention relates, such known equivalents are deemed to be incorporated herein as if individually set forth. As used herein the term '(s)' following a noun means the plural and/or singular form of that noun.

30 As used herein the term 'and/or' means 'and' or 'or', or where the context allows both.

The invention consists in the foregoing and also envisages constructions of which the following gives examples only.

**BRIEF DESCRIPTION OF THE DRAWINGS**

The present invention will now be described by way of example only and with reference to the accompanying drawings in which:

- 5 Figures 1(i) to 1(iv) are top-front perspective views illustrating four steps in a preferred form of a method for manufacturing pre-stressed beams;
- Figure 2 is a partial front perspective view of one end of a timber-based component, corresponding to the first step shown in Figure 1(i);
- Figure 3 is a partial front perspective view of the timber-based component of Figure 2 with inserted pre-stressing members, corresponding to the second step shown in  
10 Figure 1(ii);
- Figure 4 is a partial front perspective view of the timber-based component of Figures 2 and 3 with inserted pre-stressing members and the concrete anchors poured, corresponding to the third step shown in Figure 1(iii);
- Figure 5 is a partial front perspective view of the pre-stressed beam resulting from the  
15 steps shown in Figures 2 to 4, showing a cutting plane for cutting the protruding portions of the pre-stressing members and corresponding to the fourth step shown in Figure 1(iv);
- Figure 6 is a partial front perspective view of the completed pre-stressed beam of Figures 2 to 5 after the protruding ends of the pre-stressing members are cut;
- 20 Figures 7(i) to 7(iii) are perspective views showing three steps in the manufacture of an alternative 2-anchor embodiment, corresponding to steps one to three shown in Figures 1(i) to 1(iii) and Figures 2 to 4;
- Figures 8(a) to 8(d) show a timber-based component for producing a preferred form pre-stressed beam having two end anchors, where Figure 8(a) is an overhead  
25 perspective view of the timber-based component, Figure 8(b) is a front perspective view showing the position of the pre-stressing members, Figure 8(c) is a plan view of the timber-based component and pre-stressing members, and Figure 8(d) is an cross-sectional end view of the timber-based component and pre-stressing members taken through line AA of Figure 8(c);
- 30 Figures 9(a) to 9(d) are similar to Figures 8(a) to 8(d) and show an alternative timber-based component for producing a second preferred form pre-stressed beam having two end anchors, where Figure 9(a) is a perspective view of the timber-based component, Figure 9(b) is a front perspective view showing the position of the pre-stressing members, Figure 9(c) is a plan view of the timber-based component and  
35 pre-stressing members, and Figure 9(d) is an end view of the timber-based component and pre-stressing members;

- Figure 10 is a partial front perspective view of a timber-based component similar to the timber-based component in Figures 9(a) to 9(d), and an unattached pre-fabricated concrete anchor, illustrating a first step of an alternative form method for manufacturing pre-stressed beams or panels;
- 5 Figures 11(i) and 11(ii) are partial front perspective views illustrating a second step in the alternative form method of Figure 10;
- Figure 12 is a partial front perspective view illustrating a third step in the method of Figures 10, 11(i), and 11(ii);
- 10 Figure 13 is a partial front perspective view illustrating a fourth step in the method of Figures 10 to 12;
- Figure 14 is a partial front perspective view showing an end portion of a pre-stressed panel formed by the method of Figures 10 to 13;
- Figure 15 is a partial front perspective view of a timber-based component, illustrating a first step of a further alternative form method for manufacturing pre-stressed
- 15 beams or panels having a concrete topping layer;
- Figure 16 is a partial front perspective view illustrating a second step in the method of Figure 15;
- Figure 17 is a partial front perspective view illustrating a third step in the method of Figures 15 and 16;
- 20 Figure 18 is a partial front perspective view illustrating a fourth step in the method of Figures 15 to 17;
- Figure 19 is a partial front perspective view illustrating a fifth step in the method of Figures 15 to 18;
- Figure 20 is a partial front perspective view illustrating a sixth step in the method of
- 25 Figures 15 to 19;
- Figure 21 is a partial front perspective view showing an end portion of a pre-stressed panel formed by the alternative form method of Figures 15 to 20;
- Figure 22 is a partial cross sectional view of an arrangement having multiple adjacent pre-stressed panels, each panel having a concrete topping layer formed by the
- 30 method of Figures 15 to 20, with respective concrete topping layers on adjacent panels connected to form a continuous surface;
- Figure 23 is a partial front perspective view of a further alternative form timber-based component, illustrating a first step of a further alternative form method for manufacturing pre-stressed beams or panels having a concrete topping layer;
- 35 Figure 24 is a partial front perspective view illustrating a second step in the method of Figure 23;
- Figure 25 is a partial front perspective view illustrating a third step in the method of Figures 23 and 24;

- Figure 26 is a partial front perspective view illustrating a fourth step in the method of Figures 23 to 25;
- Figure 27 is a partial front perspective view illustrating a fifth step in the method of Figures 23 to 26;
- 5 Figure 28 is a partial front perspective view illustrating a sixth step in the method of Figures 23 to 27;
- Figure 29 is a partial front perspective view showing an end portion of a pre-stressed panel formed by the alternative form method of Figures 23 to 28;
- 10 Figures 30(a) to 30(e) are sectional views showing examples of alternative form pre-stressed panels without a concrete topping layer;
- Figures 31(a) to 32(e) are sectional views showing examples of alternative form pre-stressed panels having a concrete topping layer;
- Figures 32(a) to 32(e) are sectional views showing examples of alternative form pre-stressed panels having a concrete topping layer;
- 15 Figure 33 schematically shows an alternative preferred form pre-stressed beam having transverse channels for receiving transverse pre-stressing members;
- Figure 34 shows a plurality of the pre-stressed beams of Figure 33 arranged side-by-side for producing a panel that is pre-stressed in two directions;
- Figure 35 shows side members placed on either side of the pre-stressed beam arrangement of Figure 34 to contain the concrete for forming the side anchors;
- 20 Figure 36 corresponds to the arrangement of Figure 35, schematically showing the transverse reinforcing members extending between the pre-stressed beams;
- Figure 37 corresponds to Figure 36 and shows the concrete side anchors anchoring the transverse pre-stressing members;
- 25 Figure 38 corresponds to Figure 37 and shows cutting planes for cutting the ends of the pre-stressing members protruding from the cured anchors;
- Figure 39 is a perspective view of one embodiment timber-based component comprising cross-laminated timber and having transverse channels for receiving transverse pre-stressing members;
- 30 Figure 40 is a perspective view showing the timber-based component of Figure 39 with pre-stressing members arranged in the longitudinal channels;
- Figure 41 is a perspective view corresponding to Figure 40, showing the pre-stressing members embedded in concrete end anchors to pre-stress the beam;
- 35 Figure 42 is a perspective view showing two of the pre-stressed beams of Figure 41 arranged side-by-side with transverse pre-stressing members arranged in the transverse channels of the timber-based component, for producing a panel that is pre-stressed in two directions;

Figures 43(a) to (d) show exemplary features for strengthening the connection between the concrete anchors and the timber-based component, where Figure 43(a) is a front perspective view showing connector rods protruding from sidewalls of the timber-based component of Figures 1(i) to 1(iv), into the anchor region, Figure 43(b) is another perspective view corresponding to Figure 43(a), Figure 43(c) shows shear connector plates protruding from a timber member, and Figure 43(d) shows bolts protruding from a timber member;

Figure 44 is a partial plan view showing an embodiment of the timber-based component having recesses and screws or rods in the side walls in the anchor region to transfer the pre-stressing force from the anchor to the timber-based component predominantly by shear forces;

Figure 45 is a partial plan view showing an arrangement of connecting rods and pre-stressing members in an embodiment where the pre-stressing force is transferred from the anchor to the timber-based component predominantly by compression;

Figures 46(a) to (c) show an end anchor in a further embodiment pre-stressed beam or panel having steel reinforcing and shear bolts in the anchor region, where Figure 46(a) is a partial perspective view of the end of the beam or panel, Figure 46(b) is a cross sectional plan view corresponding to Figure 46(a), and Figure 46(c) is a cross sectional end view taken line BB of Figure 46(b); and

Figures 47(a) to (d) show an end anchor in a further embodiment pre-stressed beam or panel having timber shear keys and polystyrene blocks in the anchor region, where Figure 47(a) is a partial perspective view of the end of the beam or panel, Figure 47(b) is a cross sectional plan view corresponding to Figure 47(a), Figure 47(c) is a cross sectional end view taken line CC of Figure 47(b), and Figure 47(d) is a cross sectional end view taken line DD of Figure 47(b).

## **DETAILED DESCRIPTION OF PREFERRED FORMS**

### *PRE-TENSIONED, MULTIPLE BEAMS/PANELS*

Figures 1 to 6 illustrate a method for prefabricating pre-stressed beams according to a first preferred embodiment of the present invention. The method comprises four main phases. In a first phase illustrated in Figures 1(i) and 2, a timber-based component 1 is provided. In the form shown, the timber-based component 1 comprises a timber laminate elongate frame. The frame has a number of webs 4 defining a plurality of longitudinal hollow portions 3 extending through the timber-based component 1 along a substantial part of its length.

At the opposing ends of the timber-based component 1, adjacent webs 4 define a number of spaces 5a, 5b between the webs 4 that are open at least on an upper side to

receive poured concrete for forming a respective discrete end anchor. In the embodiment in Figure 1(i), two intermediate sections 7 along each hollow portion 3 are open at least on an upper side to define cavities for receiving poured concrete and forming respective discrete intermediate anchors. The timber-based component 1 is placed on a casting bed 2. The timber-based component 1 may be a single integrally formed component or comprise two or more members or sub-components 1a, 1b, 1c placed end-on-end on the casting bed.

In a second stage illustrated in Figures 1(ii) and 3, elongate pre-stressing members 9 are inserted into the hollow portions 3 to extend longitudinally along the timber-based component 1. In the forms shown, the pre-stressing members comprise parallel high-strength steel tendons 9 arranged in the hollow portions 3. In the embodiment in Figure 1(ii), three tendons 9 are placed in each hollow portion 3, whereas the embodiment shown in Figure 3 comprises only one tendon 9 in each hollow portion. More or fewer pre-stressing members could be provided.

The opposing ends of the tendons 9 are connected to tensioning equipment and a tensile force is applied to the tendons 9. The ends 9a, 9b of the tendons may comprise enlarged portions or attached blocks or other features, as shown in Figure 1(ii), to enable the tendons 9 to be more readily grasped by the tensioning equipment. Equipment commonly used for tensioning steel tendons or bars in prefabricated pre-stressed concrete beams would be suitable. In one embodiment, the pre-stressing members 9 are tensioned using a pre-stressing jack to extend the members. The tensile force in the pre-stressing members 9 is then resisted by an anchor block or plate cast in the ground while the concrete cures. In an alternative embodiment, the casting bed may comprise upwardly extending end portions and act as a strut, with the tensile force in the pre-stressing members resisted against the ends of the casting bed while the concrete cures. Where space permits, several timber-based components 1 may be placed side-by-side and pre-stressed simultaneously.

As a further alternative, one or more transverse steel plates connected to the timber-based component 1 may be positioned in or adjacent an end of the open anchor regions 5a, 5b, 7. The pre-stressing member(s) 9 would extend through apertures or notches in the plate(s) and may be tensioned against the plate(s), for example using a thread and nut arrangement or a pre-stressing cone or wedge, such that the steel plate(s) bear against a portion of the timber-based component to transfer the pre-stressing force. In embodiments with a steel plate positioned within one or more of the anchor regions 5a, 5b, 7, the poured concrete would at least partially embed the plate(s). In those embodiments, the steel plate may form the boxing for the respective anchor, to contain

the poured concrete. The plate may also reduce the required length of the concrete anchor by bearing some of the pre-stressing load.

Methods of tensioning tendons are known to a person skilled in the art. For example, from Collins M.P. and Mitchell D, *Prestressed Concrete Structures*, Prentice Hall, Englewood Cliffs, N.J., USA 1991, Response Publications, Toronto 1997, ISBN 0-9681958-0-6.

In a third stage illustrated in Figures I(iii) and 4, concrete is poured into the end open regions 5a, 5b and into the intermediate open regions 7. The ends of each open region 5a, 5b, 7 typically comprise timber framework to further define the space for the anchor and to prevent concrete from flowing into the remainder of the hollow portion 3.

When the concrete is poured, the portions of the tensioned tendons 9 positioned within the anchor regions 5a, 5b, 7 are embedded in the concrete. The concrete is then cured to form end anchors 11a, 11b and intermediate anchors 13 that fixedly couple the tendons 9 to the timber-based component 1. In embodiments where the timber-based component 1 comprises a plurality of shorter members or sub-components 1a, 1b, 1c, the intermediate cavities 7 are each defined between the ends of the respective two adjacent sub-components. When the concrete poured into those intermediate cavities 7 cures, it joins the adjacent sub-components 1a/1b, 1b/1c together.

In a fourth stage illustrated in Figures I(iv) and 5 the tension applied by the tensioning equipment to the tendons 9 is released once the concrete anchors 11a, 11b, 13 have substantially cured. The concrete is considered substantially cured, for example, when it reaches at least 70% of the nominal (28 day) compression strength of the concrete. Typically the time taken for the anchors to cure to at least 70% of the 28 day strength is between one and three days depending on the thickness of the slab. The end portions of the tendons 9a, 9b protruding from the ends of the cured end anchors 11a, 11b are then removed by cutting through the end cutting planes 15a, 15b shown in Figure I(iv) and Figure 5. The cured concrete anchors 11a, 11b, 13 maintain the tendons 9 in a tensioned state and transfer the force from the tendons 9 to the timber-based component 1 as a compressive force, pre-stressing the timber-based component to create an initial pre-stressed beam 14 of length L1.

Figure 6 shows an end portion of a pre-stressed beam or panel produced by the method of Figures 2 to 5.

The anchors may comprise any suitable concrete including, but not limited to, high strength concrete, light weight concrete, fibre reinforced concrete, or self-compacting

concrete. The concrete may additionally contain small aggregates. To reduce weight, the anchors may comprise hollow portions or a timber core. To form an anchor having hollow portions, a core comprising a material such as polystyrene or PVC may be inserted into the anchor region and the concrete poured around the inserted core. The core may be removed when the concrete has been cured. Steel reinforcing may also be used in the anchor region to reinforce the concrete anchor.

The initial pre-stressed beam 14 in Figure I(iv) may then be cut along intermediate transverse cutting planes 17, through the intermediate anchors 13 and the tendons 9, into a plurality of shorter beams or sub-beams 14a, 14b, 14c of length L2. The length of each piece 1a, 1b, 1c is the length L2 of the final pre-fabricated beams 14a, 14b, 14c. Each cut intermediate anchor 13 forms two end anchors 18a, 18b on two adjacent beams 14a/14b or 14b/14c. Because the tendons are embedded along the length of intermediate anchors 13, they are also embedded along the length of the resulting new end anchors 18a, 18b, so that the pre-stress is maintained in the shorter beams 14a, 14b, 14c. The intermediate anchors 13 as initially formed are twice the length of the end anchors 11a, 11b such that when they are cut through a mid point, the new end anchors 18a, 18b are the same length as the original end anchors 11a, 11b.

The anchors are preferably cut using a saw capable of cutting concrete and steel. Alternatively, a polystyrene divider may be placed along the intermediate plane 17 in the intermediate cavities 7 before the concrete is poured. In stage 3, concrete is then poured on both sides of the polystyrene divider. In the final stage, the initial pre-stressed beam 14 may then be cut along intermediate transverse cutting planes 17, through the polystyrene and the tendons 9. This enables faster cutting of the beam. In one example, the polystyrene divider is 10 mm thick.

It can be seen that once cut, the concrete anchors 11a, 11b, 18a, 18b are recessed in the ends of the beams or sub-beams, and preferably do not project outwardly beyond the ends of the timber-based component or sub-components.

The cut pre-stressed beams 14a, 14b, 14c may then be transported to a construction site for use. The beams may be used for constructing suspended floors, roofs, walls or some bridges, for example.

This process has the advantage that a plurality of final beams 14a, 14b, 14c can be pre-stressed at the same time, making more efficient use of tensioning equipment for high volume production.

*PRE-TENSIONED, SINGLE BEAM*

An alternative preferred embodiment method for producing a single pre-stressed beam is shown schematically in Figures 7(i) to (iii). In that embodiment, the timber-based component 101 comprises a single elongate hollow 103, with the ends 105a, 105b of the hollow defining regions for end anchors, but with no intermediate regions for intermediate anchors. The process for pre-stressing the beam is substantially as described above: the tendons 109 are inserted through the hollow and tensioned using tensioning equipment, and concrete is poured into the end spaces 105a, 105b and allowed to cure to form end anchors 111a, 111b only. Boxing or plates (not shown) at the ends of each anchor region contain the concrete and prevent the poured concrete flowing down the length of the hollow 103. The boxing or plates contain apertures or notches for the pre-stressing tendons 109 to pass through.

Once the concrete anchors 111a, 111b have substantially cured, tension is released from the tendons and protruding portions of the tendons 109 are removed to form a final pre-stressed beam 119. This embodiment differs from the above method in that the beam formed cannot be cut into shorter lengths, so only a single pre-fabricated beam or panel is produced. This process may be used where there is insufficient space for a plurality of beams to be pre-stressed end-on-end, where there are only low-volume requirements, or for beams or panels with custom dimensions, for example. The method and formed pre-stressed beam may have any one or more of the features described above in relation to the embodiment of Figures 1(i) to 6.

Figures 8(a) to 8(d) and Figures 9(a) to 9(d) show two possible preferred embodiments of a timber-based component 301, 301' suitable for producing a single pre-stressed beam such as the one shown in Figure 7(i) to (iii), or for placing in series with other like components to produce a long pre-stressed member that can be cut, as shown in Figures 1(i) to 1(iv). In the embodiment of Figures 8(a) to 8(d), the timber-based component 301 comprises four vertical timber laminate members 302 measuring about 60 mm thick, 350 mm deep, and 10-12 m long. The vertical members 302 are positioned between a lower flange member 306a and an upper flange member 306b and spaced apart by deviators 304a, 304b, 304c, 304d. The deviators 304a, 304b, 304c, 304d and the lower flange member 306a define a plurality of apertures 308 to receive pre-stressing tendons 309. The tendons 309 are arranged through the apertures 308 and extend along the hollow portions 303 between respective vertical members 302. The deviators 304a and 304b at the ends of the component and the vertical members 302 together define regions 305a, 305b for casting concrete end anchors. The cross sections of the end anchor regions 305a, 305b are much larger than the cross sections of the

apertures 308 through which the tendons 309 extend. The intermediate deviators 304c, 304d provide additional stiffness and strength for the beam.

The embodiment of Figures 9(a) to 9(d) is similar to the embodiment of Figures 8(a) to 8(d), with like numbers used to indicate like parts, but with the addition of a prime (').

5 The timber-based component 301' comprises seven vertical timber laminate members 302', with a single tendon 309 positioned between adjacent vertical timber laminate members 302'. When intermediate concrete anchor(s) 13 will be included, intermediate deviators 304c, 304c', 304d, 304d' may be positioned at spaced apart points, with at least some of the spacing of the intermediate deviators being configured to define the  
10 desired length of the intermediate anchor(s). The upper flange member 306b will be provided with corresponding recess(es).

#### *PRE-FABRICATED ANCHORS*

Rather than pre-tensioning the pre-stressing cables and pouring the anchors as described above, the concrete anchors 32 may be at least partially pre-cast, and the  
15 cables post-tensioned. Figures 10 to 14 illustrate an alternative embodiment method for pre-fabricating pre-stressed beams or panels using pre-cast anchors. The method comprises five main phases.

Figure 10 illustrates a first phase in which a timber-based component 31 and two pre-fabricated concrete end anchors 32 are positioned in a yard (only one anchor is shown).  
20 The pre-cast concrete anchors 32 comprise attachment features for attachment to the timber-based component 31. In the embodiment shown, each pre-cast anchor 32 comprises a series of starter bars 37 positioned towards the top and bottom of the anchor 32. Each starter bar 37 has an end embedded in the anchor 32 and a protruding end. The end of the timber-based component 31 comprises a series of corresponding  
25 holes 35 for receiving the starter bars 37. The holes 35 may be pre-drilled or provided in any other known manner.

In a second phase of the method, illustrated in Figures 11(i) and (ii), the anchors 32 and the timber based component 31 are assembled so that the starter bars 37 are positioned in the holes 35 in the timber-based component 31. The starter bars 37 are attached to  
30 the timber-based component 31 in any suitable manner such as by injecting epoxy or other substance in the holes 35.

The timber-based component 31 comprises a plurality of ducts 33 which extend along the length of the component 31 for receiving pre-stressing members 39. The pre-cast anchor 32 also comprises a series of ducts or apertures 38 that align with the ducts 33 in

the timber-based component 31 when the anchor and timber component 31 are assembled.

5 A single pre-stressing member 39 is placed through each duct 33 in the timber-based component 31, and the corresponding duct 38 in the anchor 32. Alternatively, several pre-stressing members 39 may be placed in each duct 33, 38. In a third phase, shown in Figure 12, the pre-stressing members 39 are tensioned. Concrete or grouting is then injected in the ducts 38 in the concrete anchors 32. Once the concrete or grouting has substantially cured, the tension is released from the pre-stressing members 39.

10 In addition to two end anchors 32, the method may also comprise placing one or more intermediate pre-cast anchors between the ends of two timber-based sub components in a similar manner to the embodiment of Figures 1(i) to (iv). Intermediate anchors would comprise starter bars or other attachment features at both ends of the anchor to connect to the ends of two adjacent timber-based components 31. While the pre-stressing members 39 are tensioned, concrete or grouting is injected in the ducts 38 in the intermediate concrete anchor(s).

20 Once the grouting has substantially cured, the initial pre-stressed beam or panel may be cut along intermediate transverse cutting planes through the intermediate anchors and the pre-stressing members 39, forming a plurality of shorter beams or panels. Because the tendons are grouted along the length of intermediate anchors, they are also embedded along the length of the resulting new end anchors so that the pre-stress is maintained in the shorter beams. As described with respect to the embodiment of Figures 1(i) to (iv), the initial, uncut intermediate anchor(s) is/are twice the length of the end anchors, so the new end anchors formed by cutting the intermediate anchor(s) are the same length as the original end anchors 32.

25 Instead of the starter rods 37 and drilled holes 33, other suitable fasteners may be used. For example, the timber-based component 31 or the concrete anchors 32 may comprise metallic ducts for receiving rods or screws attached to the other of the concrete anchors 32 or the timber-based component 31. The rods or screws may be screwed, bolted or epoxied into the other of the timber-based component 31 or the anchors 32.

30 As a further alternative, rather than using concrete or grouting to couple the pre-stressing members to the pre-cast anchors 32, the pre-stressing members 39 may be mechanically coupled to the pre-cast anchors 32. For example, the pre-stressing members may be threaded members and may be post-tensioned by tightening a nut that then abuts the end of the pre-cast anchor 32 or a plate at the end of each end anchor 32. The concrete anchors diffuse the stresses from the mechanical coupling to

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the timber-based component 31 and offer a lower-cost solution than coupling the pre-stressing members to the timber-based component using a steel plate, which would need to be thick to diffuse the stresses.

#### CONCRETE TOPPING LAYER

- 5 Any of the beam or panel embodiments described above may optionally comprise a concrete-based topping layer. Figures 15 to 21 illustrate the steps for forming a preferred embodiment panel similar to the embodiment shown in Figures 2 to 6, but having a concrete topping layer.

10 In a first phase shown in Figure 15, a timber-based component 1 similar to the timber-based component of Figure 2, is provided and placed on a casting bed. In the form shown, the timber-based component comprises a timber laminate elongate frame. The frame has a number of webs 4 defining a plurality of longitudinal hollow portions extending through the timber-based component along a substantial part of its length and a number of spaces 5a between the webs at opposing ends that are open at least on an  
15 upper side to receive poured concrete for forming respective discrete end anchors.

In a second phase shown in Figure 16, fasteners 41 are attached to the top flange of the timber-based component 1 and protrude upward from the top flange. Preferably the fasteners 41 are positioned in line with the webs 4. Suitable fasteners 41 include  
20 screws, bolts or steel bars. The screws may be inclined such as at 45° for example in both the forward and rearward directions. Steel bars may be fixed to the timber-based component such as by being epoxied. The fasteners 41 may be attached to the timber-based component 1 either before or after placing the timber-based component on the casting bed. Alternatively, the top flange of the timber-based component may contain notches in the flange, and protruding studs.

25 In a third phase, shown in Figure 17, longitudinal and transverse steel reinforcing bars 43, 45 or a steel mesh are placed on top of the timber flange. The transverse bars 43 may comprise end hooks 43a, 43b. The end hooks 43b on one side of the panel may overhang the side of the panel to facilitate joining two adjacent panels and forming a continuous surface as discussed further below.

30 Figure 18 illustrates a fourth stage, in which elongate pre-stressing members 9 are inserted into the hollow portions 3 in the timber-based component 1 in the same manner described above with reference to the embodiment of Figure 3. The opposing ends of the tendons 9 are connected to tensioning equipment and a tensile force is applied to the tendons, for example using a pre-stressing jack.

In a fifth stage shown in Figure 19, while tension is still applied to the pre-stressing members 9, concrete is poured on top of the flange of the timber-based component 1 and in the end anchor regions 5a (and anchor regions at an opposing end, not shown). This casts the topping layer 49 and the anchors 47 in a single step.

- 5 Preferably the concrete topper does not cover the two webs 4a, 4b on the sides of the timber-based component 1, and hooked ends 43a, 43b protrude from the concrete topping layer.

10 In two further stages illustrated in Figures 20 and 21, the concrete anchors 47 and the concrete layer 49 are allowed to substantially cure. Once the concrete is substantially cured, for example, when it reaches at least 70% of the nominal (28 day) compression strength of the concrete, the tension applied by the tensioning equipment to the tendons 9 is released. The protruding portions of the tendons 9 are then removed from each end of the panel by cutting through end cutting planes 50.

15 Figures 15 to 21 show a preferred embodiment panel in which the entire panel, including the topping layer, is pre-fabricated. Alternatively the concrete topping layer may be poured in situ (on site) on a pre-fabricated pre-stressed beam or panel, for example on the panel shown in Figure 6.

20 In embodiments where the concrete topping layer is poured in situ, the steps of Figures 2 to 6 are carried out in the casting yard. Fasteners 41 are attached to the top flange of the timber-based component 1 in a similar manner to in Figure 16, either while the timber-based component 1 is in the casting yard, or on site. Once the pre-stressed beam or panel is on site, reinforcing members such as the steel bars 43, 45 in Figure 17 are placed on top of the timber-based component 1. The concrete topper 49 is then cast on site.

- 25 The fasteners 41 in the above described embodiments bond the concrete topping layer to the timber-based component.

30 Once the pre-stressed panels are at the construction site, the panels may be placed side-by-side to form a large supporting surface such as a floor. Figure 22 is cross-sectional view showing connections between a plurality of pre-stressed panels with concrete topping layers 51a, 51b, and 51c. Adjacent panels are arranged with adjacent timber-based constructions 1a, 1b, and 1c abutting to define a channel/space between the adjacent concrete topping layers 51a, 51b, 51c, above the timber-based constructions 1a, 1b, and 1c.

The hooked ends 43a, 43b of the transverse reinforcing bars in the concrete topping layers protrude into the spaces between topping layers 51a, 51b, 51c and overlap with the hooked ends 43a, 43b of the reinforcing bars in an adjacent panel. In a final step, concrete 57 is poured into the spaces between the adjacent slabs 51a, 51b, 51c, embedding the protruding, hooked portions 43a, 43b of the steel reinforcing to form a continuous surface.

Optionally, fasteners 55 may also be attached to the timber-based component 1 in the spaces between adjacent topping layers 51a, 51b, 51c. Those fasteners are then embedded in the strips of concrete 57 that are poured to join the slabs to improve the connection between the topping layer and the timber based component 1.

In alternative embodiments, the concrete topping layer may not be bonded to the timber-based component or may only be partially bonded. For example, the step of attaching fasteners to the timber-based component 1 (Figure 16) may be omitted. Instead the reinforcing members 43, 45 may be placed on the timber-based component shown in Figure 15, or on site on the pre-fabricated panel of Figure 6. The concrete topping layer is then cast over the reinforcing members 43, 45.

As a further alternative, the concrete topping layer may comprise pre-cast reinforced slabs that are placed on the timber-based component 1 on site and attached by fasteners.

The concrete topping layer improves the fire, acoustic, and vibration performance of a given beam or panel. The topping layer also may improve performance of the beam or panel during a seismic event by helping to transfer inertial forces to frames and walls supporting the beam or panel.

An unbonded concrete topping layer may be cheaper and/or easier to manufacture than a fully bonded layer, but still provide most of the advantages mentioned above.

However, an unbonded concrete topping layer acts as a dead weight that must be supported by the pre-stressed timber beam or panel. In contrast, when the concrete topping layer at least partially bonded to the timber-based component, the topping layer contributes to the strength of the pre-stressed beam or panel. Therefore, a smaller beam or panel is required for a given application if the topping layer is at least partially bonded.

For example, one embodiment of a panel has an unbonded concrete topping layer between 65 and 75 mm thick. In a comparable panel with a bonded topping layer of the same thickness, the thickness/depth of the timber-based component would be less than

for the timber-based component in the panel with the unbonded topping layer, resulting in a lighter panel. The span of the beam generally determines the thickness of the timber-based component. For example, a panel having an 8 m span may be 360 mm deep, including a 65 mm concrete topping layer. Whereas a panel with a 6 m span  
 5 maybe only 210 mm deep, including a 65 mm concrete topping layer. If the concrete layer is included as a 'diaphragm' for seismic events, the thickness of the concrete topping layer in a bonded panel may be less than for an unbonded panel.

Figures 23 to 27 show an alternative embodiment panel similar to the embodiment of Figures 15 to 21, with like numbers used to indicate like parts, but with the addition of a  
 10 prime ('). In the embodiment of Figures 23 to 27, the entire panel, including the topping layer, is pre-fabricated. The topping layer 49' is poured at the same time as the concrete anchors 47' and extends over the top of the end anchor 47'.

The timber-based component 1' comprises a channel section 40 on one side, having a top flange 40a and a bottom flange 40b. The hooked ends 43b' at one end of the  
 15 transverse reinforcing bars in the concrete topping layer protrude over the top flange 40a. A plurality of the beams shown in Figure 29 can be placed side-by-side to form a larger panel.

In a similar manner as described above in relation to the embodiments of Figures 21 and 22, concrete can be poured into the spaces between topping layers on adjacent beams  
 20 to embed the hooked ends 43a', 43b' of the reinforcing bars 43' in adjacent beams 1' and join the beams to form a continuous surface. The top flange 40a acts as formwork to support the joining concrete strip during this process.

The bottom flange 40b is cosmetic, to provide a flat surface if looking at the beam from below.

## 25 *ALTERNATIVE CROSS SECTIONS*

The timber-based components 1, 101, 301 shown in Figures 1 to 22 are only exemplary embodiments. The timber-based component may take many alternative forms. Figures 30(a) to (e) give examples of pre-stressed panels having different cross-sections.

As illustrated, the timber-based component 1 may comprise either hollows (Figures  
 30 30(a), (c), and (d)) or recesses (Figures 30(b) and (e)) to receive pre-stressing members 9. Figure 30(a) shows a panel with a cassette-type cross section in which the anchors and pre-stressing members 9 are located in hollows 61 in the timber-based component 1.

Figures 30(b) and (c) show panels that are substantially solid, with either small hollows (Figure 30(c)) or recesses (Figure 30(b)) for the pre-stressing members 9 and anchors. In contrast, Figure 30(e) shows a lighter-weight panel in which the timber-based component has a T-shaped cross section.

- 5 Aspects of the cassette-based, solid, and T-shaped cross-sections may be combined to produce any number of alternative cross-sections. For example the panel shown in Figure 30(d) has a cross-section that is a combination of the cassette of Figure 30(a) and the T-section of Figure 30(e).

10 Different cross-sections provide different advantages. For example, a T-section may be light weight, but a cassette-type or solid construction such as those in Figures 30(a), (b), and (c) would typically have higher fire resistance. It will be appreciated that many other cross-sections are possible.

Any of the panels shown in Figures 30(a) to (e) may additionally comprise a concrete-based topping layer. Figures 31(a) to 23(e) show sectional views of embodiments  
15 corresponding to those in 30(a) to (e) but that also comprise a concrete topping layer 71. In each embodiment in Figures 31(a) to 31(e), the concrete topping layer 71, is connected to the timber-based component 1 by fasteners 73.

Figures 32(a) to (e) show sectional views of embodiments corresponding to those in  
20 30(a) to (e) and 31(a) to (e) that also comprise a concrete topping layer 71, but with the upper timber flange 62 substituted with a thin plywood member 81. The plywood member 81 supports the weight of the concrete topping layer 71 when it is poured, but is not structural.

In embodiments having a concrete topping layer 71, the concrete topping layer 71 primarily resists compression, while the timber-based construction 1 resists tension and  
25 bending. The connection between the timber-based construction 1 and the concrete topping layer 71 transmits the shear forces between the two components. Advantages over timber floors include increased load-carrying capacity, higher stiffness (which leads to reductions in deflections and susceptibility to vibrations), improved acoustic and thermal properties, and higher fire resistance.

30 The exemplary timber-based components 1 illustrated in Figures 30(a) to 32(e) may comprise a combination of different engineered wood materials. The material selected will typically depend on the cross-section of the timber-based component, the final application for the beam or panel, and cost and manufacturing considerations.

As an example, the embodiments shown in Figures 30/31 (a), (d) and (e) may have top flanges 62, 66, 68 and bottom flanges 64, 70 made from laminated veneer lumber (LVL), and webs made from glued laminate timber, plywood, or LVL. Similarly, the timber-based component shown in Figures 30(b), 31(b), and 32(b) may comprise glued laminate or LVL. In contrast, the embodiment shown in Figures 30(c), 31(c), and 32(c) would preferably comprise cross-laminated timber. Many other combinations of timber-based materials are possible and would be apparent to a person skilled in the art.

In the embodiments shown, the tendons 9 are offset below the vertical mid-point of the beam or panel. This produces an upward deflection or pre-camber to balance deflection from downward loading on the beam or panel in use. For example, loading when the panels form a floor. Offsetting the pre-stressing members 9 to deflect the beam or panel towards the anticipated loading enables longer span beams or panels and/or shallower depth beams or panels when compared to an equivalent beam or panel with centrally positioned tendons.

A pre-stressed panel or beam produced using the above method is typically between 6 and 12m long. However, shorter and longer beams and panels are possible. Longer lengths require increasing the depth and width of the panel or beam accordingly.

#### *BI-DIRECTIONAL PANELS*

Figure 33 shows a further embodiment in which a pre-stressed beam 200 comprises a timber-based component 201 with plurality of transverse ports in the form of channels or hollow portions 221 spaced along its length. That beam 200 also comprises one or more longitudinal hollow portions that house elongate pre-stressing members (not shown). The pre-stressing members extend between concrete end anchors 211a and 211b, in the manner described above. The beam 200 may be produced by either of the preferred embodiment methods described above; i.e. either singularly or cut from a longer beam.

Timber-based components 201 with transverse ports, such as those shown in Figure 33, may be placed side-by-side to produce a panel that can be stressed in a second, transverse direction. Such a panel may be pre-stressed in the second direction in the yard or factory at the same time as pre-stressing the beams in the first, longitudinal direction, to produce a pre-fabricated bi-directionally stressed panel. Alternatively the panel may be produced in two stages by first pre-fabricating beams or panels 200 in the factory, as described above, then arranging and post-tensioning the beams or panels 200 in the second direction on site. This alternative method is appropriate for larger panels where transport of the constructed panel would be prohibitive.

Figures 34 to 38 and Figures 39 to 42 illustrate a method for producing a bi-directionally stressed panel by arranging and post-tensioning a plurality of pre-fabricated pre-stressed beams 200.

5 In a first step shown in Figure 38, a plurality of beams 200a, 200b, 200c are placed side-by-side so that the transverse ports 221 of the beams are aligned to form continuous channels or hollow portions. The beams 200a, 200b, 200c have been formed by one of the preferred embodiment methods described above. Side members 223a, 223b are then placed on either side of the multi-beam arrangement (see Figure 35). The side members 223a, 223b have ports 225a, 225b that align with the ports 221 on the beams  
10 200a, 200b, 200c. The aligned transverse ports 221 together define a plurality of transverse channels or hollow portions for receiving transverse post-stressing members. The side members 223a, 223b define open or boxed regions 227a, 227b on either side of the transverse hollow portions.

15 After arranging the beams 200a, 200b, 200c and side members 223a, 223b, transverse tendons 209 are arranged in the transverse hollow portions, as shown in Figure 36. The side members of the beams 200a, 200b, 200c should be sanded or otherwise prepared so that the side members of adjacent beams are flush. Alternatively, epoxy, grout or concrete may be injected or grouted between two adjacent beams 200a, 200b, 200c.

20 The tendons 209 are then tensioned using suitable tensioning machinery, for example hydraulic jacks. The tendons 209 are then kept in tension, for example by reacting the tensile force in the tendons against an anchor block or plate. The anchor block or plate may be positioned in or adjacent an end of the open anchor regions 229a, 229b, with the pre-stressing members 209 extending through apertures or notches in the block or plate. Alternatively the anchor block or plate may be externally fixed, for example  
25 anchored to the ground. The tendons are then fixed against the block or plate using any mechanical anchoring means, for example a thread and nut arrangement or a pre-stressing cone or wedge. In a third step shown in Figure 37, while the tensioning force is maintained in the transverse tendons 209, concrete is poured into the open or boxed regions 227a, 227b embedding respective portions of the tendons 209 in the concrete.  
30 The concrete is then cured to form side anchors 229a, 229b. The concrete is typically cured to at least 70% of the nominal (28 day) compression strength of the concrete before the tension applied to the tendons 9 is released.

Alternatively, the concrete side anchors may be at least partially pre-cast, and the cables post-tensioned. The pre-cast anchors would be attached to the sides of the arranged  
35 pre-stressed beams of panels in a similar manner to the pre-cast anchors described

above with respect to Figures 10 to 14. The transverse pre-stressing members 209 would then be placed through transverse channels or hollow portions and corresponding ducts in the attached pre-cast side anchors.

5 After the transverse pre-stressing members 209 are tensioned, they may be fastened to the pre-cast side anchors either by injecting concrete or grouting in the ducts and allowing that to cure, or by mechanically fastening the tensioned pre-stressing members to the anchors for example, by tightening a nut.

10 In a final step, the portions of the tendons 209 protruding from the sides of the side anchors are removed by cutting through the cutting planes 231a, 231b shown in Figure 38.

This process forms a panel 233 that is pre-stressed in two directions. Such a panel may have application as a suspended floor, for example, where it is advantageous to transfer load in two directions. This arrangement would typically be suitable for covering long spans, as the panel can be lower depth than a beam that needs to span the same  
15 distance. Because the panels are either pre-tensioned prior to delivery to site, or only need to be post-tensioned in the transverse direction on site, not in both directions, this method significantly reduces the on-site labour required to construct a large bi-directionally stressed panel.

20 Figures 39 to 41 illustrate a further embodiment timber component 401 (Figures 39 and 40) and pre-stressed beam 400 (Figure 41) suitable for bi-directional pre-stressing. In that embodiment, the timber-based component 401 comprises cross-laminated timber with timber boards crossing in the longitudinal and transverse directions to make the timber-based construction 401 stronger in both directions. The timber based construction may comprise cavities to reduce weight, or may be substantially solid.

25 Cross-laminated timber is particularly suitable for bi-directional pre-stressing due to their bi-directional built-up. Cross-laminated timber provides relatively high in-plane and out-of-plane strength and stiffness in both directions, giving embodiments such as those shown in Figures 39 to 41 a two-way action capability to resist to pre-stressing forces.

30 The pre-stressed beams of Figure 41 may be used to build bi-directional pre-stressed panels in the same manner explained above in relation to Figures 33 to 38 and as illustrated in Figure 42. The timber based component has transverse channels 414 for receiving transverse pre-stressing members 410 (Figure 42). The ends of the transverse pre-stressing tendons 410 may be anchored by tensioning the tendons and pouring side anchors to anchor the tendons, or using mechanical anchors on site.

The timber component of Figures 39 to 41 also comprises timber shear keys 406 that protrude in a longitudinal direction into the end anchor regions. The timber shear keys 406 become embedded in the end anchors when the concrete is poured and assist in transferring vertical shear forces from the timber-based component 401 to the  
5 respective concrete anchor 411a, 411b.

#### ANCHORS

Force from the pre-stressing members may be transferred from the concrete anchors to the timber-based component as a predominantly compressive or shear force, or as a combination of compressive and shear forces. The end anchor regions and any  
10 intermediate anchor regions on the timber-based component 1, 101, 201 may comprise features to enhance the shear or axial connection between the timber-based component 1 and the concrete anchors 11a, 11b, 13, 18a, 18b, 111a, 111b, 211a, 211b. Figures 43(a) to 43(d), 44, 45, 46(a) to 46(c), and 17(a) to 17(d) show examples of features to improve the shear connection between the concrete anchor and the timber-based  
15 component.

Figures 43(a) and 43(b) show end anchor cavities 5a at one end of the timber-based component of Figures 1(i) to 5, with pre-stressing tendons 9 arranged in the hollow portions 3, and having shear connectors 19. In the form shown, the shear connectors comprise a plurality of screws or rods 19 projecting from side walls and a middle wall of  
20 the timber-based component 1 into the anchor region 5a. The rods are fastened to the walls. When the concrete is poured into the anchor region the concrete envelops the projecting rods 19. The concrete then cures, embedding the rods 19. The embedded rods strengthen the connection between the concrete anchors 11a and the timber-based component 1 to prevent longitudinal movement of the anchor relative to the timber-based  
25 component.

Instead of rods 19, other features may be provided to improve the shear connection between the concrete anchors 11a, 11b, 13, 18a, 18b, 111a, 111b, 211a, 211b and the timber-based component 1. For example, one or more plate members 21 such as those shown in Figure 43(c) may be provided in the anchor regions. The plate members 21  
30 would project into the anchor region and comprise apertures 22 which the poured concrete fills to connect the plate 21 to the anchor. As a further example, screws or bolts 23 may be arranged to protrude from the timber-based component in a similar manner to the rods 19, as shown in Figure 43(d).

In another embodiment, one or more of the side walls or top or bottom walls of the  
35 timber-based component in the anchor regions may be provided with undulations,

projections or recesses, to provide an uneven surface to interface with the concrete and enhance the shear connection. Figure 44 shows an example of an embodiment in which the timber-based component comprises a plurality of side recesses 25 in walls of the component in the anchor regions, and protruding screws 87, 89 to enhance the shear connection between the timber-based component and the concrete anchor.

Figure 45 shows an embodiment in which the pre-stressing force is applied to the timber-based component 1 by way of compression. In that embodiment, the pre-stressing force is axially applied to the timber-based block 83 at the end of the anchor 71. Screws or rods 85 extend from the timber block 83 into the concrete anchor 81 to enhance the connection and the force transfer between the anchor 81 and the timber block 83. The screws or rods 85 take the bending moments and shear forces induced by external loading on the beam or panel.

The pre-stressed beams or panels may comprise longitudinal reinforcing. Figures 46(a) to 47(d) show two embodiment beams having steel reinforcing 512, 612 and shear connectors 506, 606 in the anchor region. The longitudinal reinforcing 512, 612 preferably comprises conventional reinforcing steel bars, as commonly used for concrete structures. Reinforcing bars are placed at or towards the top of the timber based construction 501, 601 and prevent a gap opening between the concrete and the timber construction 501, 601 when only pre-stressing is applied. The reinforcing bars 512, 516 may be epoxied into the timber-based construction 501, 601.

The embodiment shown in Figures 47(a) to (d) additionally comprises reinforcing members 612 at or towards the bottom of the timber-based construction 601 to provide both moment capacity in the concrete-to-timber transition area and shear strength to vertical loading.

In the embodiment of Figures 46(a) to 46(c), shear bolts 512 extend longitudinally into the anchor region. The shear bolts 512 take the shear forces from the timber-based construction 501 to the concrete anchor 511.

The timber construction 501 comprises one side timber web 508 with a top lip 508a, and one side timber web 508 with a complementary recess 508b. This enables shear force to be taken by the timber webs 508 when beams 500 are placed side-by-side, without the need to connect the webs using bolts.

The force from the pre-stressing tendons 509, 609 is transferred from the concrete anchor 511, 611 to the timber-based component 501, 601 as a combination of compressive and shear forces. The compressive pre-stressing is transferred to the

timber deviators 504, 604 defining the end of the anchor 511, 611. Shear stress is transferred at the interface between the timber-based component and concrete by the timber webs 502, 602 between pre-stressing members 509, 609 and the shear connectors 506, 606 and reinforcing bars 512, 612.

- 5 The beam embodiment shown in Figures 47(a) to 47(d) comprises timber shear keys 606 that protrude in the longitudinal direction, into the anchor region 611 to enhance the connection between the timber-based component 3 and the concrete anchor 3. As best illustrated in Figure 47(b), one timber key 606 is positioned above each pre-stressing tendon 609. However, alternatively there may be more or fewer timber keys 606.
- 10 In the embodiment shown in Figures 47(a) to 47(d), the pre-stressing force is transferred to the timber component 601 mainly as a compressive force. The concrete anchor 611 pushes directly against the webs and flanges of the timber construction 601, which absorb all the pre-stressing force. The timber shear keys 606 together with the longitudinal reinforcing bars 612 provide the shear capacity at the interface.
- 15 The anchor regions further comprise transverse stirrups 618 (Figure 47(b)) made of conventional reinforcing steel. The stirrups 618 take the vertical shear induced by the gravity load in the concrete anchor 611.

To reduce the total weight of the pre-stressed beams or panels, polystyrene blocks 616 are embedded in the concrete anchor 611 and attached, for example glued, to the

20 timber shear keys 606. Each polystyrene block 616 has two recesses # that receive two respective adjacent timber keys such that polystyrene surrounds three sides of each timber key 606, with a web 616a of the polystyrene block 616 extending between two adjacent timber keys 606. The embodiment shown comprises six pre-stressing tendons, six timber shear keys 606 and three spaced apart polystyrene blocks 616. To form the

25 anchor 611, concrete is poured into a boxed anchor region, embedding the polystyrene blocks 616 pre-stressing tendons 609, and reinforcing members 612.

Preferred embodiments of the invention have been described by way of example only and modifications may be made thereto without departing from the scope of the invention. For example, rather than providing central hollow chambers in the timber-

30 based component for receiving reinforcing members, the timber-based component may comprise one or more open channels along one or more of the sides of the component. For example, a plurality of channels may be provided on the top and bottom surfaces of the timber-based component.

The features in any of the above described embodiments can be combined or replaced by features from other embodiments without departing from the scope of the invention.

5 The dimensions, numbers of components, and described arrangements described for the preferred embodiments are by way of example only. For example, rather than each sub-beam 14a, 14b, 14c being the same length, the concrete anchors 13 could be spaced unevenly so as to form sub-beams of lengths that differ from each other. Typically, longer beams or sub-beams would require a greater beam depth than shorter beams or sub-beams.

10 As another example, while the embodiment of Figures 1(i) to 5 is described as having three sub-beams 14a, 14b, 14c, the beam could instead have two, four, or more sub-beams, by varying the number of intermediate anchors 13 and cuts. If long pre-stressing equipment is used (say 200m length) it would be possible to pre-stress, say, twenty sub-beams. Similarly, for the bi-directional embodiment, twenty panels could be pre-stressed in a single stage.

15 As another example, the timber-based components could have one, two, three, or more pre-stressing members positioned in each hollow.

Other modifications are outlined in the 'summary of the invention' section.

20 The above described preferred embodiment pre-stressed timber-based beams and panels provide a high strength to weight ratio in comparison to other commonly used alternatives such as reinforced concrete. This enables longer span floors for architectural design purposes, reduces the cost of supporting beams, columns and foundations (due to lowered strength requirements), and reduces the cost of transport and lifting of the beams or panels and their supporting structures. A manufacturer is also able to supply a larger geographic region due to lower transport costs. The lower weight of the preferred embodiment timber-based beams and panels also means that in a seismic event, less energy is transferred through inertia to the supporting structures, resulting in less damage.

30 By being pre-fabricated, the preferred embodiment beams and panels are also more accessible to end users, meaning builders and other users are more likely to readily adopt the beams and panels. The preferred embodiment timber-based beams and panels also have a lower carbon footprint than many other construction materials such as concrete-based beams and other commercial flooring alternatives. This means the above described beams and panels may be an attractive option in 'green building' projects.

35

**CLAIMS**

1. A method of manufacturing a pre-stressed beam or panel comprising:  
providing a timber-based component;  
providing a pre-stressing member arranged along the timber-based  
5 component;  
applying a tensile force to the pre-stressing member;  
providing concrete anchors at locations that are spaced apart along the timber-based component;  
coupling the pre-stressing member to the concrete anchors; and  
10 releasing the tensile force on the pre-stressing member to transfer a compressive force to the timber-based component through the concrete anchors to form a pre-stressed beam or panel.
2. The method according to claim 1, wherein the concrete anchors are provided by pouring concrete at locations that are spaced apart along the timber-based  
15 component, embedding respective portions of the pre-stressing member; and wherein coupling the pre-stressing member to the anchors comprises allowing the concrete to substantially cure, before the tensile force on the pre-stressing member is released.
3. The method according to claim 2, wherein the concrete is poured at two spaced  
20 apart locations positioned at or adjacent the ends of the timber-based component to form end anchors.
4. The method according to claim 3, further comprising:  
pouring concrete at one or more locations between the two end anchors to  
form one or more intermediate concrete anchors embedding a respective  
25 intermediate portion of the pre-stressing member;  
allowing the or each intermediate concrete anchor to substantially cure; and  
cutting the beam or panel through the or each intermediate anchor and  
through the respective anchored intermediate portion of the pre-stressing  
member to form two or more shorter pre-stressed beams or panels.
- 30 5. The method according to claim 4, wherein the timber-based component comprises a plurality of sub-components arranged end-to-end, with the pre-stressing member extending along all of the sub-components, and wherein the or each intermediate concrete anchor is poured between the ends of two adjacent sub-components to join those sub-components.

6. The method according to any one of claims 2 to 5, wherein the concrete for the anchors is poured into hollows or boxed regions defined by the timber-based component.
- 5 7. The method according to any one of claims 2 to 6, wherein shear or axial connectors protrude from the timber-based component into one or more of the anchor locations and become at least partly embedded in the respective concrete anchor when the concrete is poured.
- 10 8. The method according to any one of claims 2 to 7, comprising placing timber, polystyrene or other filler material at the location for each anchor, before pouring the concrete, to create a lightweight core, region, or void in the anchors.
9. The method according to any one of claims 2 to 8, comprising placing one or more steel reinforcing members at the location for each anchor, before pouring the concrete, to reinforce the concrete anchors.
10. The method according to claim 1, wherein the concrete anchors are pre-cast.
- 15 11. The method according to claim 10, wherein the pre-stressing member is coupled to the pre-cast anchors by grouting, concrete, or mechanical fasteners.
- 20 12. The method according to claim 1, claim 10, or claim 11, comprising placing at least three discrete pre-cast anchors at spaced apart locations and coupling the pre-stressing member to each of said at least three pre-cast anchors, using concrete or grouting.
13. The method according to any preceding claim, comprising providing and tensioning a plurality of pre-stressing members.
14. The method according to any preceding claim, wherein the or each pre-stressing member comprises a rod, bar or cable.
- 25 15. The method according to any preceding claim, wherein the timber-based component comprises one or more elongate hollow portion or channel that receives at least a portion of the pre-stressing member(s).
- 30 16. The method according to claim 15, wherein the or each pre-stressing member is inserted in the respective hollow portion or channel during assembly of the timber-based component such that at least a part of the or each pre-stressing member is enclosed by the timber-based component.

17. The method according to any preceding claim, wherein the timber-based component comprises an engineered timber laminate and/or a wood-based composite and/or sawn hard wood.
18. The method according to any preceding claim, wherein the timber-based component further comprises steel, carbon fibre, or glass reinforcing.
19. The method according to any preceding claim, further comprising the step of pouring a concrete topping layer on a top side of the timber-based component.
20. The method according to claim 19, wherein the concrete topping layer is reinforced with steel or mesh reinforcing.
21. The method of claim 19 or 20, comprising providing fasteners that protrude from the top side of the timber-based component, such that the fasteners become at least partly embedded in the concrete when the topping layer is poured.
22. The method according to any preceding claim, wherein the timber-based component further comprises a transverse channel or hollow portion for receiving a transverse pre-stressing member.
23. The method according to claim 22, wherein the timber-based component comprises cross laminated timber.
24. The method according to claim 22 or 23, comprising the steps of:  
inserting a transverse pre-stressing member into the transverse channel or hollow portion;  
applying a tensile force to the transverse pre-stressing member;  
pouring concrete at spaced apart locations along the transverse pre-stressing member;  
allowing the concrete to substantially cure to anchor respective portions of the transverse pre-stressing member; and  
releasing the tension from the transverse pre-stressing member to pre-stress the beam or panel in the transverse direction.
25. The method according to claim 22 or 23, comprising the steps of:  
attaching pre-cast anchors to the timber-based component at spaced apart locations along the transverse channel or hollow portion;  
inserting a transverse pre-stressing member into the transverse channel or hollow portion;  
applying a tensile force to the transverse pre-stressing member;

coupling the tensioned transverse pre-stressing member to the respective pre-cast anchor; and

releasing the tension from the transverse pre-stressing member to pre-stress the beam or panel in the transverse direction.

- 5 26. A beam or panel manufactured according to the method claimed in any preceding claim.
27. A pre-fabricated pre-stressed beam or panel comprising:  
a timber-based component;  
spaced apart concrete anchors operatively connected to the timber-based  
10 component; and  
a pre-stressing member extending between the spaced apart concrete anchors;  
wherein the pre-stressing member comprises anchored portions coupled to the concrete anchors to apply a compressive force to the timber-based component to  
15 pre-stress the beam or panel.
28. The beam or panel of claim 27, wherein the anchored portions of the pre-stressing member are embedded in the concrete anchors.
29. The beam or panel of claim 27, wherein the anchored portions of the pre-stressing member are mechanically fastened to the concrete anchors.
- 20 30. The beam or panel of any one of claims 27 to 29, wherein the timber-based component is an elongate member comprising an elongate hollow portion or channel containing at least a portion of the pre-stressing member.
31. The beam or panel of any one of claims 27 to 30, wherein the cross sectional area of each concrete anchor is much larger than the cross sectional wall area of the  
25 timber-based component at or adjacent each anchor.
32. The beam or panel of any one of claims 27 to 31, wherein the timber-based component comprises an engineered timber laminate and/or a wood-based composite and/or sawn hard wood.
- 30 33. The beam or panel of any one of claims 27 to 32, comprising a concrete topping layer on a top side of the timber-based component.

34. The beam or panel of claim 33, comprising fasteners attached to the top side of the timber-based component and at least partly embedded in the concrete topping layer.
- 5 35. The beam or panel of claim 33 or 34, wherein the topping layer comprises steel or mesh reinforcing.
36. The beam or panel of any one of claims 27 to 35, comprising a plurality of pre-stressing members.
- 10 37. The beam or panel of any one of claims 27 to 36, wherein the timber-based component comprises a transverse channel or hollow for receipt of a transverse pre-stressing member.
38. The beam or panel of any one of claims 27 to 37, wherein the concrete anchors comprise hollow regions or timber cores.
- 15 39. The beam or panel of any one of claims 27 to 38, comprising shear and/or axial connectors that protrude from the timber-based component into one or more of the anchor regions, such that the shear connectors are at least partly embedded in the concrete anchors.
40. The beam or panel of claim 39, wherein the shear and/or axial connectors comprise timber-based protrusions on the timber based component.
- 20 41. The beam or panel of any one of claims 27 to 38, wherein the or each timber-based component comprises recesses in the anchor regions, and wherein the concrete anchors protrude into the recesses.
- 25 42. The beam or panel of any one of claims 27 to 41, comprising:  
a plurality of side-by-side timber-based components;  
spaced apart transverse concrete anchors; and  
a transverse pre-stressing member extending between the transverse concrete anchors and coupled to the transverse concrete anchors, the transverse pre-stressing member applying a compressive force to the timber-based component to pre-stress the beam or panel in the transverse direction.
- 30 43. A method of manufacturing a panel, comprising:  
placing a plurality of pre-fabricated beams or panels according to any one of claims 26 to 41 side-by-side;

providing a transverse pre-stressing member arranged transversely across the side-by-side timber-based components;

applying a tensile force to the transverse pre-stressing member;

providing transversely spaced concrete anchors;

5       coupling the transverse pre-stressing member to the transversely spaced concrete anchors; and

releasing the tensile force on the transverse pre-stressing member to transfer a transverse compressive force to the timber-based components through the transverse concrete anchors to pre-stress the panel in the transverse direction.

10   44.   The method according to claim 43, wherein each pre-fabricated beam or panel comprises a transverse channel or hollow portion, the pre-fabricated beams or panels being arranged side-by-side so the channels or hollow portions of the beams are aligned, and wherein the transverse pre-stressing member is arranged to extend through the aligned transverse channels or hollow portions.

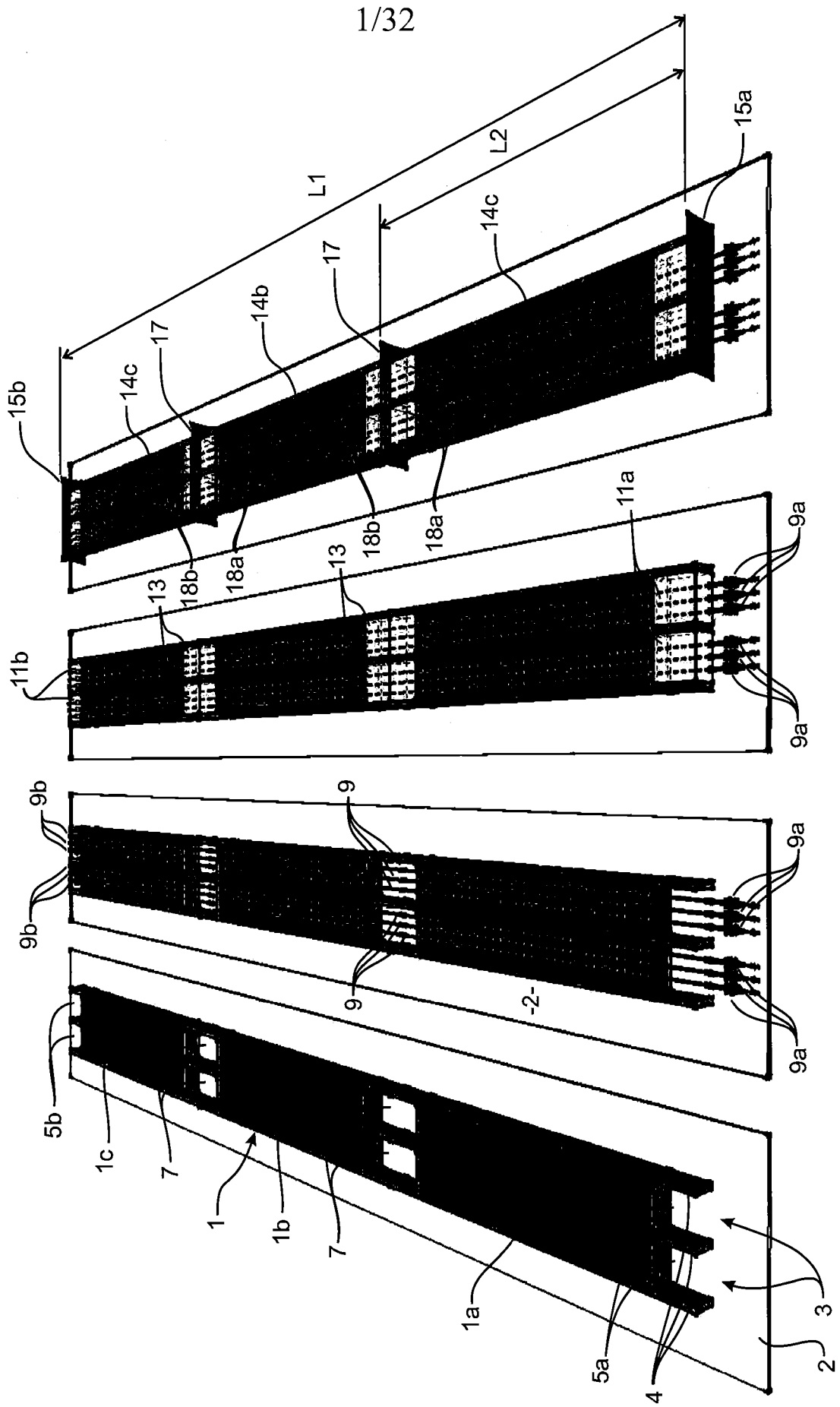
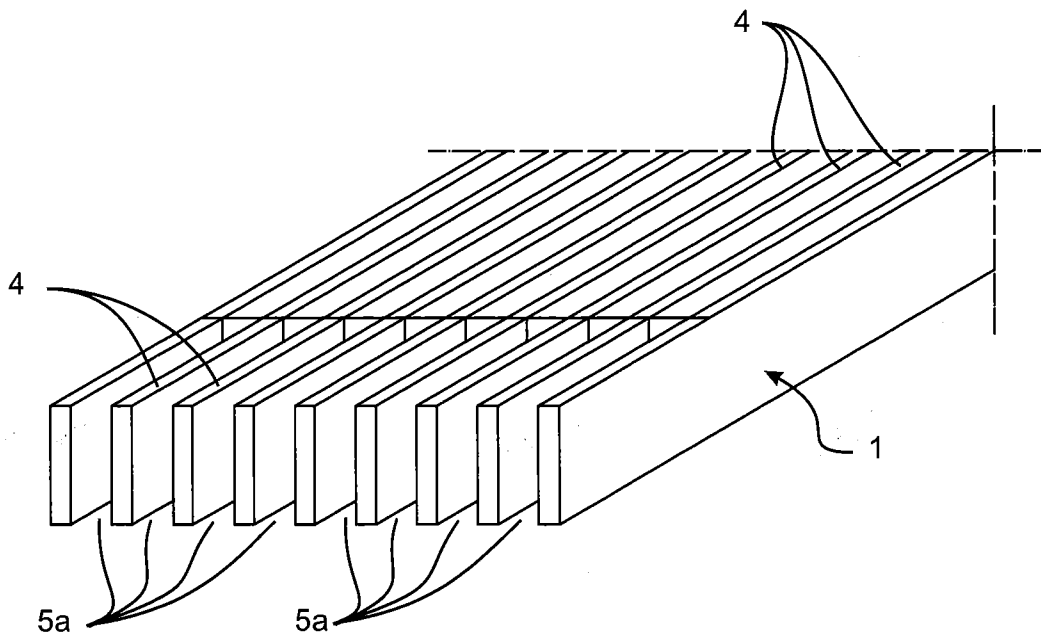
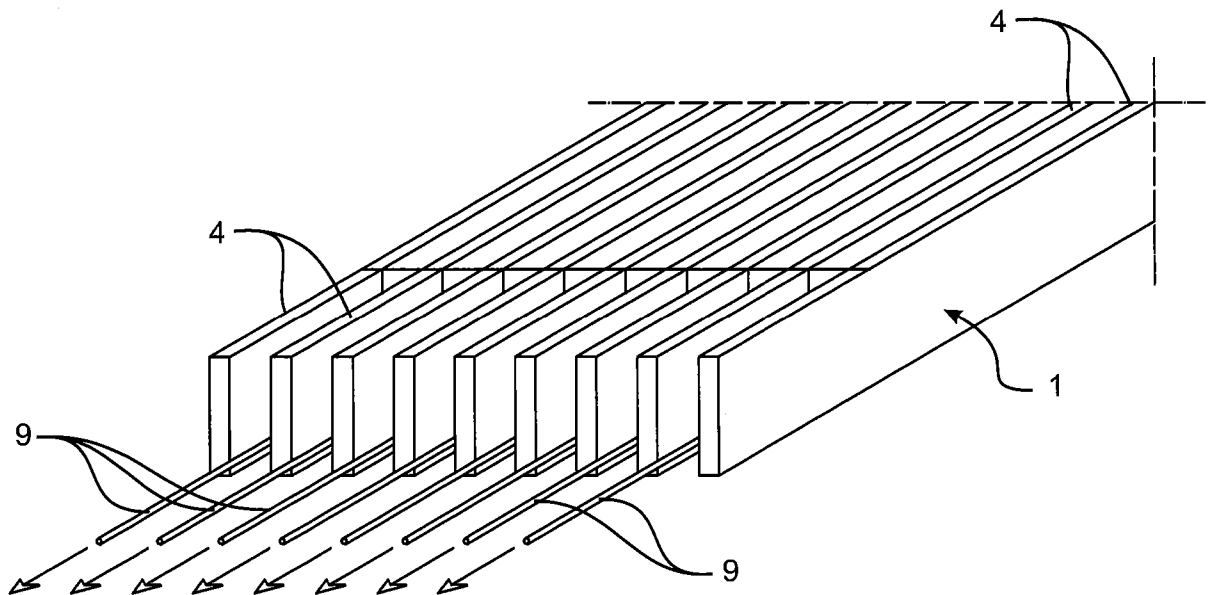


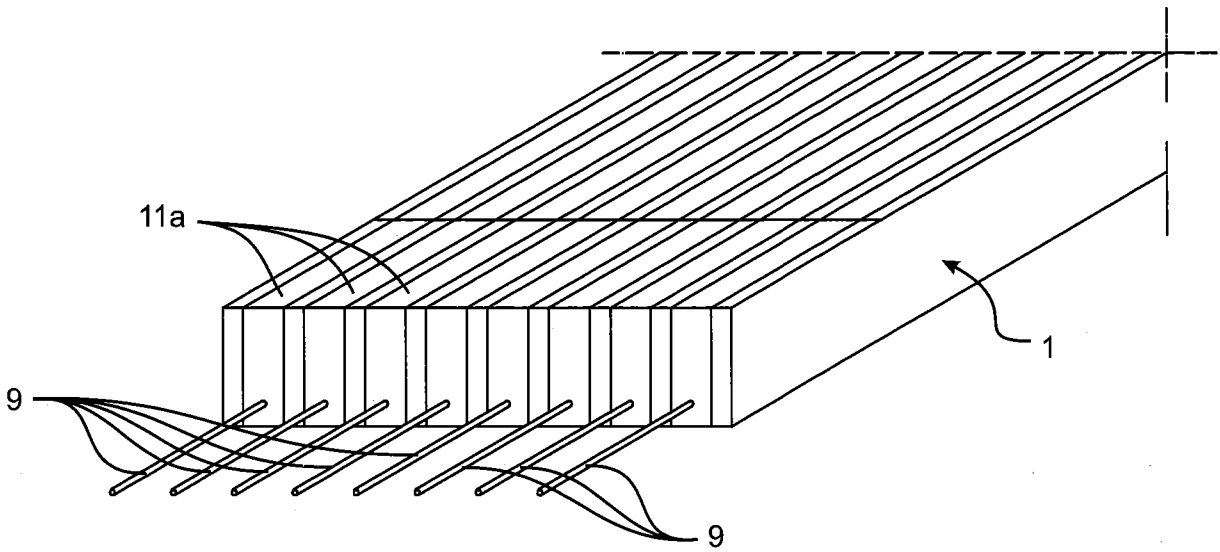
FIGURE 1



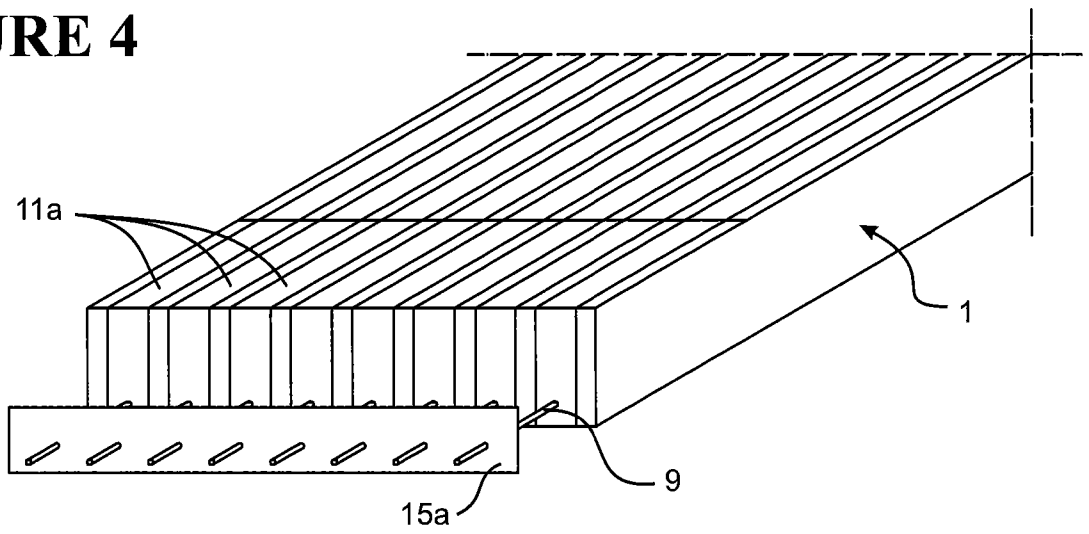
**FIGURE 2**



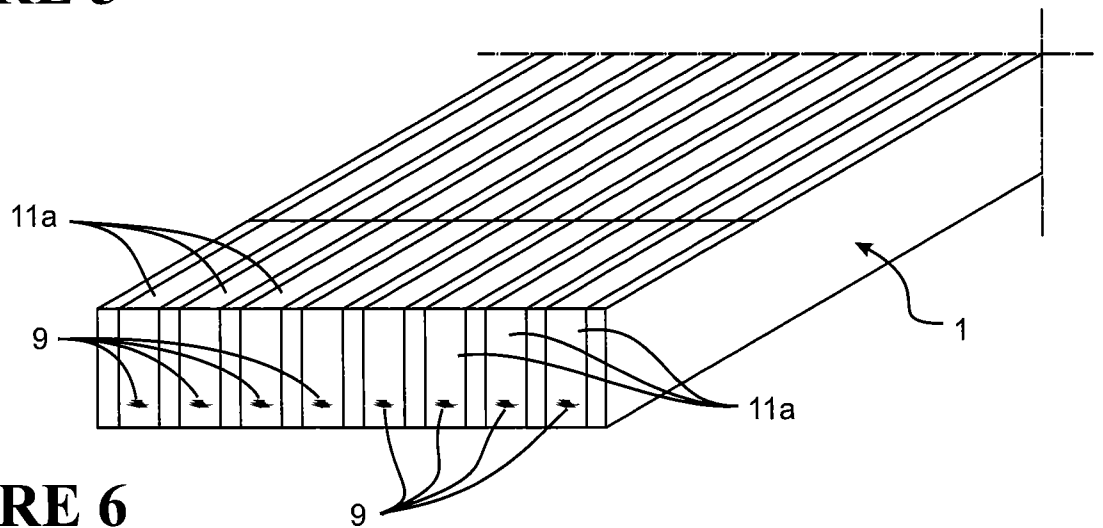
**FIGURE 3**



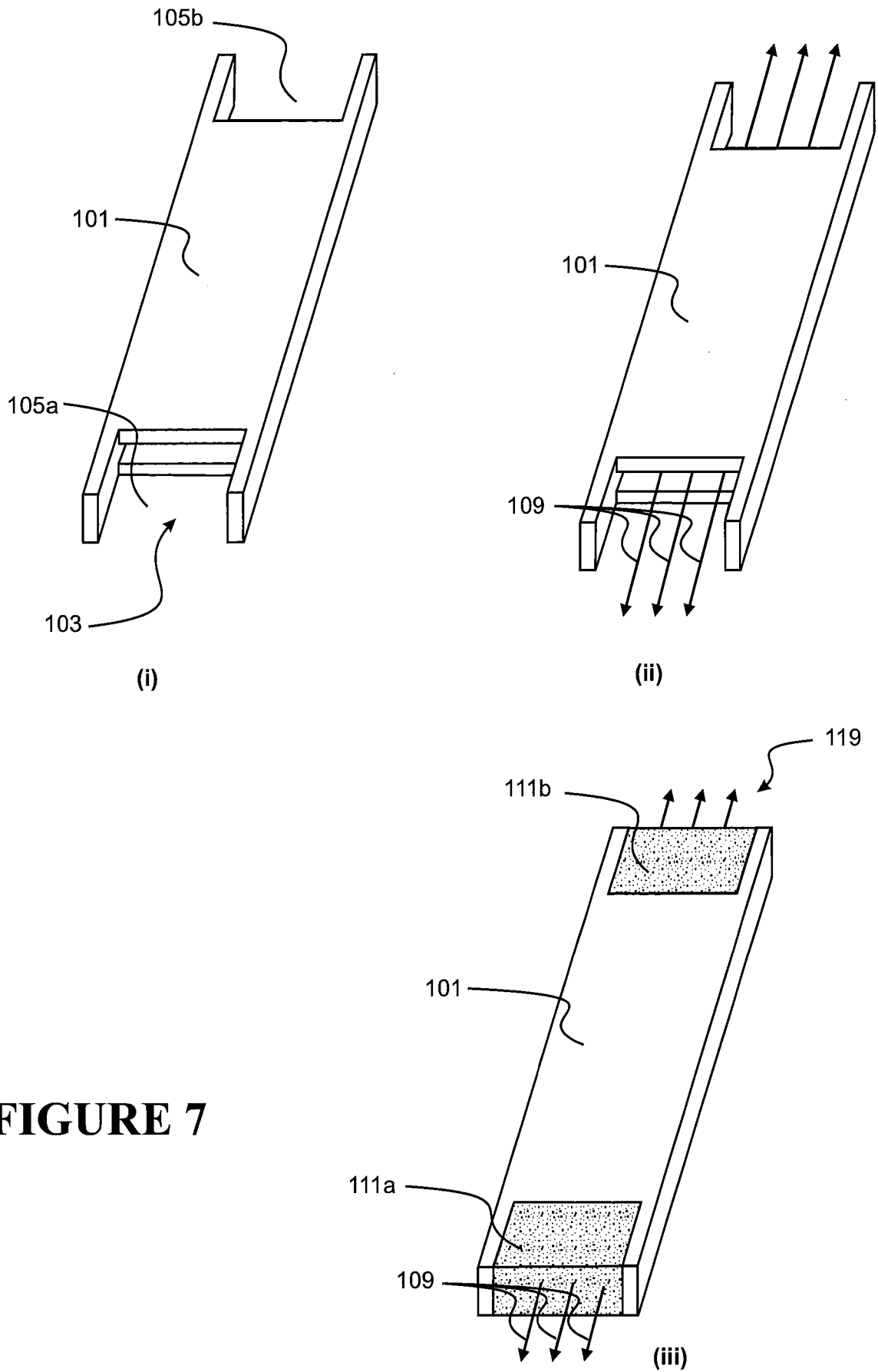
**FIGURE 4**



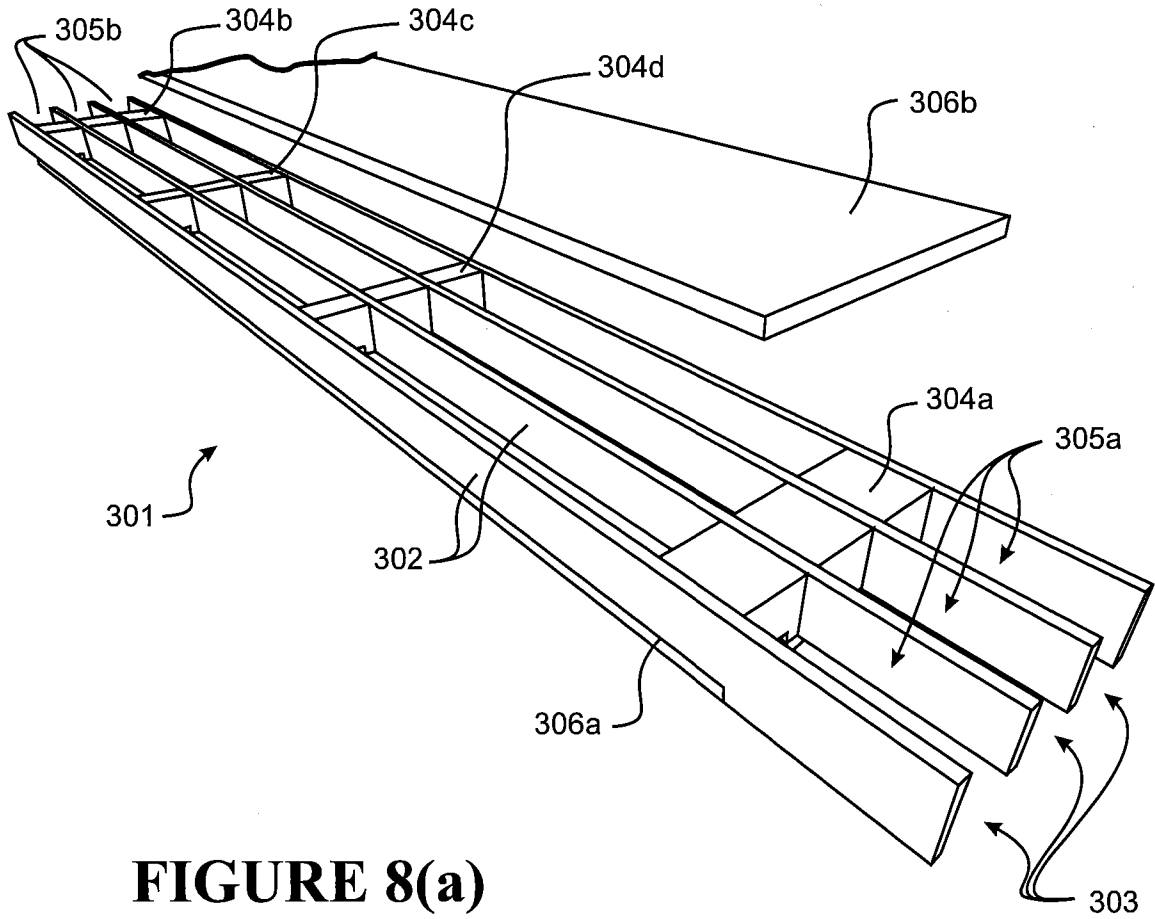
**FIGURE 5**



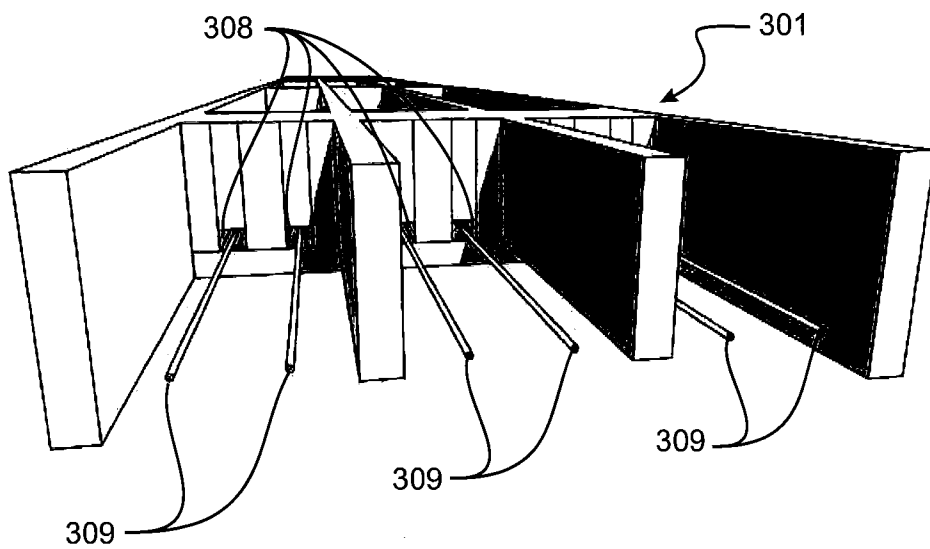
**FIGURE 6**



**FIGURE 7**

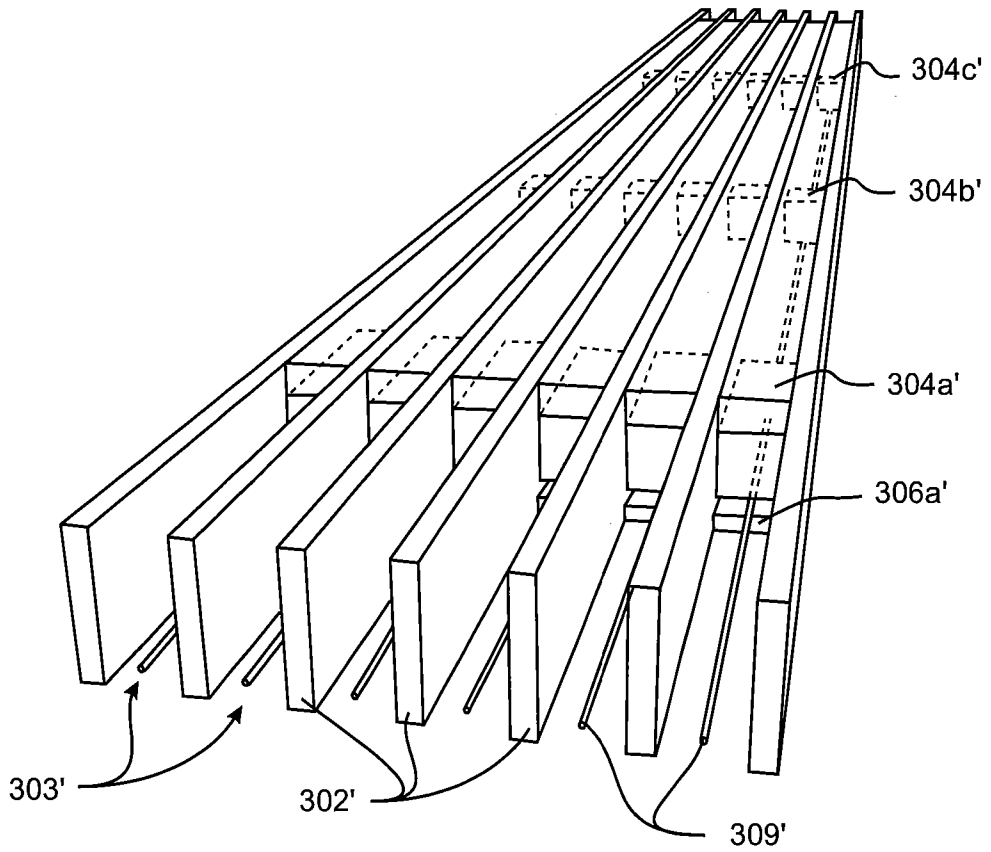


**FIGURE 8(a)**

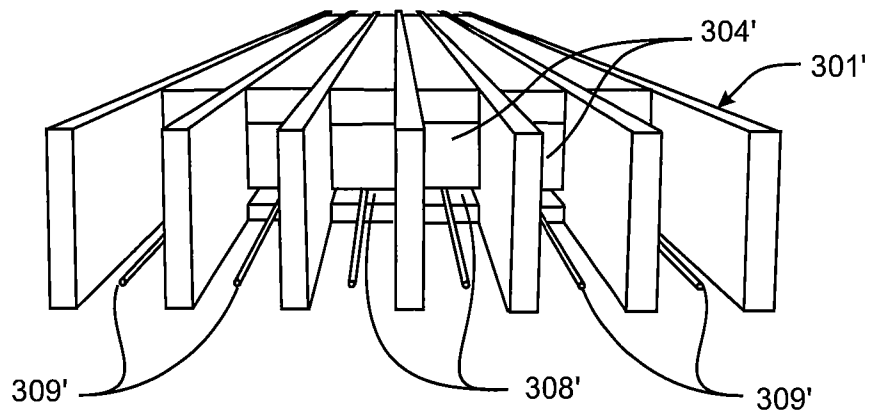


**FIGURE 8(b)**





**FIGURE 9(a)**



**FIGURE 9(b)**

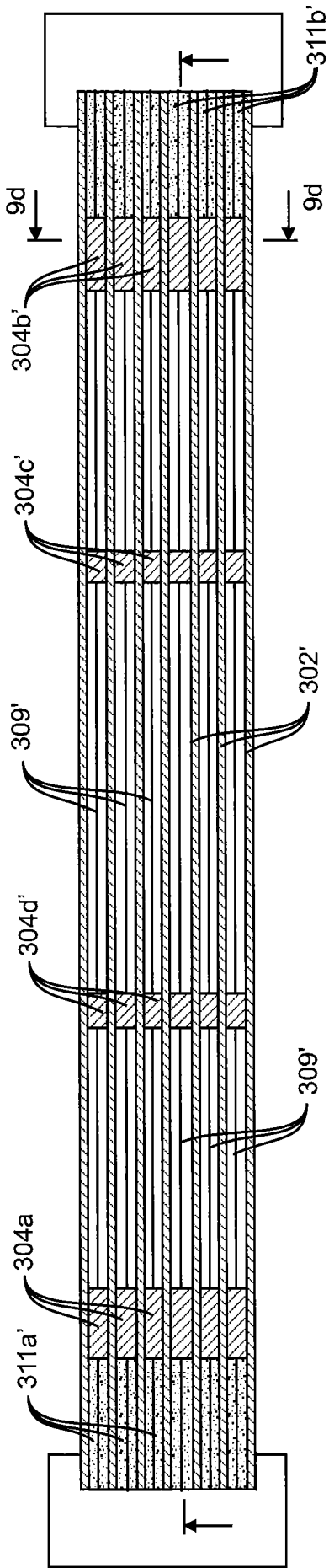


FIGURE 9(c)

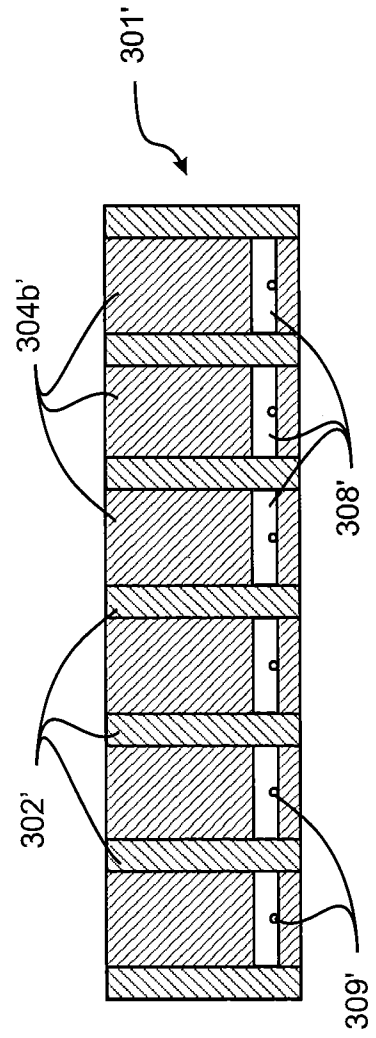


FIGURE 9(d)

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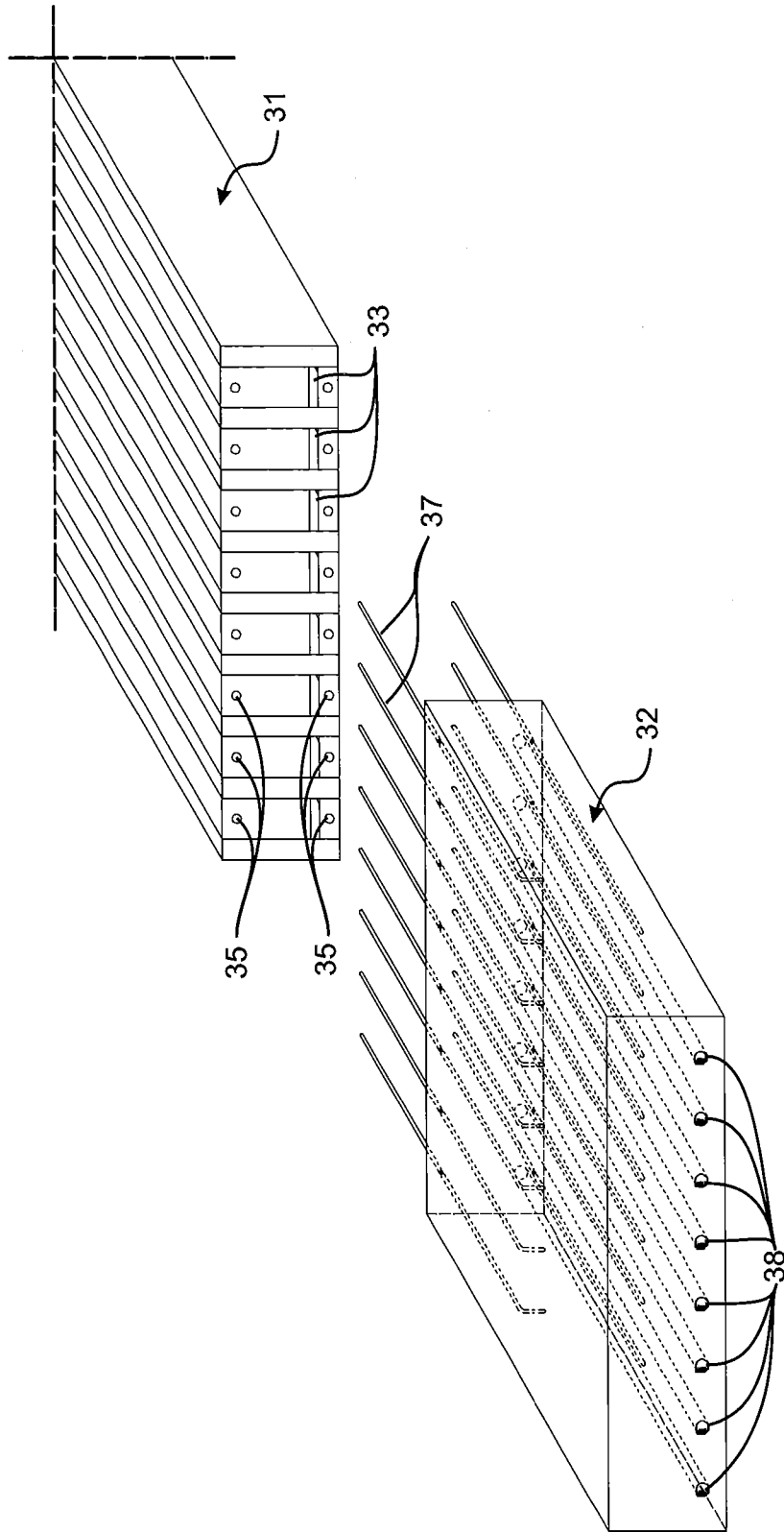
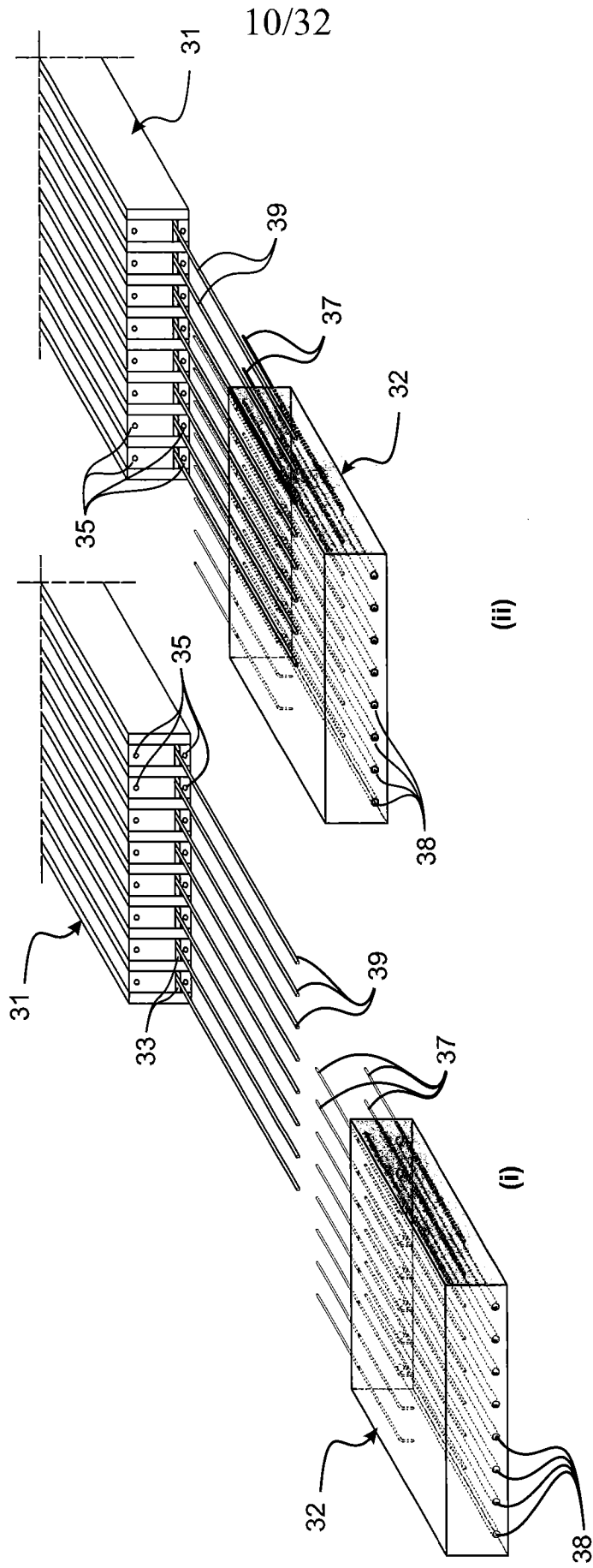
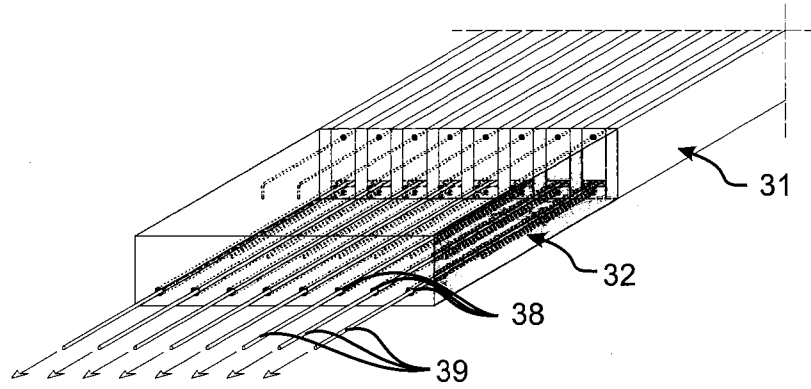


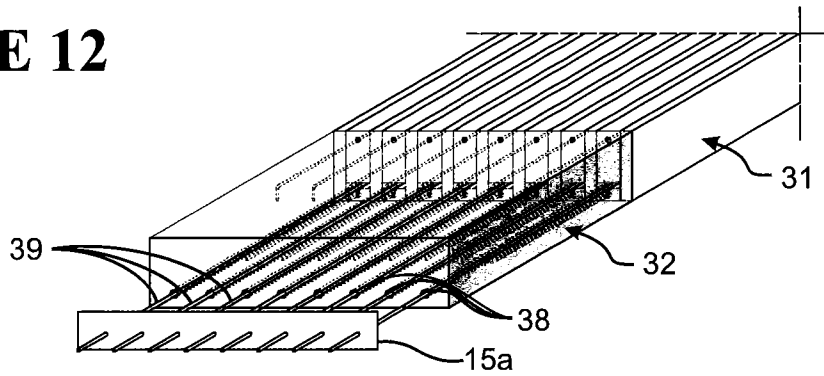
FIGURE 10



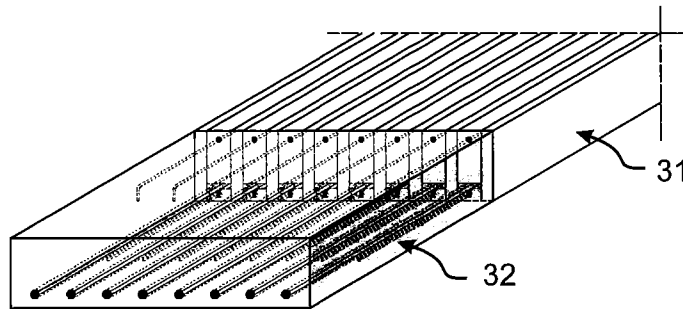
**FIGURE 11**



**FIGURE 12**

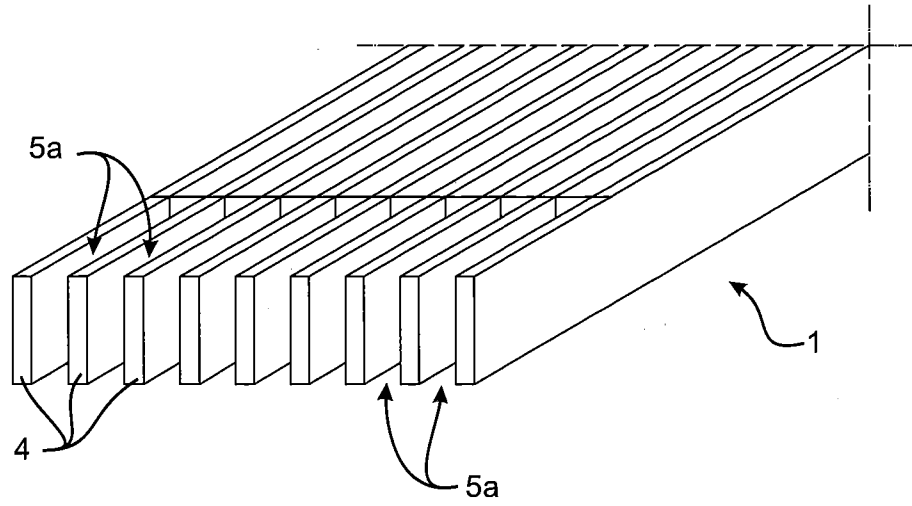


**FIGURE 13**

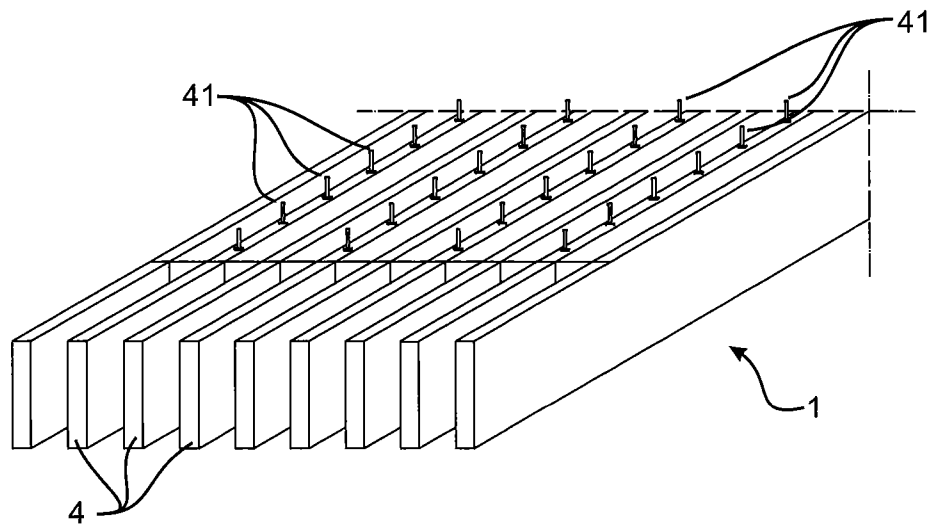


**FIGURE 14**

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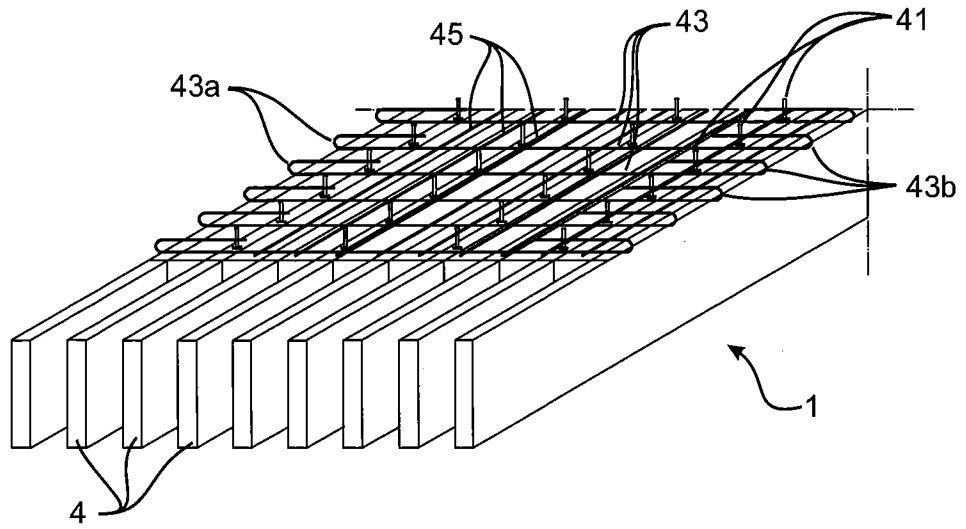


**FIGURE 15**

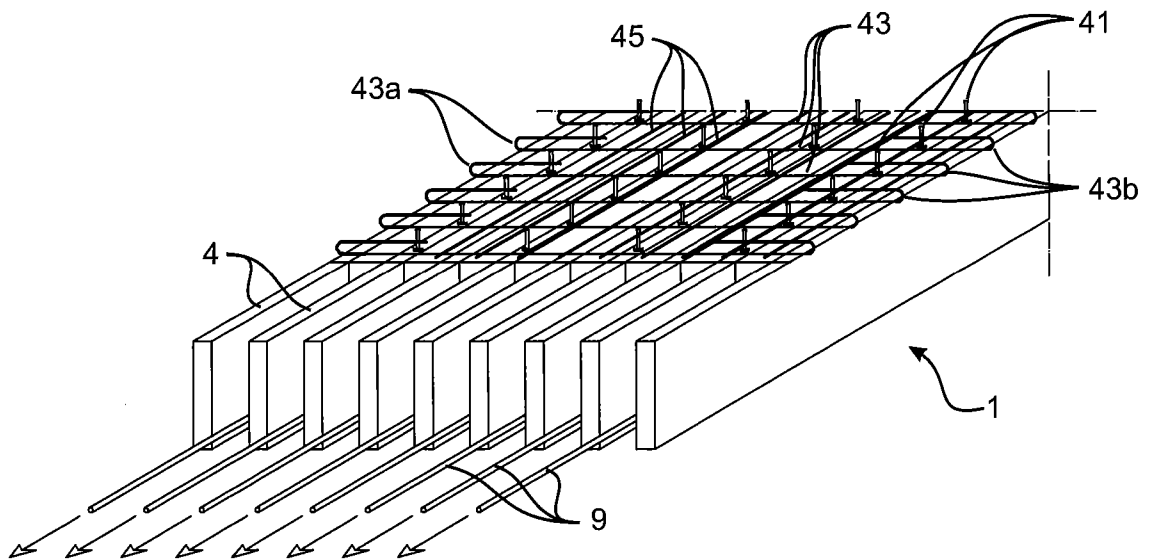


**FIGURE 16**

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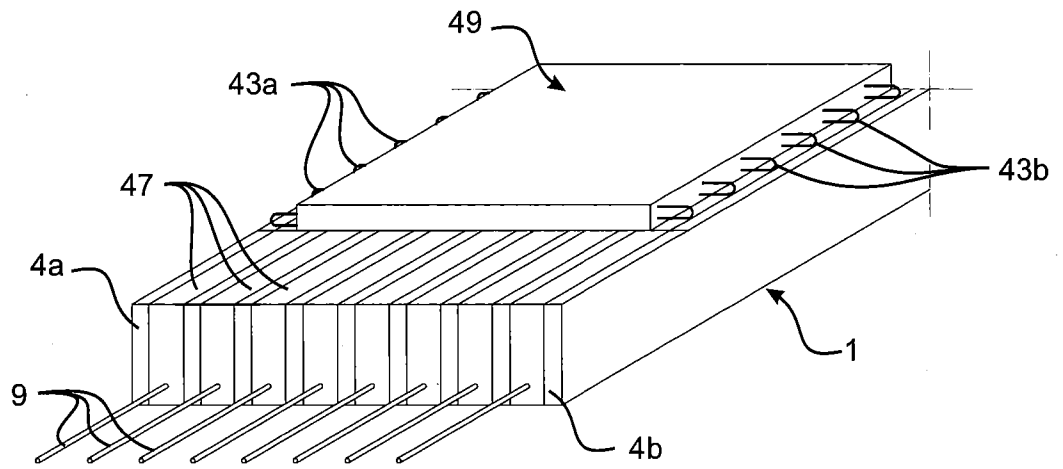


**FIGURE 17**

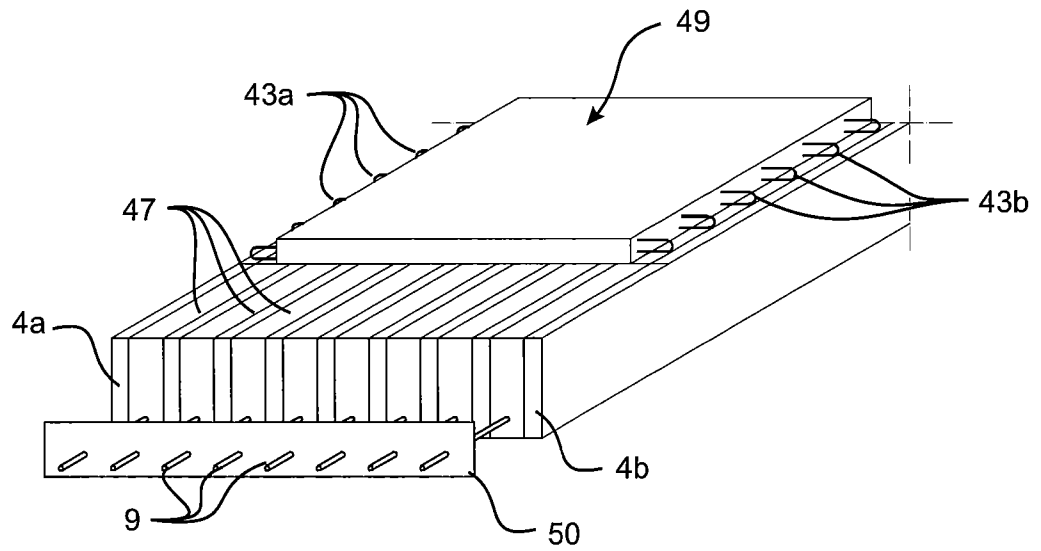


**FIGURE 18**

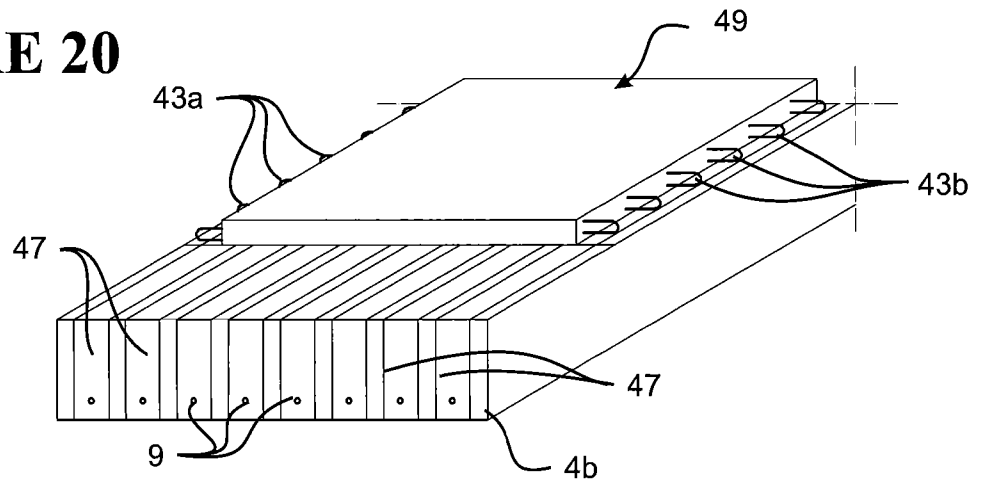
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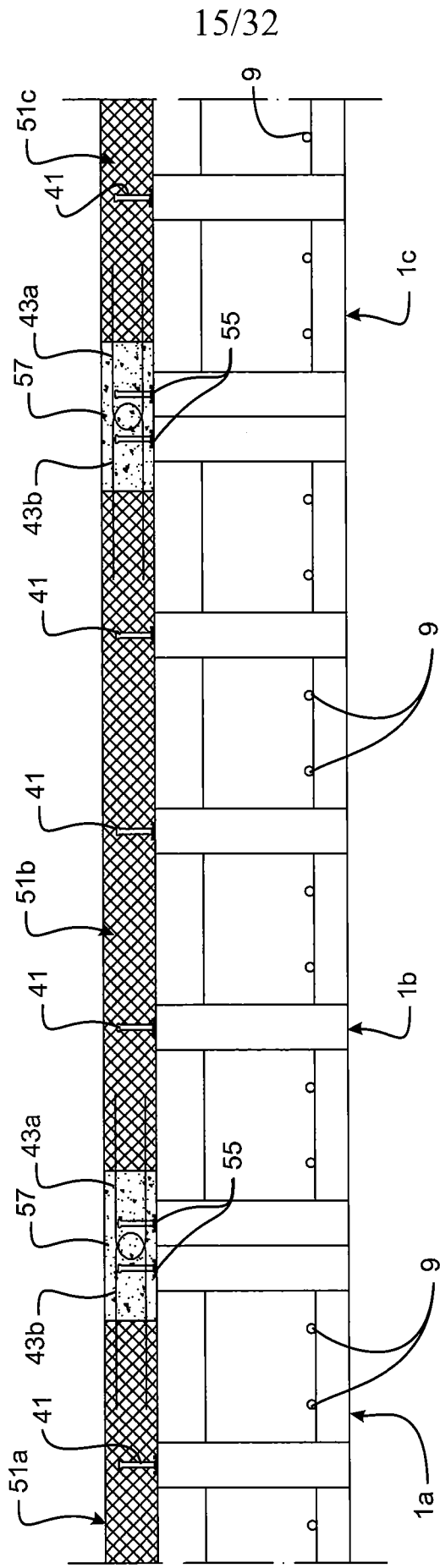
**FIGURE 19**



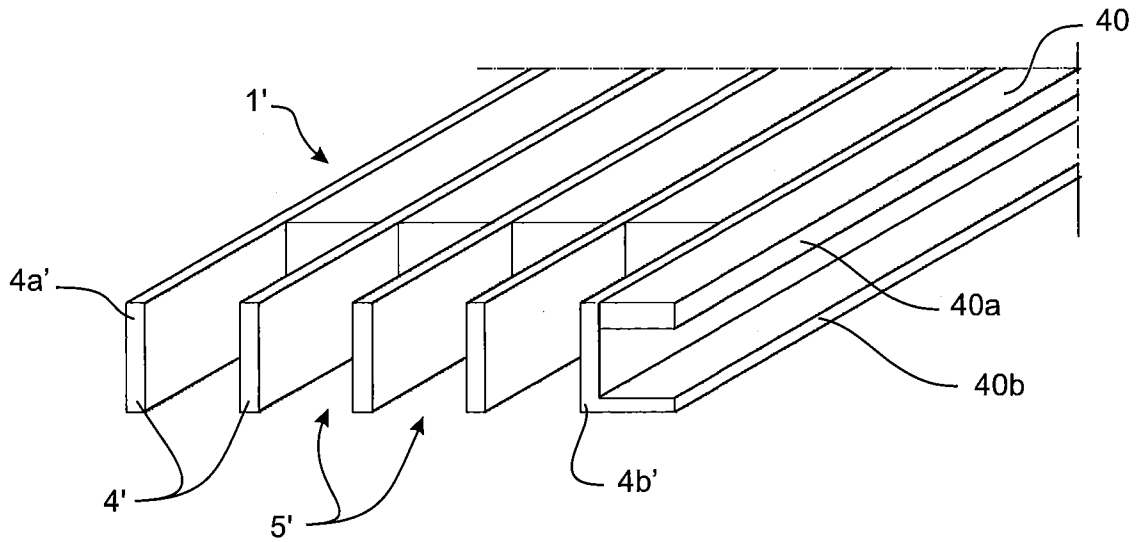
**FIGURE 20**



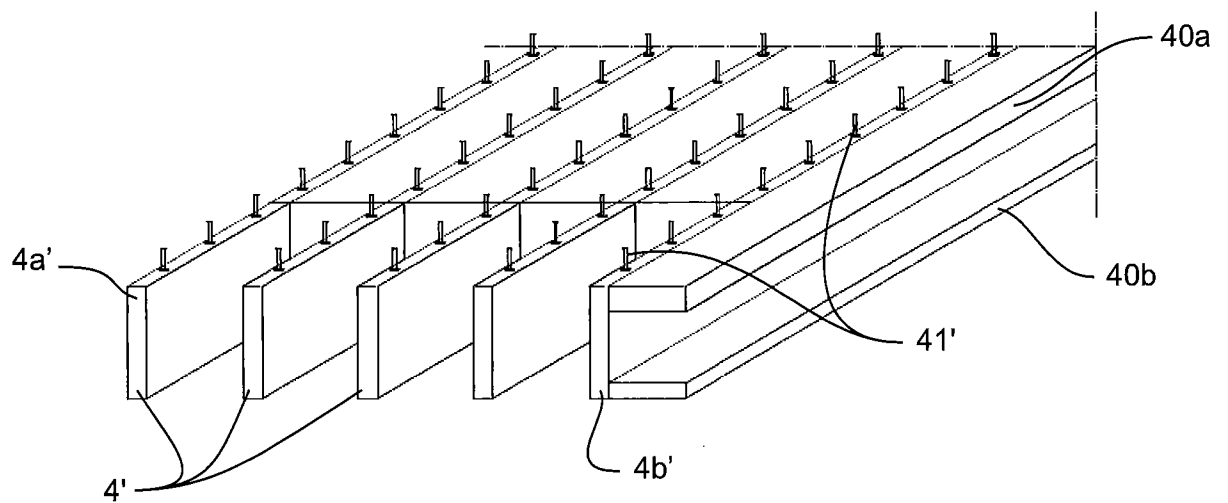
**FIGURE 21**



**FIGURE 22**

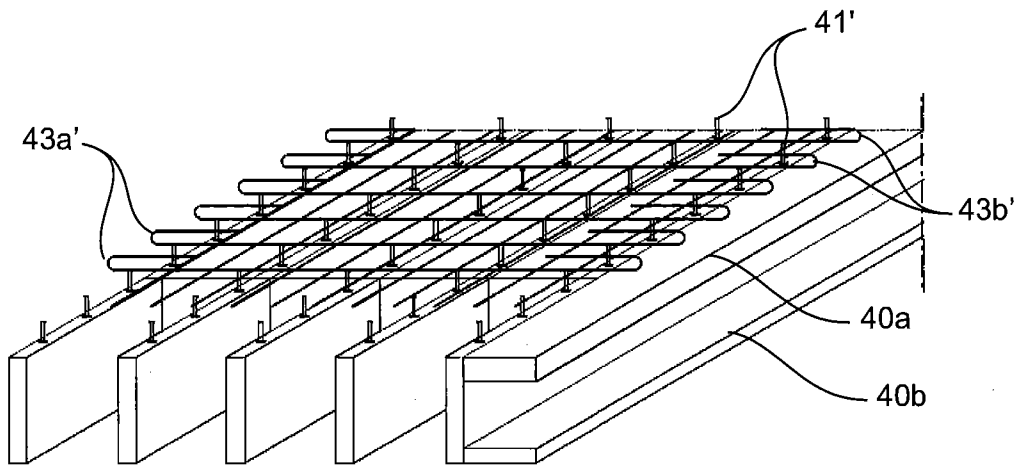


**FIGURE 23**

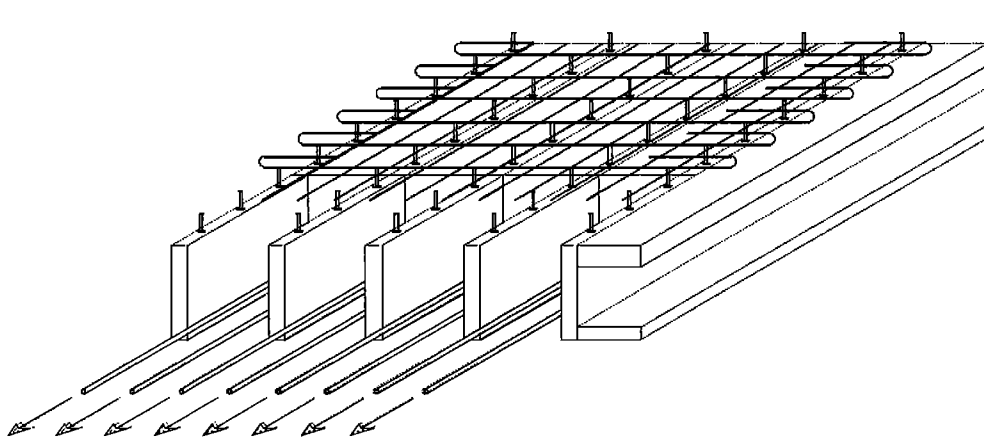


**FIGURE 24**

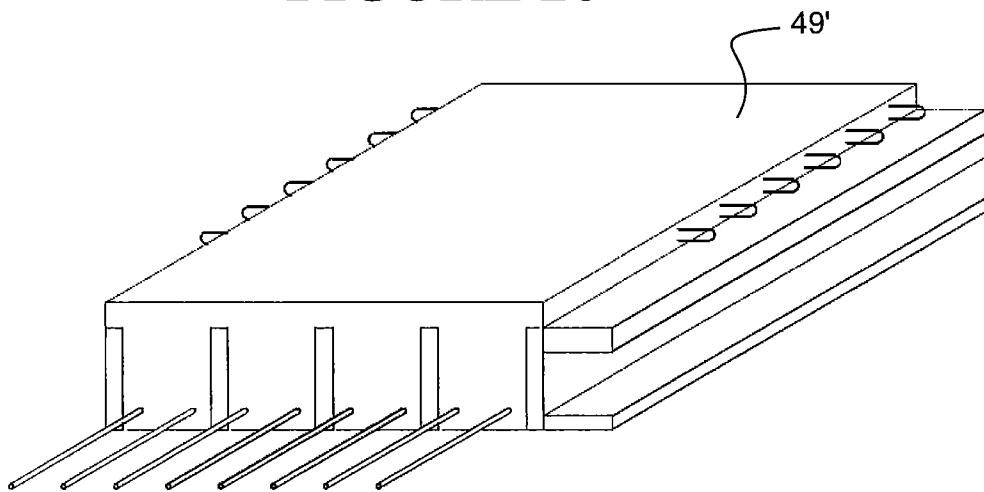
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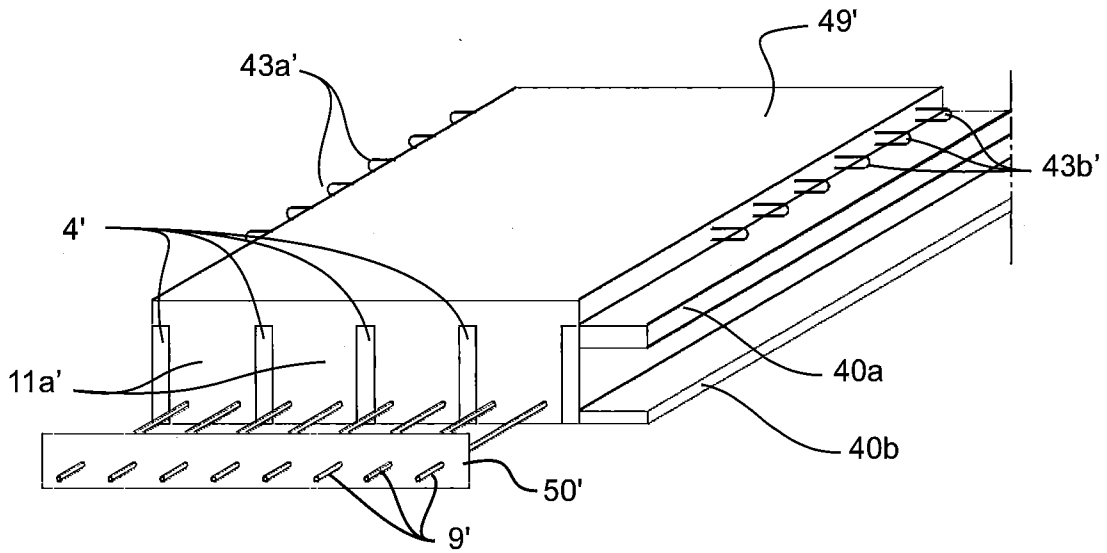
**FIGURE 25**



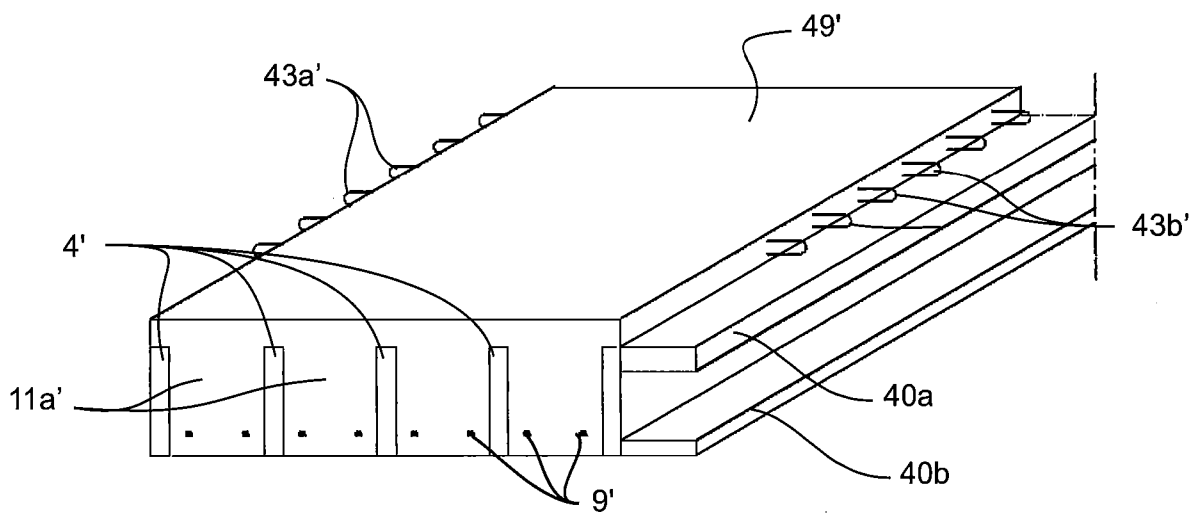
**FIGURE 26**



**FIGURE 27**

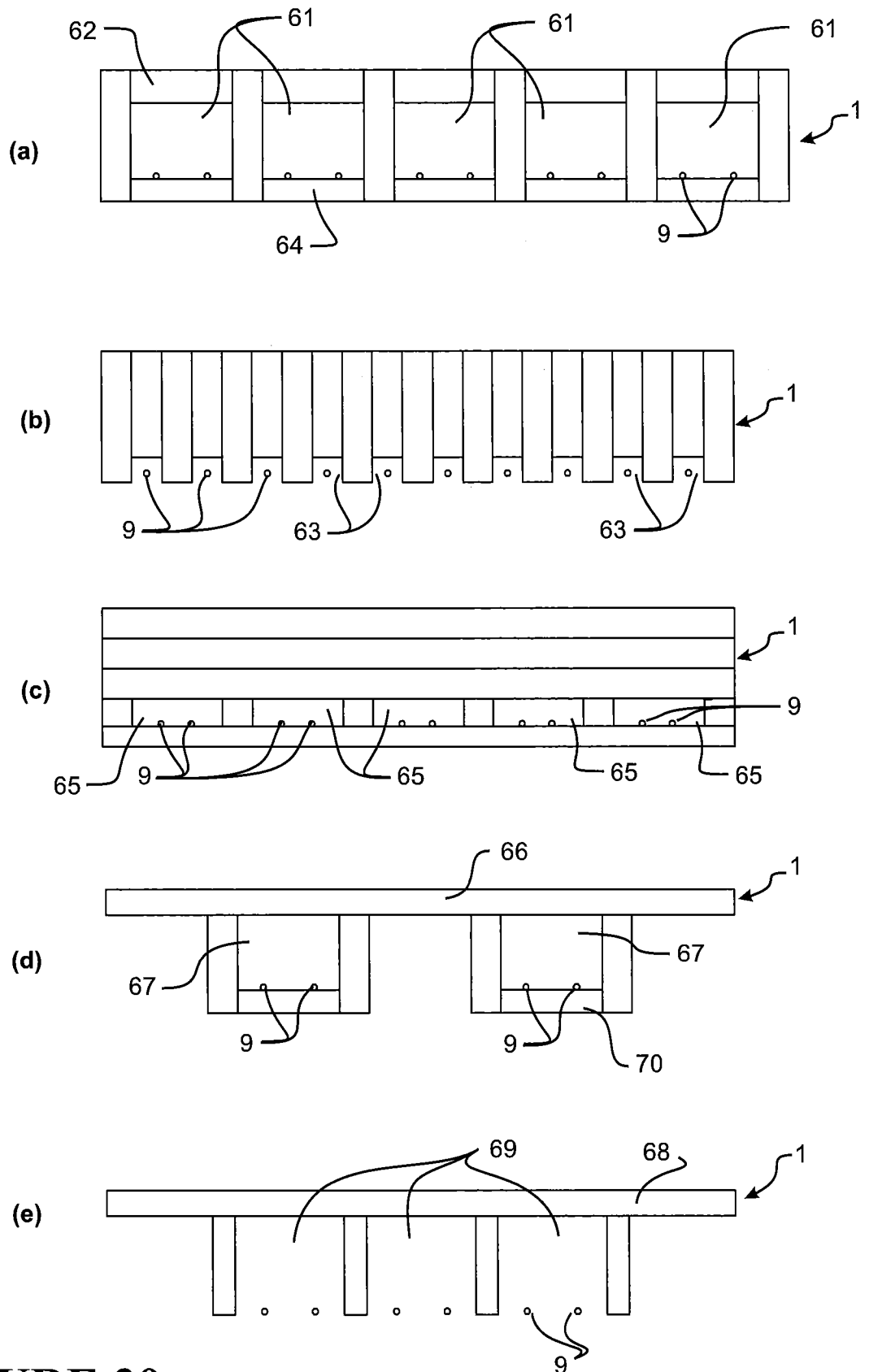


**FIGURE 28**



**FIGURE 29**

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**FIGURE 30**

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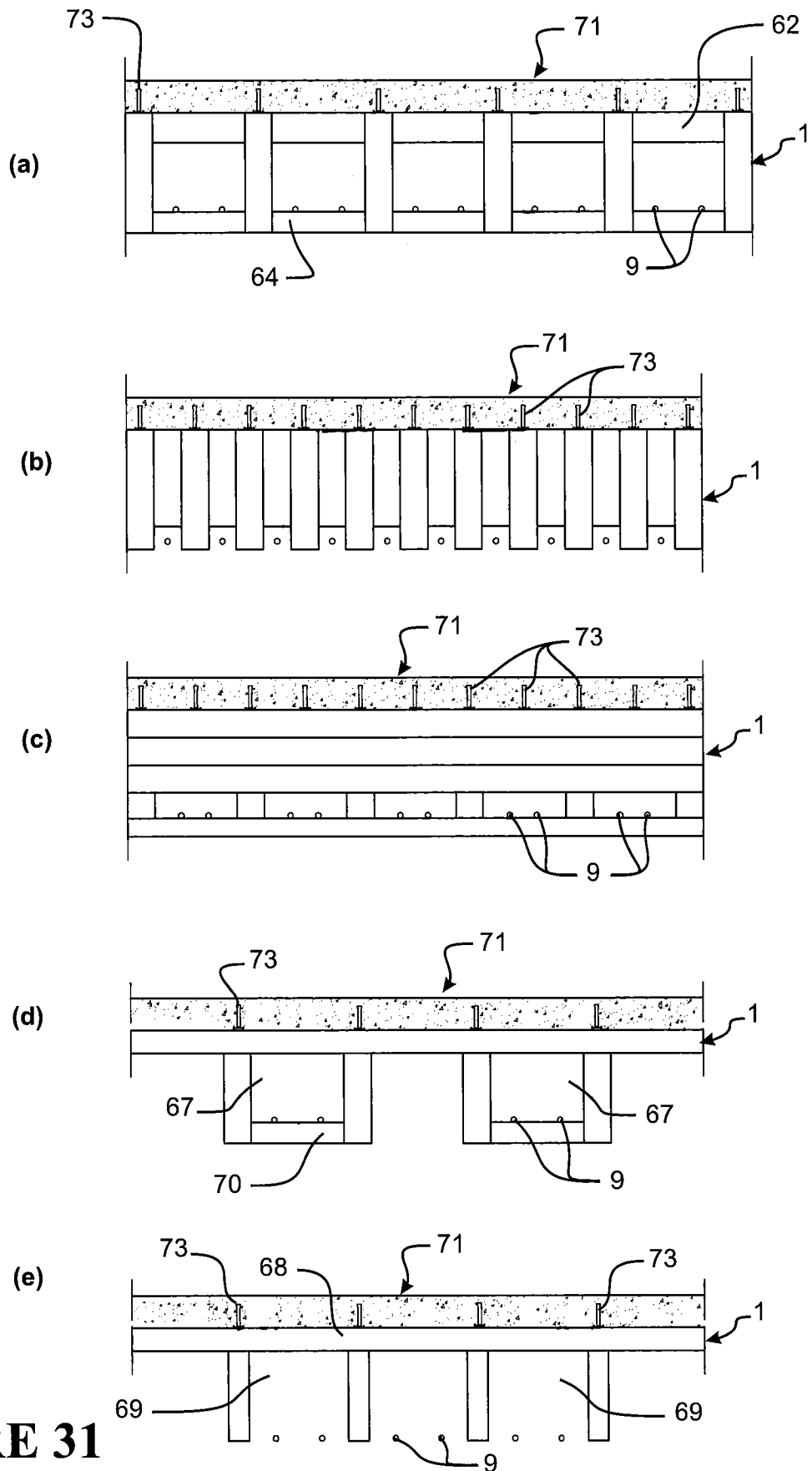
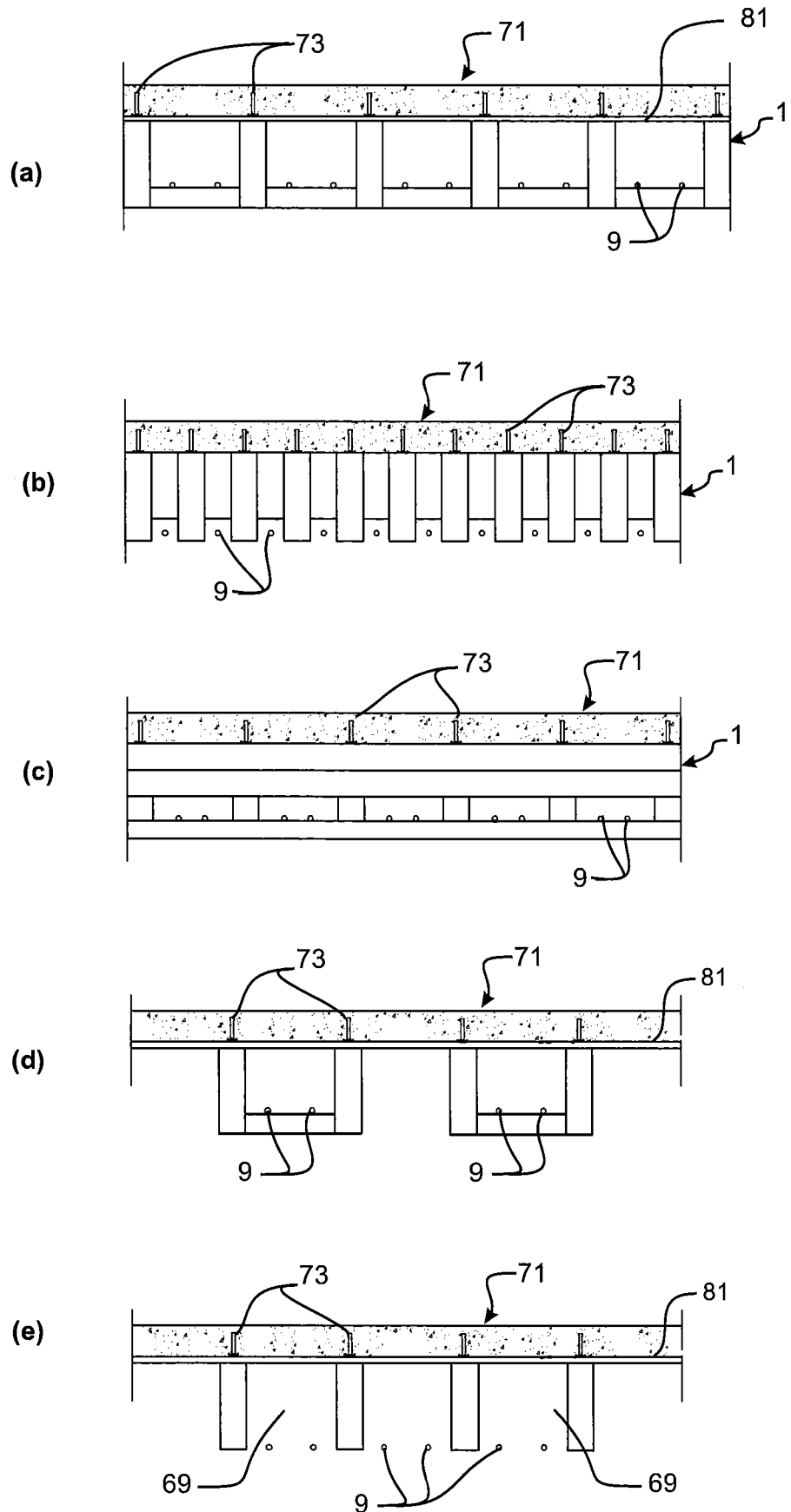


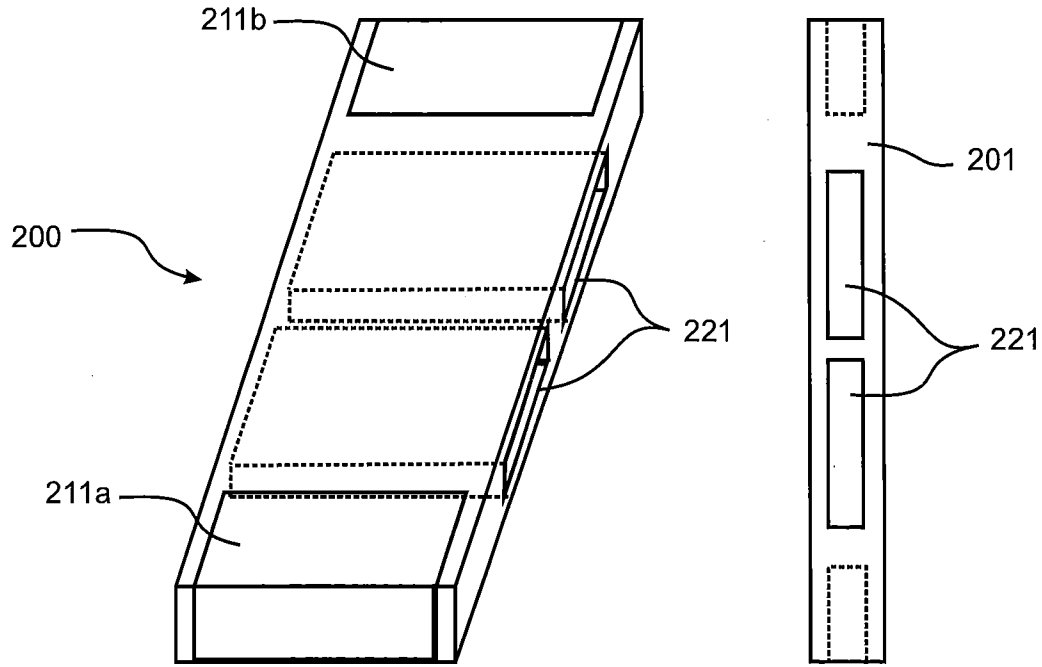
FIGURE 31

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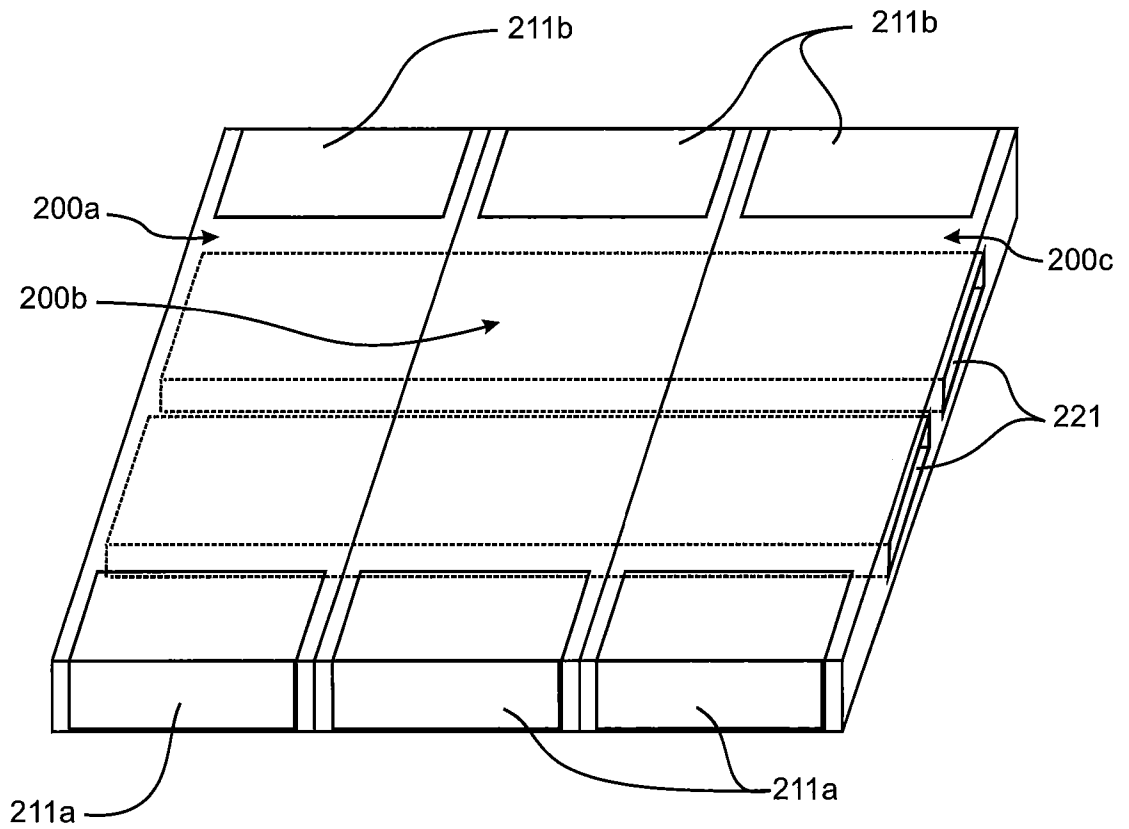


**FIGURE 32**

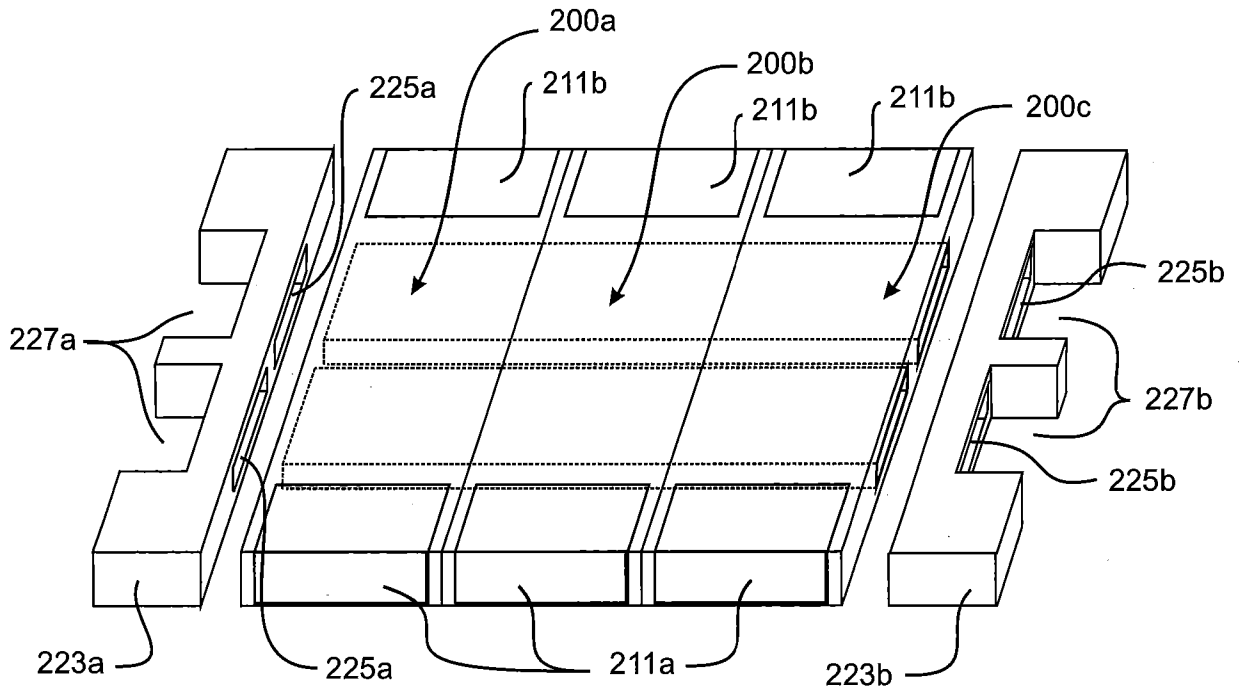
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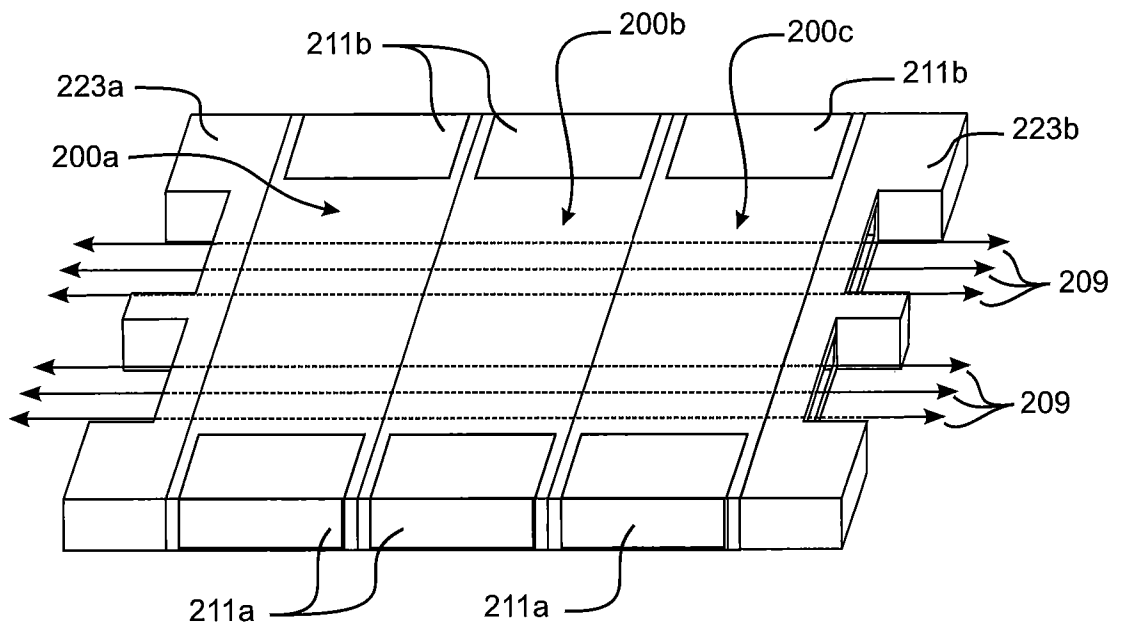
**FIGURE 33**



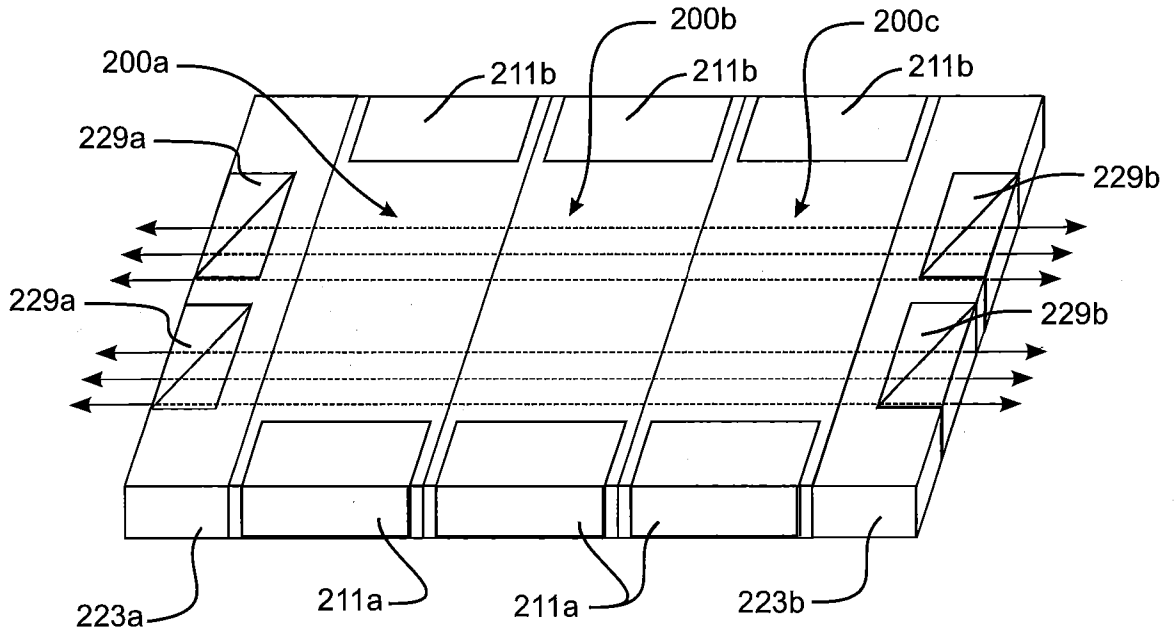
**FIGURE 34**



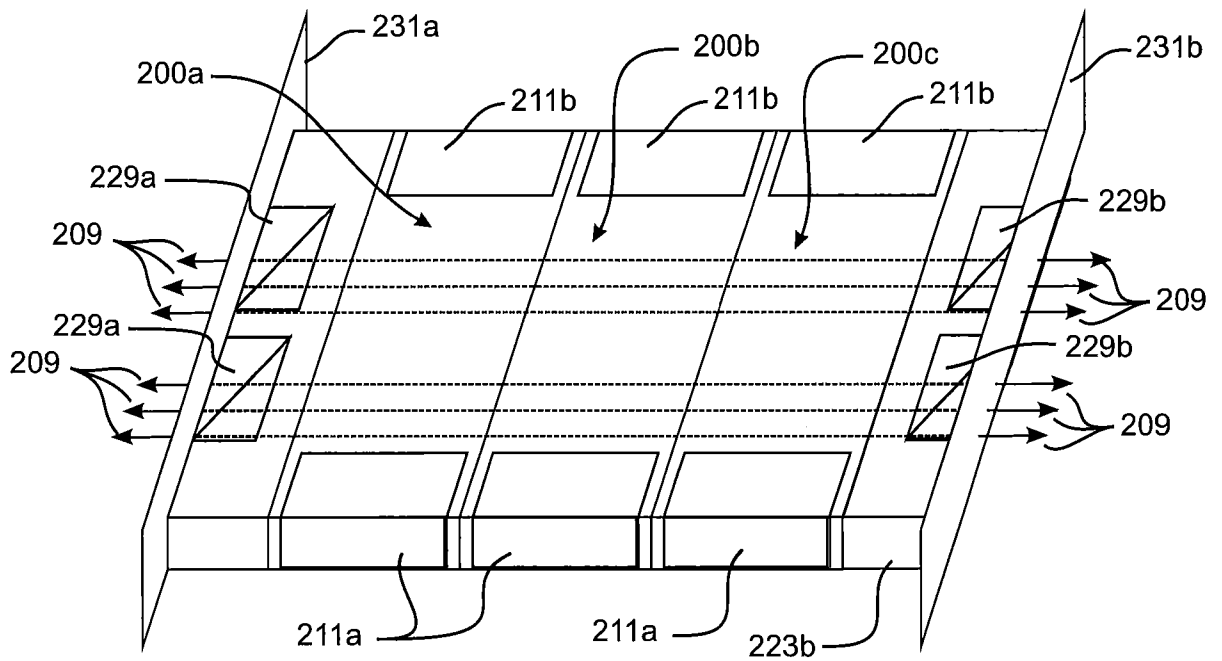
**FIGURE 35**



**FIGURE 36**



**FIGURE 37**



**FIGURE 38**

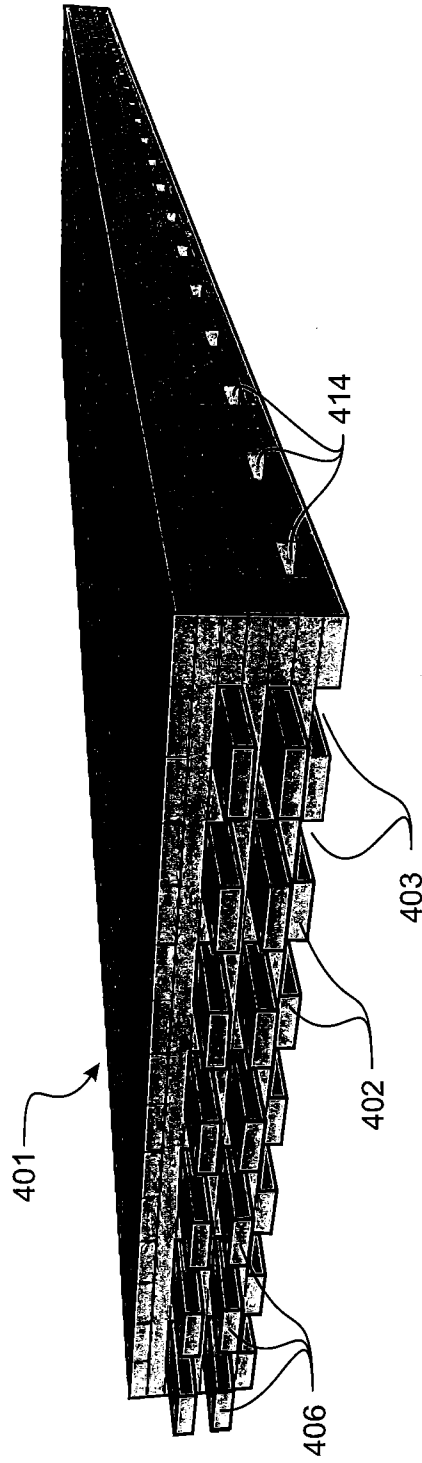


FIGURE 39

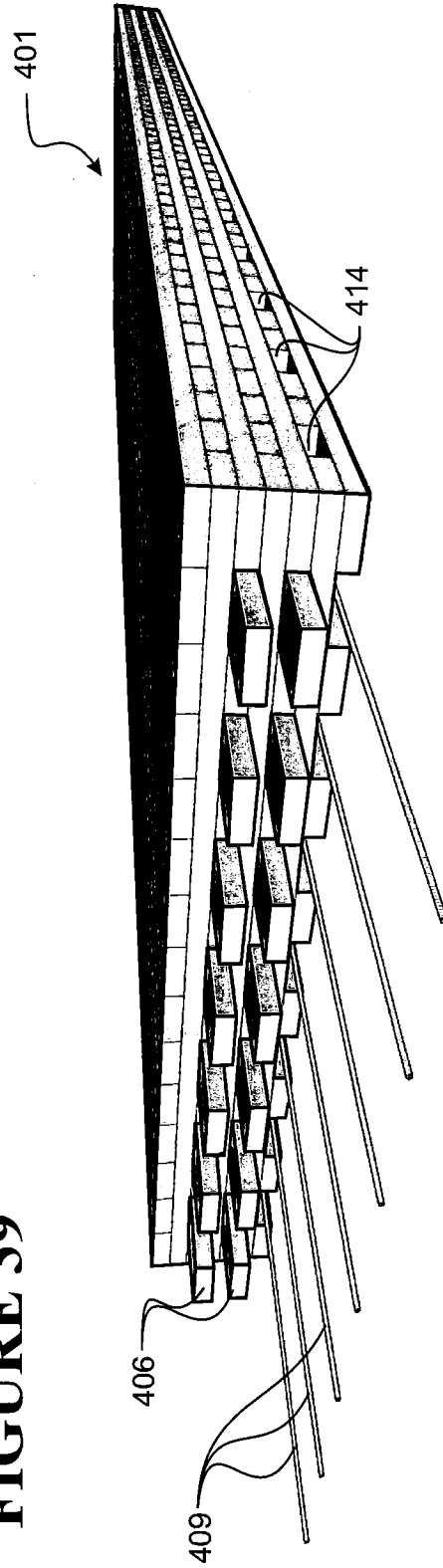


FIGURE 40

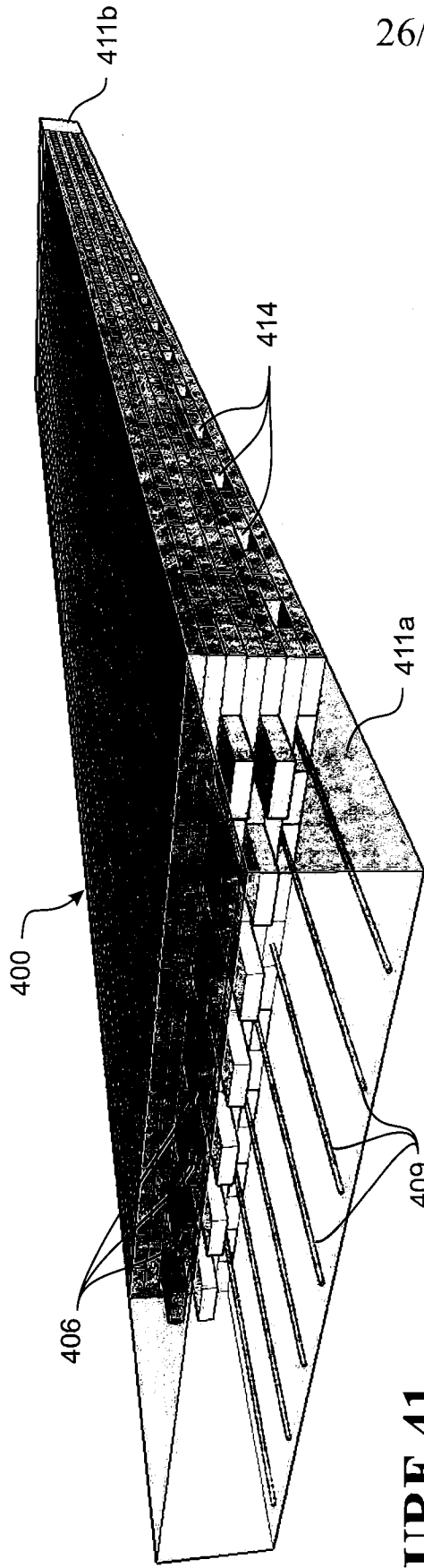


FIGURE 41

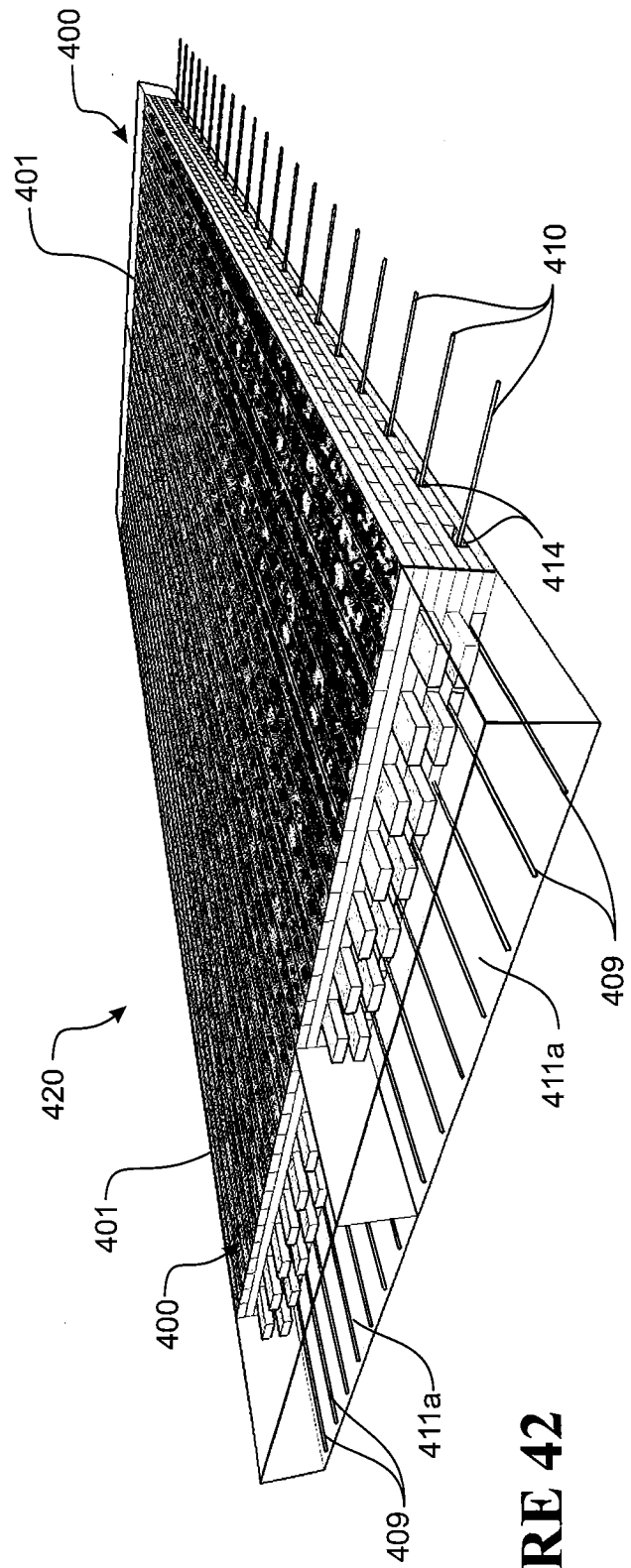


FIGURE 42

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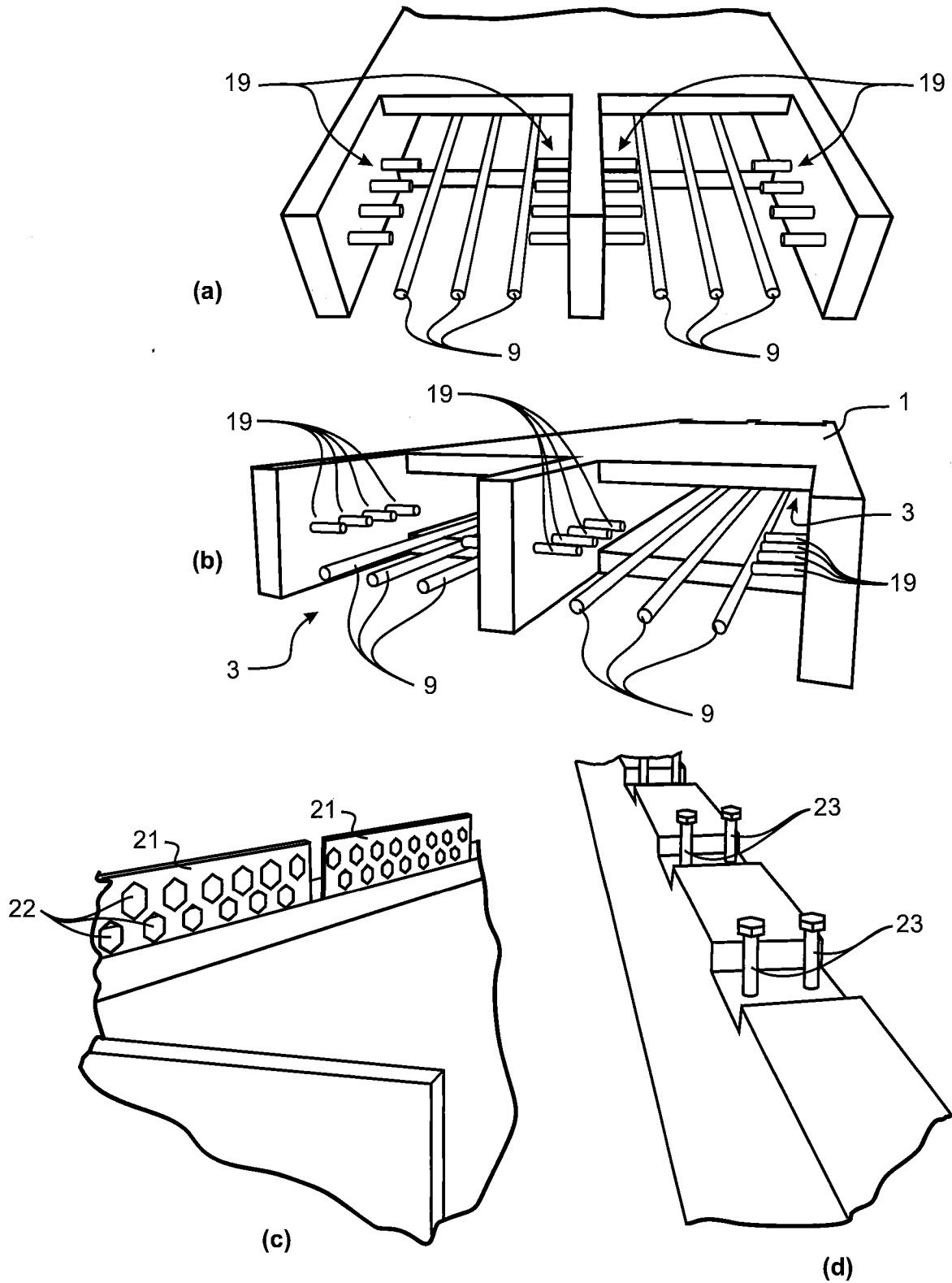
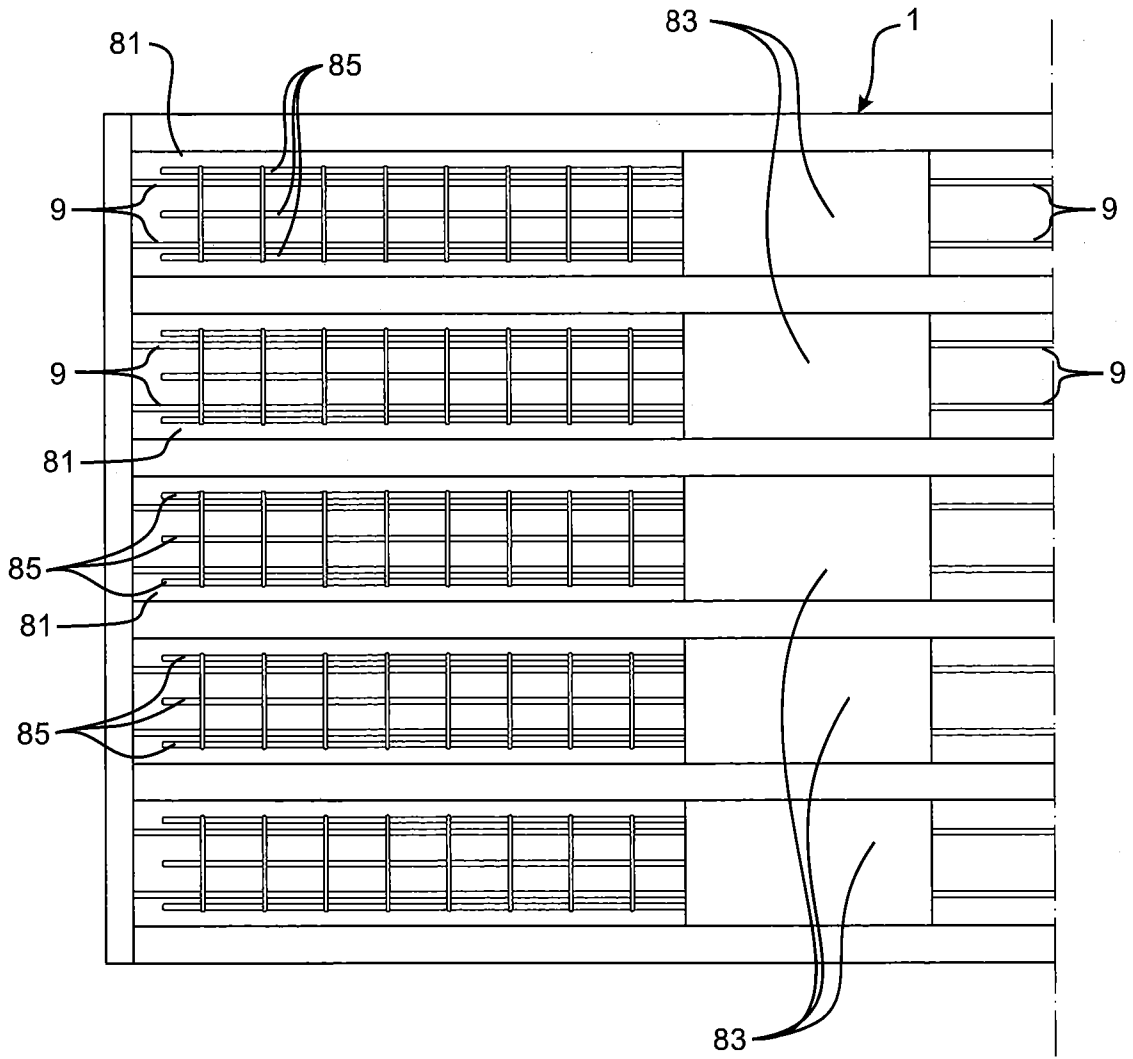
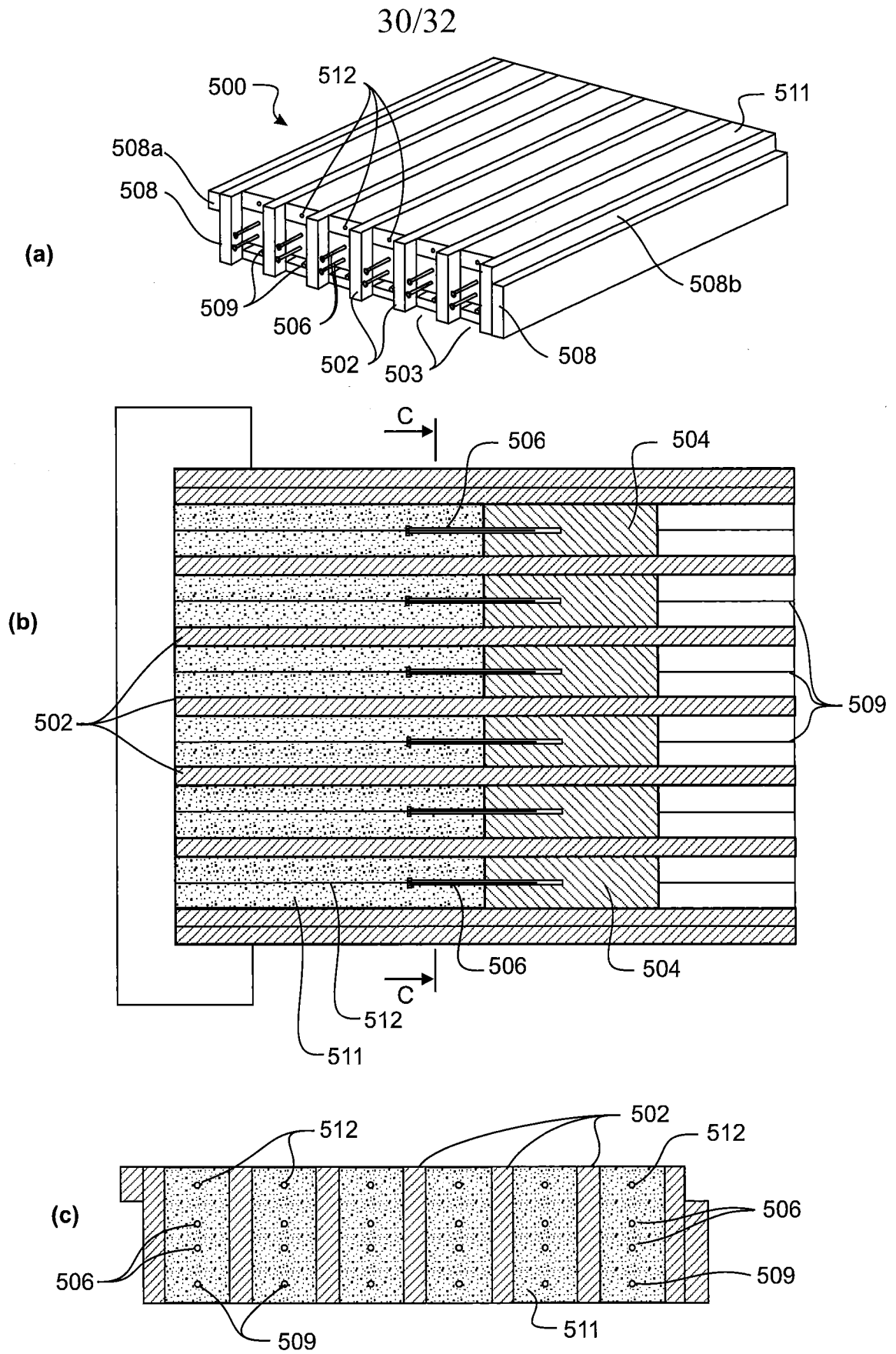


FIGURE 43



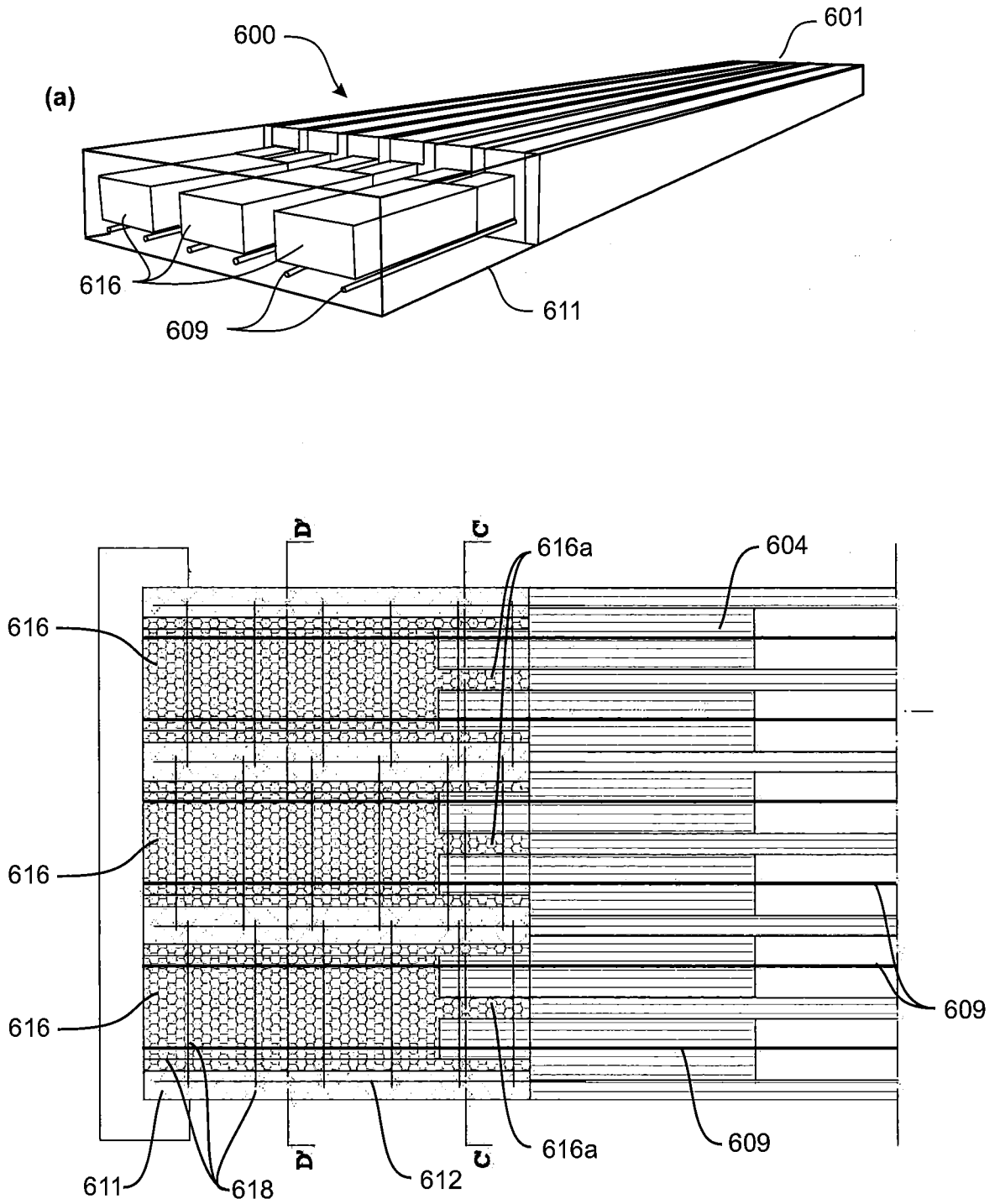


**FIGURE 45**

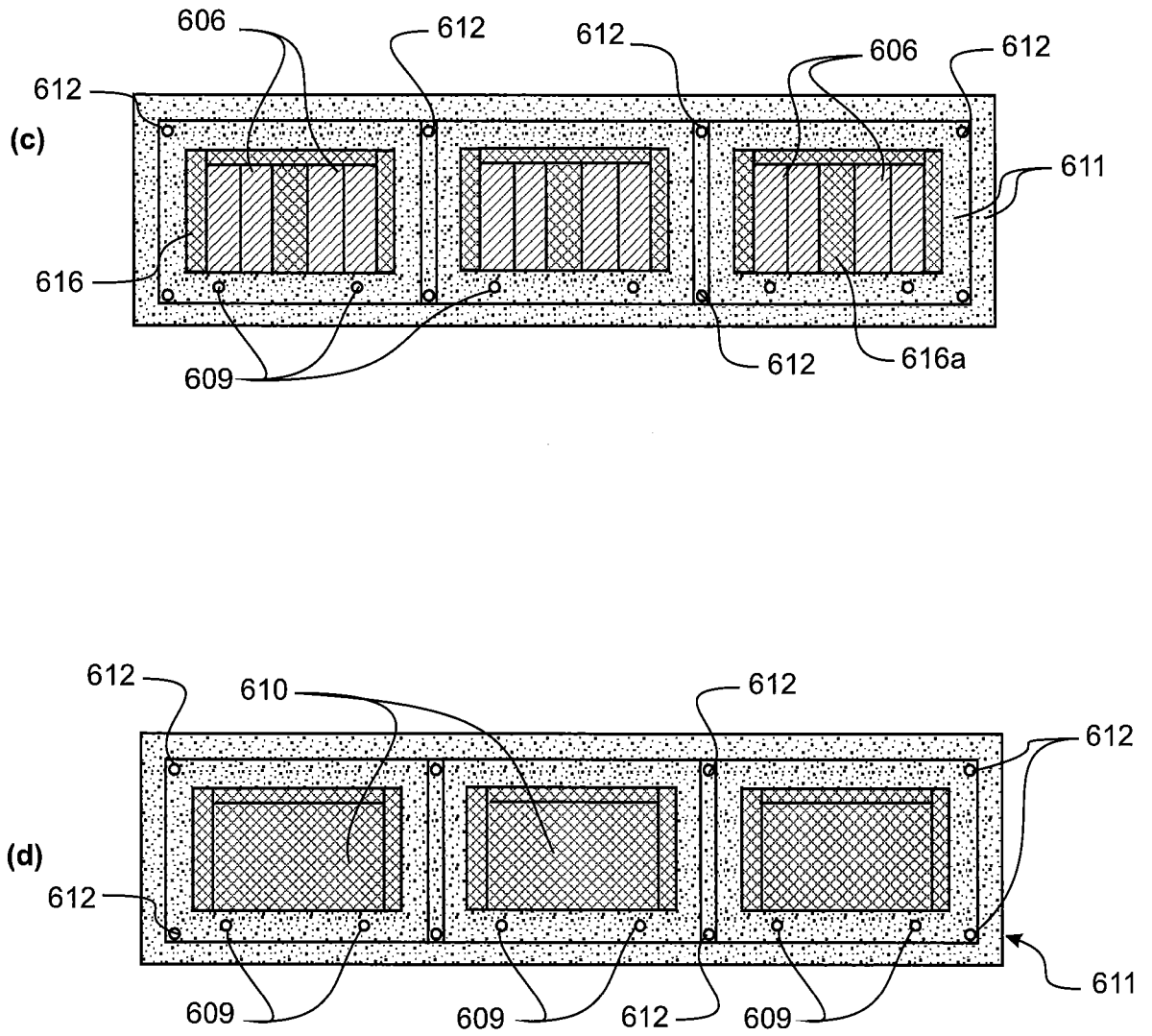


**FIGURE 46**

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**FIGURE 47**



**FIGURE 47**

# INTERNATIONAL SEARCH REPORT

International application No.

**PCT/NZ201 4/000081**

**A. CLASSIFICATION OF SUBJECT MATTER**

[See Supplemental Sheet]

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)

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)

Databse used: EPODOC, WPI, Espacenet patent search & Google patents

TPC/CPC marks searched: E04C/-

,E04C1/40/LOW,E04C2/1 0/LOW,E04C2/26/LOW,E04C2/38/LOW,E04C2/42/LOW,E04C2/386,E04C3/-  
,E04C3/1 2/LOW,E04C3/1 8,E04C3/26/LOW,E04C3/28/LOW,E04C3/29/LOW,E04C3/293,E04C5/08,E04C5/1 2,E04C5/20,E04B/-  
.E04B1/-,E04B1/06,E04B1/10,E04B1/18/LOW,E04B1/22,E04B5/12,E04B5/16,E04H/-,E04H9/02

Keywords used: timber, wood, lumber, cement, cast, concrete, prestieess, anchor, reinforce and like terms. Applicant/Inventor name search carried out on Espacenet patent search & Google patents.

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	

Further documents are listed in the continuation of Box C       See patent family annex

* Special categories of cited documents:		
"A" document defining the general state of the art which is not considered to be of particular relevance	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention	
"E" earlier application or patent but published on or after the international filing date	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone	
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art	
"O" document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family	
"P" document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search 4 September 2014	Date of mailing of the international search report 04 September 2014
Name and mailing address of the ISA/AU  AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA Email address: pct@ipaustrialia.gov.au	<b>Authorised officer</b>  Adnan Ahmed AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No. 0262832557

## INTERNATIONAL SEARCH REPORT

International application No.

C (Continuation).

DOCUMENTS CONSIDERED TO BE RELEVANT

PCT/NZ2014/000081

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 5809713 A (RAY) 22 September 1998 Abstract; Figs. 1-22; col.2 lines 27-28, 38-47; col.3 lines 4-7; Figs. 1-22	1-18, 21-32, 34, 36-44 19-20, 33, 35
X Y	SMITH, T et al., 'Design and Construction of Pressurised Timber Buildings for Seismic Areas', published 2008, [retrieved on 29 August 2014]. Retrieved from the internet <URL: <a href="http://ir.canterbury.ac.nz/bitstream/10092/2131/i/12615508_Buchanan.pdf">http://ir.canterbury.ac.nz/bitstream/10092/2131/i/12615508_Buchanan.pdf</a> > Summary; Figs. 8; page 7, Cost-Analysis; page 8, Conclusions Fig. 8; page 5, Timber-concrete composite floor	1-44 19-20, 33, 35

## Supplemental Box - IPC Marks

*E04B 1/06 (2006.01)*

*E04B 1/10 (2006.01)*

*E04B 1/18 (2006.01)*

*E04B 1/22 (2006.01)*

*E04B 5/12 (2006.01)*

*E04B 5/16 (2006.01)*

*E04C 1/40 (2006.01)*

*E04C 2/10 (2006.01)*

*E04C 2/26 (2006.01)*

*E04C 2/38 (2006.01)*

*E04C 2/42 (2006.01)*

*E04C 3/12 (2006.01)*

*E04C 3/18 (2006.01)*

*E04C 3/26 (2006.01)*

*E04C 3/28 (2006.01)*

*E04C 3/29 (2006.01)*

*E04C 3/293 (2006.01)*

*E04C 5/08 (2006.01)*

*E04C 5/12 (2006.01)*

*E04C 5/20 (2006.01)*

**INTERNATIONAL SEARCH REPORT**

Information on patent family members

International application No.

**PCT/NZ2014/000081**

This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

**Patent Document/s Cited in Search Report****Patent Family Member/s****Publication Number****Publication Date****Publication Number****Publication Date**

US 5809713 A

22 September 1998

None

**End of Annex**

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.