(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 263 795 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
03.01.2018 Bulletin 2018/01

(21) Application number: **17175623.2**

(22) Date of filing: **13.06.2017**

(51) Int Cl.:
E04B 2/86 *(2006.01)* ***E04B 1/348*** *(2006.01)*
E04B 1/04 *(2006.01)* *E04G 21/14* *(2006.01)*

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
MA MD

(30) Priority: **28.06.2016 SG 10201605306W**
15.05.2017 SG 10201703972W

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(54) COMPOSITE STRUCTURAL WALL AND METHOD OF CONSTRUCTION THEREOF

(57) The present invention relates to pre-cast wall panels and methods to join the wall panels to construct composite structural walls. The wall panel comprises a panel body, at least one guide protruding from at least one groove formed in the panel body. The composite wall is constructed by arranging a first wall panel adjacent to a second wall panel, wherein the at least one guide of the first and second wall panel are overlapped to form a channel; inserting a linking rod into the channel; dispensing grout into a gap between the first and the second wall panel; and curing the grout to join the first and the second wall panel to form the composite structural wall. The wall panel may be part of a prefabricated construction module.

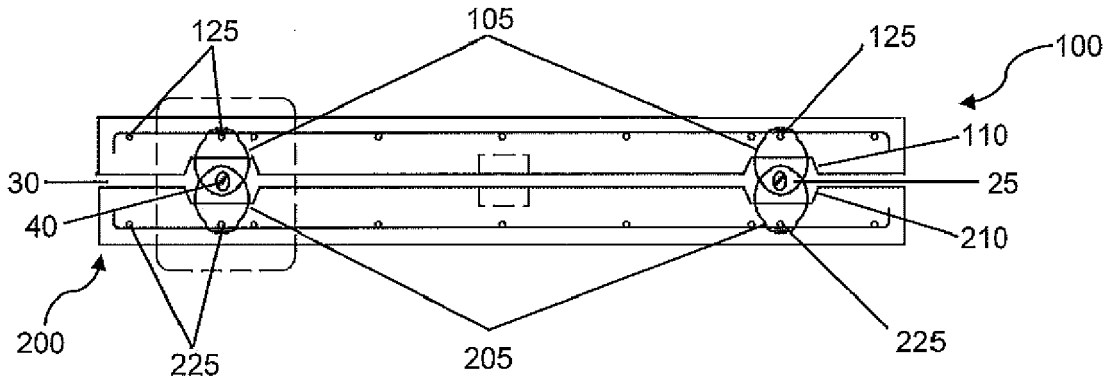


Figure 4A

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Description

Technical Field

[0001] The present invention relates to composite structural walls, methods to construct composite structural walls, prefabricated construction modules, e.g. Prefabricated Prefinished Volumetric Construction (PPVC), and building structures constructed therefrom.

Background of the invention

[0002] Construction of buildings with shear walls cast-in situ on site is known, and widely used in the industry. As it is a cast-in situ process, formwork and reinforcement of the shear wall has to be erected before casting with concrete. The curing of concrete on site is time-consuming and dependent on environmental conditions (e.g. weather and temperature). After curing the concrete, it is further necessary to remove formwork. While the cast-in situ method generally provides a monolithic concrete wall that can withstand high loads and is applicable for most, if not all, types of buildings, this method is a time and labour intensive construction activity.

[0003] To improve productivity, precast concrete walls and prefabricated construction modules have been developed and used in the construction industry. The prefabricated walls and modules are produced in a factory and transported to the building site as needed. This allows for better control, and reduces variations in the curing process of the concrete due to environmental factors (e.g. weather and temperature) at the building site. However, existing methods of joining two side-by-side precast concrete walls would result in a composite wall that functions as individual walls rather than as a single or monolithic wall. Similarly, joining precast concrete walls of side-by-side prefabricated construction modules would result in a composite wall that functions as individual walls rather than as a single or monolithic wall.

[0004] Consequently, in order to achieve same vertical loading capacity provided by a monolithic wall constructed from existing cast-in situ methods, a composite wall, i.e. a combined width of individual walls joined by existing cast-in situ method to form the composite wall, would have to be thicker than the monolithic wall. Alternatively, in order to ensure the width of the composite wall, i.e. combined width of individual walls, is no more than the monolithic wall constructed from cast-in situ methods, vertical load bearing limit of the composite wall, as well as the height limit of the building structure, would have to be reduced. Either way poses a restriction to design and construction of the building, and prevents the building owner from maximising value from the constructed building.

Summary of the invention

[0005] In a first aspect of the invention, there is provided a method for constructing a composite structural wall, the method comprises: adjacently arranging a first pair of wall panels, wherein each wall panel of the first pair of wall panels includes a first panel body, and at least one first guide attached thereto and protruding from a first groove formed in the first panel body, wherein adjacently arranging a first pair of wall panels includes overlapping the first guides of the first pair of wall panels to form a first channel; inserting a first linking rod into the first channel; dispensing a first grout into a first gap between the first pair of wall panels, wherein dispensing a first grout into a first gap includes dispensing the first grout into the first channel; and curing the first grout to join the first pair of wall panels.

[0006] In an embodiment of the first aspect of the invention, the method further comprises: vertically-stacking a second pair of adjacently arranged wall panels on the first pair of wall panels, wherein each wall panel of the second pair of wall panels includes a second panel body, and at least one second guide attached thereto and protruding from a second groove formed in the second panel body, wherein vertically-stacking a second pair of adjacently arranged wall panels on the first pair of wall panels includes overlapping the second guides of the second pair of wall panels to form a second channel; inserting a vertical securement rod into the first and the second channel such that the vertical securement rod have opposite end portions at least partially inserted into the first and the second channel respectively; dispensing a second grout into a second gap between the second pair of wall panels, wherein dispensing a second grout into a second gap includes dispensing the second grout into the second channel; and curing the second grout to join the second pair of wall panels.

[0007] In an embodiment of the first aspect of the invention, the method further comprises: inserting a second linking rod into the second channel.

[0008] In an embodiment of the first aspect of the invention, the vertical securement rod is integral with the first and/or the second linking rod.

[0009] In an embodiment of the first aspect of the invention, dispensing the first grout includes dispensing the first grout to a level below where the vertical securement rod is to be inserted to.

[0010] In an embodiment of the first aspect of the invention, each wall panel of the first and the second pair of wall panels is provided by separate prefabricated construction modules, adjacently arranging a first pair of wall panels includes

adjacently arranging a first pair of prefabricated construction modules, and vertically stacking a second pair of adjacently arranged wall panels on the first pair of wall panels includes vertically stacking a second pair of adjacently arranged prefabricated construction modules on the first pair of prefabricated construction modules.

[0011] In an embodiment of the first aspect of the invention, each wall panel of the first and the second pair of wall panels includes a bottom end portion attached to a floor slab, the method further comprising: inserting a plurality of backing rods between of the first pair of prefabricated construction modules and floor slabs of the second pair of prefabricated construction modules to provide a third gap which intersects the first and the second channel, wherein dispensing a second grout into a second gap includes dispensing the second grout into the third gap, wherein curing the second grout to join the second pair of wall panels includes curing the second grout to join the second pair of prefabricated construction modules to the first pair of prefabricated construction modules.

[0012] In an embodiment of the first aspect of the invention, each floor slab of the second pair of prefabricated construction modules includes at least one floor slab guide attached to each respective floor slab and protruding from each respective floor slab, wherein overlapping the second guides of the second pair of wall panels to form a second channel includes overlapping the floor slab guides of the second pair of prefabricated construction modules to provide the second channel.

[0013] In an embodiment of the first aspect of the invention, the at least one first guide includes a wire attached to a reinforcement structure embedded in each wall panel.

[0014] In a second aspect of the invention, there is provided a wall panel in a prefabricated construction module, the wall panel comprising: a panel body; and at least one guide attached to the panel body and protruding from a groove formed in the panel body, wherein the guide is adapted to overlap with an adjacent guide of an adjacently-arranged wall panel to provide a channel for receiving a linking rod therethrough, and wherein the wall panel is adapted to join to the adjacently-arranged wall panel by grouting a gap, including the channel, between the wall panel and the adjacently-arranged wall panel.

[0015] In an embodiment of the second aspect of the invention, the wall panel further comprises a reinforcement structure embedded in the panel body, wherein the guide is attached to the reinforcement structure.

[0016] In an embodiment of the second aspect of the invention, the reinforcement structure is any one selected from the group consisting of a plurality of steel bars, a plurality of corrugated pipes each adapted to receive a steel bar of a vertically stacked wall panel, a mesh of steel bars, a mesh of steel wires, and a plurality of steel bars each attached to a splice connector adapted to receive a steel bar of a vertically stacked wall panel.

[0017] In an embodiment of the second aspect of the invention, a surface of the panel body, which includes the groove formed therein, is roughened.

[0018] In a third aspect of the invention, there is provided a prefabricated construction module comprising: at least one wall panel according to the second aspect of the invention; and a floor slab attached to a bottom end portion of the wall panel.

[0019] In an embodiment of the third aspect of the invention, the floor slab comprises a floor slab guide attached thereto and protruding therefrom, wherein the floor slab guide is adapted to form the channel.

[0020] In a fourth aspect of the invention, there is provided a building structure comprising: at least one first composite structural wall which comprises: a first pair of wall panels arranged adjacent to each other, wherein each wall panel of the first pair of wall panels includes a first panel body and at least one first guide attached thereto and protruding from a first groove formed in the first panel body, wherein the first guides of the first pair of wall panels overlap to provide a first channel; a first linking rod disposed within the first channel; and a first grouting disposed in a first gap, including the first channel, between the first pair of wall panels, wherein the first grouting joins the first pair of wall panels.

[0021] In an embodiment of the fourth aspect of the invention, the building structure further comprises: at least one second composite structural wall which is vertically stacked on the first composite structural wall and comprises: a second pair of wall panels arranged adjacent to each other, wherein each wall panel of the second pair of wall panels includes a second panel body and at least one second guide attached thereto and protruding from a second groove formed in the second panel body, wherein the second guides of the second pair of wall panels overlap to provide a second channel; a second linking rod disposed within the second channel; a vertical securement rod having opposite end portions at least partially inserted into the first and the second channel respectively; a second grouting disposed in a second gap, including the second channel, between the second pair of wall panels, wherein the second grouting joins the second pair of wall panels.

[0022] In an embodiment of the fourth aspect of the invention, each wall panel of the first and the second pair of wall panels is provided by separate prefabricated construction modules.

[0023] In an embodiment of the fourth aspect of the invention, each wall panel of the first and the second pair of wall panels includes a top end portion attached to a ceiling slab and a bottom end portion attached to a floor slab, the building structure further comprising: a plurality of backing rods interposed between ceiling slabs of the first pair of prefabricated construction modules and floor slabs of the second pair of prefabricated construction modules to provide a third gap, wherein the second grout is further disposed in the third gap and joins the second pair of prefabricated construction

modules to the first pair of prefabricated construction modules.

[0024] In an embodiment of the fourth aspect of the invention, each floor slab of the second pair of prefabricated construction modules includes at least one floor slab guide attached to each respective floor slab and protruding from each respective floor slab, and wherein the floor slab guides of the second pair of prefabricated construction modules overlap to provide the second channel.

[0025] In an embodiment of the fourth aspect of the invention, the vertical securement rod is integral with the first and/or the second linking rod.

[0026] In an embodiment of the fourth aspect of the invention, the building structure further comprises a reinforcement structure embedded in each of the first and the second panel body, wherein the first and the second guide is attached to the respective reinforcement structure.

[0027] In an embodiment of the fourth aspect of the invention, the reinforcement structure is any one selected from the group consisting of a plurality of steel bars, a plurality of corrugated pipes each adapted to receive a steel bar of a vertically stacked wall panel, a mesh of steel bars, a mesh of steel wires, and a plurality of steel bars each attached to a splice connector adapted to receive a steel bar of a vertically stacked wall panel.

[0028] The composite structural wall, joined from the individual wall panels, functions as a single or monolithic wall and retains the advantages of both existing cast-in situ and prefabrication methods. The composite structural wall provides the benefits of precast wall panels including controllable curing of the wall panel, and reduced time required to construct the composite structural wall and/or join adjacent modules both horizontally and vertically. The dimensions of the composite structural wall are similar to a monolithic wall constructed from existing cast-in situ methods and yet the composite wall of the invention is capable of providing a similar vertical load bearing capacity as the monolithic wall constructed from existing cast-in situ methods.

Brief description of the drawings

[0029] The embodiments are described further with the following figures:

Figure 1A shows a perspective view of a construction site with prefabricated construction modules;
Figure 1B shows a perspective view of a multi-storey building constructed from prefabricated construction modules;
Figure 2 shows a prefabricated construction module;
Figures 3A - 3D show a method for constructing a composite structural wall;
Figure 4A shows a top cross-sectional view of the adjacent wall panels in Figure 3C;
Figure 4B is a partial close-up view of Figure 4A;
Figures 5A - 5C show perspective views of two pairs of wall panels being vertically stacked with different sequences of construction;
Figure 6 shows a top cross-sectional view of the composite structural wall with two rods in each channel;
Figure 7A shows a perspective view of a composite structural wall having an opening for a door, a floor slab, and a beam structure;
Figure 7B shows an expanded view of the bottom portion of Figure 7A;
Figure 8 shows a side cross-sectional view of a junction at four wall panels, e.g. bedding joint between two pairs of wall panel in a vertically stacked arrangement;
Figure 9 shows a perspective view of a composite structural wall with an example of a reinforcement structure in the wall panel;
Figure 10 shows a top cross-sectional view of the composite structural wall in Figure 9;
Figure 11 shows a perspective view of a composite structural wall with embedded corrugated pipes adapted to receive steel bars into the composite structural wall;
Figure 12A shows a top cross-sectional view of the composite structural wall in Figure 11;
Figure 12B shows a partial close-up view of Figure 12A;
Figure 13 shows a perspective view of a composite structural with splice connectors which are adapted to receive and connect to vertical steel bars;
Figure 14 shows an example of a wire rope suitable to be used as a guide.

Detailed description of embodiments of the invention

[0030] In the following description, numerous specific details are set forth in order to provide a thorough understanding of various illustrative embodiments of the invention. It will be understood, however, to one skilled in the art, that embodiments of the invention may be practiced without some or all of these specific details. It is understood that the terminology used herein is for the purpose of describing particular embodiments only, and is not intended to limit the scope of the invention. In the drawings, like reference numerals refer to same or similar functionalities or features throughout the

several views.

[0031] Embodiments described in the context of one of the methods or devices are analogously valid for the other methods or devices. Similarly, embodiments described in the context of a method are analogously valid for a device, and vice versa.

[0032] Features that are described in the context of an embodiment may correspondingly be applicable to the same or similar features in the other embodiments. Features that are described in the context of an embodiment may correspondingly be applicable to the other embodiments, even if not explicitly described in these other embodiments. Furthermore, additions and/or combinations and/or alternatives as described for a feature in the context of an embodiment may correspondingly be applicable to the same or similar feature in the other embodiments.

[0033] As used herein, the articles "a", "an" and "the" as used with regard to a feature or element include a reference to one or more of the features or elements.

[0034] As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items.

[0035] As used herein, the terms "first," "second," and "third," etc. are used merely as labels, and are not intended to impose numerical requirements on their objects.

[0036] As used herein, the term "each other" denotes a reciprocal relation between two or more objects, depending on the number of objects involved.

[0037] The embodiments of the present invention provide a mechanism to connect or join two (or a pair of) adjacently-arranged wall panels 100, 200 together to form a composite structural wall 55. In an embodiment, each connecting wall panel 100, 200 is provided with guides 105, 205 (for example, steel wire loops, or steel wire ropes, or J-connection loop as shown in Figure 14) at intervals or spaced apart from each other. A portion of each guide 105, 205 is embedded within the wall panel 100, 200 while another portion protrudes from the jointing surface. A groove 110, 210 is formed or provided in the jointing surface of the wall panel 100, 200 to accommodate the guides 105, 205. The two connecting wall panels 100, 200 are brought close to each other (leaving a gap 30 between the wall panels 100, 200) such that the guides 105, 205 of the wall panels 100, 200 are disposed or overlap to form a channel 25. A linking rod 40 (for example, a steel bar) is inserted into the channel 25 formed by the guides 105, 205 of the connecting wall panels 100, 200. The gap 30 between the wall panels 100, 200 is subsequently in-filled with concrete or grout and cured to form a composite structural wall 55. The grout should be of a high strength and non-shrink type. High strength grout is a fluid form of concrete, and is generally made from a mixture of cement, water, graded fillers and chemical additives. The two wall panels 100, 200 are held in position, by the linking rod 40 coupling the guides 105, 205, while the grout is dispensed and cured. This makes it easier for the composite wall 55 to be constructed in a faster and more efficient manner.

[0038] Embodiments of the present invention provide an innovative connection system to connect or join two adjacently-arranged wall panels 100, 200 by using guides 105, 205, with in-fill concrete or grouting 50 to form a composite structural wall system instead of forming a cast-in situ concrete shear wall in the conventional way. This allows wall panels 100, 200 to be joined in a horizontal and vertical direction. The wall panels 100, 200 may be part of separate prefabricated construction modules 5 and provide a connection means to join a plurality of prefabricated construction modules 5 to construct a structure. The constructed structure could be a single storey or a multi storey building with different compartments or modules. Each prefabricated construction module 5 could be a single habitable unit, e.g. apartment, or part of a single habitable unit.

[0039] Figure 1A shows an elevated perspective view of a construction site at which a building structure is being constructed from a plurality of prefabricated construction modules 5, an example of which is shown in Figure 2. Figure 1B shows a multi-storey structure that may be constructed by vertical stacking of the prefabricated construction modules 5. At least one wall panel 100 of each prefabricated construction module 5 is joined to another wall panel 200 of an adjacently-arranged prefabricated construction module 5, by in-situ grouting in the middle joint between the wall panels 100, 200, to form a composite structural wall 55.

[0040] Briefly, without being limited by theory, the composite structural wall 55 is designed to be built to the Standard Number SS EN 1992-1-1:2008, titled "Eurocode 2: Design of concrete structures, Part 1-1 General rules and rules for buildings", which is incorporated by reference herein.

[0041] At the mid-height, the composite wall 55 is to be designed for moment as follows:

$$Moment\ due\ to\ imperfection\ of\ ei$$

$$= qi\frac{l_0}{2}\ ,or\ 20\ mm, whichever\ is\ of\ a\ greater\ value,$$

wherein $qi = \frac{1}{200}$, *and*

l_0 = *effective length* (*vertical length of wall*) *plus slenderness moment f or slender wall, if applicable.*

[0042] The composite structural wall 55 may be built to other relevant national standards as well without deviating from the methods and wall panels 100, 200 disclosed herein.

[0043] In an embodiment where two composite walls 55 are stacked vertically, a bedding joint is formed between the upper and lower composite walls 55. At the bedding joint, the composite wall 55 is to be designed for an assumed eccentricity or imperfection of 20 mm. Key or linking bars are placed along the center line of the composite wall 55 and are designed to take moment due to this eccentricity.

[0044] Each composite wall 55 may be a shear wall of the building structure. Each composite wall 55 is designed as one element to take into account the design value of the applied axial or vertical force in the z-direction (N_{Ed}), bending moment in the x-direction ($M_{Ed,xx}$), and y-direction ($M_{Ed,yy}$), as shown in Figures 3A - 3D. The illustrated x, y, and z directions are perpendicular to each other to represent a three-dimensional axis.

[0045] In Figure 3A, a wall panel 100 is shown. The wall panel 100 comprises a panel body 101 which is provided with at least one groove 110 (on a surface of the panel body 101), and at least one guide 105 protruding from the at least one groove 110. The wall panel 100 in Figure 3A is shown to have two grooves 110 each having three guides 105, but it is to be appreciated that other number of grooves 110 and/or guides 105 are possible in various embodiments. The position and number of grooves 110 and guides 105 are dependent on the required load bearing capacity and dimensions of the composite structural wall 55.

[0046] In an example, the wall panel 100 has two grooves 110, wherein two guides 105 protrude from each groove. The guides 105 may be arranged near the ends of each groove 110 (i.e. top and bottom of the panel body) or at other suitable positions. In another example, in addition to having two guides in each groove, a third guide 105 may be provided near the middle portion of the panel body. In another example where the composite structural wall may be of a smaller dimension and load bearing capacity, a single groove 110 and guide 105 may suffice.

[0047] In various embodiments, the wall panel 100, 200 may be a precast concrete wall, i.e. the wall panel 100, 200 is fabricated at a site other than the actual site for constructing a building structure e.g. multi-storey building.

[0048] In Figure 3B, a pair of wall panels 100, 200 is shown and includes wall panel 100 of Figure 3A and another wall panel 200. Wall panel 200 comprises a panel body 201 which is provided with at least one groove 210 formed on a surface of the panel body 201, and at least one guide 205 protruding from the at least one groove 210. Both wall panels 100, 200 may have similar or complementary structure and features. When the pair of wall panels 100, 200 are adjacently arranged as shown in Figure 3B, guides 105, 205 of both wall panels 100, 200 overlap to form a channel 25 which allows one or more linking bars 40 to be subsequently inserted there into (see Figures 4A, 4B and 6).

[0049] In an embodiment where guides 105, 205 are arranged at the same height, the guides 105, 205 may have some flexibility to allow bending to form the channel 25 when the wall panels 100, 200 are adjacently arranged as shown in Figure 3B.

[0050] In an embodiment where guides 105, 205 are arranged at different heights, the guides 105, 205 may be arranged in overlapping contact when wall panels 100, 200 are adjacently arranged as shown in Figure 3B. Alternatively, the overlapping guides 105, 205 may have a vertical gap therebetween.

[0051] In an embodiment, the guides 105, 205 are fabricated from flexible high strength steel wires. The guides 105, 205 are attached to the wall panel 100, 200 with a portion, e.g. circular, semi-circular, arc, loop, protruding from the wall panel 100, 200. The semi-circular portion of the guides 105, 205 is adapted to form the channel 25 and receive a first linking rod 40 and vertical securement rod 45. The guides 105, 205 may be attached to the wall panel 100, 200 during the fabrication of the wall panel. As an example, the guides 105, 205 may be formed by making a loop with a steel wire, with a portion of the loop embedded in the wall panel 100, 200 and the remaining portion protruding from the surface of the wall panel 100, 200 as shown in Figures 4A and 4B. Two ends of the steel wire may be joined by a connector or cramp to form the loop. Alternatively, the two ends are tied together, or placed in close proximity, as shown in the J-connection loop of Figure 14, to be embedded within the wall panel with the loop or circular or oval portion of the steel wire protruding from the wall panel to form the channel 25. The steel wires may have a tensile strength equal to at least 2.5% of the induced vertical load of the wall panel 100, 200. The tensile strength of the wall panels 100, 200 depends, at least in part, on the number of guides 105, and may be varied accordingly.

[0052] A method for constructing a composite structural wall 55 and/or building structure, is shown in Figures 3A - 3D and described below.

[0053] The method comprises providing a wall panel 100 (Figure 3A), adjacently arranging a first pair of wall panels 100, 200 with a first gap 30 therebetween (Figure 3B). This step includes overlapping the guides 105, 205 (or first guides) of the first pair of wall panels 100, 200 to form a first channel 25. The first gap 30 includes the space provided by the grooves 110, 210 (or first grooves) facing each other and the first channel 25 as seen most clearly in Figures 4A and 4B. The first gap 30 further includes a space formed between facing non-grooved surfaces of the wall panels 100, 200.

[0054] The method further comprises inserting a first linking rod 40 into each first channel 25 (Figure 3C) to couple the wall panels 100, 200. The first linking rods 40 should be of sufficient length to pass through the guides 105, 205 of

both wall panels 100, 200. In an embodiment, the length of the first linking rod 40 is approximately or at least the whole longitudinal length of the at least one groove 110, 210.

[0055] The method further comprises dispensing a first grout into the first gap 30 (Figure 3D) while the first linking rods 40 couple the wall panels 100, 200.

[0056] The method further comprises curing and/or hardening the first grout to form a sealant 50 to join the first 100 and second wall panel 200 and thereby forming the composite structural wall 55 (Figure 3D). The composite structural wall 55 constructed therefrom would behave as a monolithic structural wall and has increased load bearing capacity as compared to a similarly dimensioned composite wall formed from two precast concrete walls using traditional cast-in situ methods.

[0057] Figure 4A shows a top cross-sectional view of the first pair of wall panels 100, 200 corresponding to Figure 3C while Figure 4B shows an expanded view of Figure 4A, particularly the grooves 110, 210 and first channels 25 with the first linking rod 40 inserted. The above-described method according to the invention produces a horizontal connection between adjacent wall panels 100, 200 to form a composite structural wall 55. When the wall panels 100, 200 form part of separate prefabricated construction modules 5, the invention allows horizontal securement or joining of horizontally adjacent prefabricated construction modules 5.

[0058] The invention further allows vertical securement or joining of vertically adjacent composite structural walls 55 or prefabricated construction modules 5. Accordingly, the above-described method for constructing a composite structural wall 55 and/or building structure, as shown in Figures 3A - 3D may be suitably modified as described below and shown in Figure 5A.

[0059] Continuing from the above-described method with reference to Figures 3A to 3C, the method further comprises vertically stacking a second pair of adjacently arranged wall panels on the first pair of wall panels (see Figure 5A). This step includes overlapping the guides (or second guides) of the second pair of wall panels to form a second channel. At least in some embodiments, the wall panels of the second pair may have similar or identical configuration as the wall panels of the first pair and therefore the details of wall panels 100, 200 would apply correspondingly to the second pair of wall panels.

[0060] The method further comprises inserting a vertical securement rod 45, through the second channel and partially into the first channel 25, such that a lower end of the vertical securement rod 45 is at least partially inserted into the first channel and overlaps with a portion of the first linking rod 40 (see Figure 5A). The overlapped portion is known as the lap length and allows for the vertical loads to be transferred between the first linking rod 40 and vertical securement rod 45. The grooves and channels of the first and of the second pair of wall panels 100, 200 should preferably be aligned in a substantially linear manner for greatest structural strength. Figure 5A shows the vertical securement rod 45 disposed in the second channel while the second pair of wall panels, together with vertical securement rod 45, are being stacked upon the first pair of wall panels. Alternatively, the vertical securement rod 45 may be inserted into the second and first channels after the second pair of wall panels are stacked on the first pair wall panels.

[0061] The method further comprises dispensing a second grout into a second gap between the second pair of wall panels, wherein dispensing a second grout into a second gap includes dispensing the second grout into the second channel.

[0062] Modifications may be made to the above-described method described with reference to Figure 5A and possible modifications are described but are not limited to the following.

[0063] In one embodiment, after stacking the second pair of wall panels on the first pair of wall panels and after inserting a vertical securement rod 45 through the second channel and partially into the first channel 25, but before dispensing the second grout into the second gap, the method further comprises inserting a second linking rod 47 into the second channel. The second linking rod 47 may be of sufficient length to pass through the second guides of the second pair of wall panels. In an embodiment, the length of the second linking rod 47 is approximately or at least the whole longitudinal length of the second channel.

[0064] In one embodiment, the vertical securement bar 45 is inserted into the first channel 25 prior to dispensing and curing the first grout, and also prior to vertically stacking the second pair of adjacently arranged wall panels on the first pair of wall panels. In one example of this embodiment (see Figure 5B), a second linking rod 47 may be present in the second channel at the second pair of wall panels while the second pair of wall panels, together with second linking rods 47, are being stacked on the first pair of wall panels. In another example of this embodiment (see Figure 5C), second linking rods 47 may be absent in the second channel at the second pair of wall panels while the second pair of wall panels are being stacked on the first pair of wall panels. Thereafter, the second linking rods 47 may be inserted into the second channel.

[0065] In one embodiment, the vertical securement bar 45 may be inserted into the first channel 25 after the first grout is dispensed but before the first grout has cured completely. Whereas in another embodiment, the first grout is dispensed to a level below where the vertical securement rod 45 is to be inserted to, e.g. below the lap length. In other words, only the non-overlapping portion of the first linking rod 40 or non-lap length portion is grouted; the overlapping portion of the first linking rod 40, i.e. lap length, and the corresponding portion with respect to the first channel 25 and the first gap 30

remain ungrouted for the time being. This has an advantage that the first grout dispensed may be allowed to cure without a need to quickly or immediately stack the second pair of wall panels and insert the vertical securement rod 45 into the first channel 25 before the first grout cures completely. In due course, after the first grout has cured, the second pair of adjacently arranged wall panels are stacked onto the first pair of wall panels, the vertical securement rod 45 is inserted into the second channel, a second grout is dispensed into the portion of the first channel 25 and gap 30 not filled by the first grout previously, and also into the second channel. It will be apparent that the second channel may be partially filled with the second grout, e.g. dispensed to a level below a subsequent overlap length to accommodate the third or subsequent pair of wall panels and its vertical securement rod.

[0066] In one embodiment, the vertical securement rod 45 may additionally serve as the first 40 and/or second linking rod 47. In one example, the vertical securement rod 45 is integral with or forms part of the first linking rod 40. In another example, the vertical securement rod 40 is integral with or forms part of the second linking rod 47. In yet another example, the vertical securement rod 45 is integral with or forms part of both the first 40 and the second linking rod 47. Whereas in another embodiment, the vertical securement rod 45 is only inserted partially into both the first channel 25 and the second channel. In various embodiments, the first linking rod 40, second linking rod 47, and/or vertical securement rod 45 may be steel rods.

[0067] To further increase the height of the building structure, further pairs of wall panels can be vertically stacked as described above, i.e., a third pair of adjacently arranged wall panels are stacked, in a vertical or upward direction, upon the second pair of joined wall panels, a fourth pair of adjacently arranged wall panels are vertically stacked on the third pair of joined wall panels, and so on.

[0068] In some embodiments, the wall panels 100, 200 form part of separate prefabricated construction modules 5. Accordingly, references to adjacently arranging wall panels 100, 200 and vertically stacking adjacently arranged wall panels include, respectively, adjacently arranging prefabricated construction modules and vertically stacking adjacently arranged prefabricated construction modules.

[0069] In an embodiment, the first channel 25 formed by the guides 105, 205 should be suitably sized to receive the first linking rod 40 as well as the vertical securement rod 45 to allow a second set of wall panels to be vertically stacked upon the first pair of wall panels. Figure 6 shows a top cross-sectional view of the composite structural wall 55 with the first linking rod 40 and vertical securement rod 45 in the first channel 25.

[0070] In an embodiment, the at least one groove 110, 210 may be of suitable dimensions to at least accommodate the protruded portion of the at least one guide 105, 205. In an embodiment, the combined depth of facing grooves 110, 210 (Figure 6, two of w_2) and the size of the gap 30 (Figure 6, w_3) may be slightly larger than the protruded portion of the at least one guide 105, 205. This minimises the dimensions of the structural composite wall 55 and the amount of grouting needed.

[0071] In an embodiment, each wall panel 100, 200 is attached to a floor slab 15 (Figure 7A and 8). Each floor slab 15 may further comprise a slab guide 115 or 215. The slab guide 115, 215 is similar to the guides 105, 205 in that the slab guides 115, 215 of adjacent floor slabs 15 are disposed in an overlapping arrangement to form the channel e.g. first channel 25. A portion of each slab guide 115, 215 is embedded within a substantial length of the floor slab to provide the continuity of slab reinforcement. Similar to guides 105, 205, the slab guide 115, 215 may be a high strength steel wire rope. In an embodiment, the slab guide 115, 215 has a higher tensile strength than the guide 105, 205 to provide reinforcement for the floor slab 15. In an embodiment, the floor slab 15 is further attached to a beam structure 17 to provide additional structural strength as shown in Figure 7B. Figure 7B shows the composite structural wall 55 formed with attached floor slabs 15 and beam structures 17.

[0072] In an embodiment, each wall panel 100, 200 in respective prefabricated construction modules 5 is further attached to a ceiling slab 10. In other words, opposed end portions of each wall panel are respectively attached to a ceiling slab 10 and a floor slab 15 (Figure 2). Alternatively, the floor slab 15 of the upper module 5 may serve as the ceiling of the lower module.

[0073] In an embodiment, backing rods 130, 230 are inserted or interposed between the first pair of prefabricated construction modules (optionally, ceiling slab 10 thereof) and floor slabs 15 of the second pair of prefabricated construction modules to provide a third gap which intersects the first and the second channel (Figure 8). Grout is dispensed to fill the third gap to join the first to the second pair of prefabricated construction module or floor slab 15 of the second pair of prefabricated construction module to the ceiling slab 10 of the first pair of prefabricated construction module. The backing rods 130, 230 prevent leakage of grout and when the grout is cured, the bedding joint is formed. The backing rods 130, 230, the first pair of prefabricated construction module or ceiling slab 10 thereof and floor slab 15 of second pair of prefabricated construction module may form an enclosed space for receiving grout.

[0074] The wall panel 100, 200 may further comprise a reinforcement structure to provide structural strength, in particular tensile strength, to the wall panel. The reinforcement structure may also serve as an attachment or anchoring point for the guide 105, 205 to be attached to, for example by welding or tying. The reinforcement structure may be embedded within the wall panel 100, 200 during the pre-fabrication process. The reinforcement structure may be provided as a plurality of steel bars 125, 225, a mesh of steel bars or wires, or a plurality of corrugated pipes wherein each

corrugated pipe is adapted to receive a steel bar. Figures 4A and 4B show a reinforcement structure being a plurality of steel bars 125, 225 embedded in the wall panel. Figure 9 shows a composite wall 55 which is joined from two wall panels 100, 200, each being embedded with a reinforcement structure comprising of a mesh of steel bars. The mesh comprises an arrangement of intersecting vertical steel bars 125, 225 and horizontal steel bars 135, 235.

[0075] Figure 10 shows a top cross-sectional view of the composite wall 55 in Figure 9. Figures 11, 12A and 12B show a plurality of non-intersecting corrugated pipes 140, 240 embedded in the wall panel, wherein each corrugated pipe is adapted or sized to receive a steel bar.

[0076] In an embodiment, a splice connector 145 (mechanical rebar connector) may be provided to receive steel bars 125 of vertically stacked wall panels. Figure 13 shows a composite structural wall 55 wherein in each wall panel, a splice connector 145 is attached to each steel bar 125 and is adapted to receive and secure to another steel bar of a vertically stacked wall panel. The attachment of the splice connector 145 to the steel bars 125 may be by any suitable means, for example by a taper-threaded design, by welding, or by using grout. Figure 13 shows the splice connector 145, which is arranged near the upper end of the wall panel 100, attached e.g.welded, to a vertical steel bar 125 of the wall panel 100 and positioned to receive a vertical steel bar 125 of a vertically stacked or upper wall panel (not shown). As a second (upper) pair of wall panels are being stacked on a first (lower) pair of wall panels, each vertical steel bar 125 from the upper wall panel is inserted into a splice connector and may be secured by a tapered design, welding or grout. The splice connector 145 may alternatively be arranged at the lower end of the wall panel to receive steel bars of a lower wall panel.

[0077] Other types of reinforcement structures may also be used alone or in conjunction with the non-limiting examples described herein. It may be seen from the top cross-sectional view of the various embodiments that the reinforcement structure would not affect the method for joining the wall panels.

[0078] A shear resistance check may be performed to determine the structural integrity of the composite wall 55. The shear resistance would be checked at the interface between the wall panel 100, 200 and the in-fill grout. The shear resistance could be due to:

(a) Induced shear force from lateral load in wall minor direction;
(b) Induced shear force from differential lateral load in wall major direction;
(c) Induced shear force from frame action in wall minor direction.

[0079] In an embodiment, the surface of the wall panel 100, 200 with the at least one groove 110, 210 may be roughened to provide surface roughness for interface shear transfer.

[0080] In an embodiment, the wall panel 100 is part of a prefabricated construction module 5 as shown in Figure 2. The prefabricated construction module 5 comprises a floor slab 15, at least one wall panel 100 as described herein, and optionally a ceiling 10 and/or a beam structure 17. The prefabricated construction module 5 may further comprise at least one end wall 20. The prefabricated construction module is to be joined to an adjacent prefabricated construction module using the wall panels 100, 200 and the method described herein. The at least one wall panel 100 serves as the connection means between adjacent prefabricated construction modules 5. Additional prefabricated construction modules 5 may be stacked on top of a lower pair of prefabricated construction modules 5 to stack the modules 5 and extend the building structure vertically upwards as per the addition of the wall panels vertically. For the prefabricated construction modules 5 to be joined vertically, the channel 25 formed from the wall panels 100, 200 of adjacent prefabricated construction modules should be able to receive a vertical securement rod 45.

[0081] It will be apparent that the prefabricated construction modules 5 need not be identical, in particular for the horizontally adjoining prefabricated construction modules 5. For example, a prefabricated construction module 5 placed at an end of the structure will typically have one wall panel 100 and two or three end walls 20, whereas a prefabricated construction module in the center portion of the structure may have two or three wall panels 100, 200, and one or two end walls 20. The wall panels 100, 200 serve as a connection means to join the adjoining prefabricated construction modules 5.

[0082] For example, a prefabricated construction module 5 to be placed in the middle of a structure may have four wall panels 100, 200 for attachment to four other prefabricated construction modules 5. It will be apparent that other shapes for the prefabricated construction module 5 could be similarly designed and applied.

[0083] The end wall 20 and wall panel 100 may take on any shape or dimensions as required and/or have openings for door and/or window fittings as required. The prefabricated construction module 5 may have an exposed side (i.e. no end wall or wall panel) as well to allow for different design structures. A plurality of prefabricated construction modules 5 as described may be joined together to form a structure. The structure may be a single or multi storey building. The structure may be employed as buildings for private or commercial use. The structure may possibly be of use as temporary buildings in events and disaster relief operations, where ease and speed of construction at the site is important.

[0084] According to one aspect of the invention, a building structure comprises one or more composite structural walls 55 arranged as a single-storey or multi-storey arrangement. Each composite structural wall 55 may comprise joined wall

panels 100, 200 as described above, and therefore the corresponding description of wall panels 100, 200 and their features, including additions, combinations, alternatives, attachments, may be omitted here. Each of the wall panels 100, 200 may form part of separate construction modules 5 as described above and therefore the corresponding description of their features, including additions, combinations, alternatives, attachments, may be omitted here.

Example 1

[0085] A first 100 and second wall panel 200 is each constructed with a horizontal length (l_1) of 1200 mm, a width (w_1) of 90 mm (Figure 6). The groove has a depth (w_2) 25 mm and length (l_3) of 100 mm. The wall panel 100 comprises two grooves 110 with centres which are 800 mm apart (l_2). A gap 30 of 20 mm (w_3) between the first 100 and second wall panel 200 is used to illustrate this example of the composite structural wall 55. The reinforcement structure in the wall panels 100, 200 are steel bars 125, 225 embedded in the panel body 101, 201 along the longitudinal height of the wall panels 100, 200.

[0086] The composite structural wall of Example 1 has a width or thickness of 200 mm (assuming grouting width is 20 mm) and has a load bearing capacity similar to a conventional cast- in situ wall of similar width or thickness. It is to be appreciated that other grouting width or gap width is equally possible.

Example 2

[0087] In this example of the composite structural wall 55, the reinforcement structure in the wall panels 100, 200 is a mesh of horizontal 135, 235 and vertical steel bars 125, 225 (Figure 9 and 10). The wall panels 100, 200 constructed with a length (l_1) of 1000 mm, a width (w_1) of 140 mm, and a similar groove as in Example 1. The wall panel 100 comprises two grooves 110 with centres which are 600 mm apart (l_2). The gap 30 between the first 100 and second wall panel 200 is 20 mm. Optionally, corrugated pipes 140, 240 or splice connectors 145 may be used in combination with the steel bars 125.

Example 3

[0088] A prefabricated construction module 5 is constructed as in Figure 2 with a wall panel 100 as in Example 1, a floor slab 15 with a thickness of 130 mm, an end wall 20 with a width of 150 mm, and a ceiling slab 10 with a 50 mm x 50 mm hollow section size spaced at 600 mm centre to centre.

[0089] Embodiments of the invention as described herein allow for horizontally adjacent wall panels or prefabricated construction modules to be supported relative to each other via linking rods while grouting is dispensed and cured. This reduces construction time and labour requirements and therefore reduces construction costs. Embodiments of the invention allow vertically stacked wall panels or prefabricated construction modules to be supported relative to each other via a vertical securement rod while grouting is dispensed and cured.

[0090] With the invention, pre-cast wall panels 100, 200 and prefabrication construction modules 5 can be assembled into a building structure more quickly and efficiently at a construction site. The wall panels 100, 200 and construction modules 5 may be fabricated in the factory while the foundation works at the construction site are on-going, thereby reducing the construction cycle time and leading to increased productivity. Furthermore, the quality of the wall panels 100, 200 and construction modules 5 are improved due to the controlled environment they are prepared in. Furthermore, a composite structural wall 55 constructed using the present invention would behave as a monolithic wall and therefore would be able to achieve similar load-bearing capacity as a monolithic wall constructed from existing cast-in situ method and having similar width dimensions or thickness. Accordingly, it will be appreciated that the invention will lead to reduction in construction costs while increasing productivity and economic benefits.

[0091] Whilst there has been described in the foregoing description preferred embodiments of the invention, it will be understood by those skilled in the field concerned that many variations or modifications in details of design or construction may be made without departing from the present invention.

Claims

1. A method for constructing a composite structural wall, the method comprises:

adjacently arranging a first pair of wall panels, wherein each wall panel of the first pair of wall panels includes a first panel body, and at least one first guide attached thereto and protruding from a first groove formed in the first panel body, wherein adjacently arranging a first pair of wall panels includes overlapping the first guides of the first pair of wall panels to form a first channel;

inserting a first linking rod into the first channel;
dispensing a first grout into a first gap between the first pair of wall panels, wherein dispensing a first grout into a first gap includes dispensing the first grout into the first channel; and
curing the first grout to join the first pair of wall panels.

2. The method according to claim 1 further comprises:

vertically-stacking a second pair of adjacently arranged wall panels on the first pair of wall panels, wherein each wall panel of the second pair of wall panels includes a second panel body, and at least one second guide attached thereto and protruding from a second groove formed in the second panel body, wherein vertically-stacking a second pair of adjacently arranged wall panels on the first pair of wall panels includes overlapping the second guides of the second pair of wall panels to form a second channel;
inserting a vertical securement rod into the first and the second channel such that the vertical securement rod have opposite end portions at least partially inserted into the first and the second channel respectively;
dispensing a second grout into a second gap between the second pair of wall panels, wherein dispensing a second grout into a second gap includes dispensing the second grout into the second channel; and
curing the second grout to join the second pair of wall panels.

3. The method according to claim 2, further comprising:

inserting a second linking rod into the second channel.

4. The method according to any of claims 2 to 3,
wherein each wall panel of the first and the second pair of wall panels is provided by separate prefabricated construction modules,
wherein adjacently arranging a first pair of wall panels includes adjacently arranging a first pair of prefabricated construction modules, and
wherein vertically stacking a second pair of adjacently arranged wall panels on the first pair of wall panels includes vertically stacking a second pair of adjacently arranged prefabricated construction modules on the first pair of prefabricated construction modules.

5. The method according to claim 4,
wherein each wall panel of the first and the second pair of wall panels includes a bottom end portion attached to a floor slab,
the method further comprising:

inserting a plurality of backing rods between of the first pair of prefabricated construction modules and floor slabs of the second pair of prefabricated construction modules to provide a third gap which intersects the first and the second channel,
wherein dispensing a second grout into a second gap includes dispensing the second grout into the third gap, wherein curing the second grout to join the second pair of wall panels includes curing the second grout to join the second pair of prefabricated construction modules to the first pair of prefabricated construction modules.

6. A wall panel in a prefabricated construction module, the wall panel comprising:

a panel body; and
at least one guide attached to the panel body and protruding from a groove formed in the panel body, wherein the guide is adapted to overlap with an adjacent guide of an adjacently-arranged wall panel to provide a channel for receiving a linking rod therethrough, and wherein the wall panel is adapted to join to the adjacently-arranged wall panel by grouting a gap, including the channel, between the wall panel and the adjacently-arranged wall panel.

7. The wall panel according to claim 6 further comprising:

a reinforcement structure embedded in the panel body, wherein the guide is attached to the reinforcement structure, wherein the reinforcement structure is any one selected from the group consisting of a plurality of steel bars, a plurality of corrugated pipes each adapted to receive a steel bar of a vertically stacked wall panel, a mesh of steel bars, a mesh of steel wires, and a plurality of steel bars each attached to a splice connector

adapted to receive a steel bar of a vertically stacked wall panel.

8. The wall panel according to any one of claims 6 to 7, wherein a surface of the panel body, which includes the groove formed therein, is roughened.

9. A prefabricated construction module comprising:

at least one wall panel according to any one of claims 6 to 8; and
a floor slab attached to a bottom end portion of the wall panel.

10. A building structure comprising:

at least one first composite structural wall which comprises:

a first pair of wall panels arranged adjacent to each other, wherein each wall panel of the first pair of wall panels includes a first panel body and at least one first guide attached thereto and protruding from a first groove formed in the first panel body, wherein the first guides of the first pair of wall panels overlap to provide a first channel;
a first linking rod disposed within the first channel; and
a first grouting disposed in a first gap, including the first channel, between the first pair of wall panels, wherein the first grouting joins the first pair of wall panels.

11. The building structure according to claim 10, further comprising:

at least one second composite structural wall which is vertically stacked on the first composite structural wall and comprises:

a second pair of wall panels arranged adjacent to each other, wherein each wall panel of the second pair of wall panels includes a second panel body and at least one second guide attached thereto and protruding from a second groove formed in the second panel body, wherein the second guides of the second pair of wall panels overlap to provide
a second channel;
a second linking rod disposed within the second channel;
a vertical securement rod having opposite end portions at least partially inserted into the first and the second channel respectively;
a second grouting disposed in a second gap, including the second channel, between the second pair of wall panels, wherein the second grouting joins the second pair of wall panels.

12. The building structure according to any of claims 10 to 11 wherein each wall panel of the first and the second pair of wall panels is provided by separate prefabricated construction modules.

13. The building structure according to claim 12,
wherein each wall panel of the first and the second pair of wall panels includes a top end portion attached to a ceiling slab and a bottom end portion attached to a floor slab, the building structure further comprising:

a plurality of backing rods interposed between ceiling slabs of the first pair of prefabricated construction modules and floor slabs of the second pair of prefabricated construction modules to provide a third gap,
wherein the second grout is further disposed in the third gap and joins the second pair of prefabricated construction modules to the first pair of prefabricated construction modules.

14. The building structure according to claim 13,
wherein each floor slab of the second pair of prefabricated construction modules includes at least one floor slab guide attached to each respective floor slab and protruding from each respective floor slab, and
wherein the floor slab guides of the second pair of prefabricated construction modules overlap to provide the second channel.

15. The building structure according to any of claims 11 to 14, wherein the vertical securement rod is integral with the first and/or the second linking rod.

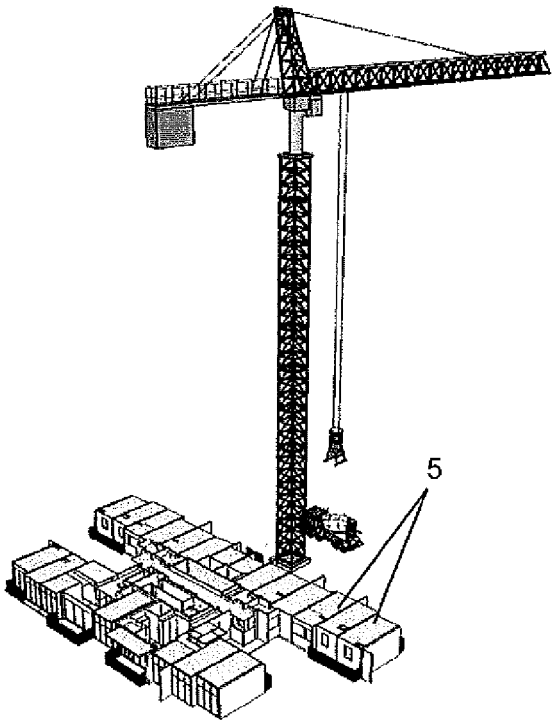


Figure 1A

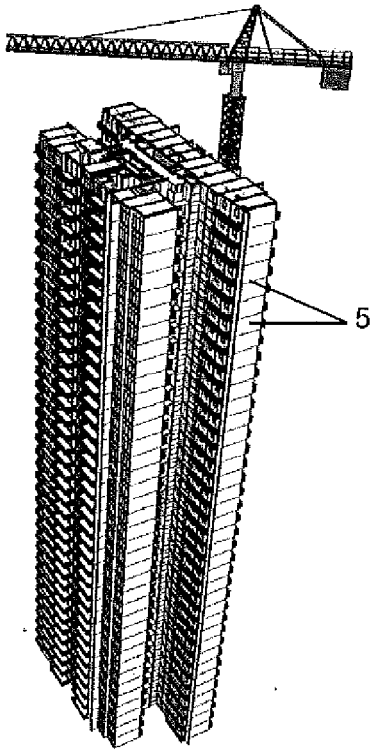


Figure 1B

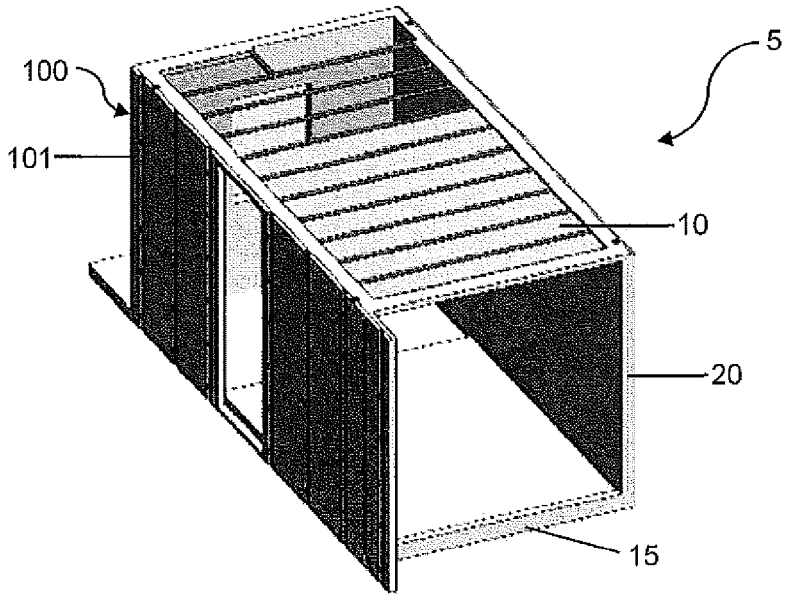


Figure 2

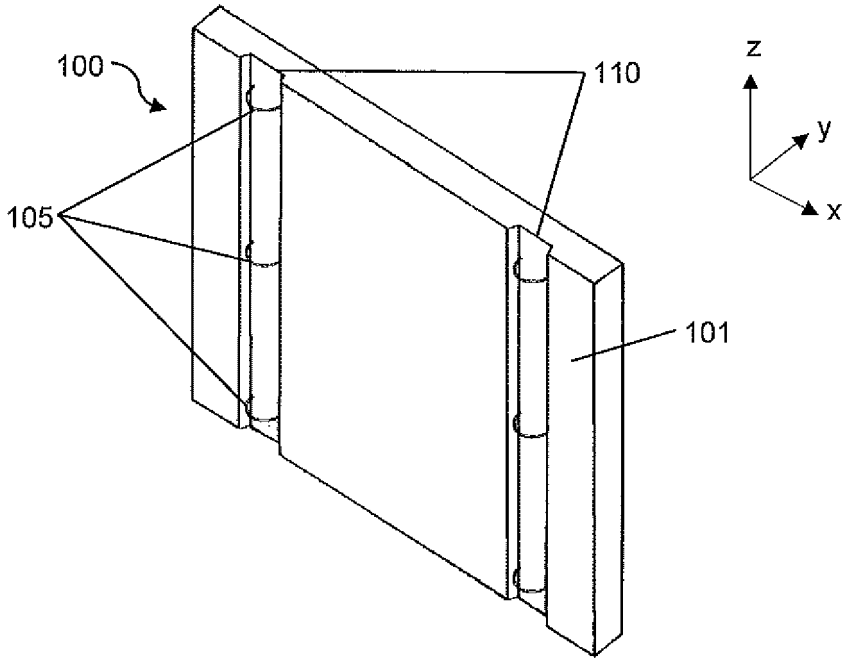


Figure 3A

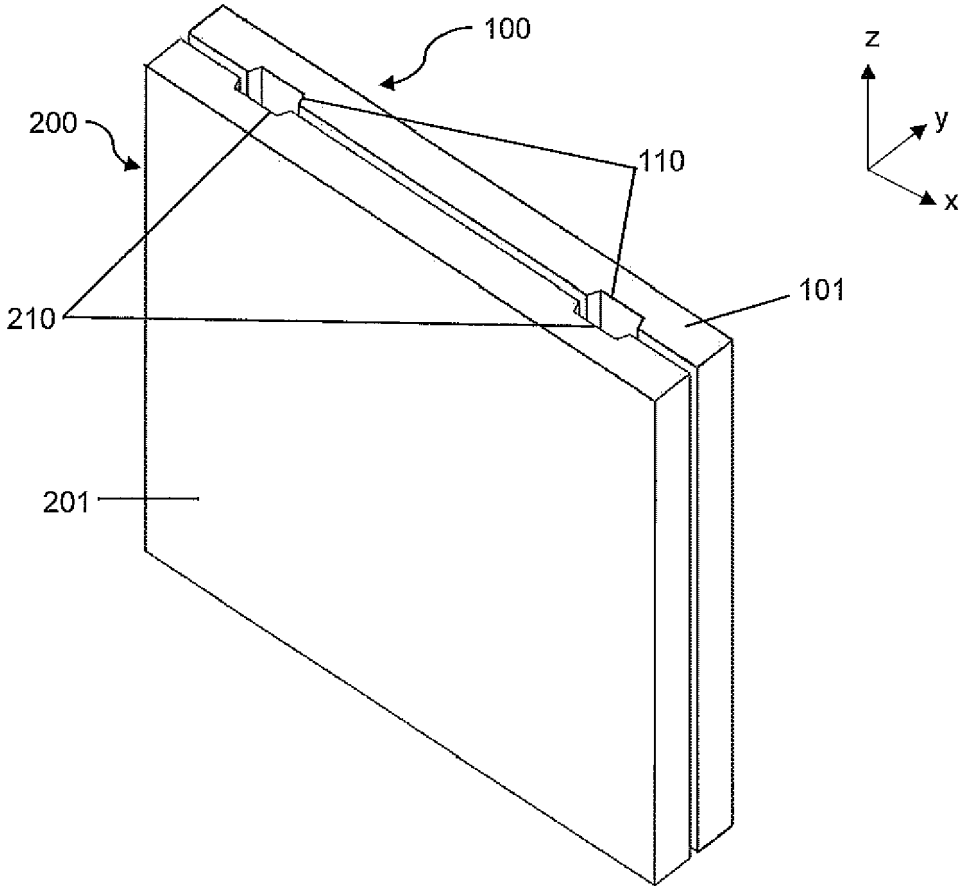


Figure 3B

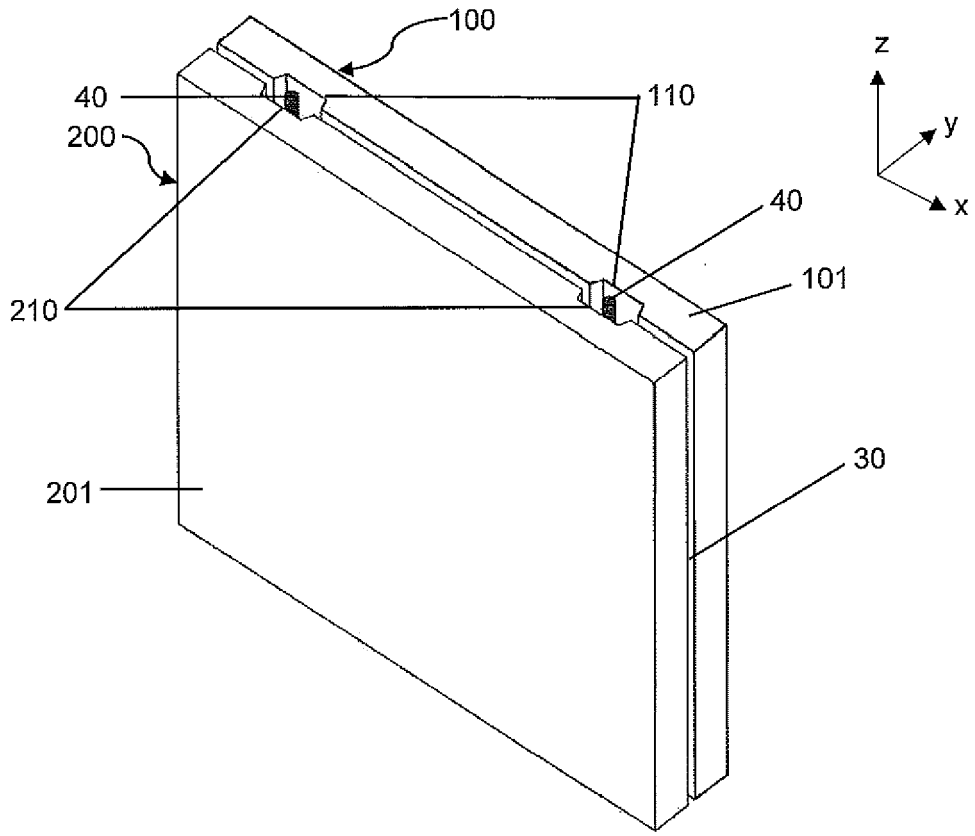


Figure 3C

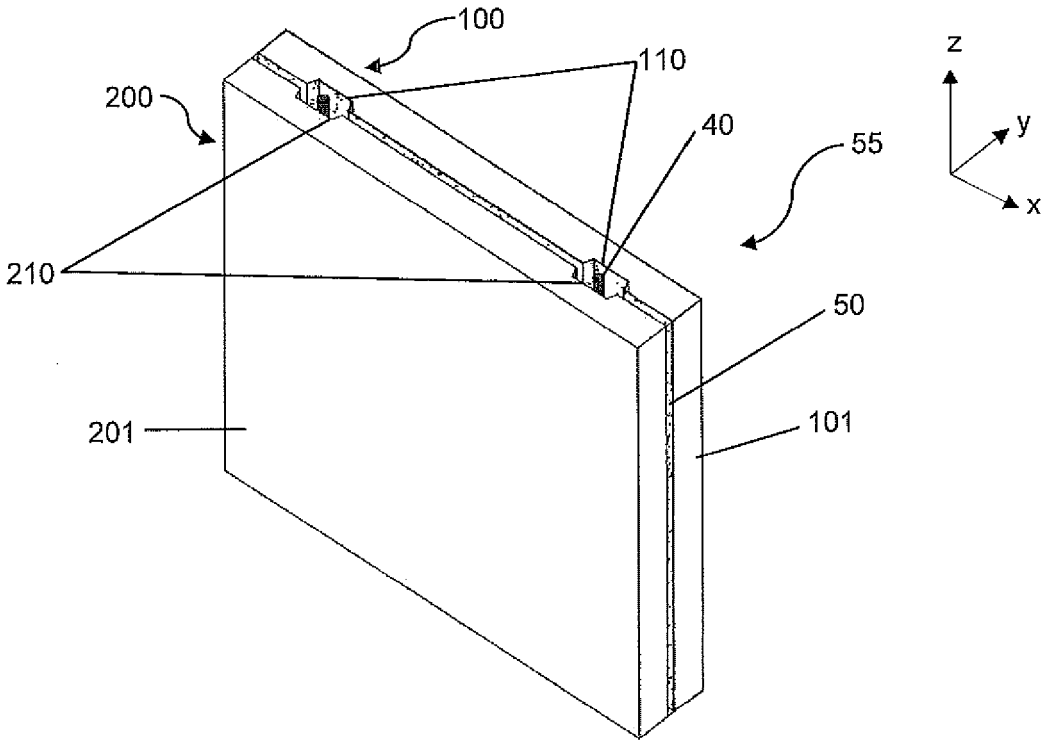


Figure 3D

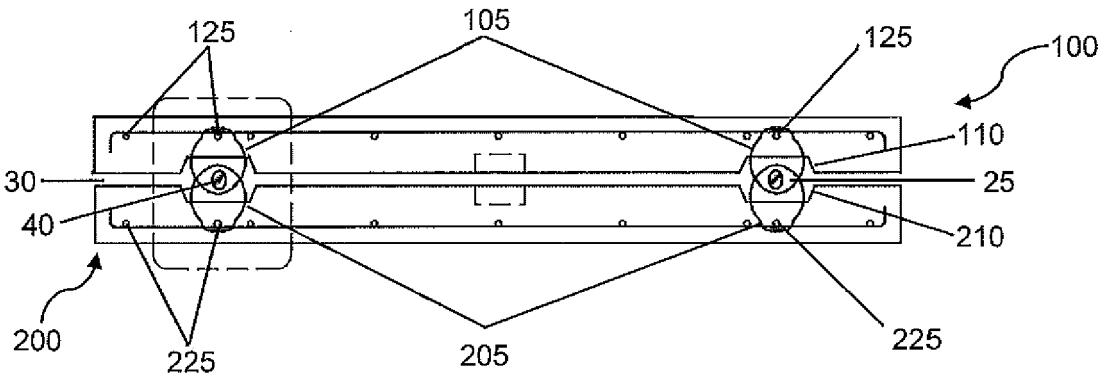


Figure 4A

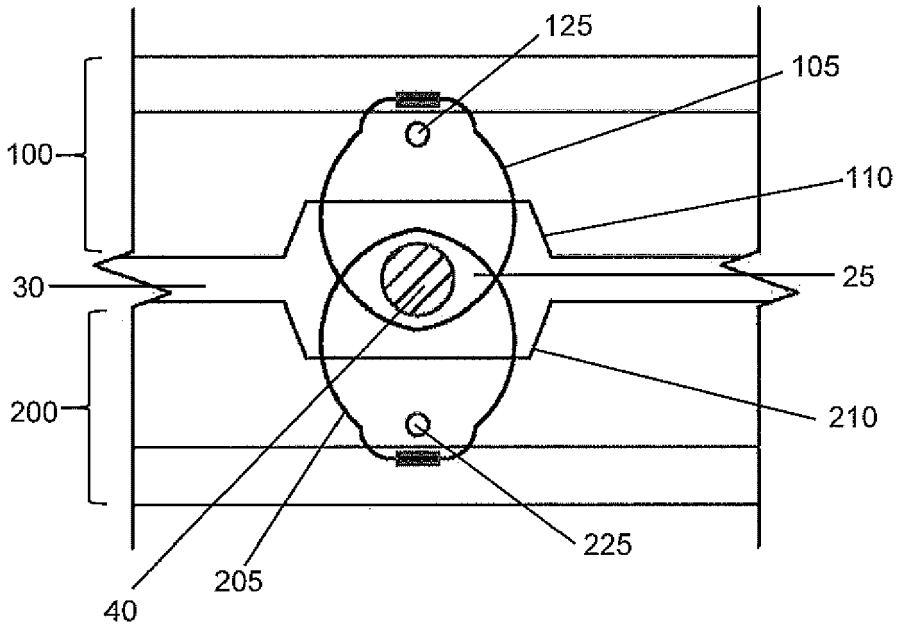


Figure 4B

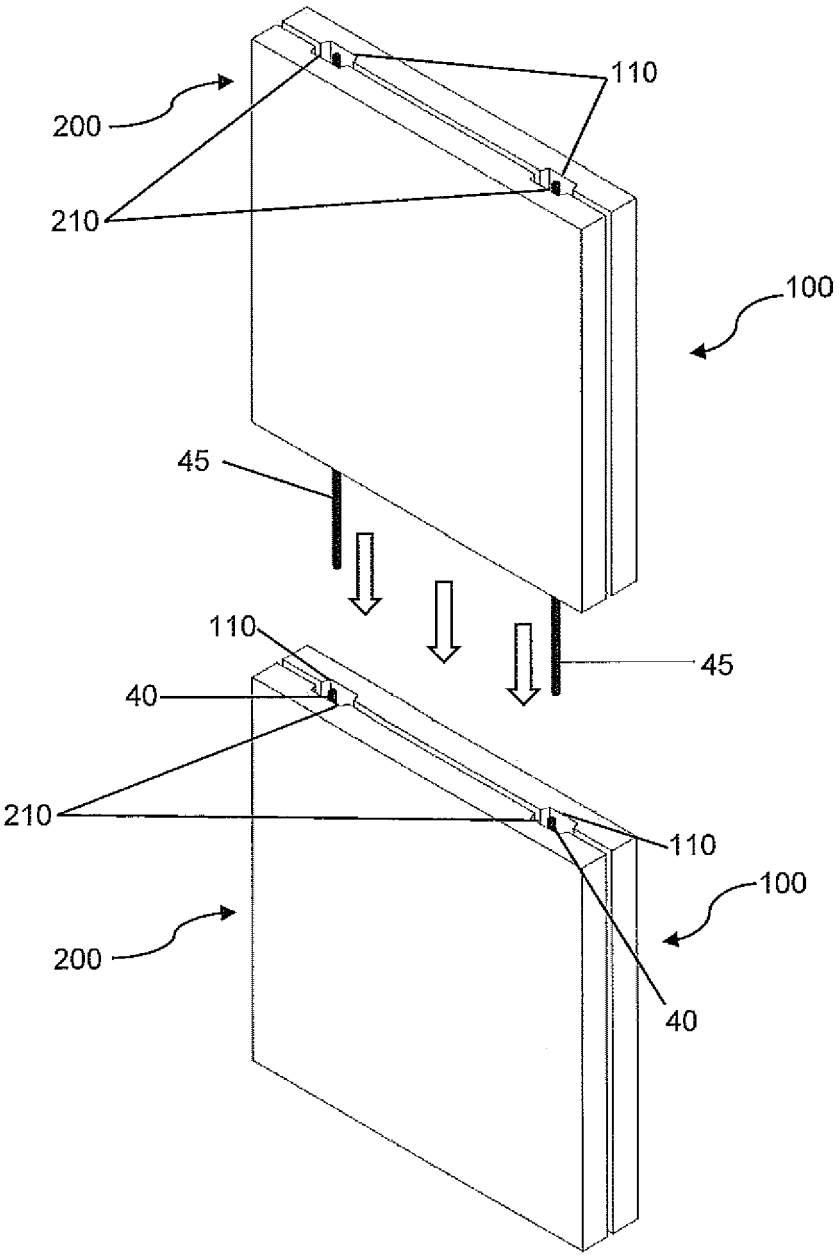


Figure 5A

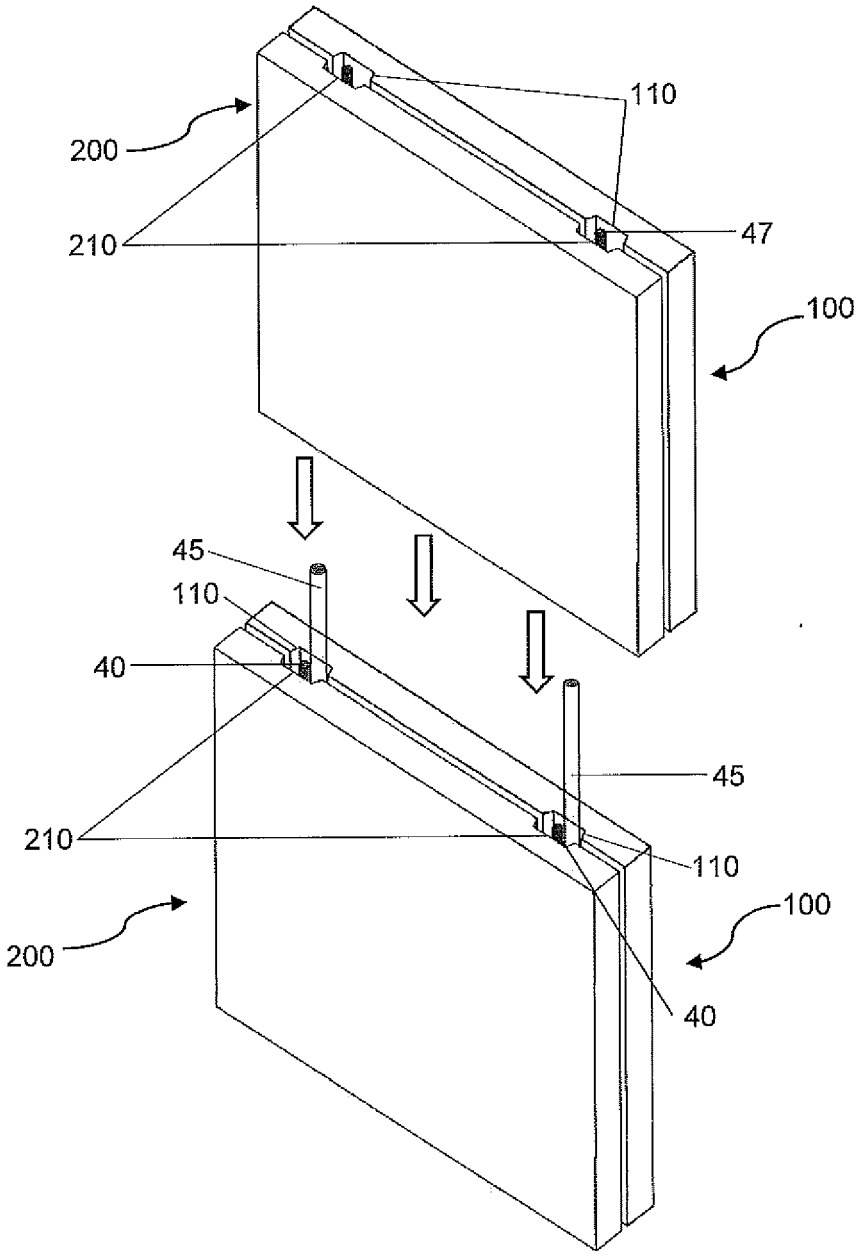


Figure 5B

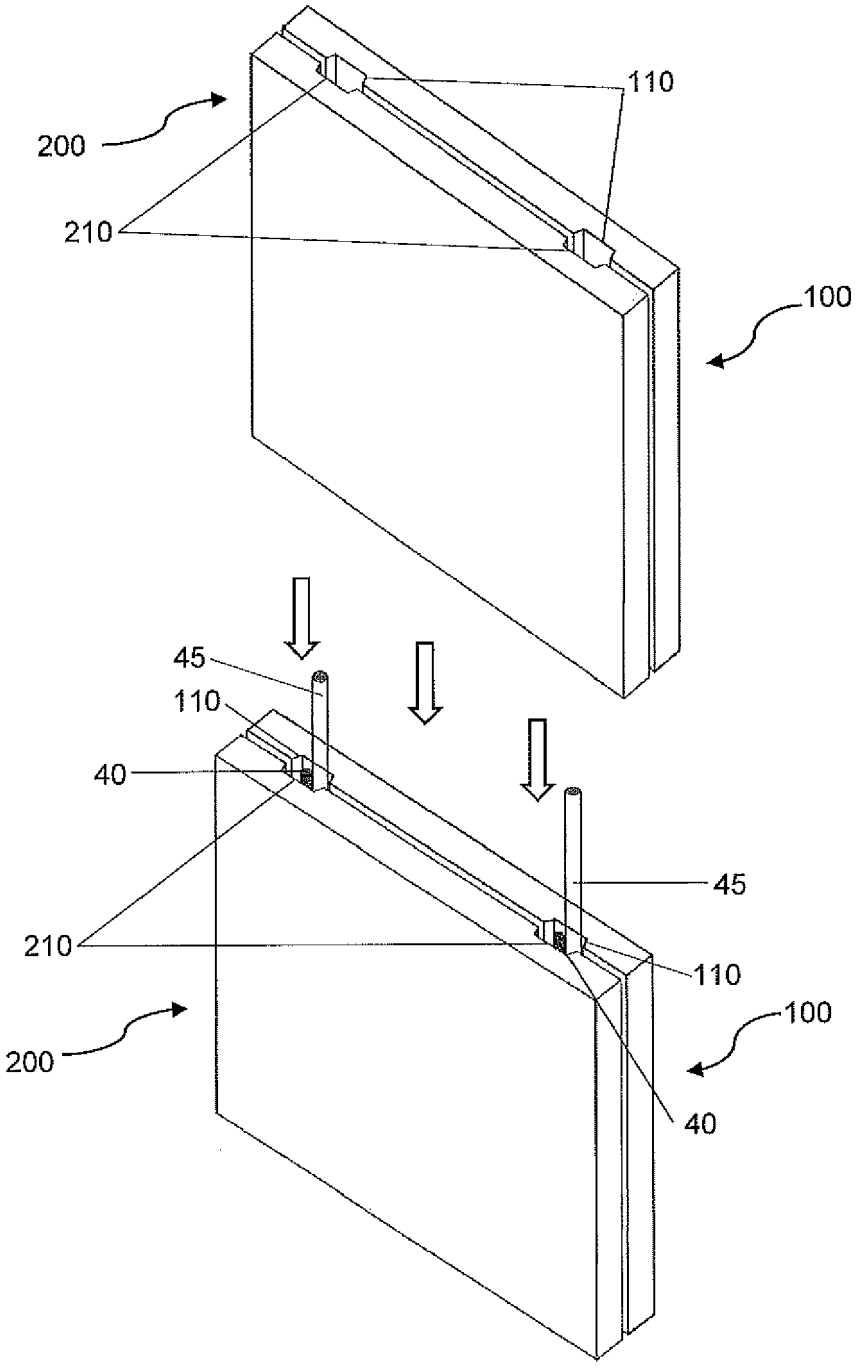


Figure 5C

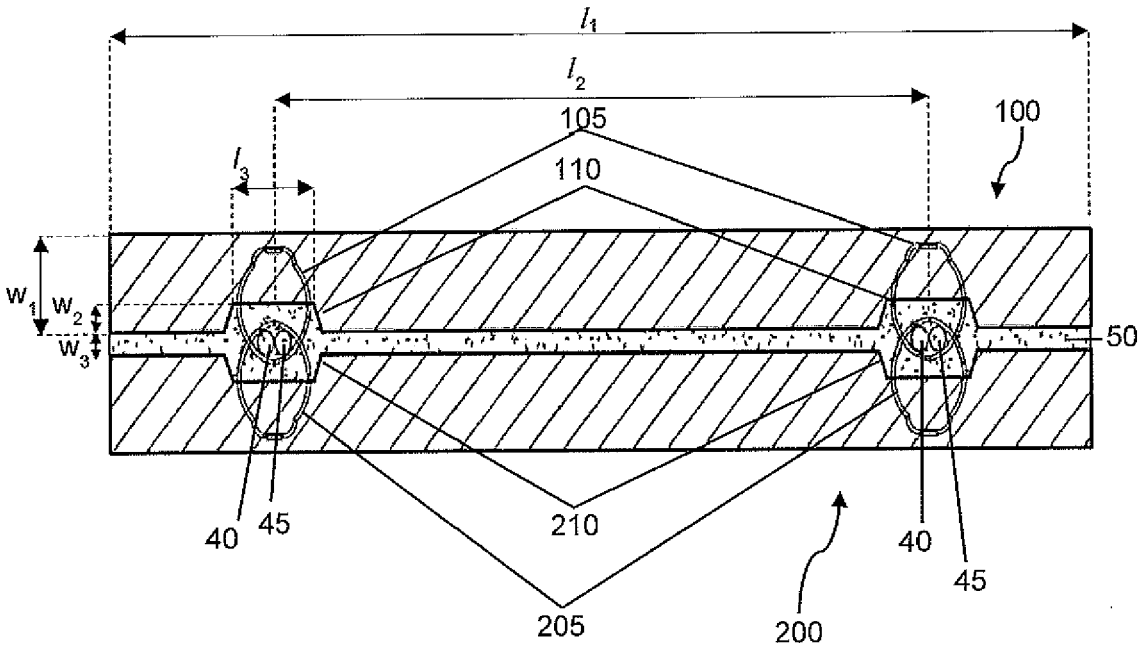


Figure 6

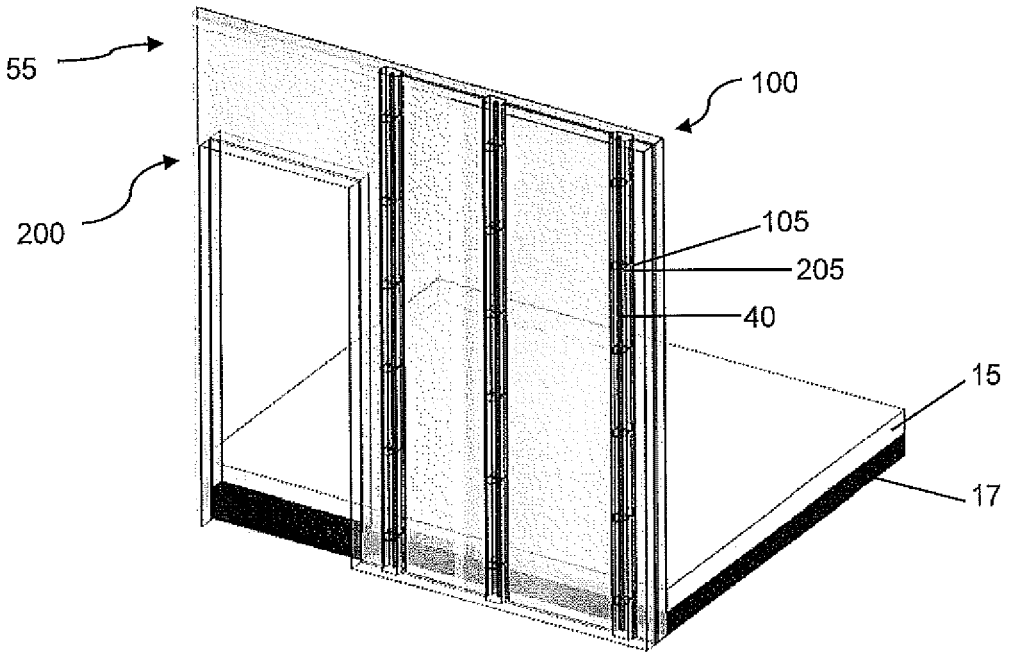


Figure 7A

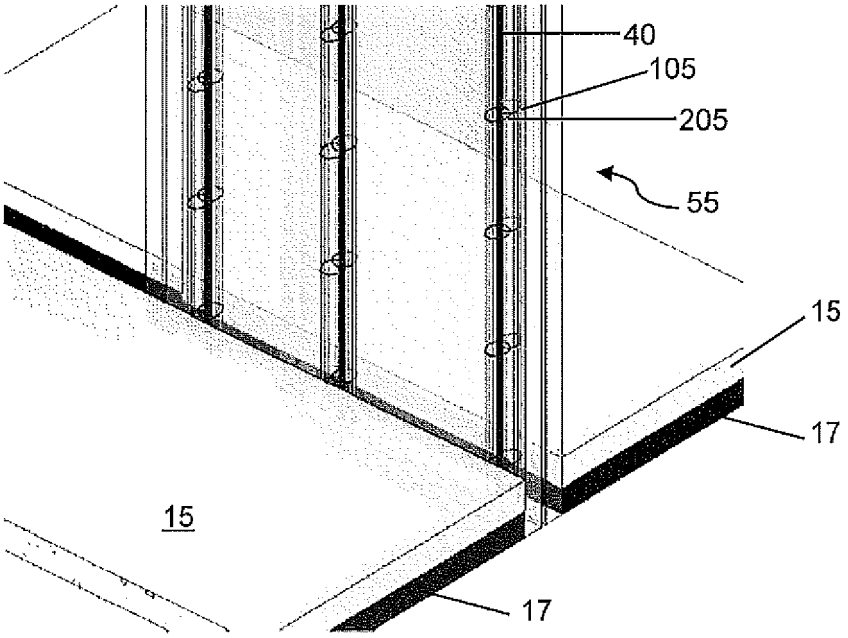


Figure 7B

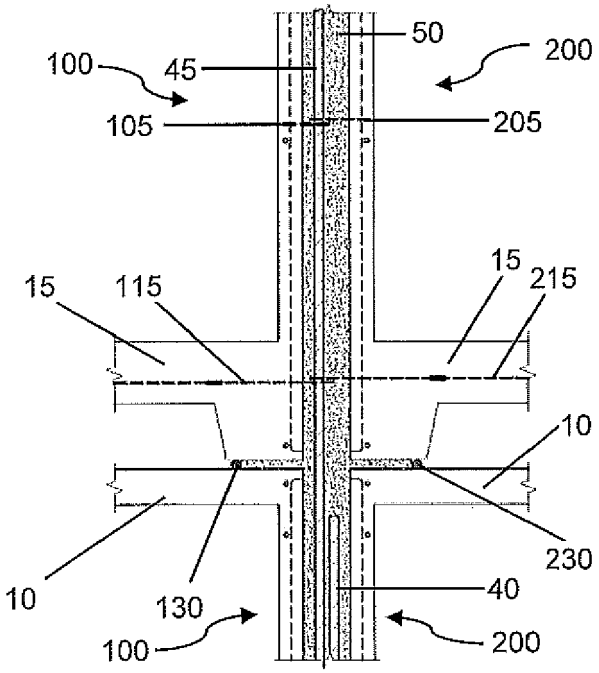


Figure 8

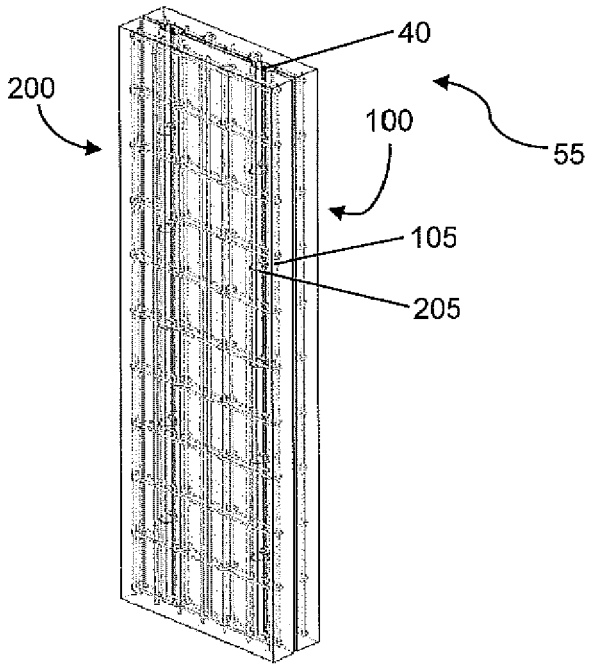


Figure 9

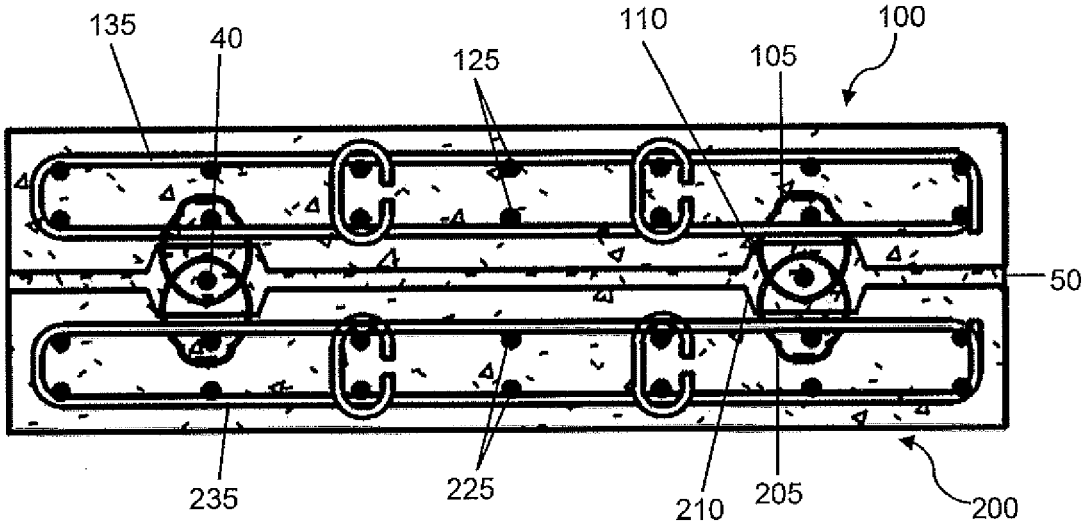


Figure 10

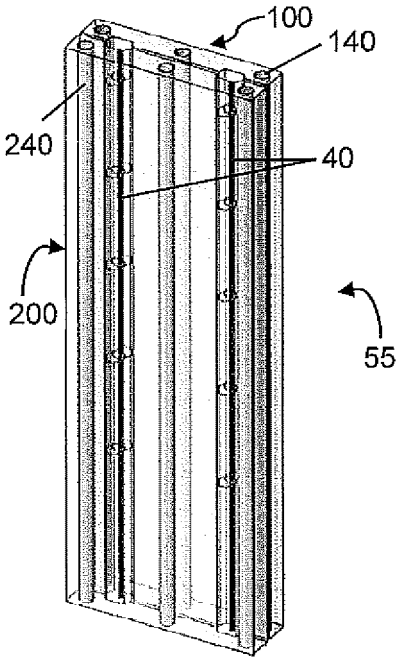


Figure 11

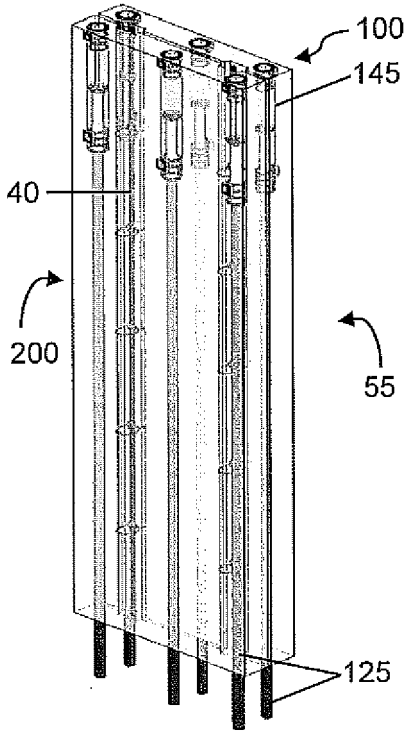


Figure 13

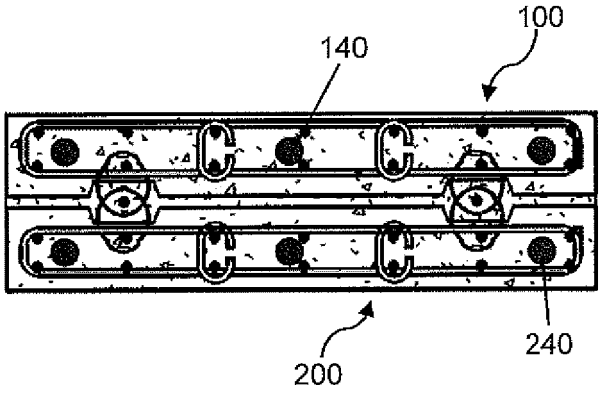


Figure 12A

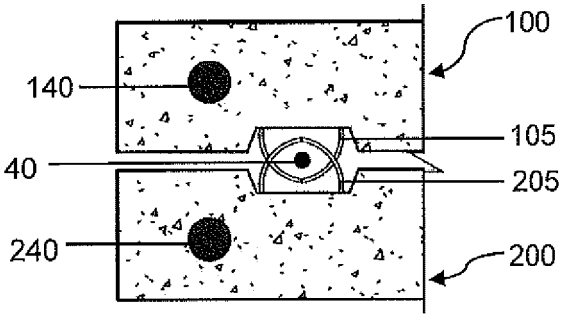


Figure 12B



Figure 14

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 17 17 5623

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	17 October 2017	Dieterle, Sibille

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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