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(54) **MODULE FOR USE IN PREPARING A
PREFABRICATED STRUCTURE, METHOD
FOR MANUFACTURING SAME AND
TRANSPORT FRAME**

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(57) **ABSTRACT**

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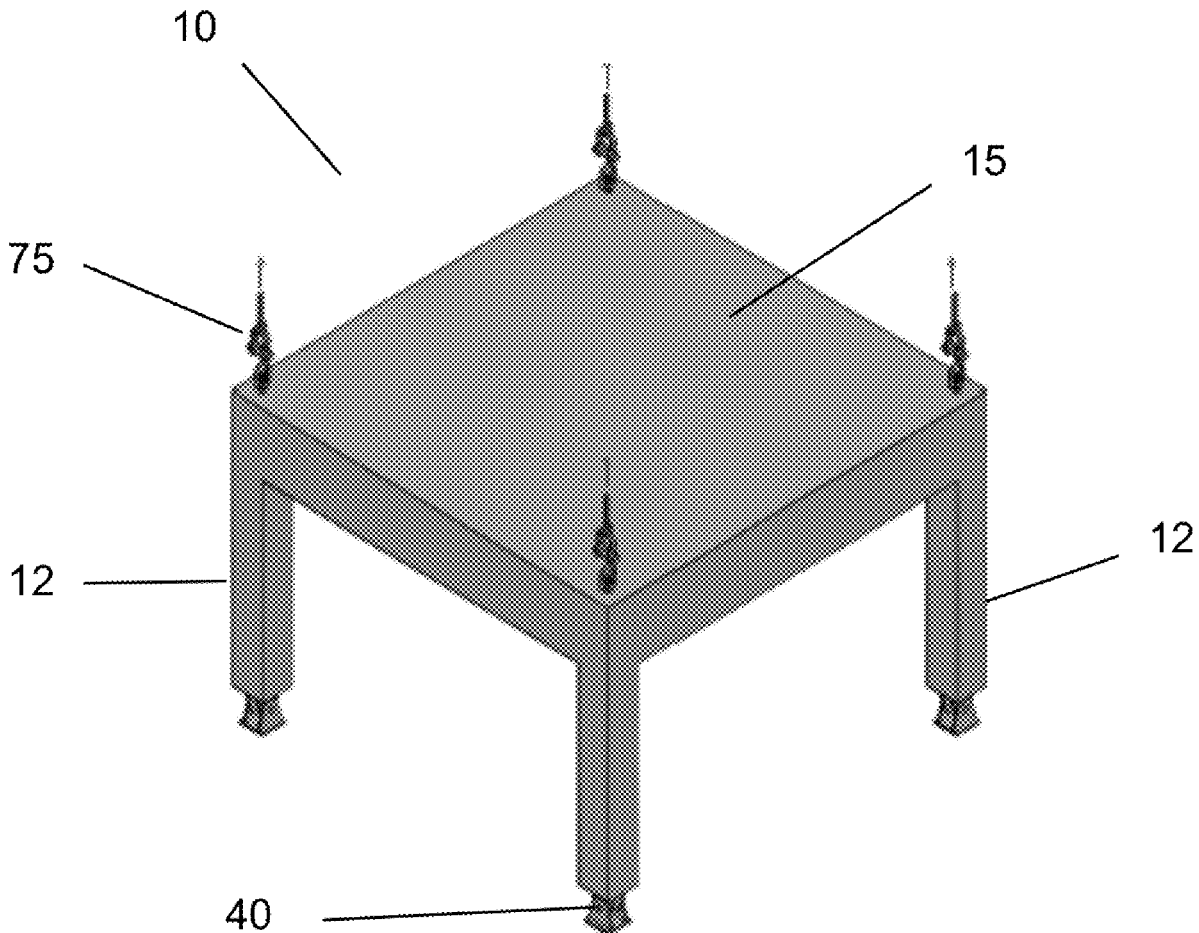
§ 371 (c)(1),

(2) Date: **Aug. 11, 2023**

Related U.S. Application Data

(60) Provisional application No. 63/148,801, filed on Feb.
12, 2021.

The present invention provides a reinforced concrete module for use in preparing a prefabricated structure comprising a horizontal slab, four corner columns, perimeter beams extending downwardly from a respective longitudinal and transversal edges of the horizontal slab and extending between and connected to adjacent columns; at least two transverse ribs located on an underside of the horizontal slab and extending between two opposing perimeter beams, wherein the module is fabricated as a unitary body. Also provided is a method for fabricating the module, as well as a transport frame configured to support a module on a transport vehicle.



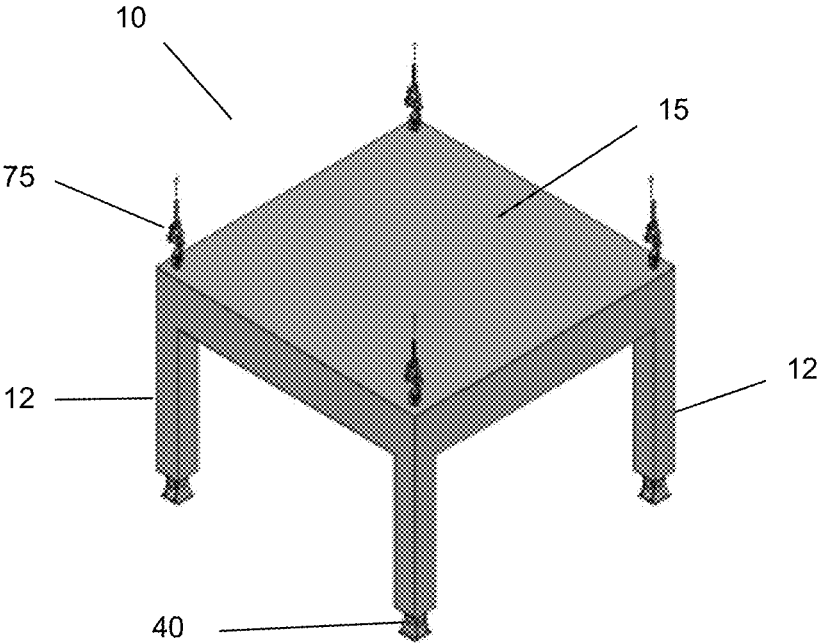


Fig. 1

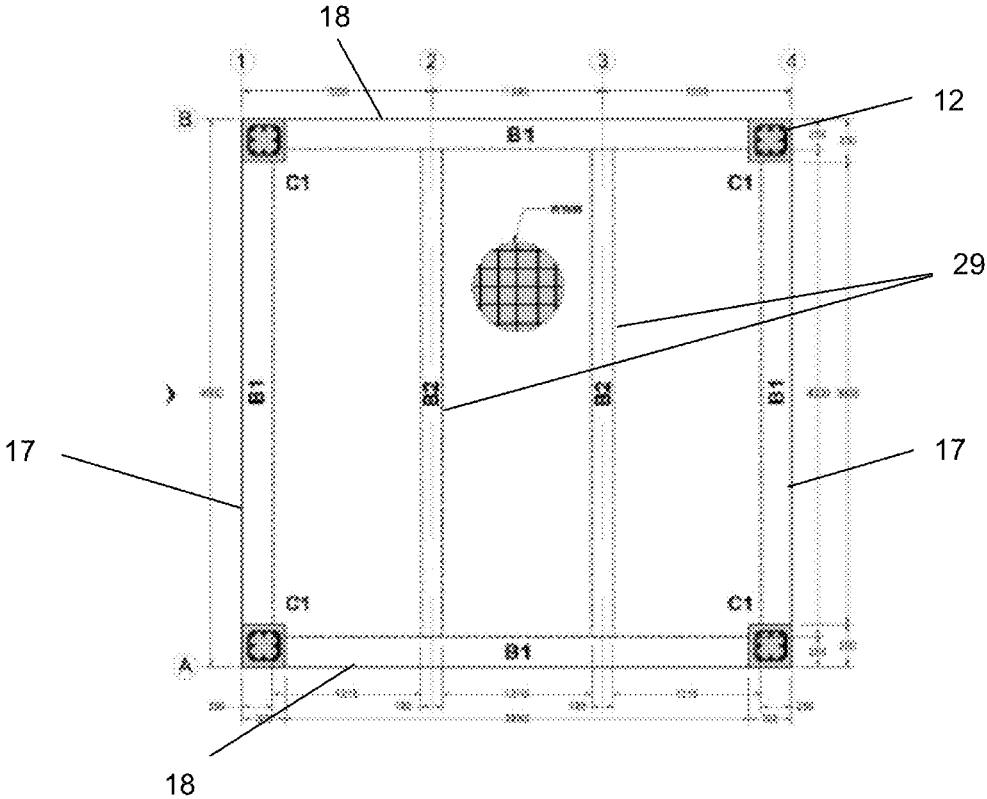


Fig. 2

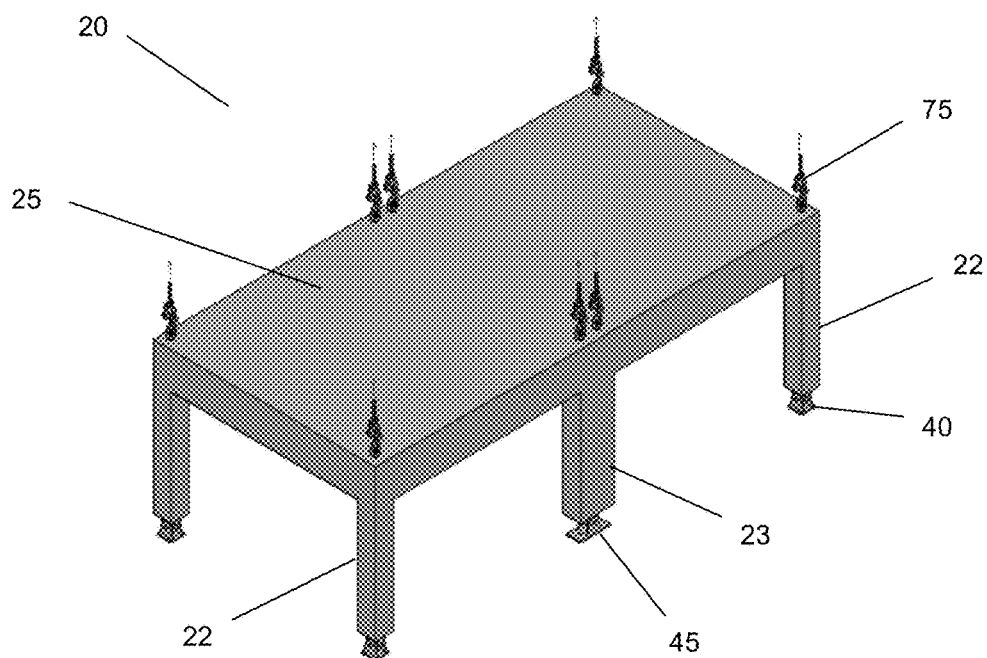


Fig. 3A

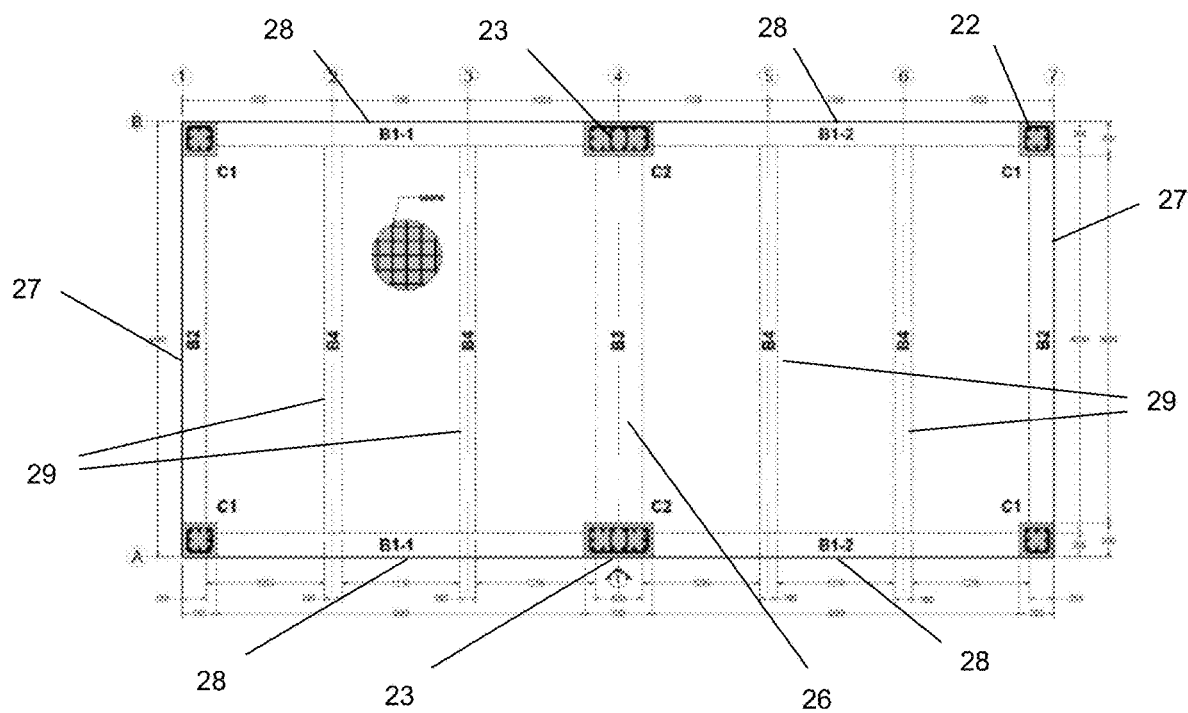


Fig. 3B

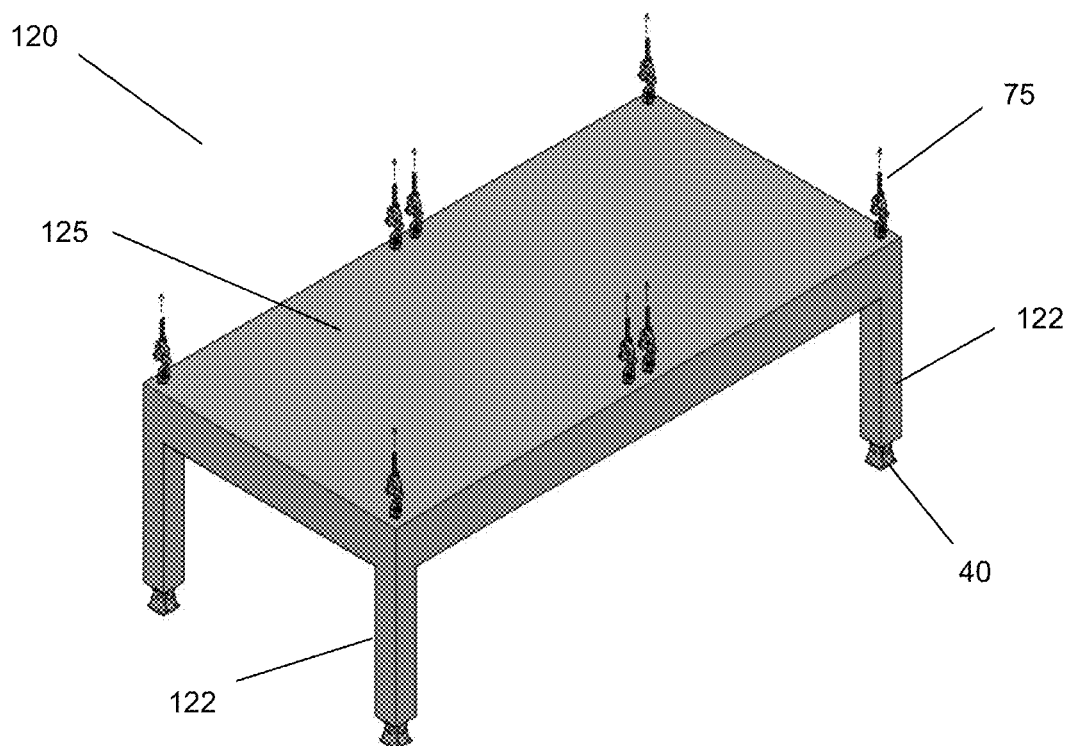


Fig. 4A

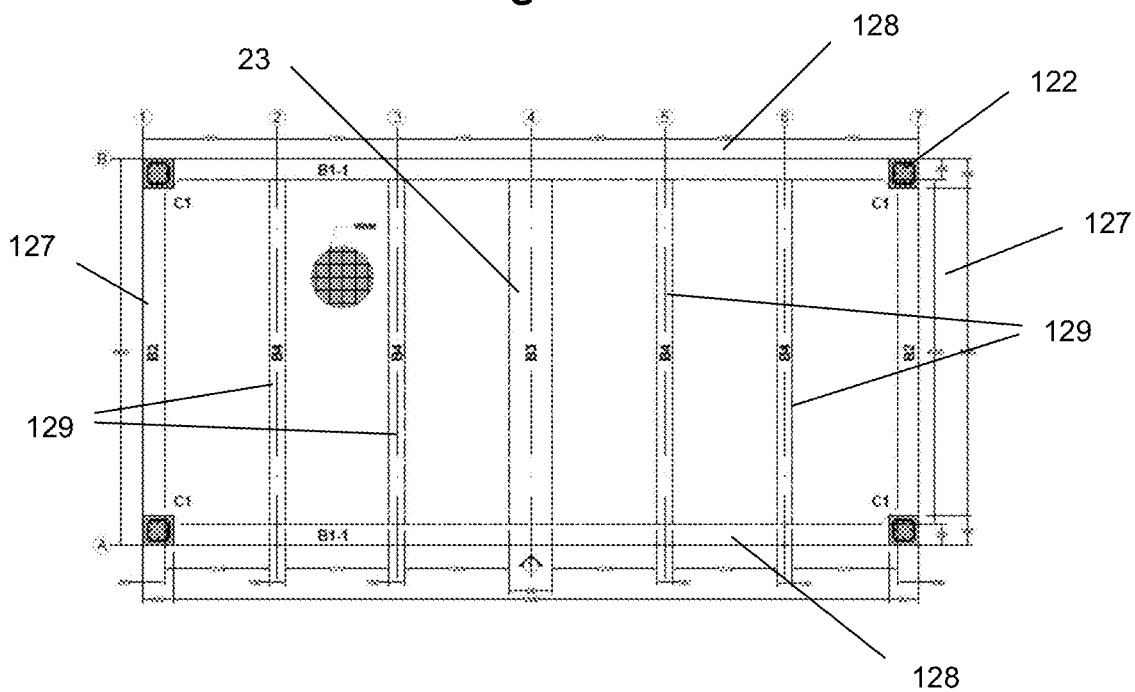


Fig. 4B

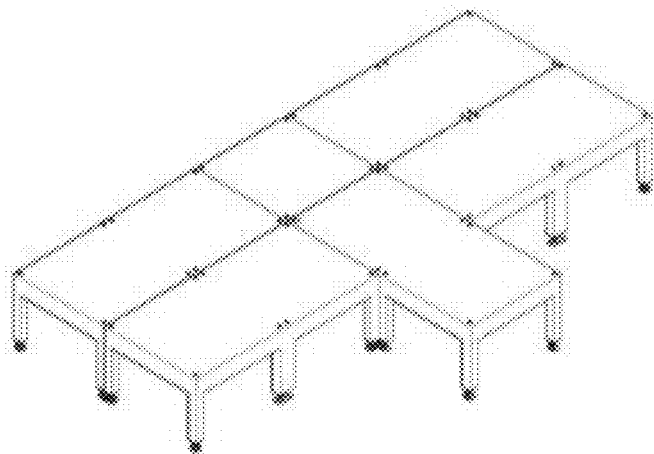


Fig. 5A

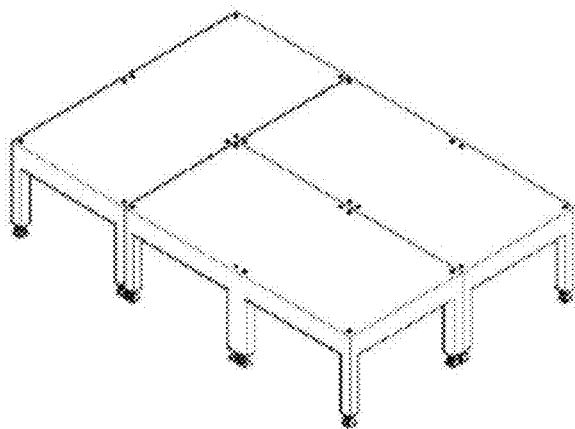


Fig. 5B

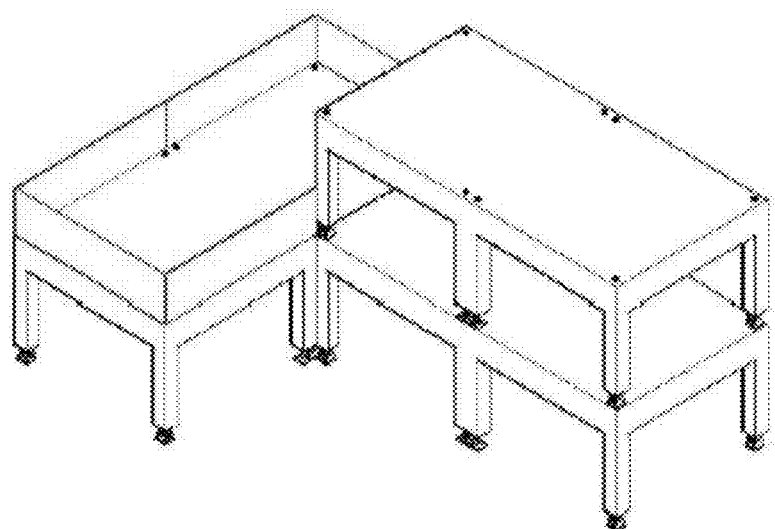


Fig. 5C

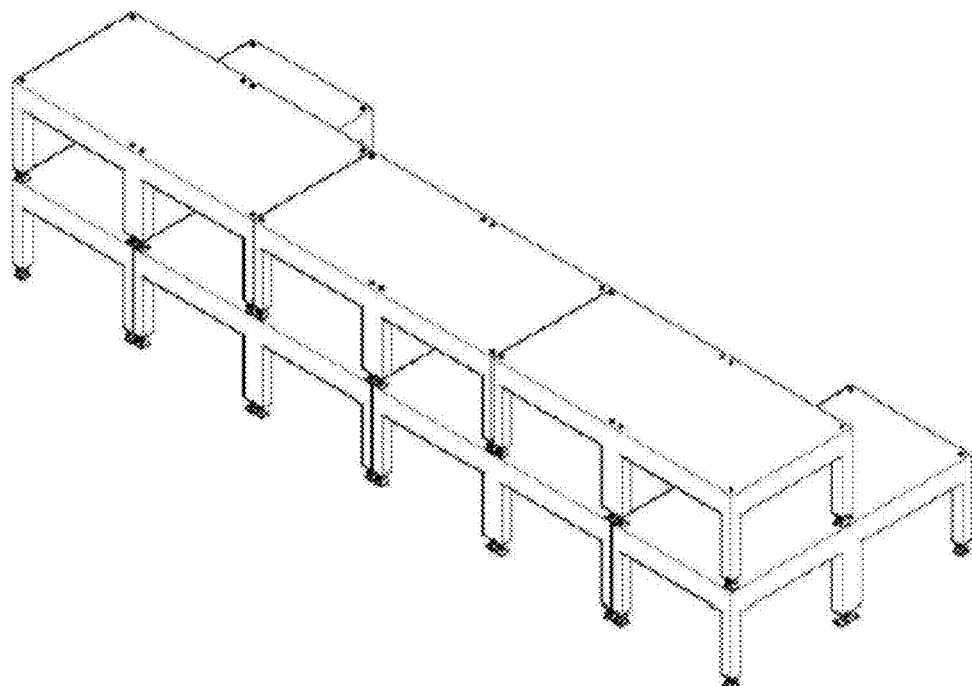


Fig. 5D

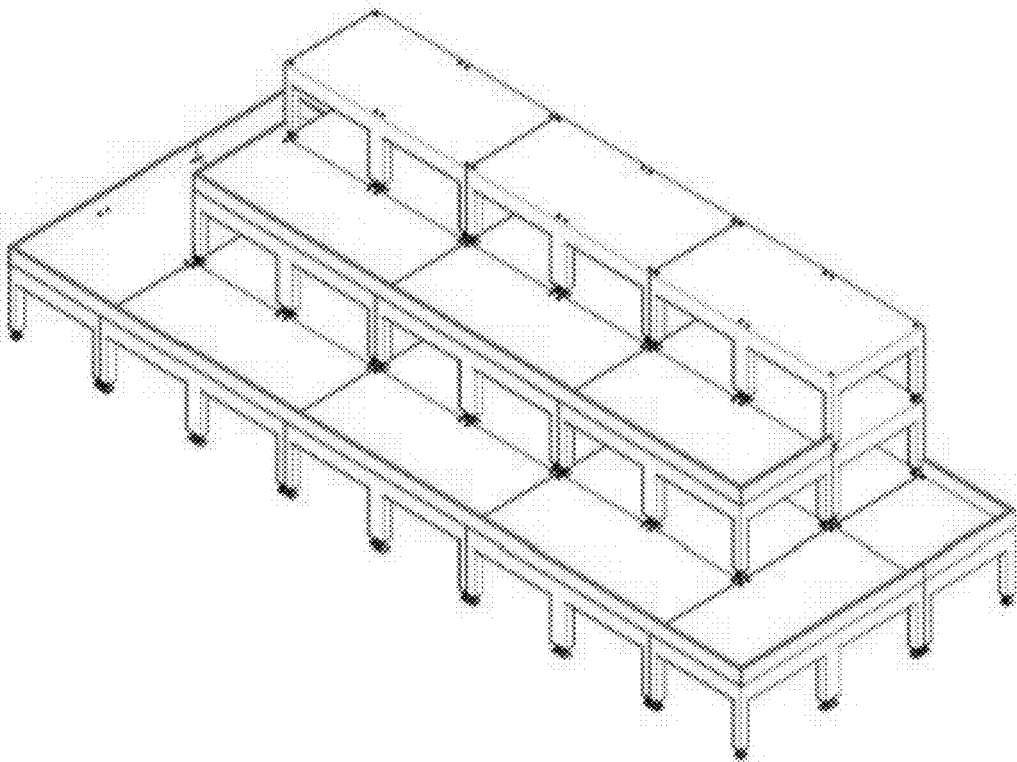


Fig. 5E

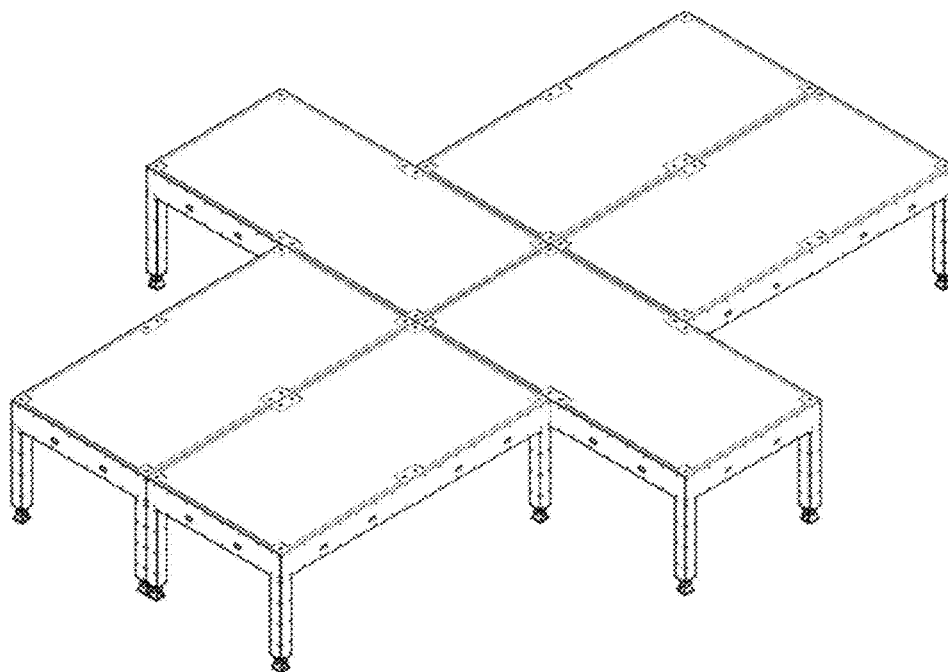


Fig. 5F

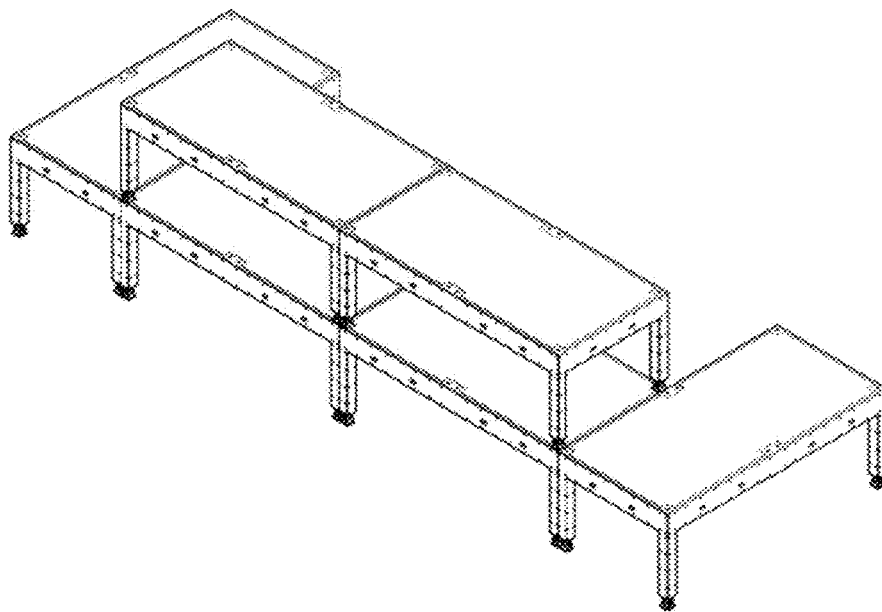


Fig. 5G

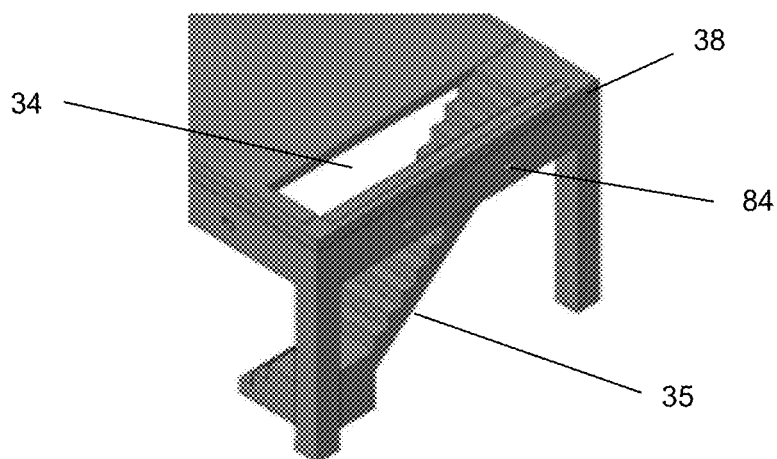


Fig. 6A

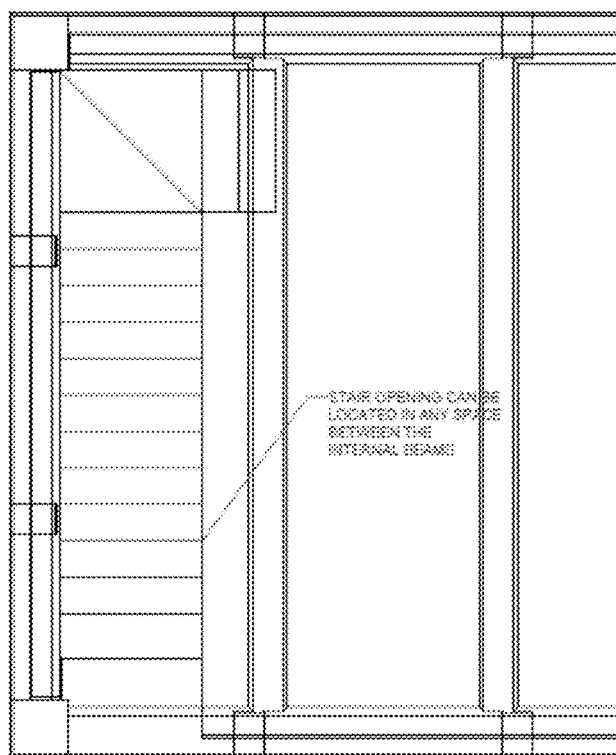


Fig. 6B

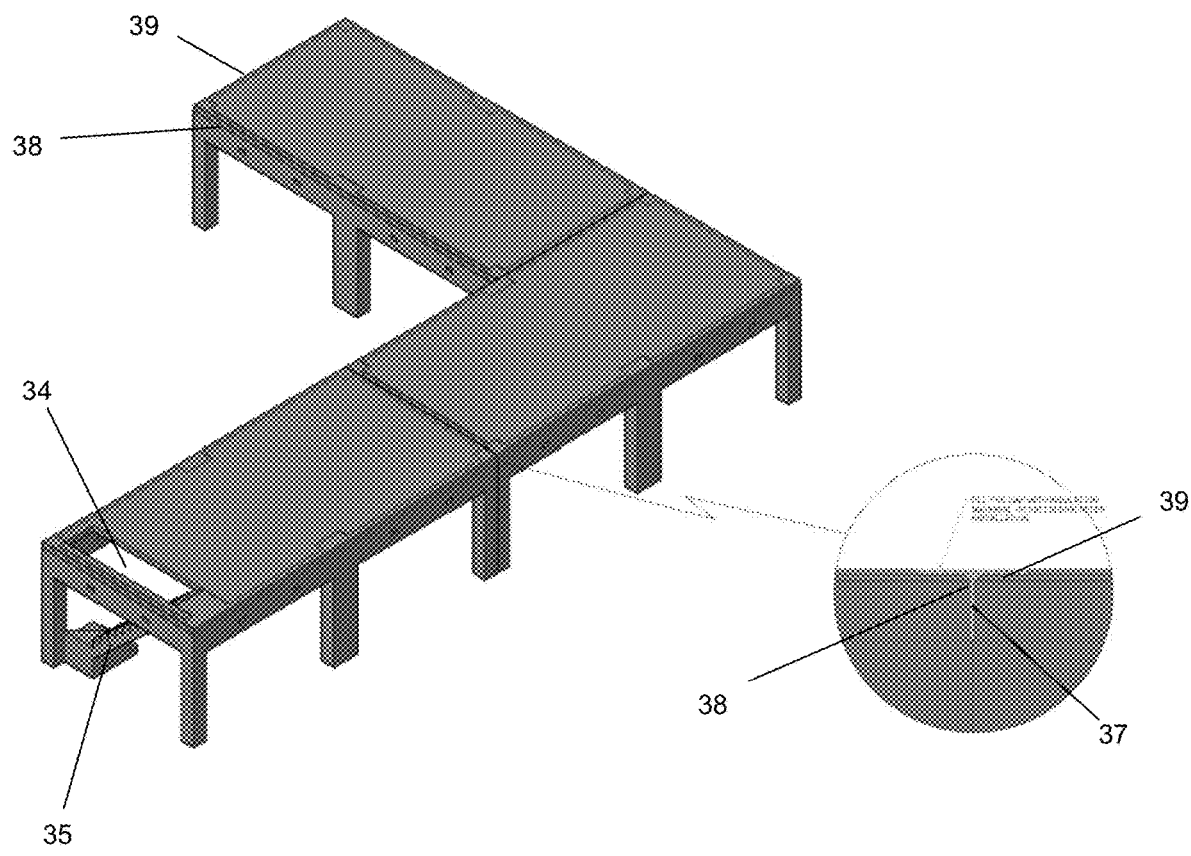


Fig. 7

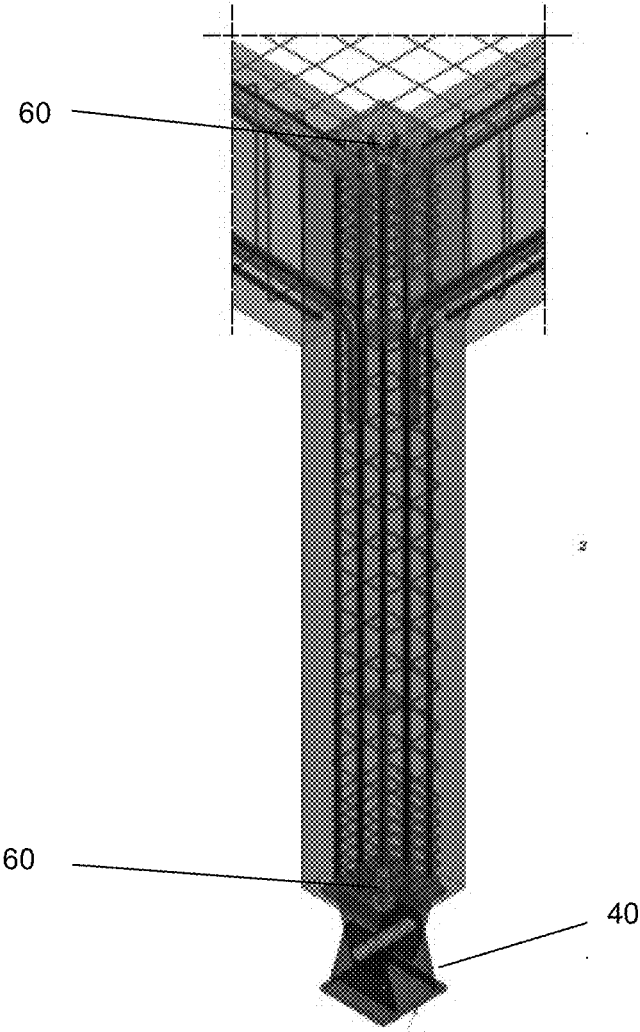


Fig. 8

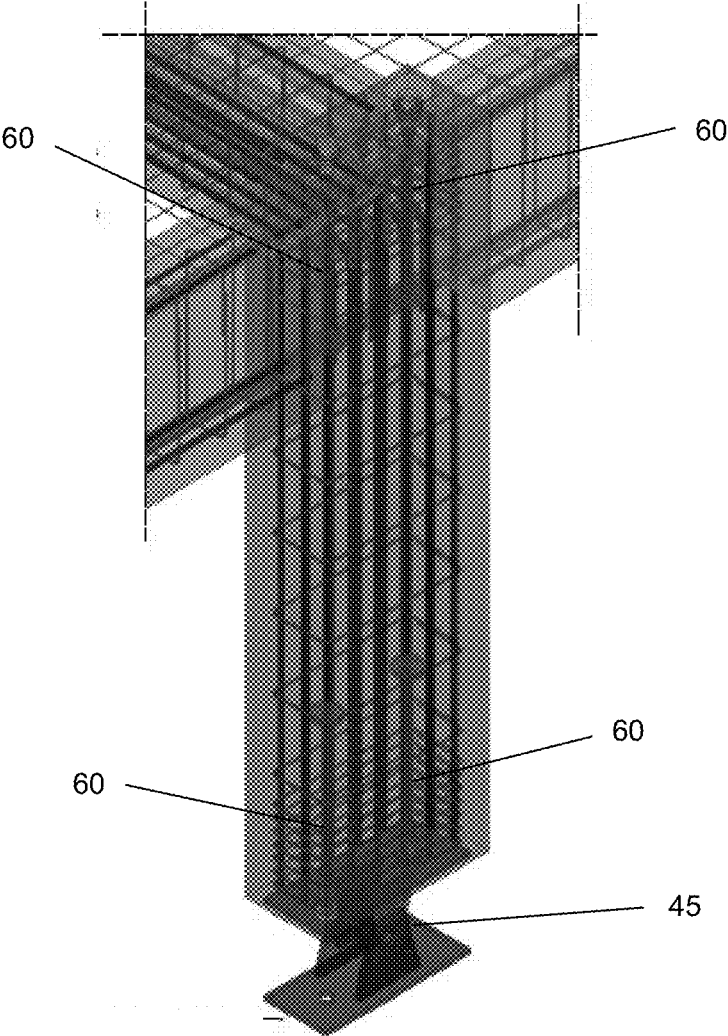


Fig. 9A

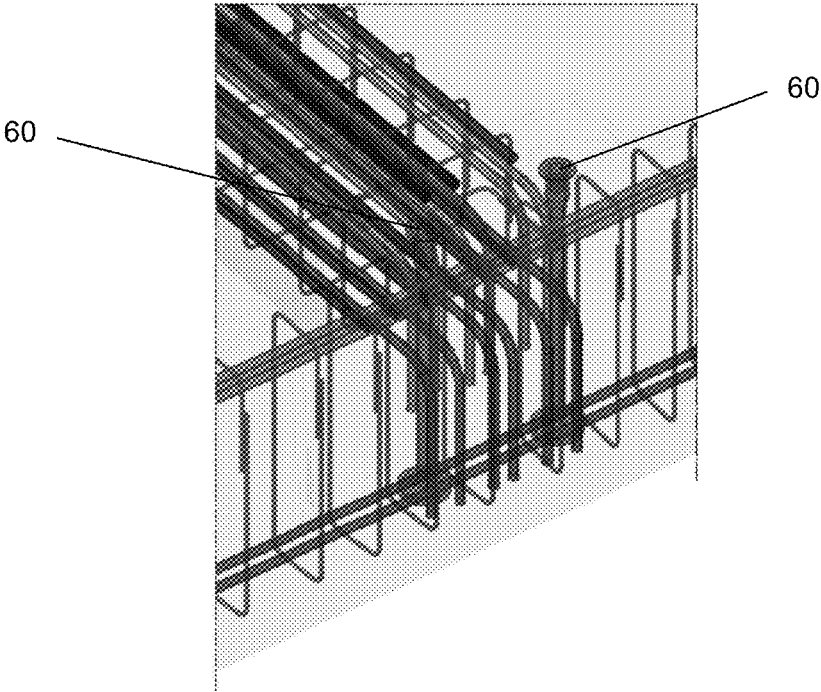


Fig. 9B

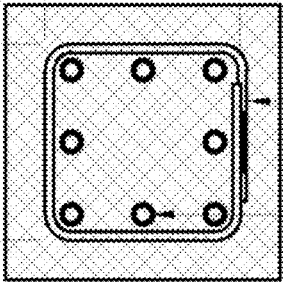


Fig. 10

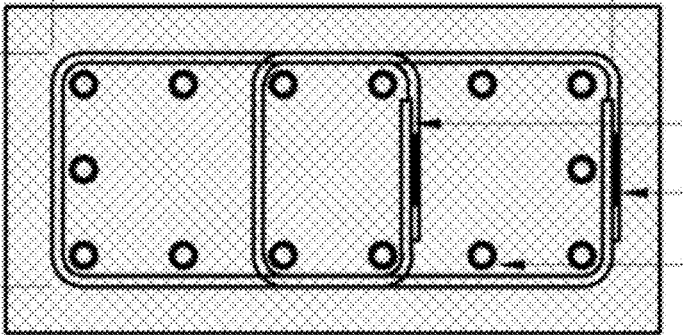


Fig. 11

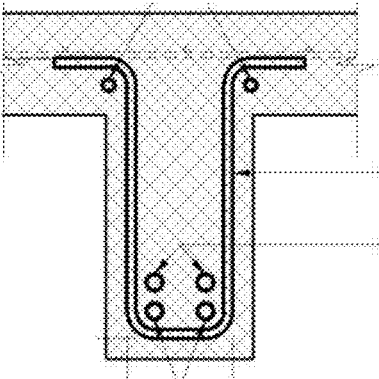


Fig. 12

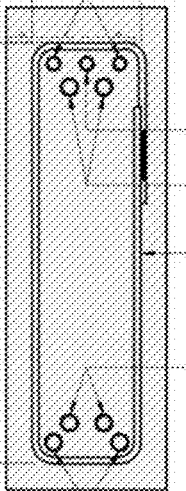


Fig. 13

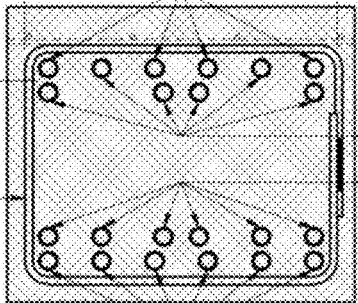


Fig. 14

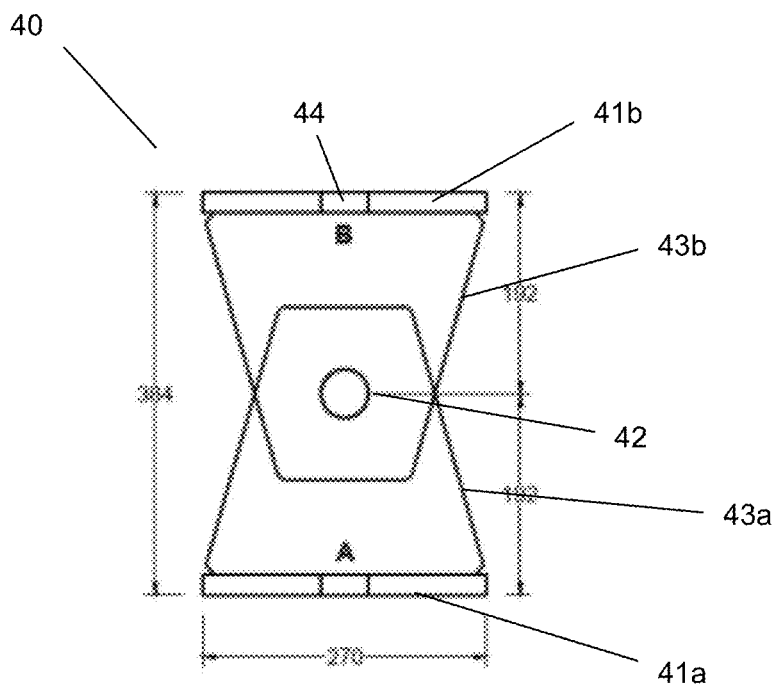


Fig. 15

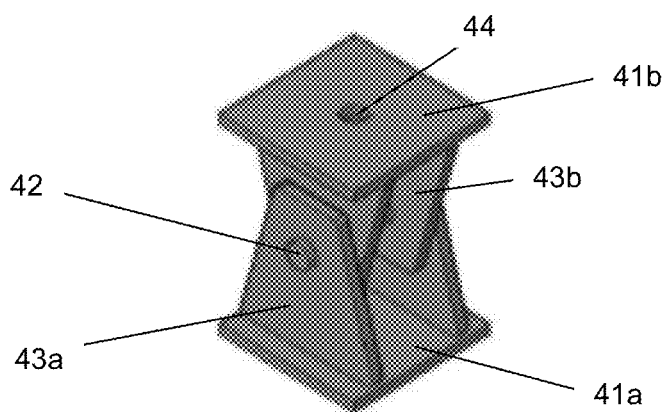
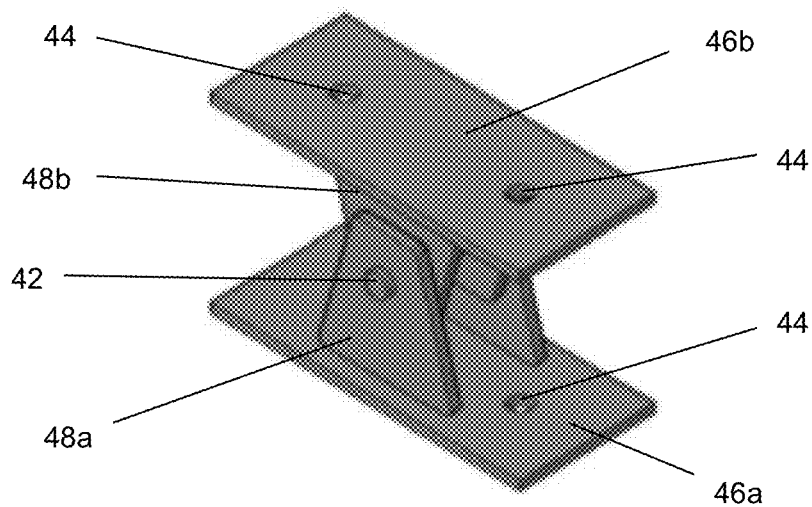
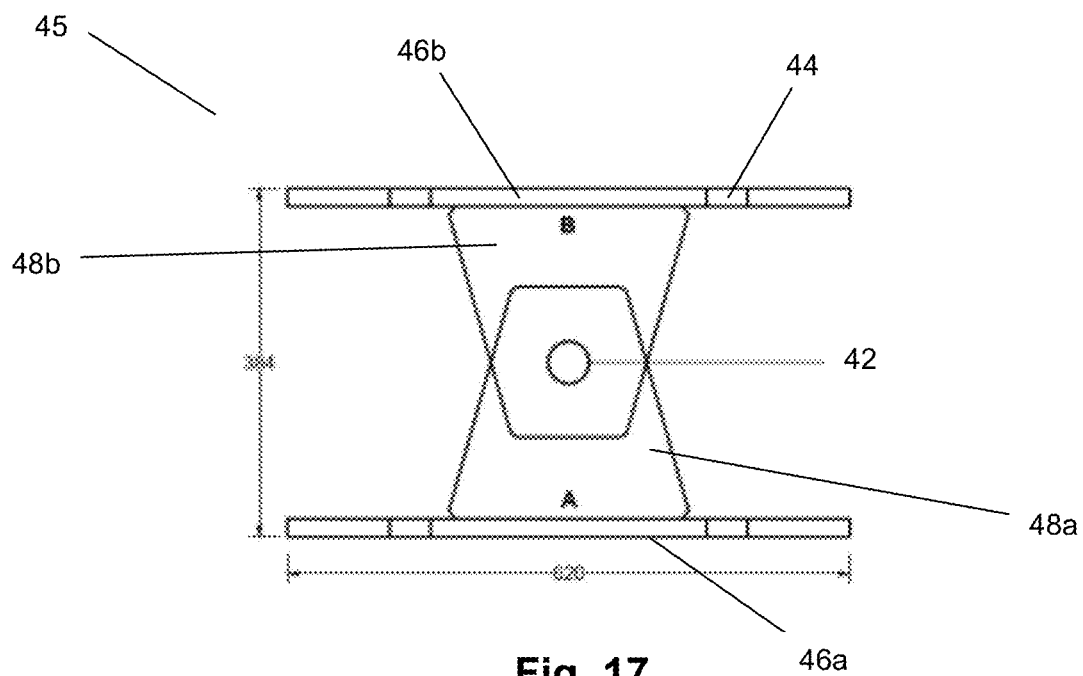


Fig. 16



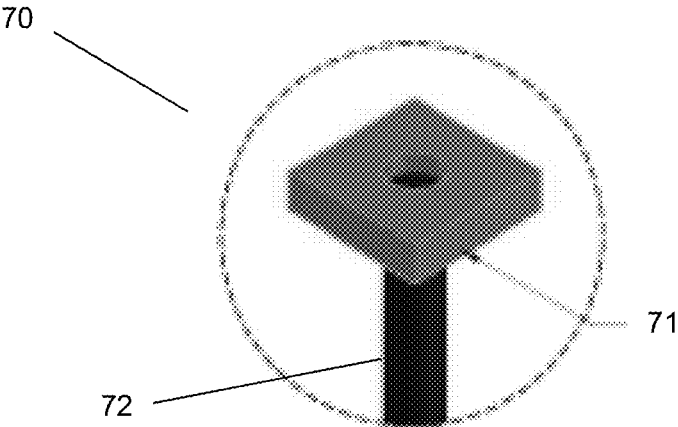


Fig. 19

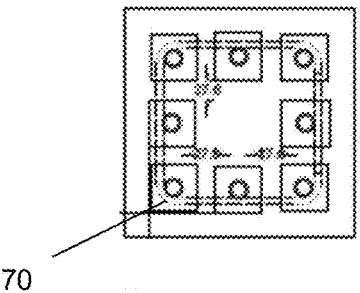


Fig. 20

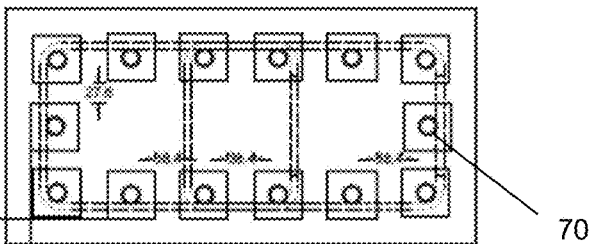


Fig. 21

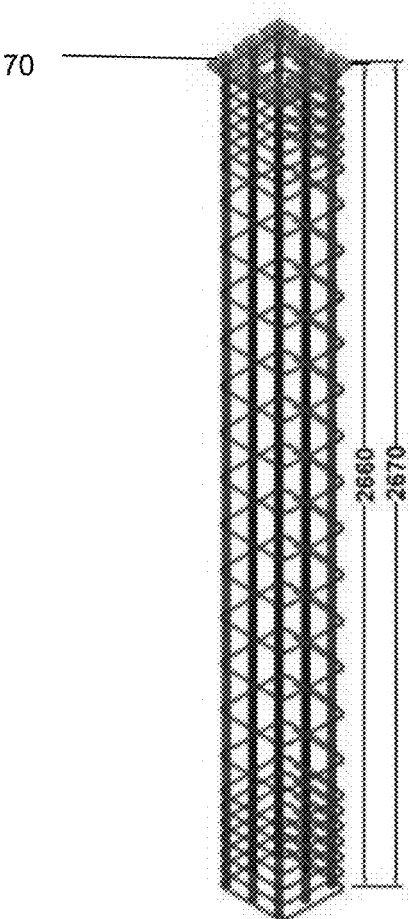


Fig. 22

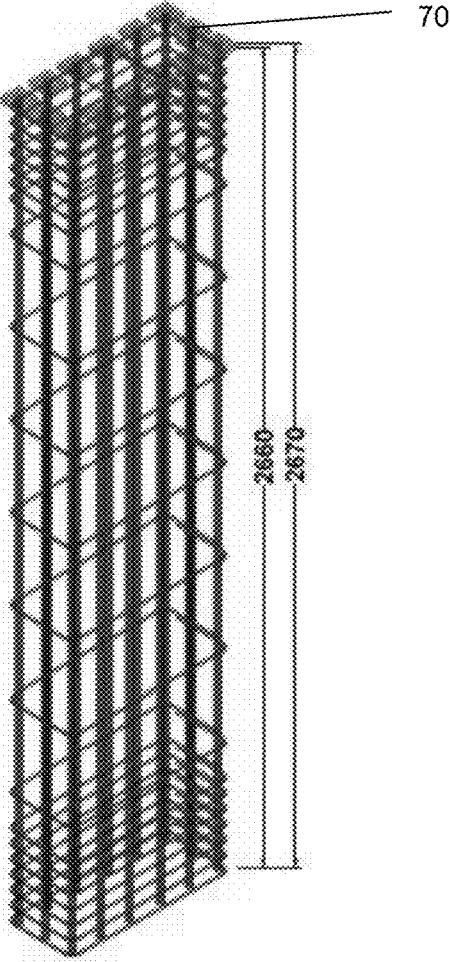


Fig. 23

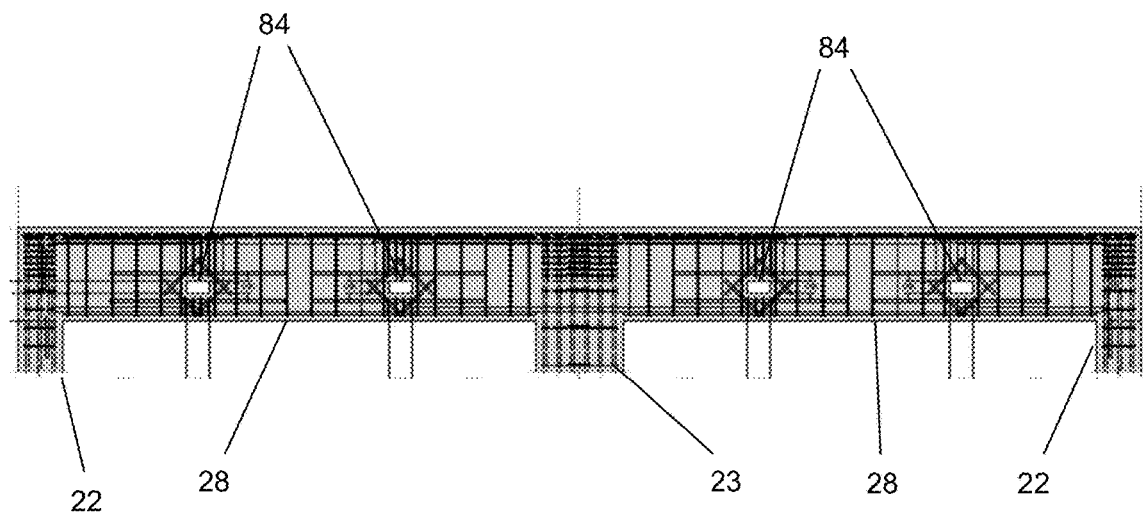


Fig. 24A

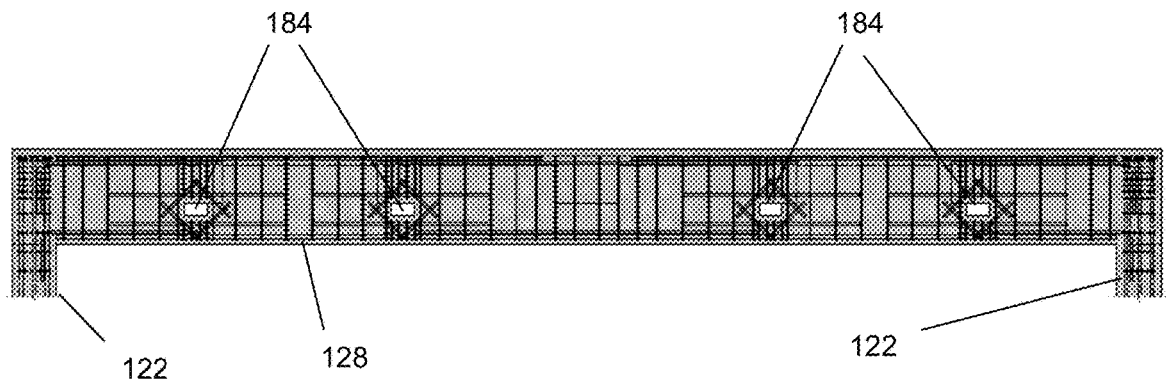


Fig. 24B

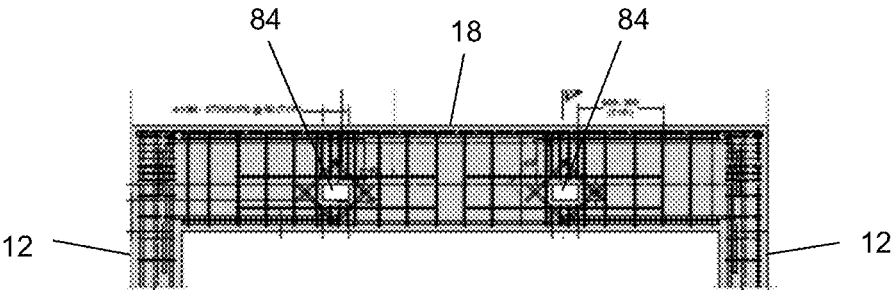


Fig. 25

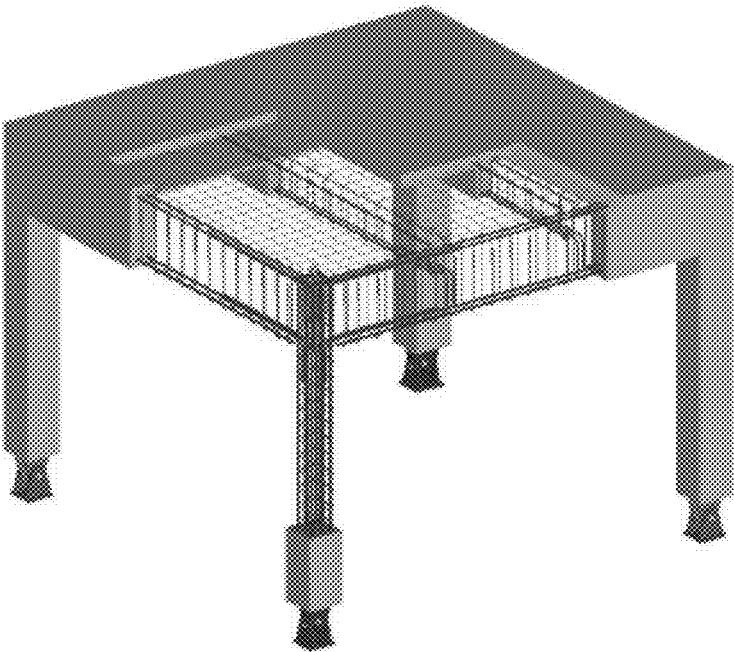


Fig. 26

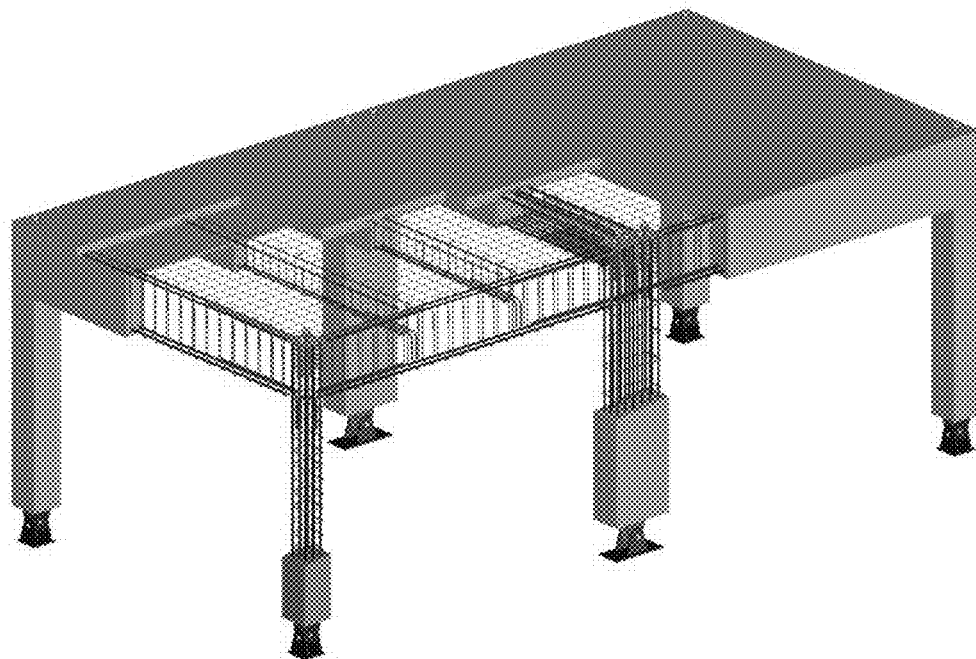


Fig. 27A

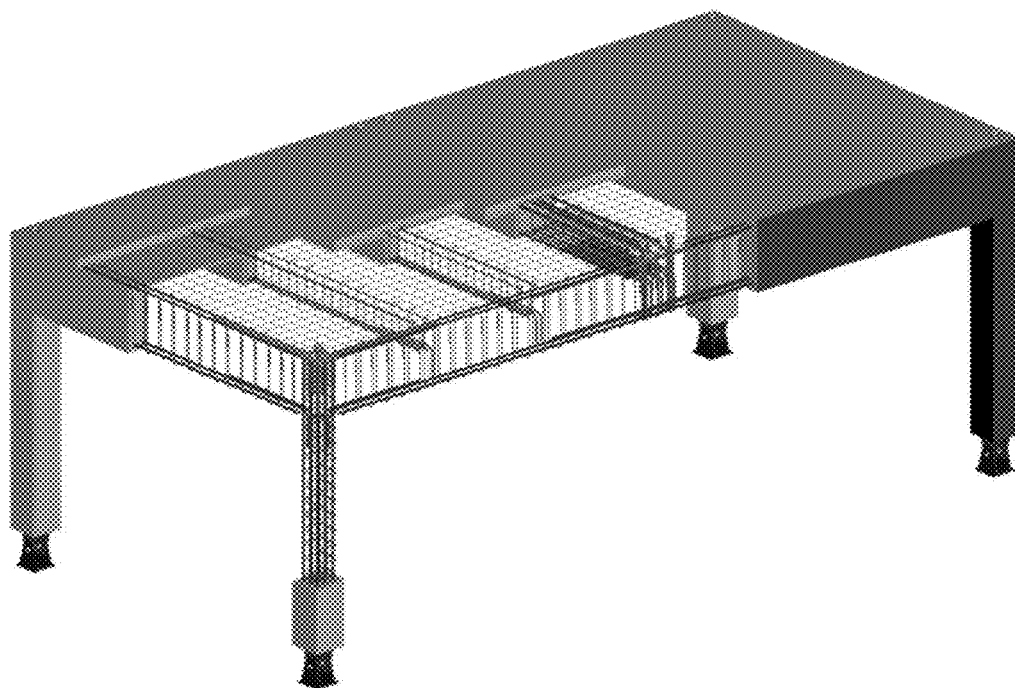


Fig. 27B

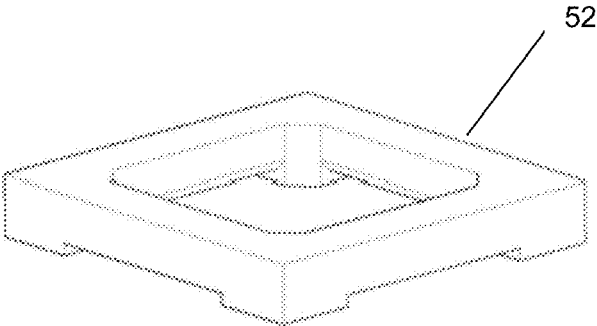


Fig. 28

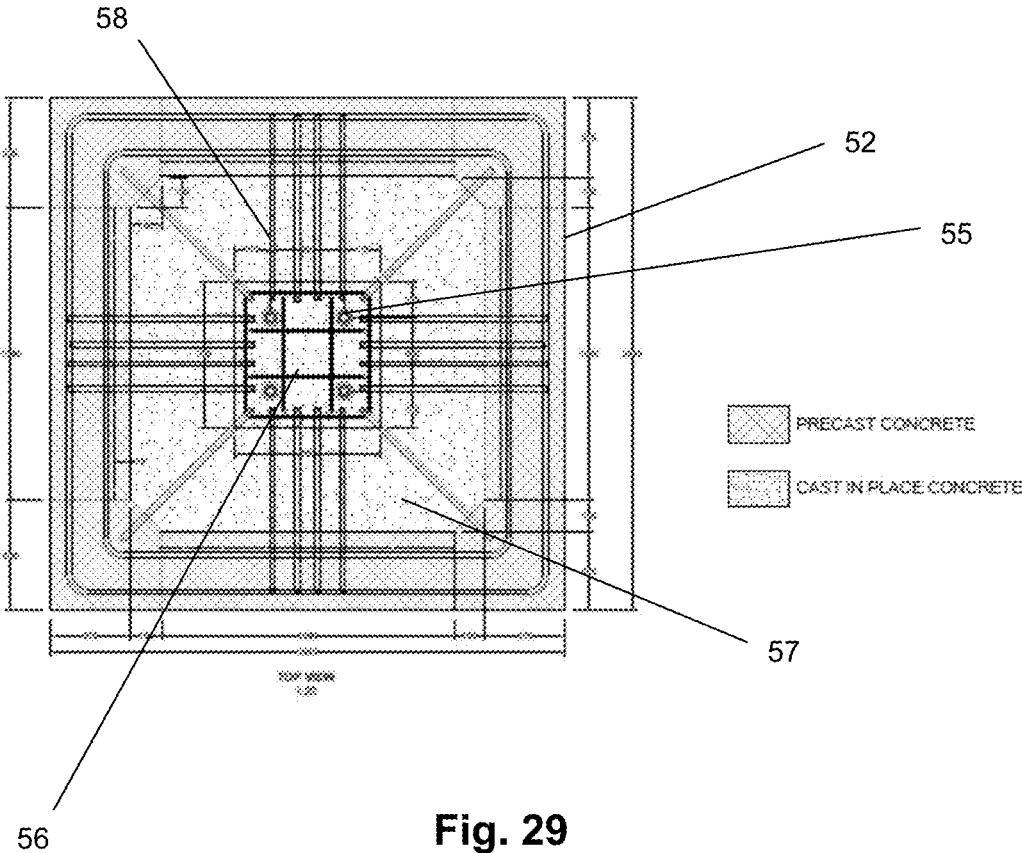


Fig. 29

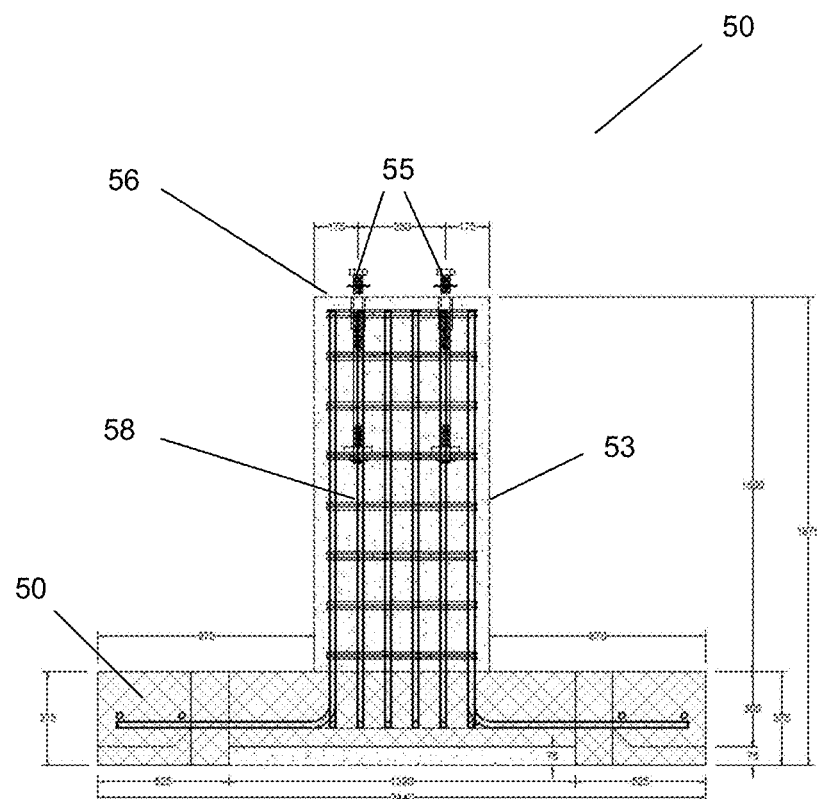


Fig. 30

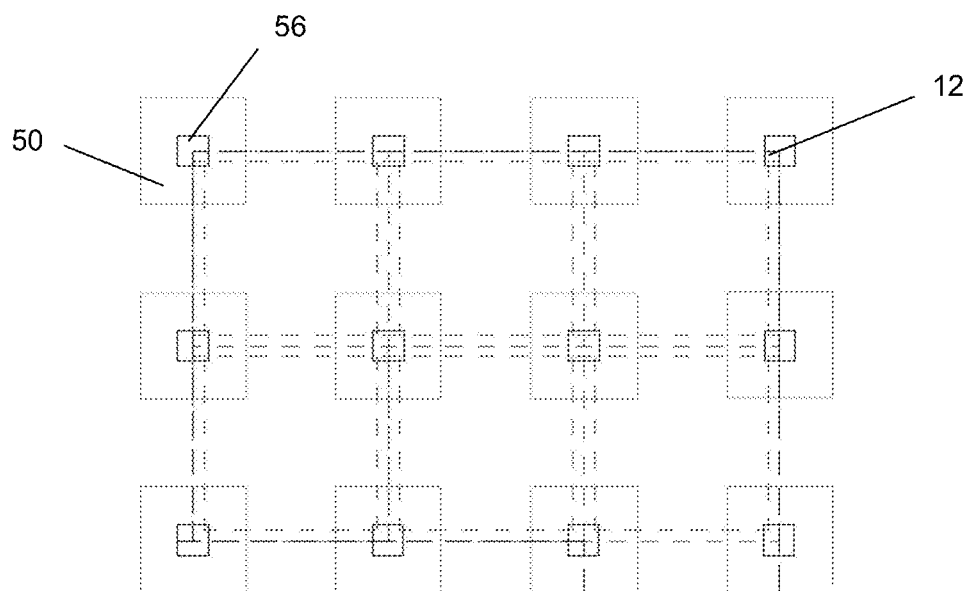


Fig. 31

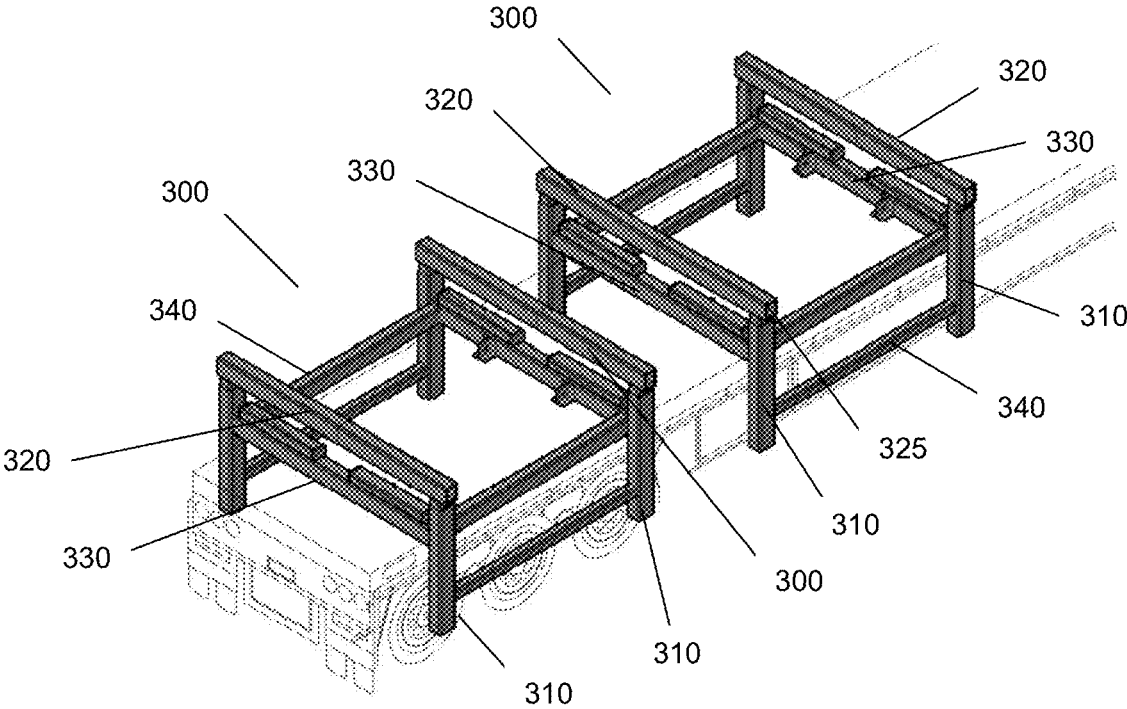


Fig. 32

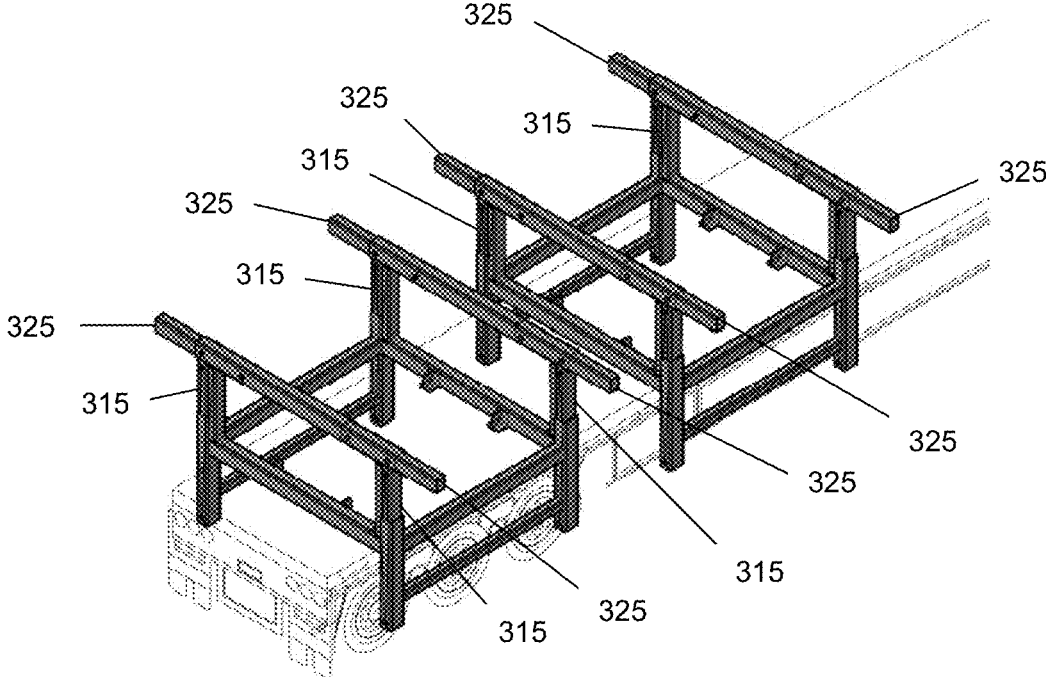


Fig. 33

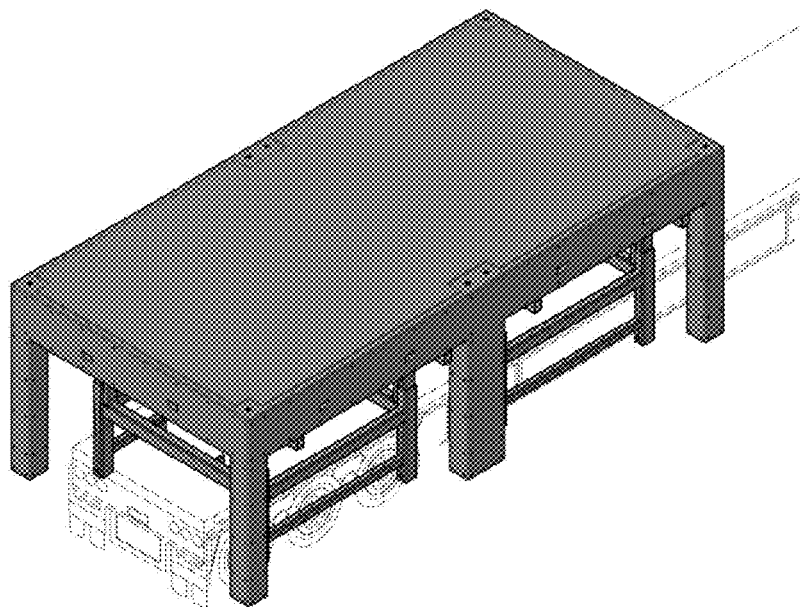


Fig. 34

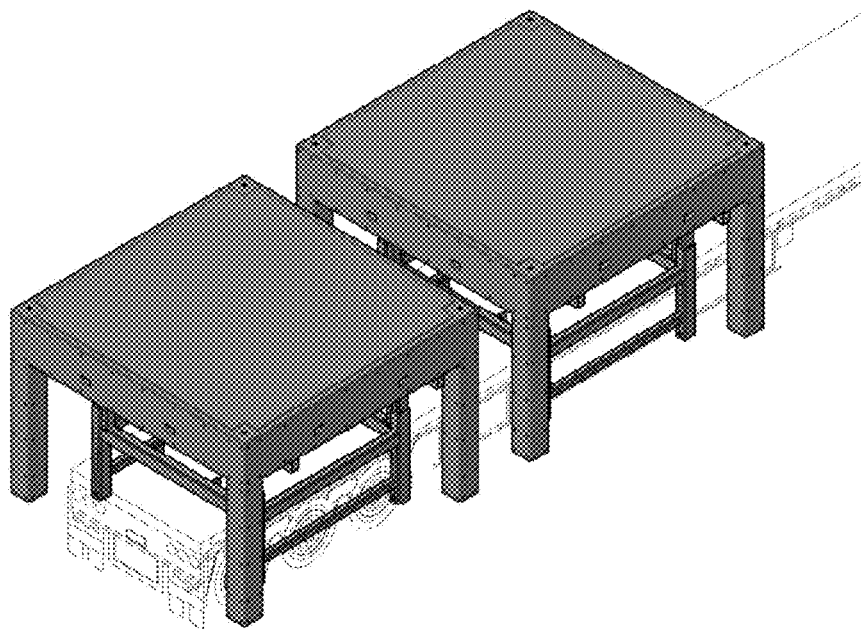


Fig. 35

**MODULE FOR USE IN PREPARING A
PREFABRICATED STRUCTURE, METHOD
FOR MANUFACTURING SAME AND
TRANSPORT FRAME**

FIELD OF THE INVENTION

[0001] The present invention pertains to the field of prefabricated buildings and in particular to reinforced concrete modular structures.

BACKGROUND

[0002] WO 2018/174825A1 discloses a method for constructing a pre-fabricated pre-finished volumetric construction (PPVC) module for a building, the method comprising: (i) casting of concrete to form a body of the PPVC module, where the body of the PPVC module comprises one or more load-bearing columns and beams, and six walls including a roof that covers a top of the PPVC module; and (ii) substantially finishing an interior of the PPVC module before the PPVC module is transported to a site for assembly into a building.

[0003] U.S. Pat. No. 3,568,380 discloses a prefabricated building unit consisting of a prefabricated rectangular floor panel structure having prefabricated vertical load-bearing columns for attachment at each corner and at an intermediate region in the length of each side.

[0004] EP3498929A1 discloses a building module with a cuboid housing formed from a stackable, monolithic tubular body consisting of a concrete material, the four tubular walls of which form the floor, the ceiling and the side walls, wherein the door and the window are provided in the end walls.

[0005] Therefore there is a need for a modular system that provides great design flexibility for a habitable structure formed from one or more modules, while also being readily customizable and transportable.

[0006] This background information is provided to reveal information believed by the applicant to be of possible relevance to the present invention. No admission is necessarily intended, nor should be construed, that any of the preceding information constitutes prior art against the present invention.

SUMMARY OF THE INVENTION

[0007] An object of the present invention is to provide a module for use in preparing a prefabricated structure and method for manufacturing same. In accordance with an aspect of the present invention, there is provided a reinforced concrete module for use in preparing a prefabricated structure, the module comprising: a horizontal slab defining two opposing longitudinal edges, two opposing transversal edges, and four corners; four corner columns, each said corner column being located at a respective corner; and two longitudinal perimeter beams, each of said longitudinal perimeter beams extending downwardly from a respective longitudinal edges of the horizontal slab and extending between and connected to adjacent columns; two transversal perimeter beams, each of said transversal perimeter beams extending downwardly from the transversal edges of the horizontal slab and extending between and connected to adjacent columns; at least two transverse ribs located on an underside of the horizontal slab and extending between opposing longitudinal perimeter beams; an attachment ele-

ment located at the base of each said corner column, configured for attachment to a support surface; wherein the module is configured to rest on a support surface; wherein adjacent columns and respective bottom edges of the perimeter beams define an opening configured to receive a wall in-fill assembly; and wherein each of the horizontal slab, the corner columns, the perimeter beams and the transverse ribs are fabricated from rebar-reinforced concrete and the module is fabricated as a unitary body.

[0008] In accordance with another aspect of the present invention, there is provided a method for fabricating a reinforced concrete module, comprising the steps of: providing an array of rebar cages comprising a horizontal slab cage, four corner column cages, four perimeter beam cages, and at least two transversal rib cages; assembling the array into a rebar framework for a desired module configuration within a formwork, wherein the rebar framework and formwork are in an upside-down configuration; casting a concrete slurry into the formwork in a single pour; and allowing the concrete slurry to cure in the formwork for a period of time sufficient to form the reinforced concrete module.

[0009] In accordance with another aspect of the present invention, there is provided a transport frame configured to support one or more modules of the present invention on a transport vehicle, the transport frame comprising: first and second pairs of support legs, each of said support legs being vertically oriented and having a telescopic leg insert configured to extend out of the respective support leg in an upward direction; a first lateral bracing beam extending between each respective leg of said first pair of support legs; a second lateral bracing beam extending between each respective leg of said second pair of support legs; first and second longitudinal bracing beams extending between said first and second pairs of support legs; a first horizontal support beam extending between and attached to a top end of the telescopic leg inserts of the first pair of support legs; and a second horizontal support beam extending between and attached to a top end of the telescopic leg inserts of the second pair of support legs; the first and second horizontal support beams each comprising a telescopic arm insert configured to extend outwardly from each end of the respective support beams.

BRIEF DESCRIPTION OF THE FIGURES

[0010] FIG. 1 illustrates a perspective view of a half module in accordance with one embodiment of the invention.

[0011] FIG. 2 illustrates a plan view of a half module in accordance with one embodiment of the invention.

[0012] FIG. 3A illustrates a perspective view of a full module in accordance with one embodiment of the invention.

[0013] FIG. 3B illustrates a plan view of a full module in accordance with one embodiment of the invention.

[0014] FIG. 4A illustrates a perspective view of a full module in accordance with another embodiment of the invention.

[0015] FIG. 4B illustrates a plan view of a full module in accordance with another embodiment of the invention.

[0016] FIGS. 5A-G illustrate perspective views of different assembled and stacked configurations of modules, in accordance with embodiments of the invention.

[0017] FIG. 6A illustrates a partial perspective view of the end of a module having a slab opening, in accordance with one embodiment of the invention.

[0018] FIG. 6B is a plan view of the module of FIG. 6A, in accordance with one embodiment of the invention.

[0019] FIG. 7 illustrates a perspective view of an assembly of three modules, in accordance with embodiments of the invention, with an inset expanded view of the upper perimeter joint between adjacent modules.

[0020] FIG. 8 illustrates a partial perspective view of the reinforcement bar framework of a corner column, in accordance with one embodiment of the invention.

[0021] FIG. 9A illustrates a partial perspective view of the reinforcement bar framework of a central column, in accordance with one embodiment of the invention.

[0022] FIG. 9B illustrates a partial perspective view of the reinforcement bar framework at the point of connection between a central beam and a perimeter beam, in accordance with one embodiment of the invention.

[0023] FIG. 10 illustrates a cross-sectional view of a corner column, in accordance with one embodiment of the invention.

[0024] FIG. 11 illustrates a cross-sectional view of a central column, in accordance with one embodiment of the invention.

[0025] FIG. 12 illustrates a cross-sectional view of a T-beam, in accordance with one embodiment of the invention.

[0026] FIG. 13 illustrates a cross-sectional view of a perimeter beam, in accordance with one embodiment of the invention.

[0027] FIG. 14 illustrates a cross-sectional view of a central beam, in accordance with one embodiment of the invention.

[0028] FIG. 15 illustrates a side view of a corner column connector assembly, in accordance with one embodiment of the invention.

[0029] FIG. 16 illustrates a perspective view of a corner column connector assembly, in accordance with one embodiment of the invention.

[0030] FIG. 17 illustrates a side view of a central column connector assembly, in accordance with one embodiment of the invention.

[0031] FIG. 18 illustrates a perspective view of a central column connector assembly, in accordance with one embodiment of the invention.

[0032] FIG. 19 illustrates perspective views of the end of a headed bar, in accordance with embodiments of the invention.

[0033] FIG. 20 illustrates an end view of a corner column, in accordance with one embodiment of the invention.

[0034] FIG. 21 illustrates an end view of a central column, in accordance with one embodiment of the invention.

[0035] FIG. 22 illustrates a perspective view of the reinforcement bar framework of a corner column, in accordance with one embodiment of the invention.

[0036] FIG. 23 illustrates a perspective view of the reinforcement bar framework of a central column, in accordance with one embodiment of the invention.

[0037] FIG. 24A illustrates a side view of the reinforcement bar framework of the longitudinal side of a full module, in accordance with one embodiment of the invention.

[0038] FIG. 24B illustrates a side view of the reinforcement bar framework of the longitudinal side of a full module, in accordance with another embodiment of the invention.

[0039] FIG. 25 illustrates a side view of the reinforcement bar framework of the transversal side of a module, in accordance with one embodiment of the invention.

[0040] FIG. 26 illustrates a perspective view of a half module, with partial cutaways to show the reinforcement bar framework, in accordance with one embodiment of the invention.

[0041] FIG. 27A illustrates a perspective view of a full module, with partial cutaways to show the reinforcement bar framework, in accordance with one embodiment of the invention.

[0042] FIG. 27B illustrates a perspective view of a full module, with partial cutaways to show the reinforcement bar framework, in accordance with another embodiment of the invention.

[0043] FIG. 28 illustrates a perspective view of a precast portion of a concrete footing assembly, in accordance with one embodiment of the invention.

[0044] FIG. 29 illustrates a top plan view of a footing assembly, in accordance with one embodiment of the invention.

[0045] FIG. 30 illustrates a side view of a footing assembly, in accordance with one embodiment of the invention.

[0046] FIG. 31 illustrates a footing plan, in accordance with one embodiment of the invention.

[0047] FIG. 32 illustrates a perspective view of a transport frame in a contracted configuration, in accordance with one embodiment of the invention.

[0048] FIG. 33 illustrates a perspective view of a transport frame in an extended configuration, in accordance with one embodiment of the invention.

[0049] FIG. 34 illustrates a perspective view of a transport frame loaded with a full module, in accordance with one embodiment of the invention.

[0050] FIG. 35 illustrates a perspective view of a transport frame loaded with two half modules, in accordance with one embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0051] As used herein, the term “about” refers to a $\pm 10\%$ variation from the nominal value. It is to be understood that such a variation is always included in a given value provided herein, whether or not it is specifically referred to.

[0052] Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs.

[0053] The present invention provides a reinforced, pre-cast concrete module suitable for use in constructing a habitable structure. The module is manufactured using pre-cast standard Portland cement construction with steel rebar reinforcement, and has a basic structural design of a ceiling/roof slab on columnar supports. In a preferred embodiment, the module is fabricated as a unitary body.

[0054] In a preferred embodiment, the module is pre-cast in a factory and transported on existing roads/highways by conventional flat-bed tractor-trailer to the site of assembly into the final structure.

[0055] In accordance with the present invention, the module can be provided as a rectangular full module or as a square half module, both of which can be positioned, interconnected and/or vertically stacked in any combination to form many different single or multi-storey configurations.

[0056] In a preferred embodiment, the module comprises a horizontal concrete slab defining two opposing longitudinal edges, two opposing transversal edges, and four corners, and four corner columns located at respective corners of the horizontal slab. The horizontal slab forms the roof of a single storey structure, while also serving as the floor of an upper storey in a stacked configuration.

[0057] In one embodiment, as shown in FIG. 1, the module is a square half module comprising a horizontal concrete slab wherein the longitudinal edges are the same length as the transversal edges.

[0058] In another embodiment, as shown in FIG. 3, the module is a rectangular full module, wherein the longitudinal edges are twice as long as the transversal edges. The rectangular module, in addition to the four corner columns located at respective corners of the horizontal slab, further comprises two central columns, wherein the central columns are located at a midpoint in each respective longitudinal edge.

[0059] In accordance with the present invention, the two basic module configurations (full module and half module) can be combined to provide access to an array of structural design configurations. The 2:1 ratio of length to width enables multiple modules to be arranged in a variety of abutting and stacked relationships, providing architectural design flexibility.

[0060] Accordingly, in a preferred embodiment, multiple pre-cast modules can be assembled together to form a larger structure comprising multiple stacked units. FIGS. 5A-G illustrate exemplary configurations that can be achieved using a combination of half and full modules of the present invention, including parallel arrangements, perpendicular arrangements, stacked arrangements, and any combination thereof. Although stacked arrangements of up to 3 units in height are exemplified in the figures, the modules of the present invention have demonstrated load strength values that make them suitable for use in constructing structures of up to stacked 7 units.

[0061] In one embodiment, the modules (both half and full) are designed for transportation to the site for assembly into the final structure, without negatively impacting structural integrity and functionality. In a preferred embodiment, the length, width and height dimensions of a module are compatible with standard highway-class tractor trailer dimensions, enabling passage under a standard bridge for unimpeded highway transport.

[0062] In a preferred embodiment, the half module has a length that is equal to the width. In one embodiment, the length and width of the half module are of from about 2.5 m to about 7.0 m. In one embodiment, the half module has a length of about 4.5 m and a width of about 4.5 m.

[0063] In a preferred embodiment, the full module has a length that is twice the width. In one embodiment, the length of the full module is of from about 5.0 m to about 14 m, and the width is from about 2.5 m to about 7 m. In one embodiment, the full module has a length of about 9.0 m and a width of about 4.5 m.

[0064] In one embodiment, the height of the full and half modules is from about 3.15 m to about 3.45 m.

[0065] In one embodiment, the module of the present invention provides a reinforced concrete structure designed to weigh less than about 1 MT per square meter of living space. In one embodiment, the module of the present invention provides a reinforced concrete structure designed to weigh from about 0.6 MT to about 0.85 MT per square meter of living space. In one embodiment, the module of the present invention provides a reinforced concrete structure designed to weigh about 0.77 MT per square meter of living space.

[0066] In one embodiment, the module of the present invention provides a reinforced concrete structure designed to weigh less than about 3 MT per cubic meter of usable habitable space. In one embodiment, the module of the present invention provides a reinforced concrete structure designed to weigh from 0.18 MT to about 2.6 MT per cubic meter of usable habitable space. In one embodiment, the module of the present invention provides a reinforced concrete structure designed to weigh about 0.22 MT per cubic meter of usable habitable space.

[0067] In accordance with the present invention, to provide additional structural strength and torsional stability, the modules further comprise perimeter beams extending downwardly from the respective edges of the horizontal slab and extending between and connected to adjacent columns.

[0068] For a half module, the perimeter beams are provided as two longitudinal perimeter beams extending downwardly from respective longitudinal edges between and connected to adjacent columns, and two transversal perimeter beams extending downwardly from respective transversal edges between and connected to adjacent columns.

[0069] For a full module, the perimeter beams are provided as longitudinal perimeter beams extending downwardly from respective longitudinal edges, extending between and connected to adjacent corner and central columns, and two transversal perimeter beams extending downwardly from respective transversal edges between and connected to adjacent corner columns.

[0070] In accordance with the present invention, the modules further comprise at least two transverse ribs (or "T-beams") located on an underside of the horizontal slab and extending between and connected to opposing longitudinal perimeter beams.

[0071] The combination of transverse ribs on the underside of horizontal slab and the "skirt" formed by the perimeter beams located around the outer edge of horizontal slab provides flexural tolerance combined with strength and rigidity. The presence of the T-beams and perimeter beams therefore provides a reinforced concrete module having a high tolerance to torsional forces, without requiring the amount of reinforced concrete typically used to manufacture solid uniform slabs having similar strength as are known in the art.

[0072] FIG. 1 depicts a perspective view of a half module 10 in accordance with one embodiment, indicating the horizontal slab 15, and the relative relationships between four corner columns 12, lifting anchors 75 located at each corner of the horizontal slab, and connector assemblies 40, located at the foot of each corner column.

[0073] FIG. 2 depicts a plan view of a half module 10 in accordance with one embodiment, indicating the relative relationships between four corner columns 12, perimeter beams 17 and two transverse ribs 29.

[0074] FIG. 3A depicts a perspective view of a full module 20 in accordance with one embodiment, indicating the horizontal slab 25, and the relative relationships between four corner columns 22, central columns 23, lifting anchors 75 located at each corner of the horizontal slab, connector assemblies 40, located at the foot of each corner column, and central connector assemblies 45, located at the foot of each central column.

[0075] FIG. 3B depicts a plan view of a full module 20 in accordance with one embodiment, indicating the relative relationships between four corner columns 22, two central columns 23, perimeter beams 27, 28, central beam 26, and four transverse ribs 29.

[0076] FIG. 4A depicts a perspective view of a full module 120 in accordance with an alternative embodiment lacking central columns, the relative relationships between four corner columns 122, lifting anchors 75 located at each corner of the horizontal slab, and connector assemblies 40, located at the foot of each corner column.

[0077] FIG. 4B depicts a plan view of a full module 120 in accordance with one embodiment, indicating the horizontal slab 125, and the relative relationships between four corner columns 122, perimeter beams 127, 128, central beam 126, and four transverse ribs 129.

[0078] In one embodiment, the perimeter beam is provided to transfer load forces from the columns to the perimeter beams, transverse beams (ribs), and roof slab. In one embodiment, the perimeter beams are manufactured to a 30 inch (760 mm) depth, to achieve the required loading tolerances for a module having dimensions of 4.5 m by 9 m, which is a highly efficient size which can both be transported and give an 'optimal' living space.

[0079] In one embodiment, each perimeter beam is provided with openings (or service accesses) passing through to allow for utilities or infrastructure to be provided to the interior of the structure. In a preferred embodiment, the service accesses are provided at regularly spaced locations along the length of the beam. The regularly spaced openings ensure that the openings on adjacent modules are co-located to facilitate the passage between and sharing of utilities or infrastructure between multiple adjacent modules, regardless of relative configurations. In a preferred embodiment, the services accesses are incorporated at the point of manufacture of the module, thus eliminating the need to introduce access openings after the module has been manufactured, which can negatively impact the structural integrity of the concrete, leading to a reduction in the lifetime of the module. By providing service access openings at the time of manufacture, post-fabrication modifications can be avoided.

[0080] In one embodiment, for a half module, each transversal and longitudinal perimeter beam includes two service accesses located across its standard length, i.e., the side of a half structure. FIG. 25 depicts the reinforcing bar framework that may be used to form the longitudinal side of a full module, including service access openings 84, in accordance with one embodiment of the invention.

[0081] In one embodiment, for a full module, the longitudinal side of a full module carries four service accesses, and the transversal perimeter beam includes two service accesses. FIG. 24A depicts the reinforcing bar framework that may be used to form the longitudinal side of a half module, including service access openings 84, in accordance with one embodiment of the invention. The longitudinal side

of an alternative embodiment of a full module having no central columns is shown in FIG. 24B, which also indicates service access openings 184.

[0082] The number of service accesses can be modified as determined by the functional requirements of the final structure, within engineering requirements to maintain overall structural strength of the module.

[0083] The modules of the present invention can also be provided with an opening in the horizontal slab to accommodate structural features such as a staircase between storeys, skylights, elevators, mechanical services, or the like. In accordance with the present invention, the slab opening is located in the space between the module's beams. In one embodiment, the opening is located between a perimeter beam and an adjacent transversal rib (T-beam), as shown, for example, in FIGS. 6A and 6B. In one embodiment, the opening is located between a central beam and an adjacent transversal rib. In one embodiment, the opening is located between adjacent transversal ribs. FIGS. 6A and 6B depict the end of a module in accordance with one embodiment, having opening 34 to accommodate staircase 35.

[0084] FIG. 7 depicts an exemplary assembly of three modules, including the module of FIG. 6A. In the embodiments shown in FIGS. 6A and 7, the modules are provided with a vertical indentation 38 extending along the vertical face around the upper outer perimeter of each module. This indentation is provided to ensure a gap, or void 37, is formed between the upper perimeters of abutting modules. In accordance with one embodiment, the upper surface of the module is also provided with a horizontal indentation 39 extending along the horizontal face around the upper outer perimeter of each module. The void 37, shown in an expanded view in the inset of FIG. 7, together with horizontal indentation 39, provides an annular space that allows for the application of a sealing material between the joints of adjacent modules to provide an exterior seal against elements for external joints, or a seal between floor levels for stacked configurations. In one embodiment, the sealing material is a liquid-type sealant applied to fill the joint, a foam-type material packed into the joint, or a combination of the both.

[0085] The modules of the present invention provide structures that have a high ratio of open, habitable space relative to the volume occupied by the structural columns, without sacrificing the strength of the overall structure. The modules of the present invention can also be combined in a variety of different configurations formed from any combination of half and full modules, with or without slab openings, and with a wide range of customizable add-on features.

[0086] The reduced volume of the structural components of the module (i.e., the slab, columns and beams) relative to the available habitable space also leads to a reduction in the amount of cementitious materials required, which can result in a significant reduction in energy demands and life-cycle carbon footprint for manufacturing and transporting the module.

[0087] Each of the horizontal slab, corner and central columns, perimeter beams, center beams, and transverse ribs are formed from reinforced concrete. Exemplary cross-sectional views of these components are provided in FIGS. 10 to 14, including corner column (FIG. 10), central column (FIG. 11), transverse rib (FIG. 12), perimeter beam (FIG. 13) and central beam (FIG. 14). As shown in FIGS. 8 and 9, the

corner and central columns are each provided with cast-in connecting elements **60** at the foot of the columns, which are used to connect to respective connector assemblies **40**, **45** for connection to a supporting surface.

[0088] FIGS. **26**, **27A** and **27B** provide perspective views of embodiments of a half module (FIG. **26**) and full modules (FIGS. **27A** and **27B**) with partial cutaways to show the underlying reinforcement bar frameworks.

[0089] While the reinforcing bars (rebar) framework for the slab, perimeter beams, central beam, and transverse ribs is manufactured using standard rebar assembly methods, the columns are provided with a headed bar configuration to provide the necessary structural requirements, e.g., strength, while minimizing the use of concrete to satisfy these structural requirements i.e., minimizing column cross-section.

[0090] A headed bar **70** is formed by welding a square plate washer **71** to the end of the rebar **72** located at the top of the respective columns, as shown in FIG. **19**. The use of multiple headed bars **70** to form the circumference of the rebar frames for the respective column, as shown in FIGS. **20** and **21**, provides the necessary vertical strength in each column. By avoiding the need to bend the top of the rebar into an 'L' shape to provide the required strength in the vertical direction as is typically done in prior art reinforced concrete constructions, incursion of the bent rebar into central space of the column can be avoided. The use of the headed bars therefore also creates an open space in the centre of each column to accommodate the placement of a cast-in attachment element **60**, as shown in FIGS. **8** and **9A**.

[0091] As also shown in FIGS. **8** and **9A**, each column is also provided with cast-in connecting elements **60** at the top of the respective column. Lifting anchors **75** (not shown) can be removably attached to respective cast-in attachment element **60** at each corner upper surface and, when present, at the upper surface of the central columns. The lifting anchors are provided to facilitate the lifting of a module by a crane or the like, for transfer onto and off a transport, as well as for placement onto the site of the habitable structure.

[0092] FIG. **9B** shows cast-in connecting elements **60**, provided in a full module embodiment without the central columns.

[0093] The cast-in attachment element **60** may also be used to attach a connector assembly to the module. In accordance with one embodiment, the connector assembly comprises a top bracket attached to a top baseplate, a bottom bracket attached to a bottom baseplate, and a pin connecting the top and bottom brackets. A cast-in attachment element located at the foot of a respective column is attached to a connector assembly via bolted connection through a top baseplate of the connector assembly. The other of the baseplates of the connector assembly (i.e., the bottom baseplate) is in turn bolted to a corresponding surface to which the module is to be attached. Accordingly, a connector assembly located at the bottom of a module's column may be used to physically connect the module to the upper surface of a lower module if provided in a stacked configuration, or to a support surface if provided as a single or lower storey. FIGS. **15** and **16** depict a connector assembly suitable for use on a corner column, including top connector baseplate **41b**, bottom connector baseplate **41a**, top bracket **43b**, bottom bracket **43a**, pin **42** and bolt holes **44**. FIGS. **17** and **18** depict a connector assembly suitable for use on a central column, including top connector baseplate **46b**, bottom connector baseplate **46a**, top bracket **48b**, bottom bracket

48a, pin **42** and bolt holes **44**. The central column connector assembly is longer than the corner column connector assembly, and is provided with two bolt holes for attachment to two corresponding bolts on a supporting surface, as will be discussed below.

[0094] The pin connection of the connector assemblies depicted in FIGS. **15** to **18** is particularly suitable for use with the modular systems of the present invention. The connector assemblies are designed to limit moment transfer from one module to another or from a module to the support surface on which it rests, while also allowing flexibility in the module orientation when stacking vertically or adjacently.

[0095] In accordance with one embodiment, the connector assembly can be fastened in any orientation through a bolted connection to the bottom of a column and a respective supporting surface. This modular connection allows for a solution that can be adjusted for different vertical and horizontal configurations of attached units. In one embodiment, each connector assembly is rotated 90 degrees relative to the connector assembly installed on an adjacent column.

[0096] The use of the pin connection allows for the ready removal of the module for relocation without necessitating destructive steps that would damage the structural integrity of the individual modules.

[0097] In accordance with the present invention, the connector assembly attached to the foot of a column can be mounted on any suitable support surface, such as a concrete foundation slab or footing, or an upper surface of a lower module, for stacked configurations.

[0098] In a one embodiment, the support surface on which the module is placed is provided as a foundation footing assembly, as shown in FIGS. **28** to **30**. In such an embodiment, a connector assembly located at the foot of a module's column is used to connect to supporting surface **56** on footing post **53** of foundation footing assembly **50** by attachment to footing bolt(s) **55** extending upwardly from supporting surface **56**.

[0099] In a preferred embodiment, the footing assembly is provided as a precast hybrid foundation footing, fabricated at the manufacturing facility and transported to the site. The footing assembly comprises a pre-cast reinforced concrete base **52** as shown in FIG. **28**. Base **52** is formed as square concrete body, or frame, having a central opening. Rebar extends inwardly from the base and upwardly to form a framework for the footing post. In a preferred embodiment, form work functioning as mold for casting the footing post is also provided at the manufacturing facility. This assembly is transported to the installation site, where it is installed in the ground to provide a support surface for one or more modules. On site, additional concrete is cast in place within the mold form to provide a footing post having a desired height.

[0100] By carrying out the final casting step on site, it is easier to achieve an identical final height for each foundation footing, to allow level final placement of each module, regardless of variability of the ground receiving foundation footing assemblies. In one embodiment, the bottom surface of the footing assembly base **52** has a central concave section to facilitate level placement on uneven ground.

[0101] The use of the footing assembly comprising the combination of pre-cast base and cast in place post has the benefits of reducing the cost attributable to both time and materials usually resulting from on-site installation of a floor

slab. The footing assembly is also more easily transportable, due to its reduced size and weight.

[0102] In one embodiment, the footing assembly, comprising the concrete base and footing post, can be cast as a unitary body.

[0103] In a one embodiment, the method for fabricating a module of the present invention comprises the steps of providing a rebar framework, or cage, for each of the horizontal slab, corner columns, central columns, central beams, perimeter beams, transversal ribs, assembling the respective frameworks into the desired module configuration within a formwork prior to the concrete casting step, wherein the casting step is carried out while the formwork for the module is in an upside-down arrangement with the horizontal slab on the bottom and the columns pointing upward. Upside-down casting ensures the top surface of the module is smooth and of a good quality. In a preferred embodiment, the module is cast in a single pour.

[0104] In one embodiment, the formwork is provided with one or more bolt inserts to provide cast-in bolt inserts in the cast module. In one embodiment, the cast-in bolt inserts are provided on one or more externally facing surfaces of the corner and/or central columns, an upper surface of the horizontal slab, and/or a lower surface of the horizontal slab. In one embodiment, the cast-in bolt inserts are provided on all faces of the corner and central columns. In one embodiment, the cast-in bolt inserts are provided on all faces of the perimeter beams and the central beam. In one embodiment, the cast-in bolt inserts are provided on all faces of the transverse ribs. In one embodiment, the cast-in bolt inserts are provided in two rows on each face.

[0105] The cast-in inserts are provided to enable the attachment of decorative, structural or functional elements to the module. For example, bolt inserts located on exterior-facing surfaces of columns can be used to attach decorative elements. As another example, bolt inserts located on interior surfaces of the horizontal slab can be used to attach ceiling components, or to support utility or other infrastructure components.

[0106] The modules of the present invention are formed having an open space extending between adjacent columns. This open design provides lightweight modules suitable for transport to the site. The open space also provides the opportunity for design flexibility through the incorporation of different wall in-fill assemblies having a range of functional attributes.

[0107] In one embodiment, adjacent columns and respective bottom edges of the perimeter beams define an opening configured to receive a wall in-fill assembly. In one embodiment, the wall in-fill assembly is configured to receive one or more decorative elements, structural elements or functional elements. Bolt inserts located on the column surfaces facing the open space between adjacent columns facilitate attachment of the wall in-fill assembly.

[0108] For example, a wall in-fill assembly may be used to incorporate functional elements, such as a window unit, a door unit, wall panels, and insulation.

[0109] In one embodiment, the wall in-fill assembly is a prefabricated wall unit, which can be incorporated after fabrication of the basic module structure, either in factory or on-site, in the opening between columns to provide options for access, light, and heat/energy conservation and control.

[0110] In one embodiment, one or more wall in-fill assemblies are affixed to the pre-cast module at the manufacturing

facility, to be transported with structure to the site. In one embodiment, the wall in-fill assemblies are affixed to the module on site.

[0111] As noted earlier, upside-down casting of the module ensures the top surface of the module is smooth and of a good quality. The integrity of the roof surface is important to ensure resistance to the elements, including impermeability to water penetration. In a preferred embodiment, no coating or pre-treatment of the concrete surface is required to render the surface impermeable to water.

[0112] In one embodiment, the roof of the module can be adapted for rainwater retention and management, through the attachment of a frame to form a rooftop water catch basin. In one embodiment, the frame can be attached using cast-in attachment points located around the perimeter of the roof slab. In one embodiment, a means to control the outflow/discharge of collected water is incorporated, to allow the rooftop catch basin to function as a water management system, e.g., for irrigation or for use in greywater applications. By controlling the release of water from rooftop catch basins, the negative environmental impact of runoff water release directly into natural waters can be mitigated.

[0113] The impermeable nature of the roof also enables the roof surface to be used as a garden or growing space.

[0114] As mentioned previously, each module can be provided with removable lifting anchors attached to cast-in attachment elements on the upper surface of the horizontal slab adjacent each column. The lifting anchors are provided to facilitate the lifting of a module by a crane or the like, for transfer onto and off of a transport, as well as for placement onto the site of the habitable structure. In one embodiment, the removable lifting anchors are threaded into the cast-in attachment elements. In one embodiment, the half module employs four lift points and the full module employs eight lift points.

[0115] In one embodiment, the module is lifted by means of bolt-on lifting devices at the locations of the cast-in attachment elements. In one embodiment, the bolt-on lifting devices are bolting lifting plates.

[0116] The design of a module and its specific components, and the material selection for the module and its components, will ensure the resultant structure is recyclable, relocatable/portable, reusable, has high durability and longevity, lowest lifecycle cost and with net positive environmental impact through to end-of-life.

[0117] The modules of the present invention satisfy performance properties required to meet or exceed building codes for snow load, wind load, and earthquake as required for the Province of Ontario, while also maintaining structural integrity during transportation. In addition, a habitable structure constructed using one or more modules of the present invention is also compliant with these building codes.

[0118] In one embodiment of the invention, a transport frame configured to support a module on a transport vehicle is provided.

[0119] In use, the transport frame is secured to the flat bed of a transport vehicle. The transport vehicle (with the transport frame secured in place) can back under the modules. When in position, the transport frame can telescope into a lift position to lift the modules. The frame is lifted and lowered by hydraulic pressure.

[0120] Each transport frame has four support legs comprising a rearward pair and a forward pair, the support legs being connected by bracing beams extending therebetween. Each of the support legs has a telescopic leg insert extending vertically upward from its upper end. A hydraulic cylinder is provided inside each of the support legs to lift and lower the leg inserts.

[0121] Each transport frame also has two horizontal support beams, wherein one of the horizontal beams is attached to the upper ends of the leg inserts in the rearward pair of support legs, and the other of the horizontal beams is attached to the upper ends of the leg inserts of the forward pair of support legs.

[0122] The transport frame also has telescopic arm inserts extending horizontally from each end of the horizontal support beam. The leg and arm inserts are extended after the transport vehicle is backed into place under the modules to raise the module off the ground and to secure the module(s) in place during transport.

[0123] FIGS. 32 and 33 show an embodiment of transport frame 300 in different stages of deployment. Shown are support legs 310, horizontally oriented support beams 320, longitudinally oriented bracing beams 340 and lateral bracing beams 330. FIG. 32 shows the transport frame in a contracted configuration, and FIG. 33 shows the transport frame with telescopic arms 325 and telescopic leg inserts 315 in an extended configuration.

[0124] Once a module has been lowered into place for site installation, the leg and arm inserts are retracted to allow the transport vehicle adequate clearance to be able to pull out from under the modules.

[0125] In one embodiment, each transport vehicle will have two transport frames secured to the flat bed. In one embodiment, both transport frames can be lifted at the same time or separately to accommodate a full module (as shown in FIG. 34), a half module, or two half modules (as shown in FIG. 35).

[0126] The transport frame is designed to reduce/eliminate the requirement for a crane to load and offload the modules from the transport vehicle.

[0127] Further, it will be very useful for onsite staging. A crane is not required for loading of the modules onto the transport vehicle or and unloading upon delivery to the installation site. When a crane is on site, a transport vehicle can be used to facilitate delivery of the modules within the site area to a distance a crane can reach, saving mobilizing and de-mobilizing of the crane positions, which is very time consuming and costly (cranes can run upwards of \$8k to \$10k per day). This provides great cost and time efficiencies for installation of the modules. The lifting/lowering can take place within minutes which is considerably quicker and requires less effort than traditional staging works. This approach will further save the need for costly and heavily planned/timed deliveries to site on the day of install which is where most delays happen in construction processes.

[0128] In one embodiment, the support frame can also be used to facilitate setting the modules in place to form the first story of a building.

[0129] It is obvious that the foregoing embodiments of the invention are examples and can be varied in many ways. Such present or future variations are not to be regarded as a departure from the spirit and scope of the invention, and all

such modifications as would be obvious to one skilled in the art are intended to be included within the scope of the following claims.

We claim:

1. A reinforced concrete module for use in preparing a prefabricated structure, the module comprising:

a horizontal slab defining two opposing longitudinal edges, two opposing transversal edges, and four corners;

four corner columns, each said corner column being located at a respective corner; and

two longitudinal perimeter beams, each of said longitudinal perimeter beams extending downwardly from a respective longitudinal edges of the horizontal slab and extending between and connected to adjacent columns; two transversal perimeter beams, each of said transversal perimeter beams extending downwardly from the transversal edges of the horizontal slab and extending between and connected to adjacent columns;

at least two transverse ribs located on an underside of the horizontal slab and extending between opposing longitudinal perimeter beams; and

an attachment element located at the base of each said corner column,

configured for attachment to a support surface;

wherein the module is configured to rest on a support surface;

wherein adjacent columns and respective bottom edges of the perimeter beams define an opening configured to receive a wall in-fill assembly; and

wherein each of the horizontal slab, the corner columns, the perimeter beams and the transverse ribs are fabricated from rebar-reinforced concrete and the module is fabricated as a unitary body.

2. The module of claim 1, wherein the longitudinal edges are the same length as the transversal edges.

3. The module of claim 1, wherein the longitudinal edges are twice as long as the transversal edges.

4. The module of any one of claims 1 to 3, further comprising lifting anchors located at an upper surface of the horizontal slab adjacent each corner column.

5. The module of claim 1, further comprising:

two central columns, each said central column being located at a midpoint in each respective longitudinal edge, wherein the longitudinal edges are twice as long as the transversal edges; and

a central beam extending between the two central columns.

6. The module of claim 5, further comprising lifting anchors located on the upper surface of the horizontal slab adjacent each corner column and each central column.

7. The module of any one of claims 1 to 6, wherein the transverse ribs have a T-shaped cross-sectional profile.

8. The module of any one of claims 1 to 7, wherein the support surface is an upper surface of a horizontal slab of one or more additional modules.

9. The module of any one of claims 1 to 7, wherein the support surface is a base slab.

10. The module of any one of claims 1 to 7, wherein the supporting surface comprises pre-cast footings adapted to support the base of a respective column, wherein the pre-cast footing comprises:

a pre-cast reinforced concrete base formed as square concrete body,

a footing post extending upward from the concrete base and having an upper surface; and
four bolts extending from the upper surface of the footing post.

11. The module of claim **10**, wherein the concrete base and footing post of the pre-cast footing are cast as a unitary body.

12. The module of any one of claims **1** to **10** wherein the attachment element is a cast-in attachment element.

13. The module of claim **12**, wherein the cast-in attachment element is configured for attachment via a connector assembly to a corresponding attachment element on the supporting surface.

14. The module of claim **13**, wherein the connector assembly comprises a top bracket connected to a top connector baseplate and a bottom bracket connected to a bottom connector baseplate, wherein the top bracket and the bottom bracket are coupled via a pin connection.

15. The module of any one of claims **1** to **14**, further comprising one or more bolt inserts located on one or more externally facing surfaces of the corner and/or central columns, an upper surface of the horizontal slab, and/or a lower surface of the horizontal slab, wherein the bolt inserts are configured to receive structural or functional elements.

16. The module of any one of claims **1** to **15**, wherein the wall in-fill assembly is configured to receive one or more decorative elements, structural elements or functional elements, wherein the one or more structural elements or functional elements are selected from a window unit, a door unit, wall panels, and insulation.

17. The module of claim **16**, further comprising one or more bolt inserts located on an inner perimeter of the opening, wherein the bolt inserts are configured to receive the wall in-fill assembly.

18. The module of claim **15** or **17**, wherein the bolt inserts are cast-in bolt inserts.

19. The module of any one of claims **1** to **18**, further comprising external elements selected from decorative or insulating panels, railings, solar panels, wind turbines, water retention or management features.

20. The module of any one of claims **1** to **19**, wherein the perimeter beams further comprise service access openings of suitable size and shape to provide service access and/or to receive utility infrastructure.

21. The module of any one of claims **1** to **20**, wherein each corner column comprises a plurality of vertical rebar elements, each said vertical rebar element being a headed bar comprising a square plate washer welded at a top end of the respective vertical rebar element for connection to the slab.

22. The module of any one of claims **1** to **21**, further comprising a vertical indentation extending around an upper outer perimeter of each module.

23. The module of claim **22**, further comprising a horizontal indentation extending around the upper surface around the outer perimeter of each module.

24. The module of any one of claims **1** to **23**, further comprising sealing means configured to provide sealing engagement between adjacent modules upon installation.

25. The module of any one of claims **1** to **24**, wherein the module is sized for transport on a standard sized tractor trailer.

26. A method for fabricating a reinforced concrete module, comprising the steps of:

providing an array of rebar cages comprising a horizontal slab cage, four corner column cages, four perimeter beam cages, and at least two transversal rib cages;

assembling the array into a rebar framework for a desired module configuration within a formwork, wherein the rebar framework and formwork are in an upside-down configuration;

casting a concrete slurry into the formwork; and

allowing the concrete slurry to cure in the formwork for a period of time sufficient to form the reinforced concrete module.

27. The method of claim **26**, wherein the assembly of rebar cages further comprises two central column cages and a central beam cage.

28. The method of claim **26** or **27**, wherein the formwork further comprises one or more bolt inserts on an inner surface of the formwork.

29. The method of any one of claims **26** to **28**, wherein the casting step is carried out in a single pour.

30. A transport frame configured to support one or more modules as defined in any one of claims **1** to **25** on a transport vehicle, the transport frame comprising:

first and second pairs of support legs, each of said support legs being vertically oriented and having a telescopic leg insert configured to extend out of the respective support leg in an upward direction;

a first lateral bracing beam extending between each respective leg of said first pair of support legs;

a second lateral bracing beam extending between each respective leg of said second pair of support legs;

first and second longitudinal bracing beams extending between said first and second pairs of support legs;

a first horizontal support beam extending between and attached to a top end of the telescopic leg inserts of the first pair of support legs; and

a second horizontal support beam extending between and attached to a top end of the telescopic leg inserts of the second pair of support legs;

the first and second horizontal support beams each comprising a telescopic arm insert configured to extend outwardly from each end of the respective support beams.

31. The transport frame of claim **30**, wherein a hydraulic cylinder is provided inside each of the support legs to lift and lower the telescopic leg inserts.

32. The transport frame of claim **30** or **31**, wherein a hydraulic cylinder is provided inside each of the support beams to extend and retract the telescopic arm inserts.

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