

MODULAR BUILDING UNIT, MODULAR BUILDING AND METHOD OF ASSEMBLING THEREOF

Technical Field

5 **[0001]** Embodiments relate generally to a modular building unit, a modular building, a method of assembling a modular building unit and a method of assembling a modular building.

Background

10 **[0002]** Modular building construction, including modular prefabricated prefinished volumetric construction (PPVC), is a construction technique in which modules, modular building units or PPVC modules are built off-site and subsequently assembled on-site. The modules, modular building units or PPVC modules may include basic structures of a complete room, parts of a room, service units such as toilets or lifts, etc. The modules, modular building units or PPVC modules may also
15 be completed with internal finishes, fixtures and fittings. Such construction technique is gaining popularity as it provides for better quality control and increase in productivity. Dust and noise pollution may also be minimised on-site as most of the construction activities are done off-site. Site safety may also be improved as most of the construction activities are done off-site in a factory controlled environment.

20 **[0003]** In modular building construction, the modules, the modular building units or the PPVC modules are required to be structurally stable components. This is because, when they are assembled into a modular building, they would provide overall stability to the building structure. The modules, the modular building units or the PPVC modules are inter-connected, usually, at the corners of the respective
25 modules, modular building units or PPVC modules. The structural members (beams and columns) of the modules, the modular building units or the PPVC modules will usually meet at these corners. The structural stability of the modules, the modular building units or the PPVC modules is derived from the strength and stiffness of its structural members (beams and columns) and the fixity or rigidity of the joints –
30 where the beams and columns are interconnected.

[0004] Typically, the body structure of the modules, the modular building units and the PPVC modules can be constructed using either reinforced concrete or steel. Constructing the modules, the modular building units and the PPVC using only steel

may provide lighter modules that put lesser demand on crane capacity for lifting. However, steel modules, steel modular building units or steel PPVC modules do not have fire protection and have to be insulated separately. In addition, steel modules, steel modular building units or steel PPVC modules also need to be protected against corrosion. These involve cost and in some cases may not be practical.

[0005] On the other hand, the modules, the modular building units and the PPVC modules constructed using reinforced concrete are naturally fire protected. However, reinforced concrete modules, reinforced concrete modular building units and reinforced concrete PPVC modules are much heavier. To reduce the weight, the size of the concrete structural members (concrete beams and concrete columns) of the modules, the modular building units or the PPVC modules is usually kept to the minimum.

[0006] To construct a modular building, the modules, the modular building units and the PPVC modules are typically connected at the corners of the respective modules, modular building units or PPVC modules using connectors. The connectors are generally fabricated in steel and are fitted onto the respective modules, the modular building units and the PPVC modules on-site during the assembling of the modular building. Certain elements of the connectors may be embedded into the concrete at the corners of the respective modules, modular building units or PPVC modules. There can be practical issues with using existing connector, for example missing connectors, unsuitable connectors, misalignment during installation etc., which may delay the assembling process.

[0007] Accordingly, example embodiments seek to provide a modular building unit, a modular building, a method of assembling a modular building unit and a method of assembling a modular building that addresses at least some of the issues identified above.

Summary

[0008] According to various embodiments, there is provided a modular building unit including a concrete structure and a support framework embedded in the concrete structure to reinforce the concrete structure. A joint of the support framework may be configured to rigidly couple at least two frame members of the support framework

together. The joint of the support frame work may further be configured to connect the modular building unit with another modular building unit.

[0009] According to various embodiments, there is provided a modular building including the modular building unit as described according to the various
5 embodiments.

[0010] According to various embodiments, there is provided a method of assembling a modular building unit. The method may include providing a concrete structure and providing a support framework embedded in the concrete structure to reinforce the concrete structure. The joint of the support framework may be
10 configured to rigidly couple at least two frame members of the support framework together. The joint of the support frame work may further be configured to connect the modular building unit with another modular building unit.

[0011] According to various embodiments, there is provided a method of assembling a modular building. The method may include providing the modular
15 building unit as described according to the various embodiments.

Brief description of the drawings

[0012] In the drawings, like reference characters generally refer to the same parts
20 throughout the different views. The drawings are not necessarily to scale, emphasis instead generally being placed upon illustrating the principles of the invention. In the following description, various embodiments are described with reference to the following drawings, in which:

FIG. 1 shows a side view of a modular building unit with a cut out portion in
25 the top left corner according to various embodiments;

FIG. 2A shows a perspective view of a joint of the support framework embedded in the concrete structure of the modular building unit of FIG.1 according to various embodiments;

FIGS. 2B and 2C show a cross-sectional side view and a cross-sectional top
30 view of the joint of the support framework embedded in the concrete structure of the modular building unit according to various embodiments;

FIG. 2D shows an exploded view of the joint of the support framework of FIG. 2A according to various embodiments;

FIGs. 3A to 3E show a sequence of forming the modular building unit according to various embodiments;

FIG. 4 shows a side view of a modular building unit with a cut out portion in the bottom left corner according to various embodiments;

5 FIG. 5A shows a perspective view of a joint of the support framework embedded in the concrete structure of the modular building of FIG. 4 according to various embodiments;

10 FIGs. 5B and 5C show a cross-sectional side view and a cross-sectional top view of the joint of the support framework embedded in the concrete structure of the modular building unit according to various embodiments;

FIG. 5D shows an exploded view of the joint of the support framework of FIG. 5A according to various embodiments;

15 FIG. 6 shows a perspective view of a support column of a support framework embedded in a concrete structure of a modular building unit according to various embodiments; and

FIGs. 7A to 7D illustrate assembling of modular building units for side-to-side connections and top-down connections according to various embodiments.

Detailed description

20 **[0013]** Embodiments described below in context of the apparatus are analogously valid for the respective methods, and vice versa. Furthermore, it will be understood that the embodiments described below may be combined, for example, a part of one embodiment may be combined with a part of another embodiment.

25 **[0014]** It should be understood that the terms “on”, “over”, “top”, “bottom”, “down”, “side”, “back”, “left”, “right”, “front”, “lateral”, “side”, “up”, “down” etc., when used in the following description are used for convenience and to aid understanding of relative positions or directions, and not intended to limit the orientation of any device, or structure or any part of any device or structure. In addition, the singular terms “a”, “an”, and “the” include plural referents unless
30 context clearly indicates otherwise. Similarly, the word “or” is intended to include “and” unless the context clearly indicates otherwise.

[0015] For steel modules, steel modular building units or steel PPVC modules, the connectors for connecting the respective modules during assembling of modular

building may be integrated to the respective steel body with ease. However, this is not the case for reinforced concrete modules, reinforced concrete modular building units or reinforced concrete PPVC modules. This is because reinforced concrete involves embedding steel reinforcing bars (rebar) in the concrete before the concrete is set. For stability, corners of reinforced concrete modules, reinforced concrete modular building units or reinforced concrete PPVC modules where the beams and column meets have to be rigid. The rigidity may be achieved by providing the necessary anchorage steel reinforcements at the corners of the modules. However, before even considering embedding the connectors into the reinforced concrete modules, reinforced concrete modular building units or reinforced concrete PPVC modules, the corners/junctions of the modules where the beams and columns meet are already congested due to the strengthening done at these corners/junctions. As the corners are rather congested, the connectors and the steel reinforcement of the concrete members have to compete for space if one wishes to embed the connectors or elements of the connectors into the concrete. This generally leads to poor construction. As a result, the connectors may be a mere addition to the concrete and may be at the expense of the steel reinforcement thus compromising the rigidity and strength at the corners. Accordingly, the connectors may affect the structural stability of the module while trying to fulfill the role for connection during assembling.

[0016] Various embodiments seek to provide a hybrid reinforced concrete module, reinforced concrete modular building unit or reinforced concrete PPVC module that addresses the issue of congestion and poor construction at the corner. According to various embodiments, the corners of the reinforced concrete modules, reinforced concrete modular building units or reinforced concrete PPVC modules in which the embedded support beams and embedded support columns meet may be configured to serve as the inter-module connector as well as the connectors for the embedded support beams and embedded support columns, which may be made of steel. In doing so, the issue of congestion and poor construction may be overcome. Such reinforced concrete modules, reinforced concrete modular building units or reinforced concrete PPVC modules may also enable stronger inter-module connections with better overall structural stability.

[0017] FIG. 1 shows a side view of a modular building unit 100 with a cut out portion in the top left corner 102 according to various embodiments. As shown, the

modular building unit 100 may include a concrete structure 110. The concrete structure 110 may include a wall, a pillar, a floor, a ceiling, a partition or any parts or combination of parts of the modular building unit 100. The modular building unit 100 may further include a support framework 120, which is partially shown in the cut out
 5 portion in the top left corner 102 and represented by dotted lines in the rest of the concrete structure 110 in FIG. 1. The support framework 120 may be embedded in the concrete structure 110 to reinforce the concrete structure 110. Accordingly, to form the modular building unit 100, the support framework 120 of the modular building unit 100 may be assembled and a mold may be placed around the support framework
 10 120 to enclose the support framework 120. Concrete may then be poured into the mold such that the concrete may be set with the support framework 120 embedded inside the concrete structure 110.

[0018] According to various embodiments, the support framework 120 may include a plurality of frame members. The plurality of frame members may include
 15 support columns, support beams, truss or any suitable support components. These support components may include reinforcing bar such as steel channel, steel rod, steel bar or mesh of steel wires. According to various embodiments, the support framework 120 may include a joint 150. The joint 150 of the support framework 120 may be configured to rigidly couple at least two frame members of the support framework
 20 120 together. Accordingly, the joint 150 of the support framework 120 may contribute to the stability and rigidity of the support framework 120 so as to reinforce and strengthen the concrete structure 110. According to various embodiments, the joint 150 may be further configured to connect the modular building unit 100 to another modular building unit. Accordingly, the joint 150 of the support framework 120 may
 25 additionally function as a connector to connect the modular building unit 100 to another modular building unit for assembling a modular building. Advantageously, the joint 150 of the support framework 120 may serve dual purposes for inter-unit connections between the modular building units as well as intra-member connections between the frame members of the support framework 120 without compromising the
 30 strengthening and reinforcing effect provided by the joint 150 of the support framework 120 to the concrete structure 110. Further, the joint 150 may provide immediate vertical and horizontal rigidity between the assembled modular building units right after assembling.

[0019] According to various embodiments, the joint 150 may be configured to couple the at least two frame members of the support framework 120 such that they are at an angle relative to each other. For example, the at least two frame members of the support framework 120 may be coupled such that they are orthogonal to each other. According to various embodiments, the at least two frame members of the support framework 120 may include a support column 156 and a support beam 158 (see FIG. 2B) which are coupled to the joint 150 such that they are substantially perpendicular to each other.

[0020] According to various embodiments, the joint 150 of the support framework 120 may be integral with one of the at least two frame members of the support framework 120 being coupled together. Accordingly, the joint 150 may be a separate component that may be so fixedly attached and integrated to the one of the at least two frame members such that the joint 150 may become an integral part of the one of the at least two frame members. For example, the joint 150 may be welded to an end of the one of the at least two frame members. According to various embodiments, the joint 150 may also be integrally formed with the one of the at least two frame members.

[0021] Referring to FIG.1, the joint 150 of the support framework 120 may be disposed at a corner of the concrete structure 110. In this configuration, the joint 150 may connect the modular building unit 100 to the other modular building unit at the corner of the concrete structure 110. Advantageously, this may allow flexibility in using the joint 150 either for side-to-side connection of the modular building unit 100 to another modular building unit or for top-down connection of the modular building unit 100 to another modular building unit.

[0022] FIG. 2A shows a perspective view of the joint 150 of the support framework 120 embedded in the concrete structure 110 according to various embodiments. FIG. 2B shows a cross-sectional side view of the joint 150 of the support framework 120 according to various embodiments. FIG. 2C shows a cross-sectional top view of the joint 150 of the support framework 120 according to various embodiments. FIG. 2D shows an exploded view of the joint 150 of the support framework 120 according to various embodiments.

[0023] As shown in FIG. 2A, the dotted lines represent part of the concrete structure 110. As shown, the joint 150 may include a body portion 152. The body

portion 152 may be a hollow tube section. The hollow tube section may have a rectangular cross-section, a square cross-section, or any suitable cross-section. The body portion 152 may comprises two metal channels 152a and 152b being placed together or integrated together to form the hollow tub section of the body portion 152, as shown in FIG. 2D. The metal channels may have a suitable cross-section, such as a U-shape, C-shape or any suitable shape. As shown in FIG. 2D, the metal channel may be a C-channel having a C-shape cross-section.

[0024] Referring to FIG. 2A, the joint 150 may include a coupling element 154 on the body portion 152. According to various embodiments, the coupling element 154 may be configured to couple the at least two frame members 156, 158 of the support framework 120 together (see FIGs. 2B and 2C). Accordingly, the joint 150 may couple the at least two frame members 156, 158 via the coupling element 154. As shown in FIGs. 2B and 2C, the at least two frame members may be a support column 156 and a support beam 158.

[0025] As shown in FIG. 2A, the support column 156 may include a metal channel 160 and the joint 150. According to various embodiments, the metal channel 160 and the body portion 152 of the joint 150 may be integrated together to form the support column 156 as a whole. For example, the metal channel 160 may be joined to the body portion 152 via welding or other suitable binding methods. According to various embodiments, the metal channel 160 and the body portion 152 of the joint 150 may also be integrally formed as one piece to form the support column 156. Accordingly, the body portion 152 of the joint 150 may be an end section of the support column 156.

[0026] As shown in FIG. 2A, the metal channel 160 may include an opening 162. The opening 162 may allow concrete to flow through such that, when setting the metal channel 160 in concrete, the concrete may intercross with the metal channel 160 so as to adhere the concrete to the metal channel 160. Further, as shown in FIG. 2B and 2C, steel rods 164 may be further tied to the support column 156 using steel wire 166 such that the steel rods 164 may further enhance the reinforcement provided by the support column 156.

[0027] As shown in FIG. 2A, the coupling member 154 may include an arm 168 extending from the body portion 152 of the joint 150. The arm 168 may be configured to be coupled to an end of the support beam 158. According to various embodiments,

the arm 168 may be fixedly attached or integrated to the body portion 152 of the joint 150 such that the arm 168 may be a rigid and integral part of the joint 150 for rigidly coupling the support beam 158 to the joint 150. For example, the arm 168 may be joined to the body portion 152 via welding or other suitable binding methods.

5 According to various embodiments, the arm 168 and the body portion 152 of the joint 150 may also be integrally formed as one piece.

[0028] In FIG. 2A, the arm 168 of the joint 150 is shown to be a C-channel having a C-shape cross-section. Advantageously, a C-channel may allow easy reinforcement lapping, accommodate support beam 158 and improve end connection. According to
10 various embodiments, the arm 168 may have a U-shape cross-section, a T-shape cross-section, a rectangular shape cross-section, a square shape cross-section or other suitable cross-section.

[0029] As shown in FIGs. 2B and 2C, the support beam 158 may include steel rods 170 received on an exterior surface of the arm 168 of the joint 150. The steel
15 rods 170 may be tied to the arm 168 via steel wires 172 so as to couple the steel rods 170, forming the support beam 158, to the arm 168 of the joint 150.

[0030] As shown in FIG. 2A, the joint 150 may further include an interlocking element 174. According to various embodiments, the interlocking element 174 may be configured to engage with a corresponding interlocking element of another
20 modular building unit. Accordingly, the interlocking element 174 may connect the modular building unit 100 to another modular building unit in a manner that prohibit relative movement between the respective modular building units. Further, the interlocking element 174 may also connect the modular building unit 100 to the other modular building unit such that the support framework 120 of the modular building
25 unit 100 may be interconnected to a support framework of the other modular building unit in order for the assembled modular building to have an interconnected overall support framework that strengthen the support for the assembled modular building.

[0031] As shown in FIG. 2A, the interlocking element 174 may include a protrusion 176 projecting from the body portion 152 of the joint 150. As shown, a top
30 plate 178 may be disposed on the body portion 152 of the joint 150. According to various embodiments, the top plate 178 may be fixedly attached or integrated to the body portion 152 of the joint 150 such that the top plate 178 may be a rigid and integral part of the joint 150. For example, the top plate 178 may be joined to the

body portion 152 via welding or other suitable binding methods. According to various embodiments, the top plate 178 and the body portion 152 of the joint 150 may also be integrally formed as one piece. The protrusion 176 may be disposed on the top plate 178 and may project away from the top plate 178. As shown, the protrusion 176 may project out of a surface 112 of the concrete structure of the modular building unit 100 such that the protrusion 176 may be inserted into a corresponding aperture of a corresponding interlocking element of another modular building unit. Accordingly, the protrusion 176 may serve as a guide for receiving the other modular building unit. According to various embodiments, the protrusion 176 may be a solid piece of material to minimize damage during on-site handling. According to various embodiments, the protrusion 176 may have a rectangular cross-section, a square cross-section, or any other suitable cross-section that may allow alignment.

[0032] According to various embodiments, each joint 150 may include two protrusions 176. Accordingly, the two protrusions 176 may provide moment resistance at the joint 150 of the modular building units 100.

[0033] As shown in FIG. 2A, the protrusion 176 may include a hole 182 extending from a distal end 184 of the protrusion 178 towards the body portion 152 of the joint 150. According to various embodiments, the hole 182 may extend into the body portion 152 of the joint 150. According to various embodiments, the hole 182 may include a fastening portion 186. The fastening portion 186 may be a portion of the hole 182 within the body portion 152 of the joint 150. Accordingly, the portion of the hole 182 in the protrusion 178 may guide a fastening element from the other modular building unit to be fastened with the fastening portion 186. As shown in FIG. 2D, a nut 188 may be fixedly attached or integrated to an underside of the top plate 178 and below the protrusion 176 such that the nut 188 may be aligned to the hole 182. Accordingly, the nut 188 may be contained inside the body portion 152 of the joint 150 when the top plate 178 is fixed onto a top of the body portion 152, and an inner cavity of the nut 188 may form part of the hole 182 that extends into the body portion 152. Further, in this configuration, the fastening portion 186 of the hole may also be an internal screw thread of the nut 188.

[0034] FIGs. 3A to 3E show a sequence of forming a modular building unit according to various embodiments. In FIG. 3A, the support framework 120 of the modular building unit may be assembled. As shown, the joint 150 of the support

framework 120 may couple the support column 156 and the support beam 158 of the support framework 120 together. The joint 150 may also include the interlocking elements 174 in the form of protrusions configured for engaging with corresponding interlocking elements of another modular building units. FIGs. 3B to 3C show an inner mold 307 being placed within the support framework 120 and defining in the interior of the modular building unit to be formed. FIGs. 3D to 3E show sections of an outer mold 309 being placed around the support framework 120 defining the exterior of the modular building unit to be formed and enclosing the support framework 120. Accordingly, the support framework 120 may be enclosed between the inner mold 307 and the outer mold 309. Subsequently, concrete may then be poured into the space between the inner mold 307 and the outer mold 309 such that the concrete may be set with the support framework 120 embedded inside the concrete structure defining the formed modular building unit.

[0035] FIG. 4 shows a side view of a modular building unit 400 with a cut out portion in the bottom left corner 403 according to various embodiments. As shown, the modular building unit 400 may include a concrete structure 410 similar to the concrete structure 110 of the modular building unit 100 in FIG.1. The modular building unit 400 may further include a support framework 420, which is partially shown in the cut out portion in the bottom left corner 403 and represented by dotted lines in the rest of the concrete structure 410 in FIG. 4. The support framework 420 may, similar to the support framework 120 of the modular building unit 100 of FIG. 1, be embedded in the concrete structure 410 to reinforce the concrete structure 310 and may include a plurality of frame members.

[0036] According to various embodiments, the support framework 420 may include a joint 451. The joint 451 of the support framework 420 may be configured to rigidly couple at least two frame members of the support framework 420 together. Accordingly, the joint 451 of the support framework 420 may contribute to the stability and rigidity of the support framework 420 so as to reinforce and strengthen the concrete structure. According to various embodiments, the joint 451 may be further configured to connect the modular building unit 400 to another modular building unit. Accordingly, the joint 451 of the support framework 420 may additionally function as a connector to connect the modular building unit 400 to another modular building unit for assembling a modular building. Advantageously,

the joint 451 of the support framework 420 may serve dual purposes for inter-unit connections between the modular building units as well as intra-member connections between the frame members of the support framework 420 without compromising the strengthening and reinforcing effect provided by the joint 451 of the support framework 420 to the concrete structure 410. Further, the joint 451 may provide immediate vertical and horizontal rigidity between the assembled modular building units right after assembling.

[0037] According to various embodiments, the joint 451 may be configured to couple the at least two frame members of the support framework 420 such that they are at an angle relative to each other. For example, the at least two frame members of the support framework 420 may be coupled such that they are orthogonal to each other. According to various embodiments, the at least two frame members of the support framework 420 may include a support column 456 and a support beam 459 (see FIG. 5B) which are coupled to the joint 451 such that they are substantially perpendicular to each other.

[0038] According to various embodiments, the joint 451 of the support framework 420 may be integral with one of the at least two frame members of the support framework 420 being coupled together. Accordingly, the joint 451 may be a separate component that may be so fixedly attached and integrated to the one of the at least two frame members such that the joint 451 may become an integral part of the one of the at least two frame members. For example, the joint 451 may be welded to an end of the one of the at least two frame members. According to various embodiments, the joint 451 may also be integrally formed with the one of the at least two frame members.

[0039] Referring to FIG.4, the joint 451 of the support framework 420 may be disposed at a corner of the concrete structure 410. In this configuration, the joint 451 may connect the modular building unit 400 to the other modular building unit at the corner of the concrete structure 410. Advantageously, this may allow flexibility in using the joint 451 either for side-to-side connection of the modular building unit 400 to another modular building unit or for top-down connection of the modular building unit 400 to another modular building unit.

[0040] FIG. 5A shows a perspective view of the joint 451 of the support framework 420 embedded in the concrete structure 410 according to various

embodiments. FIG. 5B shows a cross-sectional side view of the joint 451 of the support framework 420 according to various embodiments. FIG. 5C shows a cross-sectional top view of the joint 451 of the support framework 420 according to various embodiments. FIG. 5D shows an exploded view of the joint 451 of the support framework 420 according to various embodiments.

[0041] As shown in FIG. 5A, the dotted lines represent part of the concrete structure 410. As shown, the joint 451 may include a body portion 453. The body portion 453 may include a hollow box section. Advantageously, a fully closed up box section may enhance the joint 451 rigidity. The fully closed up box section may also easily accommodate external reinforcing bar and closed up links. The hollow box section may have a rectangular cross-section, a square cross-section, or any suitable cross-section. The body portion 453 may comprises two metal channels 453a, 453b, a base plate 453c and a top plate 453d being placed together or integrated together to form the hollow box section of the body portion 453, as shown in FIG. 4D. The metal channels may have a suitable cross-section, such as a U-shape, C-shape or any suitable shape. As shown in FIG. 4D, the metal channel may be a C-channel having a C-shape cross-section.

[0042] Referring to FIG. 5A, the joint 451 may include a coupling element 455 on the body portion 453. According to various embodiments, the coupling element 455 may be configured to couple the at least two frame members 456, 459 of the support framework 420 together (see FIGs. 5B and 5C). Accordingly, the joint 451 may couple the at least two frame members 456, 459 via the coupling element 455. As shown in FIGs. 5B and 5C, the at least two frame members may be a support column 456 and a support beam 459.

[0043] As shown in FIG. 5A, the support column 456 may include a metal channel 460 and the joint 451. According to various embodiments, the metal channel 460 and the body portion 453 of the joint 450 may be integrated together to form the support column 456 as a whole. For example, the metal channel 460 may be joined to the body portion 453 via welding or other suitable binding methods. According to various embodiments, the metal channel 460 and the body portion 453 of the joint 451 may also be integrally formed as one piece to form the support column 456. Accordingly, the body portion 453 of the joint 451 may be an end section of the support column 456.

[0044] As shown in FIG. 5A, the metal channel 460 may, similar to the metal channel 160 in FIG. 2A, include an opening 462. The opening 462 may allow concrete to flow through such that, when setting the metal channel 460 in concrete, the concrete may intercross with the metal channel 460 so as to adhere the concrete to the metal channel 460. Further, as shown in FIG. 5B and 5C, steel rods 464 may be further tied to the support column 456 using steel wire 466 such that the steel rods 464 may further enhance the reinforcement provided by the support column 456.

[0045] As shown in FIG. 5A, the coupling member 455 may include an arm 469 extending from the body portion 453 of the joint 451. The arm 469 may be configured to be coupled to an end of the support beam 459. According to various embodiments, the arm 469 may be fixedly attached or integrated to the body portion 453 of the joint 451 such that the arm 469 may be a rigid and integral part of the joint 451 for rigidly coupling the support beam 459 to the joint 451. For example, the arm 469 may be joined to the body portion 453 via welding or other suitable binding methods. According to various embodiments, the arm 469 and the body portion 453 of the joint 451 may also be integrally formed as one piece.

[0046] In FIG. 5A, the arm 469 of the joint 451 is shown to include two T-channels, each having a T-shape cross-section. The two T-channels may be arranged such that they are opposing each other. Advantageously, a T-channel may allow easy reinforcement lapping, accommodate support beam 459 and improve end connection. According to various embodiments, the arm 469 may have a C-shape cross-section, a U-shape cross-section, a T-shape cross-section, a rectangular shape cross-section, a square shape cross-section or other suitable cross-section.

[0047] As shown in FIGS. 5B and 5C, the support beam 459 may include steel rods 471 received on an outer surface of the arm 469 of the joint 451. The steel rods 471 may be tied to the arm 469 via steel wires 473 so as to couple the steel rods 471, forming the support beam 459, to the arm 469 of the joint 451.

[0048] As shown in FIG. 5A, the joint 451 may further include an interlocking element 475. According to various embodiments, the interlocking element 475 may be configured to engage with a corresponding interlocking element of another modular building unit. For example, the interlocking element 475 of the modular building unit 400 may engage with the interlocking element 174 of the modular building unit 100. Accordingly, the interlocking element 475 may connect the

modular building unit 400 to another modular building unit in a manner that prohibit relative movement between the respective modular building units. Further, the interlocking element 475 may also connect the modular building unit 400 to the other modular building unit such that the support framework 420 of the modular building unit 400 may be interconnected to a support framework of the other modular building unit in order for the assembled modular building to have an interconnected overall support framework that strengthen the support for the assembled modular building.

[0049] According to various embodiments, the interlocking element 475 may include a first aperture 477 in a first surface of the body portion 453 of the joint 451.

As shown in FIG. 5D, the first surface of the body portion 453 of the joint 451 may be the base plate 453c. Accordingly, the first aperture 477 may be in the base plate 453c. According to various embodiments, the first aperture 477 may be exposed through a surface 414 of the concrete structure of the modular building unit 400 such that the first aperture 477 may receive a corresponding protrusion of a corresponding interlocking element of another modular building unit. For example, the first aperture 477 may be configured to receive the protrusion 176 of the modular building unit 100 of FIG. 1A. In this manner, the first aperture 477 and the protrusion 176 may engage with each other so as to connect the modular building unit 100 to the modular building unit 300. According to various embodiments, the first aperture 477 may be shaped to conform with the cross-section of the corresponding protrusion of the other modular building unit to be received in the first aperture 477.

[0050] According to various embodiments, the interlocking element 475 may further include a second aperture 479 in a second surface of the body portion 453 of the joint 451. The second surface of the body portion 453 may be opposite the first surface of the body portion 453. As shown in FIG. 5D, the second surface of the body portion 453 of the joint 451 may be the top plate 453d. According to various embodiments, the second aperture 479 may be exposed through a cavity (see cavity 711 in FIG. 7C) in the concrete structure 410 of the modular building unit 400. Accordingly, a user may access to the second aperture 479 through the cavity of the concrete structure 410.

[0051] According to various embodiments, the interlocking element 475 may include two first apertures 477 and two second apertures 479.

[0052] According to various embodiments, the interlocking element 475 may include a fastening element 481 inserted through the second aperture 479. Accordingly, the fastening element 481 may be accessed via the cavity (see cavity 711 in FIG. 7C) of the concrete structure 410. The fastening element may include a bolt 483 inserted through the second aperture 479. Accordingly, when the protrusion 176 of the modular building unit 100 is received in the first aperture 477 of the modular building unit 400, the fastening element may be driven into the hole 182 of the protrusion 176 of the modular building unit 100 to tighten the connection between the joint 150 of the modular building unit 100 to the joint 351 of the modular building unit 300. According to various embodiments, having a preplaced fastening element 481 may reduce the cavity size for accessing the fastening element 481 and thus reduce the amount of grout required for post-filling the cavity after the modular building units are assembled. By having the fastening element 481 preplaced may also reduce the time required on-site for aligning or adjusting the fastening element 481 during tightening.

[0053] FIG. 6 shows a perspective view of a support column 656 of a support framework 620 embedded in a concrete structure 610 according to various embodiments. FIG. 6 shows a portion of the modular building unit 600.

[0054] According to various embodiments, the modular building unit 600 may include a support column 656 embedded in a concrete structure 610. The dotted lines in FIG. 6 represent part of the concrete structure 610. The support column 656 may be similar to the support column 156 of the modular building unit 100 and the support column 456 of the modular building unit 400. As shown, a first end (or a top end) 690 of the support column 656 may include a first joint 650 of the support framework 620. The first joint 650 may be similar to the joint 150 of the modular building unit 100. Accordingly, the first joint 650 may include a coupling element 654 that is similar to the coupling element 154 of the modular building unit 100. The first joint 650 may also include an interlocking element 674 that is similar to the interlocking element 174 of the modular building unit 100. Accordingly, the interlocking element 674 of the support column 656 may include a protrusion 676 that is similar to the protrusion 176 of the modular building unit 100 for inserting into a corresponding aperture of a corresponding interlocking element of another modular building unit.

[0055] Further, a second end (or a bottom end) 692 of the support column 656 may include a second joint 651 of the support framework 620. The second joint 651 may be similar to the joint 451 of the modular building unit 400. Accordingly, the second joint 651 may include a coupling element 655 that is similar to the coupling element 455 of the modular building unit 400. The first joint 651 may also include an interlocking element 675 that is similar to the interlocking element 475 of the modular building unit 400. Accordingly, the interlocking element 675 of the support column 656 may include a first aperture 677 and a second aperture 679 that are similar to the first aperture 477 and the second aperture 479 of the modular building unit 400.

[0056] According to various embodiments, the concrete structure 110, 410, 610 of the respective modular building units 100, 400, 600 may include a conduit (see conduits 713, 715 in FIG. 7C) or an opening in the respective concrete structure for grouting of voids in the respective joints of the respective support framework after connecting the respective modular building unit to another modular building unit.

[0057] According to various embodiments, the joint of the support structure may be at the corners of the modular building unit. According to various embodiments, the joint of the support structure may also be along an edge of the modular building unit. For example, the joint of the support structure may be at a mid-point of a top edge or a bottom edge of a wall of the modular building unit.

[0058] According to various embodiments, a modular building may include the modular building units according to the various embodiments. The modular building may further include a connection plate configured for side-to-side or sideways connections of the modular building units.

[0059] According to various embodiments, the modular building may include a plurality of modular building units stacked up to form the modular building. According to various embodiments, the modular building units forming the base layer of the modular building may only include joints similar to joints 150 of modular building unit 100 as shown in FIG. 2A. According to various embodiments, the modular building units forming the top layer of the modular building may only include joints similar to joints 451 of modular building 400 as shown in FIG. 5A. According to various embodiments, the modular building units forming the layers between the top layer and the bottom layer of the modular building may include a

support column, with a top joint and a bottom joint, similar to the support column 656 of the modular building unit 600 as shown in FIG. 6.

[0060] FIGs. 7A to 7D illustrate assembling of modular building units for side-to-side connections and top-down connections according to various embodiments. In FIG. 7A a top right corner of a first modular building unit 702 and a top left corner of a second modular building unit 704 are shown. To connect the first modular building unit 702 to the second modular building unit 704 in a side-to-side connection, a connection plate 798 may be used. As shown, the respective corners of the respective modular building units 702, 704 may include a joint similar to the joint 150 of the modular building unit 100 of FIG. 2A. As shown, the connection plate 798 may include through holes 799. Accordingly, the respective protrusions of the interlocking elements of the respective joints of the respective modular building units 702, 704 may be inserted through the through holes 799 of the connection plate 798 such that the connection plate 798 may link the modular building units 702, 704 in a sideway arrangement. According to various embodiments, the connection plate 798 may tie adjacent modular building units together. The through holes 799 may also be configured to accommodate the protrusions of the interlocking elements of the respective joints of the respective modular building units. The connection plate 798 may also be configured to accommodate shear and tensile force between the modular building units. The connection plate 798 may also be configured for levelling purposes during assembly of the modular building units.

[0061] FIGs. 7B to 7D further illustrate top-down connection. In FIG. 7B, a bottom right corner of a third modular building unit 706 and a bottom left corner of a fourth modular building unit 708 are further shown. The respective bottom corners of the third modular building unit 706 and the fourth modular building unit 708 may include a joint similar to the joint 451 of the modular building unit 400 as shown in FIG. 5A. Accordingly, the respective protrusions of the interlocking elements of the respective joints of the first and second modular building units 702, 704 may be received in the respective first apertures of the interlocking elements of the respective joints of the third and fourth modular building units 706, 708 for top-down connections of the respective modular building units. As shown in FIG. 7C, respective bolts 783 may then be driven into the respective holes of the protrusions of the interlocking elements of the respective joints of the first and second modular building

units 702, 704 to tighten the top-down connections. Subsequently, grout may be used to fill in the voids in the respective joints via conduits 715, 713 in the respective modular building units 706, 708. For example, cavity 711 in the concrete structure of the modular building units 706 and 708 for accessing the bolts may be filled with
 5 grout 717 via conduit 715. Further, the void in the box shaped joint of the support framework of the respective modular building units 706, 708 may be filled with grout via conduit 713.

[0062] According to various embodiments, there may be provided a modular building unit including a concrete structure and a support framework embedded in the
 10 concrete structure to reinforce the concrete structure. A joint of the support framework is configured to rigidly couple at least two frame members of the support framework together. The joint of the support framework is further configured to connect the modular building unit with another modular building unit.

[0063] According to various embodiments, the joint of the support framework
 15 may be integral with one of the at least two frame members of the support framework.

[0064] According to various embodiments, the at least two frame members may include a support column and a support beam.

[0065] According to various embodiments, the joint of the support framework may be at a corner of the concrete structure.

20 **[0066]** According to various embodiments, the joint may include a body portion and a coupling element on the body portion. The coupling element may be configured to couple the at least two frame members of the support framework together.

[0067] According to various embodiments, the body portion of the joint may be an end section of one of the at least two frame members.

25 **[0068]** According to various embodiments, the coupling element may include an arm extending from the body portion of the joint. The arm may be configured to be coupled to an end of another one of the at least two frame members.

[0069] According to various embodiments, the arm may include a C-shape cross-section, a U-shape cross-section, a T-shape cross-section, a rectangular shape cross-section or a square shape cross-section.
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[0070] According to various embodiments, the joint may further include an interlocking element. The interlocking element may be configured to engage with a corresponding interlocking element of the other modular building unit.

[0071] According to various embodiments, the interlocking element may include a protrusion projecting from the body portion of the joint. The protrusion may be configured to project out of a surface of the concrete structure of the modular building unit for inserting into a corresponding aperture of a corresponding interlocking element of the other modular building unit.

[0072] According to various embodiments, the protrusion may include a hole extending from a distal end of the protrusion towards the body portion of the joint.

[0073] According to various embodiments, the hole may include a fastening portion.

[0074] According to various embodiments, the interlocking element may include a first aperture in a first surface of the body portion of the joint. The first aperture may be exposed through a surface of the concrete structure of the modular building unit for receiving a corresponding protrusion of a corresponding interlocking element of the other modular building unit.

[0075] According to various embodiments, the interlocking element may include a second aperture in a second surface of the body portion of the joint, the second surface being opposite the first surface. The second aperture may be exposed through a cavity in the concrete structure of the modular building unit.

[0076] According to various embodiments, the interlocking element may include a fastening element inserted through the second aperture.

[0077] According to various embodiments, one of the at least two frame member of the support framework may include a support column. A first end of the support column may include a first joint of the support framework and a second end of the support column may include a second joint of the support framework.

[0078] According to various embodiments, each of the first joint and the second joint may include the joint as described according to the various embodiments.

[0079] According to various embodiments, the first joint may include the interlocking element similar to the interlocking element 174 of the modular building unit 100 of FIG. 2A.

[0080] According to various embodiments, the second joint may include the interlocking element similar to the interlocking element 475 of the modular building unit 400 of FIG. 5A.

[0081] According to various embodiments, the concrete structure may include openings or conduits for grouting of voids in the joint of the support framework after connecting the modular building unit to the other modular building unit.

[0082] According to various embodiments, there may be provided a modular building including the modular building unit as described according to the various embodiments.

[0083] According to various embodiments, the modular building may include a connection plate configured to connect the modular building unit to another modular building unit in a side-to-side arrangement.

[0084] According to various embodiments, there may be provided a method of assembling a modular building unit. The method may include providing a concrete structure and providing a support framework embedded in the concrete structure to reinforce the concrete structure. A joint of the support framework may be configured to rigidly couple at least two frame members of the support framework together. The joint of the support framework may be further configured to connect the modular building unit with another modular building unit.

[0085] According to various embodiments, the method may further include configuring the modular building unit according to the various embodiments.

[0086] According to various embodiments, there may be provided a method of assembling a modular building. The method may include providing the modular building unit according to the various embodiments.

[0087] According to various embodiments, the method may further include connecting the modular building unit to another modular building unit in a top-down arrangement via the joint of the supporting framework.

[0088] According to various embodiments, the method may further include providing a connection plate configured to connect the modular building unit to another modular building unit in a side-to-side arrangement.

[0089] Various embodiments have provided a modular building unit that is rigid and strong at its corners and can be connected to other modular building unit at the corners. Various embodiments have also provided a modular building unit in which the support framework may be interconnected to the support framework of other modular building unit when the modular building units are assembled to form a modular building. Accordingly, the resulting modular building may be stronger with

better stability as the respective support framework of the respective modular building units are connected to form an overall support structure for the modular building.

[0090] While the invention has been particularly shown and described with reference to specific embodiments, it should be understood by those skilled in the art
5 that various changes in form and detail may be made therein without departing from the scope of the invention as defined by the appended claims. The scope of the invention is thus indicated by the appended claims and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced.

Claims

1. A modular building unit comprising:
a concrete structure; and
5 a support framework embedded in the concrete structure to reinforce the concrete structure,
wherein a joint of the support framework is configured to rigidly couple at least two frame members of the support framework together, and
wherein the joint of the support framework is further configured to connect the
10 modular building unit with another modular building unit.
2. The modular building unit as claimed in claim 1, wherein the joint of the support framework is integral with one of the at least two frame members of the support framework.
- 15 3. The modular building unit as claimed in claim 1 or 2, wherein the at least two frame members comprises a support column and a support beam.
4. The modular building unit as claimed in any one of claims 1 to 3, wherein the
20 joint of the support framework is at a corner of the concrete structure.
5. The modular building unit as claimed in any one of claims 1 to 4, wherein the joint comprises:
a body portion; and
25 a coupling element on the body portion, the coupling element being configured to couple the at least two frame members of the support framework together.
6. The modular building unit as claimed in claim 5, wherein the body portion of
30 the joint is an end section of one of the at least two frame members.

7. The modular building unit as claimed in claim 5 or 6, wherein the coupling element comprises an arm extending from the body portion of the joint, the arm being configured to be coupled to an end of another one of the at least two frame members.
- 5 8. The modular building unit as claimed in claim 7, wherein the arm comprises C-shape cross-section, U-shape cross-section, T-shape cross-section, rectangular shape cross-section or square shape cross-section.
9. The modular building unit as claimed in any one of claims 5 to 8, wherein the
10 joint further comprises an interlocking element, the interlocking element being configured to engage with a corresponding interlocking element of the other modular building unit.
10. The modular building unit as claimed in claim 9, wherein the interlocking
15 element comprises a protrusion projecting from the body portion of the joint, the protrusion being configured to project out of a surface of the concrete structure of the modular building unit for inserting into a corresponding aperture of a corresponding interlocking element of the other modular building unit.
- 20 11. The modular building unit as claimed in claim 10, wherein the protrusion comprises a hole extending from a distal end of the protrusion towards the body portion of the joint.
12. The modular building unit as claimed in claim 11, wherein the hole comprises
25 a fastening portion.
13. The modular building unit as claimed in claim 9, wherein the interlocking element comprises a first aperture in a first surface of the body portion of the joint, and wherein the first aperture is exposed through a surface of the concrete structure of
30 the modular building unit for receiving a corresponding protrusion of a corresponding interlocking element of the other modular building unit.

14. The modular building unit as claimed in claim 13, wherein the interlocking element comprises a second aperture in a second surface of the body portion of the joint, the second surface being opposite the first surface, and wherein the second aperture is exposed through a cavity in the concrete structure of the modular building unit.

15. The modular building unit as claimed in claim 14, wherein the interlocking element comprises a fastening element inserted through the second aperture.

16. The modular building unit as claimed in claim 1 wherein one of the at least two frame member of the support framework comprises a support column, wherein a first end of the support column comprises a first joint of the support framework and a second end of the support column comprises a second joint of the support framework.

17. The modular building unit as claimed in claim 16, wherein each of the first joint and the second joint comprises the joint according to any one of claims 5 to 9.

18. The modular building unit as claimed in claim 17, wherein the first joint comprises the interlocking element according to any one of claims 10 to 12.

19. The modular building unit as claimed in claim 18, wherein the second joint comprises the interlocking element according to any one of claims 13 to 15.

20. The modular building unit as claimed in any one of claims 1 to 19, wherein the concrete structure comprises opening for grouting of voids in the joint of the support framework after connecting the modular building unit to the other modular building unit.

21. A modular building comprising the modular building unit according to any one of claims 1 to 20.

22. The modular building as claimed in claim 21, further comprising a connection plate configured to connect the modular building unit to another modular building unit in a side-to-side arrangement.
- 5 23. A method of assembling a modular building unit, the method comprises providing a concrete structure; and providing a support framework embedded in the concrete structure to reinforce the concrete structure, wherein a joint of the support framework is configured to rigidly couple at least two frame members of the support framework together, and wherein the joint of the support framework is further configured to connect the modular building unit with another modular building unit.
- 10 24. The method of claim 23 further comprising configuring the modular building unit according to any one of claims 1 to 20.
- 15 25. A method of assembling a modular building, the method comprising providing the modular building unit according to any one of claims 1 to 20.
- 20 26. The method as claimed in claim 25, further comprising connecting the modular building unit to another modular building unit in a top-down arrangement via the joint of the supporting framework.
- 25 27. The method as claimed in claim 25 or 26, further comprising providing a connection plate configured to connect the modular building unit to another modular building unit in a side-to-side arrangement.