

MODULAR BUILDING AND METHOD FOR CONSTRUCTING A MODULAR BUILDING

Technical Field

5 **[001]** Embodiments relate to a modular building and to a method for constructing a modular building.

Background

10 **[002]** Modular building construction, including modular prefabricated prefinished volumetric construction (PPVC), is a construction technique in which modules, modular units or PPVC modules are built off-site and subsequently assembled on-site. The modules, modular 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 units or PPVC modules may also be completed with internal finishes,
15 fixtures and fittings. Such construction technique is gaining popularity as it provides for better quality control and increased 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 **[003]** However, the current state of the art for modular building construction has several limitations. One of the limitations with modular building construction is that the height of the modular building is restricted by the structural strength of the modules, modular units or PPVC modules used for the modular building, and the strength of the connections between the modules, modular units or PPVC modules.
25 The modules, modular units or PPVC modules may include load bearing members, in

addition to the finishes such as floorings, ceilings, partitions, cabinets, etc. Generally, a modular building may be constructed by assembling or stacking layers of the modules, modular units or PPVC modules one layer after another. In such a modular building, each layer of module, modular units or PPVC modules is required to support the loads from the layers of modules, modular units or PPVC modules on top of that layer.

[004] To build a tall modular building, the modules, modular units or PPVC modules of the lower layers of the modular building are required to have strong loading bearing members to support the loads of the layers of modules, modular units or PPVC modules above, in addition to the strong connections between the modules, modular units or PPVC modules. Typically, load bearing members are manufactured with larger dimensions in order to provide the necessary support. However, this would compromise on the spaces, thus yielding smaller usable spaces within the modules, modular units or PPVC modules which would be contrary to the purpose of modular building.

[005] Another limitation of the modular building construction is that overall structural instability will occur if one of the modules or its load bearing member is removed. The removal of the modules or its load bearing member can happen in the event of accidents and this jeopardizes the safety of the whole building. This condition becomes more critical with taller modular buildings.

[006] Example embodiments provide a modular building and a method for constructing a modular building that seek to address at least some of the issues identified above.

Summary

[007] According to various embodiments, there is provided a method for constructing a modular building, including providing at least two frame elements on a base for accommodating one or more modular building units therebetween, and
5 suspending at least one frame beam between the two frame elements for distributing a load generated by one or more further modular building units supported on the at least one frame beam via the at least two frame elements.

[008] According to various embodiments, there is provided a modular building
10 including a base, at least two frame elements on the base, one or more modular building units accommodated therebetween, at least one frame beam suspended between the two frame elements, and one or more further modular building units supported on the at least one frame beam, wherein the at least one frame beam is configured for distributing a load generated by the one or more further modular
15 building units supported on the at least one frame beam via the at least two frame elements.

Brief description of the drawings

[009] 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. 1A shows a typical architectural plan for a storey of a modular building;

FIG. 1B shows a closed up view of a residential apartment for the storey of FIG. 1A separated into individual modular building units;

FIGs. 2A and 2B show conventional modular buildings based on a section of the architectural plan of FIG. 1A;

5 FIGs. 3A and 3B show modular buildings respectively according to various embodiments of the invention;

FIG. 4A and 4B show the base of the modular building of FIGs. 3A and 3B according to various embodiments;

10 FIGs. 5A and 5B show schematic diagrams for forming a first storey of the modular building of FIGs. 3A and 3B according to various embodiments;

FIG. 6A shows a closed up view of a connection between the base and the one or more modular building units according to an embodiment;

FIG. 6B shows a closed up view of a connection between the base and the one or more modular building units according to another embodiment;

15 FIG. 6C shows a plan view of a connection between the modular building unit and the frame element according to various embodiments;

FIG. 6D shows a cross-sectional A-A view of the connection in FIG. 6C;

FIG. 7 shows a schematic diagram for forming a second storey of the modular building of FIGs. 3A and 3B according to various embodiments;

20 FIG. 8 shows a modular building connector assembly for connecting modular building units in sideways arrangements and in top-down arrangements according to various embodiments;

FIGs. 9A and 9B show schematic diagrams for suspending at least one frame beam between the at least two frame elements;

FIG. 10A shows a closed up view of the frame beam of the modular building according to various embodiments;

FIG. 10B shows a connection between the one or more modular building units and the at least one frame beam according to an embodiment;

5 FIG. 10C shows a connection between the one or more modular building units and the at least one frame beam according to another embodiment; and

FIG. 11 shows an example of the connection between the frame beam and the frame elements.

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Detailed description

[0010] 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.

15 [0011] 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.

20 [0012] FIG. 1A shows a typical architectural plan for a storey 100 of a modular building. The storey 100 may be a level, a floor, or a deck of the modular building. The storey 100 of the modular building may include living spaces, office spaces, storage spaces, recreation spaces, retail spaces, etc. or a combination thereof. As shown, the storey 100 of the modular building may include living spaces and may be
25 segmented into several residential apartments 102. Each residential apartment 102

may include several modular building units 104, 106, 108, 110, 112 connected in sideways arrangement.

[0013] FIG. 1B shows a closed up view of the residential apartment 102 separated into individual modular building units. The residential apartment 102 may include
 5 five modular building units 104, 106, 108, 110, 112, which may be in the form of, but are not limited to, PPVC modules. The first modular building unit 104 may include a toilet fixtures and an entry hallway section with a main door. The second modular building unit 106 may include a bedroom section and a first part of a living room section with a partition wall separating the two sections. The third modular building
 10 unit 108 may include another toilet fixtures and a second part of the living room section with a partition wall having a door separating the two sections. The fourth modular building unit 110 may include another bedroom section and a third part of a living room section with a partition wall separating the two sections. The fifth modular building unit 112 may be a balcony section. The residential apartment 102
 15 may be formed by connecting the five modular building units 104, 106, 108, 110 and 112 via sideway connections.

[0014] According to various embodiments, each of the modular building units 104, 106, 108, 110 and 112 may be cuboid in shape. A top surface of the cuboid may form a ceiling of the modular building units 104, 106, 108, 110 and 112. A bottom surface
 20 of the cuboid may form a floor of the modular building units 104, 106, 108, 110 and 112. One or more of the side surfaces of the cuboid may be walled. Accordingly, to maintain the cuboid shape, each of the modular building units 104, 106, 108, 110 and 112 may include a skeletal frame including vertical columns and horizontal beams. The vertical columns and the horizontal beams may be formed along the edges of the
 25 cuboid shape. In other words, the vertical columns may be formed along the vertical

corners of the cuboid and the horizontal beams may be formed along the horizontal corners of the cuboid. As shown in FIG. 1B, the vertical columns of the modular building units 104, 106, 108, 110 and 112 are indicated by the grey rectangles at the corners of each modular building units 104, 106, 108, 110 and 112. For example, the modular building unit 106 may include vertical columns 114, 116, 118, 120. The modular building unit 108 may include vertical columns 122, 124, 126, 128.

[0015] According to various embodiments, a modular building connector assembly may be provided at a top of the vertical column of a modular building unit. The modular building connector assembly may connect two adjacent vertical columns from two different modular building units such that the two modular building units are connected sideways. For example, to connect modular building unit 106 to modular building unit 108, the vertical column 114 of modular building unit 106 may be connected to the vertical column 122 of modular building unit 108 via a modular building connector assembly, and the vertical column 120 of modular building unit 106 may be connected to the vertical column 128 of modular building unit 108 via another modular building connector assembly.

[0016] FIGs. 2A and 2B show conventional modular buildings 200, 201 based on a section 130 of the architectural plan 100 of FIG. 1A. As shown, the conventional modular buildings 200, 201 may include multiple storeys of residential apartments 202 stacked on top of each other. Accordingly, other than being connected sideways to form the residential apartment 202 of the modular buildings 200, 201, each modular building units 204, 206, 208, 210 and 212 may be connected to one or more other modular building units forming another residential apartment on top of the residential apartment 202. The modular building connector assembly at the top of the vertical columns connecting two modular building units sideways may also function to

connect with other modular building units stacked on top. In other words, the modular buildings 200, 201 may be constructed by assembling or stacking layers of the modular building units 204, 206, 208, 210 and 212 which form the residential apartment 202 such that multiple storeys of residential apartments 202 may be formed within the modular buildings 200, 201.

[0017] In the conventional modular buildings 200, 201, the modular building units are assembled by directly stacking the modular building units on top of each other. Thus, the modular building units at the bottom of the conventional modular buildings 200, 201 will bear the weight of the modular building units above. Accordingly, the height of the conventional modular buildings 200, 201 is dependent on the strength of the load bearing members, e.g, vertical columns, of the modular building units, and the strength of the connections, i.e. modular building connector assembly, joining the modular building units. For example, the height achievable for conventional modular buildings 200, 201 shown in FIG. 2A, 2B may be 8 storeys. The conventional modular buildings 200, 201 may include a center wall 203 and lift shafts 205 as shown in FIG. 2A and 2B.

[0018] As shown, FIG. 2B differs from FIG. 2A in that the conventional modular building 201 includes a roof structure 290 received directly on the top most layer of the modular building units, the center wall 203 and the lift shafts 205. As shown, in the conventional modular building 201, the roof structure 209 is directly supported on the modular building units, the center wall 203 and the lift shafts 205. Accordingly, the load of the roof structure is distributed among the modular building units, the center wall 203 and the lift shafts 205. In other words, the modular building units, the center wall 203 and the lift shafts 205 will bear the weight of the roof structure 290.

[0019] FIGs. 3A and 3B show modular buildings 300, 301 respectively according to various embodiments of the invention. As shown, the modular buildings 300, 301 may be provided with at least two frame elements on a base 304 for accommodating one or more modular building units 306 therebetween.

5 **[0020]** According to various embodiments, one or both of the at least two frame elements may include frame walls e.g. 303, frame columns 302, or lift shafts 305. As shown in both FIGs. 3A and 3B, the at least two frame elements may be connected to the base 304 such that the at least two frame elements may extend vertically upward from the base 304. The at least two frame elements may be extended to a
10 predetermined height such that a predetermined number of layers of modular building units 306 may be accommodated between the at least two frame elements. In this arrangement, a predetermined number of storeys of modular building units 306 may be formed between the at least two frame elements.

[0021] According to various embodiments, the one or more modular building units
15 306 may be provided on the base 304 between the at least two frame elements. A first layer of the one or more modular building units 306 may be provided on the base 304 such that the first layer of the one or more modular building units 306 may be laid directly on the base 304. Each subsequent layer of the one or more modular building units 306 may be provided on the base 304 between the at least two frame elements
20 such that each subsequent layer may be stacked on top of the previous layer of the one or more modular building units 306. Accordingly, each layer of the one or more modular building units 306 may be configured to support a load from the layers of the one or more modular building units 306 above that layer of the one or more modular building units 306.

[0022] According to various embodiments, at least one frame beam 320 may be suspended between the at least two frame elements. The at least one frame beam 320 may be suspended at the top of the at least two frame elements. The at least one frame beam 320 may be an elongated member configurable to be connected horizontally to the at least two frame elements such that the at least one frame beam 320 may extend across from one of the at least two frame elements to the other of the at least two frame elements. In suspending the at least one frame beam 320 between the at least two frame elements, a gap may be formed between the at least one frame beam 320 and the top layer of the one or more modular building units 306 below the at least one frame beam 320.

[0023] Accordingly, the modular building 300, 301 may include a structural frame having the at least two frame elements and the at least one frame beam 320 which may frame an assembly of one or more modular building units 306. The at least two frame elements may include columns 302. The at least two frame elements may also include walls, such as center wall 303, which may have higher width to thickness aspect ratio compared to columns 302.

[0024] According to various embodiments, one or more further modular building units 326 may be received on top of the at least one suspended frame beam 320 such that the at least one frame beam 320 may support one or more further modular building units 326 above the at least one frame beam 320. According to various embodiments, a floor (not shown) may be suspended on the at least one frame beam 320 for the support of the one or more further modular building units 326. The at least one frame beam 320 may be configured to distribute a load generated by the one or more further modular building units 326 supported on the at least one frame beam 320 via the at least two frame elements. Accordingly, the load from the one or more

further modular building units 326 may be supported by the at least one frame beam 320, which in turn may transmit the load to the at least two frame elements. The at least two frame elements may then transfer the load to the base 304. In other words, the layers of modular building units 306 within the at least two frame elements and below the at least one frame beams 320 may not receive or support any load from the one or more further modular building units 326 supported on the at least one frame beam 320.

[0025] Accordingly, the modular building 300, 301 may include the base 304, the at least two frame elements on the base 304, the at least one frame beam 320 suspended between the at least two frame elements, and the one or more further modular building units 326 supported on the at least one frame beam 320, wherein the at least one frame beam 320 may be configured for distributing a load generated by the one or more further modular building units 326 supported on the at least one frame beam 320 via the at least two frame elements.

[0026] According to various embodiments, the one or more modular building units 306 may be provided on the base 304 prior to suspending the at least one frame beam 320 across the at least two frame elements. To construct the modular building 300, 301 according to various embodiments, the base 304 may first be provided to form the foundation of modular building 300, 301. The at least two frame elements may then be provided on the base 304. Subsequently, the one or more modular building units 306 may be provided on the base 304 and between the at least two frame elements. After a predetermined number of layers (in other words a desired number of storeys) of the one or more modular building units 306 are provided between the at least two frame elements, the at least one frame beam 320 may then be suspended across the at

least two frame elements. The method as described above may form the lower section 310 of the modular building 300, 301 as shown in FIGs. 3A and 3B.

[0027] With the lower section 310 of the modular building 300, 301 formed, the one or more further modular building units 326 may be provided on the at least one suspended frame beam 320 to form a subsequent section of the modular building 300, 301. The subsequent section of the modular building 300, 301 may include at least two further frame elements 322 provided on the at least one suspended frame beam 320 for accommodating one or more further modular building units 326 therebetween. According to various embodiments, at least one further frame beam 340 (FIG. 3A) may be suspended between the at least two further frame elements 322 for distributing a load generated by one or more yet further modular building units (not shown) supported on the at least one further frame beam 340 via the at least two further frame elements 322 and the at least two frame elements.

[0028] In FIGs. 3A and 3B, the modular buildings 300, 301 are illustrated with 16 storeys including two sections of 8 storeys of the one or more modular building units 306 by way of an example only. According to various embodiments, the number of storeys in each section, the number of sections in the modular building, and the total number of storeys may vary accordingly and is not limited by FIGs. 3A and 3B.

[0029] According to various embodiment, for example as shown in FIG. 3B, when a desired number of storeys of the one or more modular building units is constructed, a top of the modular building 301 may be provided with a roof structure 390 in the form of a precast concrete slab provided on the at least two further frame elements 322 and/or the one or more modular building units.

[0030] A method for constructing the modular building 300 of FIG. 3A according to various embodiments will be described in the following.

[0031] FIG. 4A and 4B show the base 304 of the modular building 300, 301 according to various embodiments. The base 304 may include multiple foundation beams 307 assembled to form a skeleton structure of the base 304 as shown in FIG. 4A. The base 304 may also include a single layer of foundation slab 309 as shown in
 5 FIG. 4B. The base 304 may also include a plurality of pile foundations for embedding into the ground. Each pile foundation may include at least one pile 310 or other type of elongated member suitable for being driven into the ground, and a pile cap 312 that rests at a top of the pile 310. The pile cap 312 may be configured to receive a load from above and distribute the load received on the pile cap 312 to the at least one pile
 10 310 below the pile cap 312.

[0032] FIGs. 5A and 5B show schematic diagrams for forming a first storey of the modular building 300 according to various embodiments. As shown in FIG. 5A, the base 304 may include a single layer of foundation slab 309. First segments of the at least two frame elements may be provided on the base 304. As shown, the first
 15 segment of the at least two frame elements may be provided directly on the foundation slab 309 of the base 304. The at least two frame elements may include column elements 302, wall element 303 and lift shafts 305. To complete the first storey of the modular building 300, the one or more modular building units 306 may be provided on the base 304 and accommodated between the first segments of the at
 20 least two frame elements . FIG. 5B shows the completed first storey of the modular building 300.

[0033] According to an embodiment, all the first segments of the at least two frame elements may be provided on the base 304 before all the one or more modular building units 306 are accommodated between the first segments of the at least two
 25 frame elements . According to another embodiment, the first segments of the at least

two frame elements and the one or more modular building units 306 may be provided individually on the base 304 according to various suitable order of sequence.

[0034] FIG. 6A shows a closed up view of a connection between the base 304 and the one or more modular building units 306 according to an embodiment. As shown, bearing plate 642 may be embedded into the foundation slab or the foundation beam of the base 304. An elongated member 644 of the one or more modular building units 306 may be received in the bearing plate 642, with a retainer 646 engaging the bearing plate from below. The elongated member 644 with the retainer 646 and the bearing plate 642 may be pre-cast into the base 304. A fastener 648 may secure the elongated member 644 to the bearing plate 642 from the top, further facilitating arresting of the elongated member 644 against vertical movement.

[0035] FIG. 6B shows a closed up view of a connection between the base 304 and the one or more modular building units 306 according to another embodiment. As shown, the foundation slab 309 or the foundation beam 307 of the base 304 may include a cavity 650. A link plate 652 may be embedded on the foundation slab 309 or the foundation beam 307 of the base 304. To form the connection, a retainer 654 may be first coupled to a first rod 660. The first rod 660 may then be inserted through a hole in a coupler element 656 such that the retainer 654 abuts the coupler element 656. Subsequently, the coupler element 656 with the first rod 660 and the retainer 654 may be coupled to the link plate 652 by screwing the coupler element 656 through a hole in the link plate 652. The coupler element 656 may be coupled to the link plate 652 such that the retainer 654 and an end of the first rod 660 in engagement with the retainer 654 may be disposed in the cavity 650 of the base 304 while the other end of the first rod 660 protrudes upward from the coupler element 656. A fastener 658 may then be fastened onto the other end of the first rod 660 protruding upwards from the

coupler element 656. The fastener 658 and the retainer 654 may function to restrain vertical movement of the first rod 660 with respect to the coupler element 656. An elongated member 662 of the one or more modular building units 306 may then be connected to the fastener 658 such that the elongated rod 662 may be an extension of the first rod 660 in a vertically upward direction. In other words, the fastener 658 may connect a top end of the first rod 660 to a bottom end of the elongated rod 662 of the one or more modular building units 306.

[0036] According to various embodiments, the at least two frame elements may be customized with features for connecting and/or supporting the one or more modular building units 306.

[0037] FIG. 6C shows a plan view of a connection between the modular building unit 306 and the frame element according to various embodiments. FIG. 6D shows a cross-sectional A-A view of the connection in FIG. 6C. The modular building unit 306 may include a load bearing element 670. As shown, the load bearing element 670 of the modular building unit 306 may include a plurality of connection links 672 embedded along the length of the vertical load bearing element 670. The plurality of connection links 672 may be U-shaped with both the free ends embedded into the load bearing element 670. The frame element may include a recessed portion 674. Within the recessed portion 674 of the frame element, a plurality of corresponding connection links 676 may be provided along a length of the recessed portion 674. The corresponding connection links 676 may also be U-shaped with both the free ends embedded into the recessed portion 674 of the frame element. To connect the modular building unit 306 with the frame element, the modular building unit 306 and the frame element may be positioned such that the plurality of connection links 672 of the modular building unit 306 may be adjacent to the plurality of corresponding

connection links 676 of the frame element. A C-shaped link 678 may be used to hook the connection link 672 of the modular building unit 306 to the corresponding connection link 678 of the frame element. After hooking the connection links 672 of the modular building unit 306 to the corresponding connection links 678 of the frame element, a cavity formed by the recessed portion 674 of the frame element may be filled with fillers 680, and using a vertical formwork 682 to close the access opening to the cavity. The fillers 680 may be a suitable concrete mixture.

[0038] FIG. 7 shows a schematic diagram for forming a second storey of the modular building 300 according to various embodiments. After a first storey of the modular building 300 has been formed (FIG. 5B), second segments of the at least two frame elements may be provided on the base 304 by connecting on top of the first segments of the at least two frame elements. Modular building connector assemblies 800 (FIG. 8) may also be provided on top of the first storey of the one or more modular building units 306. A second storey of the one or more modular building units 306 may be provided on the base 304 by connecting second storey of the one or more modular building units 306 to the first storey of the one or more modular building units 306 via the modular building connector assemblies 800. Accordingly, the second segments of the at least two frame elements may be provided on the base 204, and the second storey of the one or more modular building units 306 may also be provided on the base 204 between the second segments of the at least two frame elements. The above may be iteratively repeated until a desired number of storeys of the modular building 300 is constructed.

[0039] According to various embodiments, the method for constructing modular building may include providing respective segments of the at least two frame elements on the base 304, providing a storey of the one or more modular building

units 306 on the base 304 between the first segments of the at least two frame elements , and iteratively providing respective further segments of the at least two frame elements on the previous segments of the at least two frame elements and a further storey of the one or more modular building units 306 between the further segments of the at least two frame elements until a desired number of storeys is constructed.

[0040] According to various embodiments, the segment of a first one of the at least two frame elements may be provided, followed by providing the storey of one or more modular building units 306, followed by providing the segment of the second one of the at least two frame elements adjacent the storey of one or more modular building units 306.

[0041] FIG. 8 shows a modular building connector assembly 800 for connecting modular building units in top-down arrangements and in sideways arrangements according to various embodiments. An example of a suitable modular building connector assembly 800 is described in “Singapore patent application 10201508200S filed on 2 October 2015”. The modular building connector assembly 800 may include a retainer 812. The modular building connector assembly 800 may further include a fastener 814. The modular building connector assembly 800 may further include a link plate 820 having first and second stopper surfaces 822, 824 for abutting bottom modular building unit 802 and top modular building unit 804 respectively. The modular building connector assembly 800 may further include a coupler element 830 having an engagement portion 832 for engaging with the link plate 820. The coupling element 830 may be configured to be coupled to a first elongated rod 840 of the bottom modular building unit 802 in a manner so as to be restrained against movement along the first elongated rod 840 by way of the retainer 812 and fastener

814. The link plate 820 may be restrainable against movement along the first elongated rod 840 by way of engagement with the coupler element 830. A second elongated member 860 of the top modular building unit 804 may then be connected to the fastener 814 such that the second elongated rod 860 may be an extension of the first elongated rod 840 in a vertically upward direction. In other words, the fastener 814 may connect a top end of the first elongated rod 840 of the bottom modular building unit 802 to a bottom end of the second elongated rod 860 of the top modular building units 804. As shown, the link plate 820 may extend sideways for sideway connections with adjacent top and bottom modular building units 854, 852. The adjacent top and bottom modular building units 854, 852 may be connected in the top-down arrangement in a similar manner as the top and bottom modular building units 804, 802 as described earlier.

[0042] FIGs. 9A and 9B show schematic diagrams for suspending at least one frame beam 320 between the at least two frame elements, such as the frame columns 302, the center wall 303 or lift shafts 305 . The at least one frame beam 320 may be suspended between the at least two frame elements after the desired number of storeys of the one or more modular building units 306 is reached. According to various embodiments, the one or more modular building units 306 may be secured to the at least one frame beam 320 such that the load from the one or more further modular building units (not shown) on top of the at least one frame beam 320 may be decoupled from the one or more modular building units 306 secured to the at least one frame beam 320. According to various embodiments, the at least one frame beam 320 may be customized with features for connecting and/or supporting the one or more modular building units 306 and/or the one or more further modular building units.

[0043] According to various embodiments, the one or more further modular building units may be connected to and supported on a top of the at least one frame beam 320. The connection may allow the transfer of load from the one or more further modular building units to the at least one frame beam 320 which in turn may transfer the load to the at least two frame elements. Accordingly, the at least one frame beam 320 and the at least two frame elements of the modular building 300, 301 may receive and support the load generated from the one or more further modular building units supported on the at least one frame beam 320. Accordingly, the at least one frame beam 320 and the at least two frame elements may allow taller modular building to be built because the load of the one or more further modular building units, which may form an upper section of the modular building 300, 301, are not supported by the one or more modular building units 306 of a lower section of the modular building 300, 301. Thus, the height of the modular building 300 may not be restricted by the structural strength of the one or more modular building units 306 of the lower section of the modular building 300, 301. Rather, the modular building 300, 301 could be built higher because the load of the one or more further modular building units may be supported by the at least one frame beam 320 and the at least two frame elements of the modular building 300, 301.

[0044] As shown in FIG. 9B, a further modular building unit 326 (shown in dashed lines) may be supported by two long beams 930 and 932, in conjunction with center wall 303, two columns 936, 938 and beam 934. However, it will be appreciated that in different embodiments, the number of frame elements and frame beams 320 supporting any one further modular building unit can vary depending on the specific disposition of the frame elements and the frame beams 320. Preferably, each further modular building unit 326 may be supported by at least one frame beam 320 and at

least two frame elements. The at least one frame beam 320 may be suspended between the at least two frame elements for distributing a load generated by one or more further modular building units 326 supported on the at least one frame beam 320 via the at least two frame elements.

5 [0045] According to various embodiments, the one or more modular building units 306 of the lower section of the modular building 300, 301 may be connected to a bottom of the at least one frame beam 320 of the structural frame. The connection may provide structural stability to the assembly of the one or more modular building units 306 below the at least one frame beam 320. The connection may be configured
10 such that, in the event that the structural integrity of anyone of the one or more modular building units 306 below the at least one frame beam 320 is compromised, the remaining one or more modular building units 306 above the structurally impaired modular building unit may remain in position because they are in connection, either directly or via one or more modular building units 306 above a particular modular
15 building unit, with the at least one frame beam 320, i.e. a hanging load is applied as will be described in the following. Thus, the connection may prevent the collapse of the one or more modular building units 306.

[0046] According to various embodiments, the connection between the one or more modular building units 306 and the bottom of the at least one frame beam 320 may be
20 configured such that the load generated by the one or more further modular building units 326 supported on the at least one frame beams 320 may not be transferred from the at least one frame beam 320 to the one or more modular building units 306. This may be achieved by the separation between the at least one frame beam 320 and the one or more modular building units 306 below the at least one frame beam 320, i.e.

the frame beam is suspended above the one or more modular building units, as described above. The separation may be filled with compressive material.

[0047] FIG. 10A shows a closed up view of the frame beam 320 of the modular building 300 according to various embodiments. As shown, a compressible material 1030 may be provided on respective bottom surfaces of the at least one frame beam 320 for sealing a gap between the bottom surfaces of the at least one frame beam 320 and respective top surfaces of one or more of the modular building units 306 accommodated between the at least two frame elements and below the at least one frame beam 320. The gap between the at least one frame beam 320 and the one or more modular building units 306 below the at least one frame beam 320 may allow the at least one frame beam 320 to maintain suspension between the at least two frame elements. The gap may prevent the at least one suspended frame beam from coming into contact with the one or more modular building units 306 below the at least one suspended frame beam. Accordingly, the gap may prevent the load acting on the at least one frame beam 320 from above to be transmitted to the one or more of the modular building units 306 below the at least one frame beam 320. This is because the gap may decouple from the underlying modular building units 306 any downward force from the at least one frame beam 320 caused by the load acting on the at least one frame beam 320. The load acting on the at least one frame beam 320 from above may include the load from the one or more one or more further modular building units 326 supported on the at least one frame beam 320. According to various embodiments, sealing of the gap with the compressible material 1030 is preferred to avoid water ingress etc.. Since the compressible material 1030 may be deformable, sealing the gap with compressible material 1030 preferably does not cause the load acting on the at least one frame beam 320 from above to be transferred to the one or

more of the modular building units 306 below the at least one frame beam 320. That is, the suspension state of the frame beam 320 is substantially maintained from a load decoupling perspective.

[0048] FIG. 10B shows a connection between the one or more modular building units 306 and the at least one frame beam 320 according to an embodiment. As shown, the at least one frame beam 320 may include a recessed portion 1032. An elongated member 1034 may extend from the one or more modular building units 306 into the frame beam 320 from a bottom surface of the frame beam 320. The elongated member 1034 may extend through the frame beam 320 and protrude from a top surface of the recessed portion 1032 of the frame beam 320. A fastener 1036 may be fastened to a portion of the elongated member 1034 protruding from the recessed portion 1032 such that the elongated member 1034 may be secured to the recessed portion 1032 of frame beam 320. A plate 1038 may be provided on the frame beam 320 to seat the fastener 1036. Accordingly the plate 1038 may function as a washer for securing of the fastener 1036.

[0049] As shown in FIG. 10B, at the bottom of the one or more modular building units 306 below the frame beam 320, modular building connector assembly 800 (previously described in FIG. 8) may connect the modular building units 306, sideways and top-down to further modular building units 1045, 1047. In this arrangement, the one or more modular building units 306 below the frame beam 320 may be seated on the link plate 820 of the modular building connector assembly 800. Since the modular building connector assembly 800 may restrain the movement of the link plate 820 along the elongated member 1034 and the elongated member 1034 may be secured to the recessed portion 1032 of the frame beam 320, the one or more modular building units 306 below the frame beam 320 may be arrested against

vertical downward movement by the securing to the at least one frame beam 320 such that the one or more modular building units 306 may apply a hanging load on the frame beam 320. It will be appreciated that the one or more modular building units 1045, 1047 further below those shown in FIG. 10B may be connected by the modular building connector assembly 800 of FIG. 8 in a similar manner. Thus, the one or more modular building units 1045, 1047 further below may also contribute to the hanging load on the frame beam 320.

[0050] According to various embodiments, in the event of any damage to an intermediate modular building unit further below the frame beam 320, the modular building units 326 (not shown) above it can still be supported without experiencing total collapse of the modular building. According to an implementation, when the one or more modular building units 306 are PPVC modules, the elongated member 1034 may be a tie rod of the PPVC modules. The tie rod may be threaded through the core of the frame beam 320 and secured by a fastener 1036 in the form of a nut. This arrangement according to various embodiments allows the frame beam 320 to be installed top down.

[0051] As shown in FIG. 10B, a bearing plate 1040 may be provided to the frame beam 320. The bearing plate 1040 may be provided on the frame beam 320 such that the bearing plate 1040 may be spaced apart from the fastener 1036 secured on the elongated member 1034 of the one or more modular building unit 306. A filler 1042 may fill the space between the bearing plate 1040 and the fastener 1036. The filler 1042 may be suitable concrete mixture. The bearing plate 1040 may be configured to receive an elongated member 1044 of the one or more further modular building units (not shown) assembled above the frame beam 320 for disposing the one or more further modular building units 326 above the frame beam 320. The elongated member

1044 may include a retainer 1046 co-operating with a fastener (not shown) to arrest the elongated member 1044 against vertical movement. The bearing plate 1040 may be cast into the frame beam 320 such that a lower end of the elongated member 1044 of the one or more further modular building units above the frame beam 320 may be spaced apart from an upper end of the elongated member 1034 of the one or more modular building units 306 below the frame beam 320. The connection between the one or more further modular building units above the frame beam 320 may proceed in the same fashion as the connection between the first storey of the one or more modular buildings units 306 to the foundation/base, which was described in detail above with reference to FIG. 6A.

[0052] According to various embodiments, before the filler 1042 is added, an alignment spacer 1048 may be provided to hold the bearing plate 1040 in a position, which may be spaced apart from the end of the elongated member 1034 of the one or more modular building units 306, and align the bearing plate 1040 for receiving the elongated member 1044 of the one or more further modular building units 326. Advantageously, the alignment spacer 1048 may allow embedding or casting the bearing plate 1040 into frame beam 320 while spaced apart from the end of the elongated member 1034 in a single process, thus preferably reducing construction time. Without the alignment spacer 1048, the filler 1042 has to partially fill the recessed portion 1032 to a predetermined height above the end of the elongated member 1034 such that filler 1042 may cover the fastener 1036 and the end of elongated member 1034. Subsequently, upon curing of the filler 1042, the plate 1040 may then be placed and aligned on the hardened filler 1042 before more filler 1042 may be added to embed the plate 1040.

[0053] FIG. 10C shows a connection between the one or more modular building units 306 and the at least one frame beam 320 according to another embodiment. As shown, the at least one frame beam 320 may include a bearing plate 1050. A first elongated member 1054 may extend from the one or more modular building units 306 into the frame beam 320 from a bottom surface of the frame beam 320. The first elongated member 1054 may extend through the frame beam 320 and protrude from a top surface of the bearing plate 1050 of the frame beam 320. A modular building connector assembly 1060, similar to the modular building connector assembly 800 in FIG. 8, may be used for connecting the one or more modular building units 306 to the frame beam 320. The modular building connector assembly 1060 may include a retainer 1056. The modular building connector assembly 1060 may further include a fastener 1058. The modular building connector assembly 1060 may further include a link plate 1062 having first and second stopper surfaces 1066, 1064 for abutting the frame beam 320 and the further one or more modular building units 326 respectively. The modular building connector assembly 1060 may further include a coupler element 1068 having an engagement portion for engaging with the link plate 1062. The coupling element 1068 may be configured to be coupled to the first elongated member 1054 of the one or more modular building units 306 in a manner so as to be restrained against movement along the elongated member 1054 by way of the retainer 1056 and fastener 1058. The link plate 1062 may be restrainable against movement along the first elongated member 1054 by way of engagement with the coupler element 1068. A second elongated member 1070 of the further one or more modular building units 326 may then be connected to the fastener 1058 such that the second elongated rod 1070 may be an extension of the first elongated member 1054 in a vertically upward direction. In other words, the fastener 1058 may connect a top end

of the first elongated member 1054 of the one or more modular building unit 306 to a bottom end of the second elongated member 1070 of the further one or more modular building units 326.

[0054] As shown in FIG. 10C, at the bottom of the one or more modular building units 306 below the frame beam 320, modular building connector assembly 800 (previously described in FIG. 8) may connect the modular building units 306, sideways and top-down to further modular building units 1045, 1047. In this arrangement, the one or more modular building units 306 below the frame beam 320 may be seated on the link plate 820 of the modular building connector assembly 800.

Since the modular building connector assembly 800 may restrain the movement of the link plate 820 along the elongated member 1034 and the elongated member 1034 may be secured to the recessed portion 1032 of the frame beam 320, the one or more modular building units 306 below the frame beam 320 may be arrested against vertical downward movement by the securing to the at least one frame beam 320 such that the one or more modular building units 306 may apply a hanging load on the frame beam 320. It will be appreciated that the one or more modular building units 1045, 1047 further below those shown in FIG. 10C may be connected by the modular building connector assembly 800 of FIG. 8 in a similar manner. Thus, the one or more modular building units 1045, 1047 further below may also contribute to the hanging load on the frame beam 320. According to various embodiments, in the event of any damage to an intermediate modular building unit further below the frame beam 320, the modular building units 326 above it can still be supported without experiencing total collapse of the assembly.

[0055] Further, since the further one or more modular building units 326 above the frame beam 320 are received directly on the link plate 1062 which in turn is received

directly on the frame beam 320, the load from the further one or more modular building units 326 may be passed onto the frame beam 320 which in turn would distribute the load to the frame elements. Accordingly, the load from the further one or more modular building units 326 will not be passed onto the one or more modular building units 306 below the frame beam 320.

[0056] FIG. 11 shows an example of the connection between the frame beam 340 and the frame elements. Various types of connection may be used to connect the frame beam 340 to the frame elements. FIG. 11 is show by way of an example only and the connection used is not limited to FIG. 11. In FIG. 11, the frame element may include recessed portion 1102 adapted to receive an end of the frame beam 320. In this arrangement, the frame beam 320 may be suspended between two frame elements and a load acting downward on the frame beam 320 may be transferred downward onto the frame elements as indicated by the arrow. Accordingly, the load of the further one or more modular building units 326 received on the frame beam 320 may be distributed to the frame elements.

[0057] According to various embodiments, the method as described above may form the lower section 310, the intermediate section and subsequent sections, if applicable, of the modular building 300, 301 as shown in FIGs. 3A and 3B.

[0058] Embodiments may provide a method for constructing tall modular buildings without the need to increase the structural strength or size of the load bearing component of the modular building units as well as the strength of the connections. In particular, embodiments may provide a method for constructing tall PPVC buildings which is currently unachievable by the current PPVC modules. Embodiments may also address the shortcomings of the conventional modular building whereby

accidental removal of the load bearing members of the modular building units may jeopardize the overall stability and hence safety of the building.

[0059] Embodiments may provide a structural frame, including at least two frame elements and at least one frame beam, within which one or more modular building units or assemblies of modular building units may be fitted into. The method may allow concurrent constructions of the structural frame and the assembly of the modular building units to build a monolithic structure. The structural frame may support an assembly of one or more modular building units at regular or prescribed intervals. This may allow customization of the height of each assembly of the one or more modular building units within the regular or prescribed intervals such that each assembly is within the safety stacked height limit of the one or more modular building units. At the same time, the height of the modular building may not be restricted as the structural frame may support multiple assemblies of one or more modular building units at the regular or prescribed intervals.

[0060] Embodiments may allow taller modular building to be constructed by varying the dimensions of the structural frame of the modular building without requiring any change to the dimensions of the modular building units. By doing so, the strength of the load bearing members of the modular building units and the strength of the connections may only limit the height of the assembly of the modular building units within the structural frames and not the overall height of the building.

[0061] According to various embodiments, the structural frame may provide structural stability to the assemblies of the one or more modular building units and transfer the load generated from the assemblies of the one or more modular building units to a foundation of the modular building. In addition, the structural frame may also provide a mechanism through which overall instability of the building can be

averted in the event of any accidental removal of the structural components of the modular building units.

[0062] According to various embodiments, the structural frame may achieve the above advantages by providing unique features to securely connect and support the multiple assemblies of modular building units through which structural stability and transfer of load takes place. For example, the structural frame may incorporate a connection system for suspending the modular building units to the structural frames to avert any structural instability in the event of accidental removal of the structural components of the modular building units.

[0063] While the invention has been particularly shown and described with reference to specific embodiments, it should be understood by those skilled in the art 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 method for constructing a modular building, comprising:
providing at least two frame elements on a base for accommodating one or more modular building units therebetween; and
5 suspending at least one frame beam between the at least two frame elements for distributing a load generated by one or more further modular building units supported on the at least one frame beam via the at least two frame elements.
2. The method of claim 1, further comprising providing the one or more modular
10 building units on the base between the at least two frame elements.
3. The method of claim 2, wherein the one or more modular building units are provided on the base prior to suspending the at least one frame beam across the at least two frame elements.
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4. The method of any one of the preceding claims, further comprising providing the one or more further modular building units on the at least one suspended frame beam.
- 20 5. The method of any one of the preceding claims, further comprising providing a compressible material on respective bottom surfaces of the at least one frame beam for sealing a gap between the bottom surfaces of the at least one frame beam and respective top surfaces of one or more of the modular building units accommodated between the at least two frame elements.

6. The method of any one of the preceding claims, further comprising securing one or more of the modular building units to the at least one frame beam such that the modular building units apply a hanging load to the at least one frame beam.
- 5 7. The method of claim 6, whereby the one or more modular building units are arrested against vertical downward movement by the securing to the at least one frame beam.
8. The method of any one of the preceding claims, wherein providing the at least
10 two frame elements comprises:
 - providing respective segments of the at least two frame elements on the base;
 - providing a storey of the one or more modular building units on the base between the respective segments of the at least two frame elements; and
 - iteratively providing respective further segments of the at least two frame
15 elements on the previous segments of the at least two frame elements and a further storey of the one or more modular building units between the further segments of the at least two frame elements until a desired number of storeys is constructed.
9. The method of claim 8, wherein the at least one frame beam is suspended
20 between the at least two frame elements after the desired number of storeys is reached.
10. The method of claims 8 or 9, wherein the segment of a first one of the at least two frame elements is provided, followed by providing the storey of one or more

modular building units, followed by providing the segment of the second one of the at least two frame elements adjacent the storey of one or more modular building units.

11. The method of any one of the preceding claims, comprising iteratively
 5 providing at least two further frame elements on the at least one suspended frame beams for accommodating the one or more further modular building units therebetween, and
 suspending at least one further frame beam between the at least further two frame elements for distributing a further load generated by one or more yet further modular
 10 building units supported on the at least one further frame beam via the at least two frame elements and the at least two further frame elements.

12. The method of any one of the preceding claims, further comprising suspending
 a floor on the at least one frame beam for the support of the one or more further
 15 modular building units.

13. The method of any one of the preceding claims, wherein one or both of the frame elements of the at least two frame elements comprise a frame wall.

20 14. The method of any one of the preceding claims, wherein one or both of the frame elements of the at least two frame elements comprise a pair of frame columns.

15. A modular building comprising:
 a base,
 25 at least two frame elements on the base;

one or more modular building units accommodated therebetween;

at least one frame beam suspended between the at least two frame elements;

and

one or more further modular building units supported on the at least one frame

5 beam;

wherein the at least one frame beam is configured for distributing a load generated by the one or more further modular building units supported on the at least one frame beam via the at least two frame elements.

10 16. The modular building of claim 15, wherein the one or more of the modular building units are secured to the at least one frame beam such that the modular building units apply a hanging load to the at least one frame beam.

15 17. The modular building of claim 16, whereby the one or more modular building units are arrested against vertical downward movement by the securing to the at least one frame beam.