

CONNECTION SYSTEM AND METHOD FOR PREFABRICATED VOLUMETRIC CONSTRUCTION MODULES

Field of Invention

Embodiments of the invention relate to prefabricated volumetric construction modules
5 having connection mechanism for securement with other modules, building construction
utilizing such modules and methods for assembling or erecting such building construction.

Background

In sharp contrast to rapid development of technology in many other fields,
construction technology has proceeded at a relatively slow pace over the last half century.
10 Construction industry remains labour-intensive and of a handcraft nature and, as a result,
housing and building costs have remained very high.

Prefabrication has been cited as a potential solution, but many prefabrication
proposals to date have not proven to be commercially successful and relatively few
prefabrication techniques have been adopted by the industry. Prefabrication techniques fall
15 under two major categories, namely, steel structure module construction and pre-cast
volumetric concrete modules.

These prefabrication systems tend to be costly, requiring expensive prefabrication
factories and relatively expensive handling and erection equipment and techniques. To be
viable such concepts usually require a very high degree of repetition.

20 One common problem which remains largely unsolved is that the existing prefabricated
systems provide only limited architectural and space flexibility.

Summary

According to a first aspect of the invention, a prefabricated volumetric construction
25 module is provided and comprises:

a plurality of beams and columns joined together to provide a self-supporting
structure;

a plurality of pairs of upper and lower corner castings, each pair is arranged at distal ends of a column and adapted to receive therethrough a first connection rod having an internally threaded socket head and an externally threaded tail, wherein threads of the socket head and the tail are complementary,

- 5 wherein the upper corner casting is adapted to engage the socket head, and the lower corner casting is adapted to allow the tail penetrate therethrough to threadably engage with an internally threaded socket head of a second connection rod, which is engaged with an upper corner casting of a vertically adjoining module, to provide vertical securement between the prefabricated
10 volumetric construction module and the vertically adjoining module.

According to one embodiment of the first aspect, the upper corner casting includes a first upper plate having a first upper plate opening, a first lower plate having a first lower plate opening and a passageway extending between the first upper plate opening and the first lower plate opening,

- 15 wherein the first lower plate opening is smaller than the first upper plate opening such that the lower plate is adapted to prevent the socket head of the first connection rod from penetrating the lower plate.

- According to one embodiment of the first aspect, the lower corner casting includes a second upper plate having the second upper plate opening, a second lower plate having the
20 second lower plate opening and a passageway extending between the second upper plate opening and the second lower plate opening,

wherein the second lower plate opening is adapted to allow penetration of the socket head of the second connection rod.

According to one embodiment of the first aspect, each module further comprises:

- 25 at least one cross-bracing joining the beams and columns;
a plurality of roof purlins joining upper ones of the beams;
at least one roof mounted to the roof purlins;
a plurality of floor joists joining lower ones of the beams; and

at least one floor mounted to the floor joists.

According to one embodiment of the first aspect, at least some of the pairs of upper and lower corner castings are arranged at corners of the self-supporting structure.

According to one embodiment of the first aspect, remaining ones of the pairs of upper
5 and lower corner castings are arranged adjacent to the at least some of the pairs of upper and lower corner castings.

According to a second aspect of the invention, a building structure is provided and comprises:

10 a plurality of pre-fabricated volumetric construction modules including vertically adjoining modules, wherein each module comprises:

a plurality of beams and columns joined together to provide a self-supporting structure;

a plurality of pairs of upper and lower corner castings, each pair is arranged at distal ends of a column,

15 a plurality of first connection rods, wherein each first connection rod secures an upper-level module of the vertically adjoining modules with an adjoining lower-level module to provide vertical securement therebetween, wherein each first connection rod penetrates both an upper corner casting and a lower corner casting of a respective pair of corner castings at the upper-level module, each
20 first connection rod having an internally threaded socket head and an externally threaded tail, wherein the socket head is engaged with the upper corner casting at the upper-level module and the tail is threadably engaged with an internally threaded socket head of an other connection rod which is engaged with the upper corner casting of the adjoining lower-level module.

25 According to one embodiment of the second aspect, the building structure further comprises:

at least one interlocking plate having a main plate, at least one interlocking plate opening formed therein and at least one guide projection arranged at least partially around the interlocking plate opening, wherein the interlocking plate

is interposed between the upper-level module and the adjoining lower-level module, wherein the internally thread socket head of the other connection rod is fitted within the interlocking plate opening, and wherein an upper and a lower portion of the guide projection are fitted within the lower corner casting of the upper-level module and upper corner casting of the lower-level module respectively.

According to one embodiment of the second aspect, the building structure further comprises:

at least one interlocking plate having a main plate, at least one interlocking plate opening formed therein and at least one guide projection arranged at least partially around the interlocking plate opening, wherein the interlocking plate is interposed between horizontally adjoining upper-level modules of the vertically adjoining modules and horizontally adjoining lower-level modules which vertically adjoin the horizontally adjoining upper-level modules, and wherein the internally thread socket head of the other connection rod is fitted within the interlocking plate opening to provide horizontal securement between the horizontally adjoining upper-level modules and further between the horizontally adjoining lower-level modules, and wherein an upper and a lower portion of the guide projection are fitted within the lower corner casting of the upper-level module and upper corner casting of the lower-level module respectively.

According to one embodiment of the second aspect, the building structure further comprises: a core structure constructed on-site and secured to at least one of the modules.

According to one embodiment of the second aspect, each module further comprises:

at least one cross-bracing joining the beams and columns;
a plurality of roof purlins joining upper ones of the beams;
at least one roof mounted to the roof purlins;
a plurality of floor joists joining lower ones of the beams; and
at least one floor mounted to the floor joists.

According to one embodiment of the second aspect, at least some of the pairs of upper and lower corner castings are arranged at corners of the self-supporting structure.

According to one embodiment of the second aspect, remaining ones of the pairs of upper and lower corner castings are arranged adjacent to the at least some of the pairs of upper and lower corner castings.

According to one embodiment of the second aspect, each module is provided with architectural finishes including interior decoration and fixtures.

According to a third aspect of the invention, a method for constructing a building structure is provided and comprises:

stacking at least one upper-level pre-fabricated volumetric construction module on at least one lower-level module to provide vertically adjoining modules, wherein each module comprises:

a plurality of beams and columns joined together to provide a self-supporting structure;

a plurality of pairs of upper and lower corner castings, each pair is arranged at distal ends of a column,

providing vertical securement between the vertically adjoining modules by:

using a plurality of connection rods, penetrating each connection rod through an upper corner casting and a lower corner casting of a respective pair of corner castings of the upper-level module, each connection rod having an internally threaded socket head and an externally threaded tail;

threadably engaging the tail with an internally threaded socket head of an other connection rod which is engaged with an upper corner casting of the lower-level module.

According to one embodiment of the third aspect, before stacking at least one upper-level pre-fabricated volumetric construction module on at least one lower-level module to provide vertically adjoining modules, the method further comprises:

arranging at least one interlocking plate between the upper-level module and the lower-level module, wherein the interlocking plate includes a main plate, at least one interlocking plate opening formed therein and at least one guide projection arranged at least partially around the interlocking plate opening;
5 and

fitting the socket head of the other connection rod within the interlocking plate opening and fitting a lower portion of the guide projection within the upper corner casting of the lower-level module.

10 According to one embodiment of the third aspect, before stacking at least one upper-level pre-fabricated volumetric construction module on at least one lower-level module to provide vertically adjoining modules, the method further comprises:

providing horizontal securement between horizontally adjoining upper-level modules and further between horizontally adjoining lower-level modules by:

15 arranging at least one interlocking plate between the horizontally adjoining upper-level modules of the vertically adjoining modules and the horizontally adjoining lower-level modules which vertically adjoin the horizontally adjoining upper-level modules, wherein the interlocking plate includes a main plate, at least one interlocking plate opening formed therein and at least one guide projection arranged at
20 least partially around the interlocking plate opening; and

fitting the socket head of the other connection rod within the interlocking plate opening and fitting a lower portion of the guide projection within the upper corner casting of the lower-level module.18.

25 The method of claim 16 or 17, wherein stacking at least one upper-level pre-fabricated volumetric construction module on at least one lower-level module to provide vertically adjoining modules further includes:

fitting an upper portion of the guide projection within the lower corner casting of the upper-level module.

According to one embodiment of the third aspect, the step of stacking at least one upper-level pre-fabricated volumetric construction module on at least one lower-level module to provide vertically adjoining modules further includes:

5 fitting an upper portion of the guide projection within the lower corner casting of the upper-level module.

According to one embodiment of the third aspect, the method further comprises: securing at least one of the modules to a core structure which is built on-site.

According to one embodiment of the third aspect, each module further includes:

10 at least one cross-bracing joining the beams and columns;
a plurality of roof purlins joining upper ones of the beams;
at least one roof mounted to the roof purlins;
a plurality of floor joists joining lower ones of the beams; and
at least one floor mounted to the floor joists.

15 **Brief Description of Drawings**

The invention will be described in detail with reference to the accompanying drawings, in which:

20 Figure 1A shows a prefabricated volumetric construction module according to one embodiment of the invention;

Figure 1B shows the module of Figure 1A provided with a roof and a side wall;

Figure 1C shows an exploded view of the module of Figure 1B;

Figure 2A shows a plan view of two unsecured modules and locations of corner castings;

25 Figure 2B shows a plan view of two adjoining modules and locations of corner castings in these modules;

Figure 2C shows a plan view of four adjoining modules and locations of corner castings in these modules;

Figures 3A to 3E show various shapes for prefabricated volumetric construction modules;

Figures 4A to 4H show various examples of building structures constructed from prefabricated volumetric construction modules;

5 Figures 5A to 5E show various examples of building structures constructed from one or more concrete cores and prefabricated volumetric construction modules secured thereto;

Figure 6 shows modular floor layouts in an apartment building;

Figure 7 is a close-up view of a modular floor layout from Figure 6;

10 Figure 8A is a perspective view of a connection rod according to one embodiment of the invention;

Figure 8B is a side view of the rod of Figure 8A;

Figure 8C is a top view of the rod of Figure 8A;

Figure 9A is a perspective view of an upper corner casting according to one embodiment of the invention;

15 Figure 9B is a top view of the upper corner casting of Figure 9A;

Figure 9C is a side view of the upper corner casting of Figure 9A;

Figure 9D is a side view of the upper corner casting of Figure 9A;

Figure 10A is a perspective view of a lower corner casting according to one embodiment of the invention;

20 Figure 10B is a top view of the lower corner casting of Figure 10A;

Figure 10C is a side view of the lower corner casting of Figure 10A;

Figure 10D is a side view of the upper corner casting of Figure 10A;

Figure 11A is a perspective view of an interlocking plate according to one embodiment of the invention;

25 Figure 11B is a side view of the interlocking plate of Figure 11A;

Figure 11C is a side view of the interlocking plate of Figure 11A;

Figure 11D is a top view of the interlocking plate of Figure 11A;

Figure 12 is a partial side view of a pair of corner castings according to one embodiment of the invention;

30 Figure 13 is a partial side cross-sectional view of two pairs of corner castings according to one embodiment of the invention;

Figure 14 is a partial perspective view of two corner castings of two modules being secured together;

Figure 15 is a partial perspective view of four corner castings of two modules modules being secured together;

Figure 16A shows insertion of rods into corner castings of a first and a second module forming a lower level;

5 Figure 16B shows tightening of rods after insertion in Figure 16A;

Figure 16C shows the tightened rods housed within the corner castings of the first and the second module;

Figure 16D shows a third and a fourth unsecured module stacked upon the first and the second module shown in Figures 16A to 16C to form an upper level;

10 Figure 16E shows insertion of rods into corner castings of the third and the fourth module;

Figure 16F shows tightening of rods after insertion in Figure 16E;

Figure 16G shows the tightened rods housed within the corner castings of the third and the fourth module;

15 Figure 16H shows a fifth and a sixth unsecured module stacked upon the third and the fourth module shown in Figures 16E to 16G to form a further upper level; and

Figure 17 shows a flow chart describing a method for constructing a building structure from pre-fabricated volumetric construction modules.

20 **Detailed Description of Embodiments of the Invention**

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

30 It should be understood that the terms “comprising”, “including”, “includes” and “having” are intended to be open-ended and mean that there may be additional elements other than the listed elements. Use of identifiers such as first, second, third and fourth should not be construed in a manner imposing any relative position or time sequence between limitations.

Furthermore, terms such as “top”, “bottom”, “front”, “back”, “side”, “end”, “under”, “upper”, “lower” used herein are merely for ease of description and refer to the orientation of the components as shown in the figures. It should be understood that any orientation of the components described herein is within the scope of the invention. Furthermore, the term “adjoining” is intended to mean adjacent to or next to in any direction regardless of any direct or indirect contact or connection with the reference object.

According to one aspect of the invention, a prefabricated volumetric construction module 1 having connection mechanism is provided and illustrated in Figures 1A to 1C. A prefabricated volumetric construction module 1 includes a plurality of columns and beams 5A, 5B and columns 4 joined together, to provide a self-supporting structure. The self-supporting structure at least defines a top, a bottom, opposite sides and opposite ends. Upper beams may be provided as top rails 5A, and lower beams may be provided as bottom rails 5B. Columns 4 are provided as hollow posts to provide a passageway therethrough.

The module 1 may further include one or more cross-bracings 6 joining the beams and columns 4. The module 1 may further include one or more roof purlins 8 joining upper beams and one or more roofs 10, e.g. corrugated roof or ceiling boards 16, mounted to the roof purlins 8. The module 1 may further include one or more floor joists 9 joining lower beams 5B and one or more floor boards 15 mounted to the floor joists 9.

The module 1 includes a plurality of pairs of corner castings 2, 3. The pairs of corner castings 2, 3 are arranged at corners of the module 1 and, optionally, at a mid-point position or other positions along the length of the module 1 (see Figure 2A). In some embodiments, it is to be appreciated that two or more pairs of corner castings may be arranged adjacent to each other (see Figure 15).

Each pair of corner castings 1, 2 includes an upper corner casting 2 and a lower corner casting 3 which are arranged at distal ends of a column 4.

The upper corner casting 2 includes a first upper plate, a first lower plate, first front plates and first side plates (see Figures 9A to 9D) joined or cast together to provide a casting housing. The first upper plate is provided with a first upper plate opening 215, and the first lower plate is provided with a first lower plate opening 214. A passageway extends between the first upper plate opening 215 and the first lower plate opening 214. The first lower plate opening 214 is smaller than the first upper plate opening 215. Dimensions of the first upper

plate opening 215 are adapted to allow penetration of a socket head 210 of an elongate connection rod 11 while dimensions of the first lower plate opening 214 are adapted to prevent penetration of the socket head 210. Dimensions of both the first upper plate opening 215 and the lower plate opening 214 are adapted to allow penetration of a tail of the connection rod. One of the first front plates is provided with a first front plate opening 216. One of the first side plates is provided with a first side plate opening 217. The first front plate opening 216 and the first side plate opening 217 lead to the passageway to provide access to the connection rod 11 when it is inserted through the passageway.

The lower corner casting 3 includes a second upper plate, a second lower plate, second front plates and second side plates (see Figures 10A to 10D) joined or cast together to provide a casting housing. The second upper plate is provided with a second upper plate opening 218, and the second lower plate is provided with a second lower plate opening 219. A passageway extends between the second upper plate opening 218 and the second lower plate opening 219. The second lower plate opening 219 is larger than the second upper plate opening 218. Dimensions of the second upper plate opening 218 are adapted to allow penetration of a tail of an elongate connection rod 11 and, optionally, prevent penetration of a socket head 210 of the connection rod. Dimensions of the second lower plate opening 219 are adapted to allow penetration of the socket head 210. Dimensions of both the second upper plate opening 218 and the second lower plate opening 219 are adapted to allow penetration of a tail of the connection rod. One of the second front plates is provided with a second front plate opening 220. One of the second side plates is provided with a second side plate opening 221. The second front plate opening 220 and the second side plate opening 221 lead to the passageway to provide access to the connection rod 11 when it is inserted through the passageway.

While the modules 1 of Figures 1A to 1C are illustrated as having cuboid shape (see Figure 3A), it is to be appreciated that the modules 1 may take on other shapes, such as the various shapes illustrated in Figures 3B to 3E.

The aforementioned prefabricated volumetric construction modules 1 may also be construed as prefabricated pre-finished volumetric construction modules (PPVC) in which architectural finishes including interior decorations and fixtures are installed offsite in the modules at the factory before the prefabricated pre-finished volumetric construction modules (PPVC) are transported and assembled on-site.

Reference is made to Figures 8A to 8C which show various views of an elongate connection rod 11. The connection rod 11 includes an internally threaded socket head 210, a rod body 211 which is attached to the socket head 210 and includes an externally threaded tail. Threads 212, 213 of the socket head 210 and the tail are complementary. The socket head 210 has a larger external cross-sectional dimension e.g. diameter, than the rod body and tail, and a socket dimension adapted to threadably engage with a tail of another similar connection rod 11.

Reference is made to Figures 11A to 11D which show various views of an interlocking plate 12. The interlocking plate 12 includes a main plate 222 having at a plurality of openings 224 (or interlocking plate openings 224) therethrough. The interlocking plate openings 224 are suitably dimensioned to allow penetration of the internally threaded socket head 210. The interlocking plate 12 further includes guide projections 223 machined with engineering tolerance to be seated or fitted precisely within openings 215 and 219 of the castings shown in Figures 9A to 9D and 10A to 10D. The guide projections 223 are arranged on the main plate 222 and at least partially around the interlocking plate openings 224. The guide projections 223 are provided on opposed sides of the main plate 222 as lower and upper portions of the guide projections.

Figures 4A to 4H show various examples of multi-storey building structures constructed from prefabricated volumetric construction modules 1. Depending on the configuration of the building structure, the modules 1 forming the building structure may have similar, different or complementary configurations.

Figures 5A to 5E show various examples of multi-storey building structures constructed from prefabricated volumetric construction modules 1 which are secured to one or more core structures 106. The core structures 106 may be concrete, steel or other suitable structures which are built on-site.

Figure 6 shows modular floor layouts in an apartment building. As illustrated, each apartment unit 100 is provided as a pre-fabricated volumetric construction module. Figure 7 is a close-up view of a modular floor layout of an apartment unit 100 of Figure 6. However, it is also to be appreciated that in some embodiments each apartment unit may be provided by securing two or more pre-fabricated volumetric construction modules together.

According to one aspect of the invention, a building structure includes one or more stacks of vertically adjoining pre-fabricated volumetric construction modules 1 secured together. The components, structure and configuration of each module 1 are described in the foregoing paragraphs.

5 Vertical securement is provided to vertically adjoining modules 1 within a stack (see Figures 13 to 15). Particularly, within a stack, e.g. a first stack, a plurality of first connection rods 11 secure an upper-level module 1 with an adjoining lower-level module 1. Each first connection rod 11 penetrates both an upper corner casting 2 and a lower corner casting 3 of a respective pair of corner castings at the upper-level module. The socket head 210 is engaged
10 with the upper corner casting 2 at the upper-level module. The tail penetrates into an upper corner casting 2 of the adjoining lower-level module and is threadably engaged with an internally threaded socket head 210 of an other connection rod which is engaged with the upper corner casting 2 of the adjoining lower-level module. Accordingly, the upper-level module is secured to the lower-level module.

15 This vertical securement between an upper-level and a lower-level module is replicated at various corner castings and throughout the first stack such that the modules within the first stack are vertically secured to one another.

 At the bottom-most module or first level module of the first stack, additional base plate having a threaded socket may be arranged under each lower corner casting of the first
20 level module to threadably engage with the connection rod penetrating the first level module. The additional base plates may be casted in non-shrink grouting and/or fixedly secured to a transfer slab, ground or foundation structure. This would secure the first level module to the ground or foundation.

 In some embodiments, at least one interlocking plate 12 is arranged interposed
25 between each upper-level module and its adjoining lower-level module. Socket head of a connecting rod engaged with the lower-level module is fitted within the interlocking plate opening 224 and guide projections 223 to prevent movement of the socket head including horizontal movement.

 In some other embodiments, the interlocking plate 12 provides horizontal securement
30 to horizontally adjoining modules. Particularly, in a building structure constructed from at least two stacks of vertically adjoining modules, in addition to vertical securement of the

vertically adjoining modules, horizontal securement of horizontally adjoining modules from two adjoining stacks are essential. For example, at a first and an adjoining second stack of vertically adjoining pre-fabricated volumetric construction modules, at least one interlocking plate is arranged overlapping or traversing the first and the second stack and interposed
5 between horizontally adjoining upper-level modules and horizontally adjoining lower-level modules which vertically adjoin the horizontally adjoining upper-level modules. This may be illustrated by Figure 2B which shows a plan view of two horizontally adjoining modules 1A, 1B provided as a first and a second stack. Interlocking plates 12 are arranged overlapping or traversing horizontally adjoining modules.

10 Similarly, Figure 2C shows a plan view of four adjoining modules and locations of corner castings in these modules. The four adjoining modules are provided in adjoining or different stacks. Interlocking plates 12 are arranged to overlap or traverse horizontally adjoining modules from adjoining stacks such that connection rods 11 securing the horizontally adjoining upper-level modules to the horizontally adjoining lower-level modules
15 also penetrate the interlocking plate openings to provide horizontal securement between the horizontally adjoining upper-level modules and further between the horizontally adjoining lower-level modules. By overlapping or traversing an interlocking plate with modules from adjoining stacks, penetrating and fitting a socket head from the module below through the interlocking plate(s), the interlocking plate(s) restrain horizontal or lateral movement of
20 horizontally adjoining modules.

In yet some other embodiments, the building structure includes a core structure 106 which is constructed on-site and secured to at least one of the modules or one of the stacks of modules.

25 According to one aspect of the invention, a method for constructing a building structure from pre-fabricated volumetric construction modules is provided and described with reference to a flow chart of Figure 17 as well as Figures 16A to 16H.

In block 1701 of Figure 17, a plurality of pre-fabricated volumetric construction modules are provided and arranged to produce one or more stacks of modules. This may
30 include arranging modules horizontally adjoining each other to provide first level modules.

In block 1703, connection rods are provided. A connection rod is inserted into respective upper corner casting and lower corner casting of each pair of corner castings of the

first level module (see Figures 16A and 14). Each connection rod penetrates the upper corner casting, the column supporting the pair of upper and lower corner castings, and the lower corner casting. Insertion of connection rod is performed at each pair of upper and lower corner castings of the first level modules.

5 In block 1705, each inserted connection rod is turned at its socket head or tightened to drive its tail into threaded engagement with an internally threaded socket head arranged in the lower corner casting (see Figure 16B). If the first level module is the bottom-most module of the stack, this internally threaded socket head may be provided at/by a base plate which is arranged under the bottom-most module and may be casted in non-shrink grouting and/or
10 fixedly secured to a transfer slab, ground or foundation structure. The tightened connection rod is housed within the corner castings and column, except for a portion of the socket head projecting from the upper corner casting and free-standing (see Figure 16C). The head socket of the connection rod is abutted against the upper corner casting of the first level module such that the connection rod is prevented from further vertical penetration and horizontal
15 movement.

In block 1707, an interlocking plate is arranged on one or more upper corner castings of the first level modules such that the projected and free-standing socket heads of the first level modules are penetrated through and fitted within the interlocking plate openings and further such that lower portions of the guide projections are seated or fitted within a first
20 upper plate opening of the upper corner casting of the first level module. In some embodiments, the interlocking plates overlap horizontally adjoining modules to provide horizontal securement therebetween. These interlocking plates are held in place by vertical forces due to weight of the upper module.

25 In block 1709, additional modules are stacked on the first level modules and interlocking plates to provide second level modules (see Figure 16D). During stacking of the second level modules, the guide projections on the interlocking plates provide a means for guiding the placement of the second level modules. Particularly, an operator lifts and lands a second level module onto the first level module such that the upper portions of the guide
30 projections are received into second plate openings of lower corner castings of the second module and seated or fitted within the lower corner castings to prevent lateral or horizontal movement (see Figure 13). After a second level module is stacked on the first level module,

projected socket head from the first level module is received into the lower corner casting of the second level module and fitted therein (see Figure 13).

5 In block 1711, connection rods are provided. A connection rod is inserted into
respective upper corner casting and lower corner casting of each pair of corner castings of the
second level module (see Figure 16E). Each connection rod penetrates the upper corner
casting, the column supporting the pair of upper and lower corner castings, the lower corner
casting, and the interlocking plate, until the tail end of each connection rod comes into
10 contact with a head socket below which is engaged with an upper corner casting of the first
level module. Insertion of connection rod is performed at each pair of upper and lower
corner casting of the second level modules.

15 In block 1713, each inserted connection rod is turned at its socket head or tightened to
drive its tail into threaded engagement with an internally threaded socket head which is
arranged in the lower corner casting and belongs to a secured connection rod of the first level
module (see Figures 16F and 13). The tightened connection rod is housed within the corner
castings and column, except for a portion of the socket head projecting from the upper corner
casting of the second level module (see Figure 16G). The head socket of the connection rod is
20 abutted against the upper corner casting of the second level module such that the connection
rod is prevented from further vertical penetration and horizontal movement.

25 In block 1715, an interlocking plate is arranged on one or more upper corner castings
of the second level modules such that the projected socket heads of the second level modules
are penetrated through and fitted within the interlocking plate openings and further such that
lower portions of the guide projections are seated or fitted within a first upper plate opening
of the upper corner casting of the second level module (see Figure 16H). In some
embodiments, the interlocking plates overlap horizontally adjoining modules to provide
horizontal securement therebetween.

30 In block 1717, additional modules may be stacked on the second level modules to
provide third level modules (see Figure 16H).

Embodiments of the invention provide several advantages including but not limited to the following:

- 5 - As the modules are relatively small in size, large or special factory and handling equipment are not needed thus resulting in efficiency and economies in fabrication, transporting, erecting and connecting. The self-standing or self-supporting modules can be erected quickly (without scaffolds, shoring, bracing, etc.) and directly and incorporate levelling and centering means which may be positioned prior to placement of the modules thereby to further accelerate the building erection process and to provide accuracy of placement of the modules.
- 10 - The modules provide an open system to allow builders customise their choice of local standard windows, doors, roofs and other equipment. The local standard windows and doors are preferably arranged between the modules, although they can, if desired, be fabricated and incorporated in the modules. Windows and doors set adjacent to the modules provide the advantage on connecting them to the modules on-site using standard connection details and further provide the construction tolerances required.
- 15 - Connection of building modules to each other, to floors and roofs, requires only the use of on-site connection details and practices.
- The modules can be designed to be of sufficient depth to define multi-purpose functional containers capable of enclosing and delineating kitchens, bathrooms, closets, other appliances and facilities, retail shelving, machines and show space for offices and retail buildings.
- 20 - The modules may be of a height which is a multiple of the normal floor-to-ceiling height of residential and commercial constructions. In multi-storey applications, such modules can retain their structural, self-supporting and self-standing capabilities while serving as full height exterior wall systems or as interior wall systems of a divider nature. Such modules desirably have the capabilities of using normal concrete inserts, dry wall panels with vertical
- 25 structures to support floors of prestressed slabs, or metal deck floors of steel structures.

The engineer transforming a single steel component forming 2D frames further refine into a 3D module The modules are assembled together by means of automation welding machine and a robotic 3D assembling process for accuracy, precision and better quality. This process eliminates rework, improves productivity and removes human fatigue.

- The number of sizes for modules for wide design flexibility is small, example from 3 to 5 types. The modules can be made simply and created by linking them together. These three to five sizes of modules can be interrelated, connected and positioned to create a virtually limitless set of room or enclosure configurations.

- 5 The corner-casting guide on the interlocking plate serves as the perpendicular guide to receive the bottom corner casting of the upper modules in its vertical plane. These interlocking plates are installed on the top of each module, checked for levelling and lateral tolerance before the top modules are lowered to match and fit perfectly during an installation operation. Therefore, the erection process is significantly speeded up, and costly crane and
- 10 equipment stay are utilized more efficiently. The need for highly skilled labour is greatly reduced as compared with traditional methods, this being a great advantage in regions where there is a shortage of skilled labour or where labour costs are exceedingly high.

- Vertical securement is provided to vertically adjoining modules. Horizontal securement is provided by the interlocking plate to horizontally adjoining modules.

- 15 It is to be understood that the embodiments and features described above should be considered exemplary and not restrictive. Many other embodiments will be apparent to those skilled in the art from consideration of the specification and practice of the invention. Furthermore, certain terminology has been used for the purposes of descriptive clarity, and not to limit the disclosed embodiments of the invention.

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Listing of Reference Numerals

01	PPVC Module
02	Upper Corner Casting
03	Lower Corner Casting
04	Post
05A	Bottom Rail
05B	Top Rail
06	Cross-bracing
07	Wall Profile

08	Roof Purlin
09	Floor Joist
10	Corrugated Roof
11	Connection Rod
12	Interlocking Plate
13	Wall stud
14	Wall Board
15	Floor Board
16	Ceiling Board
01A	Module
01B	Module
100	Apartment Unit
106	Concrete Core
210	Connection Rod Head
211	Connection Rod Body
212	Female Thread
213	Male Thread
214	Upper Corner Casting Hole / Opening
215	Upper Corner Casting Plate Hole / Opening
216	Upper Corner Casting Front Hole / Opening
217	Upper Corner Casting Side Hole / Opening
218	Lower Corner Casting Hole / Opening
219	Lower Corner Casting Plate Hole / Opening
220	Lower Corner Casting Front Hole / Opening
221	Lower Corner Casting Side Hole / Opening
222	Interlocking Plate – Main Plate
223	Interlocking Plate – Guide projection
224	Interlocking Plate – Hole / Opening

Claims

1. A prefabricated volumetric construction module comprising:

a plurality of beams and columns joined together to provide a self-supporting structure;

a plurality of pairs of upper and lower corner castings, each pair is arranged at distal ends of a column and adapted to receive therethrough a first connection rod having an internally threaded socket head and an externally threaded tail, wherein threads of the socket head and the tail are complementary,

wherein the upper corner casting is adapted to engage the socket head, and the lower corner casting is adapted to allow the tail penetrate therethrough to threadably engage with an internally threaded socket head of a second connection rod, which is engaged with an upper corner casting of a vertically adjoining module, to provide vertical securement between the prefabricated volumetric construction module and the vertically adjoining module.

2. The module of claim 1, wherein the upper corner casting includes a first upper plate having a first upper plate opening, a first lower plate having a first lower plate opening and a passageway extending between the first upper plate opening and the first lower plate opening,

wherein the first lower plate opening is smaller than the first upper plate opening such that the lower plate is adapted to prevent the socket head of the first connection rod from penetrating the lower plate.

3. The module of claim 2, wherein the lower corner casting includes a second upper plate having the second upper plate opening, a second lower plate having the second lower plate opening and a passageway extending between the second upper plate opening and the second lower plate opening,

wherein the second lower plate opening is adapted to allow penetration of the socket head of the second connection rod.

4. The module of any one of claims 1 to 3, further comprising:

at least one cross-bracing joining the beams and columns;

a plurality of roof purlins joining upper ones of the beams;

at least one roof mounted to the roof purlins;

5 a plurality of floor joists joining lower ones of the beams; and

at least one floor mounted to the floor joists.

5. The module of any one of claims 1 to 4, wherein at least some of the pairs of upper and lower corner castings are arranged at corners of the self-supporting structure.

6. The module of claim 5, wherein remaining ones of the pairs of upper and lower corner
10 castings are arranged adjacent to the at least some of the pairs of upper and lower corner castings.

7. A building structure comprising:

a plurality of pre-fabricated volumetric construction modules including vertically adjoining modules, wherein each module comprises:

15 a plurality of beams and columns joined together to provide a self-supporting structure;

a plurality of pairs of upper and lower corner castings, each pair is arranged at distal ends of a column,

a plurality of first connection rods, wherein each first connection rod secures an
20 upper-level module of the vertically adjoining modules with an adjoining lower-level module to provide vertical securement therebetween, wherein each first connection rod penetrates both an upper corner casting and a lower corner casting of a respective pair of corner castings at the upper-level module, each first connection rod having an internally threaded socket head and an externally threaded tail, wherein the socket head is engaged with the upper corner
25 casting at the upper-level module and the tail is threadably engaged with an internally threaded socket head of an other connection rod which is engaged with the upper corner casting of the adjoining lower-level module.

8. The building structure of claim 7, further comprising:

at least one interlocking plate having a main plate, at least one interlocking plate opening formed therein and at least one guide projection arranged at least partially around the interlocking plate opening, wherein the interlocking plate is interposed between the upper-level module and the adjoining lower-level module, wherein the internally thread socket head of the other connection rod is fitted within the interlocking plate opening, and wherein an upper and a lower portion of the guide projection are fitted within the lower corner casting of the upper-level module and upper corner casting of the lower-level module respectively.

9. The building structure of claim 7, further comprising:

at least one interlocking plate having a main plate, at least one interlocking plate opening formed therein and at least one guide projection arranged at least partially around the interlocking plate opening, wherein the interlocking plate is interposed between horizontally adjoining upper-level modules of the vertically adjoining modules and horizontally adjoining lower-level modules which vertically adjoin the horizontally adjoining upper-level modules, and

wherein the internally thread socket head of the other connection rod is fitted within the interlocking plate opening to provide horizontal securement between the horizontally adjoining upper-level modules and further between the horizontally adjoining lower-level modules, and wherein an upper and a lower portion of the guide projection are fitted within the lower corner casting of the upper-level module and upper corner casting of the lower-level module respectively.

10. The building structure of any of claims 7 to 9, further comprising:

a core structure constructed on-site and secured to at least one of the modules.

11. The building structure of any one of claims 7 to 10, wherein each module further comprises:

at least one cross-bracing joining the beams and columns;

a plurality of roof purlins joining upper ones of the beams;

at least one roof mounted to the roof purlins;

a plurality of floor joists joining lower ones of the beams; and
at least one floor mounted to the floor joists.

12. The building structure of any one of claims 7 to 11, wherein at least some of the pairs of upper and lower corner castings are arranged at corners of the self-supporting structure.

5 13. The building structure of claim 12, wherein remaining ones of the pairs of upper and lower corner castings are arranged adjacent to the at least some of the pairs of upper and lower corner castings.

14. The building structure of claim 12, wherein each module is provided with architectural finishes including interior decoration and fixtures.

10 15. A method for constructing a building structure, the method comprising:

stacking at least one upper-level pre-fabricated volumetric construction module on at least one lower-level module to provide vertically adjoining modules, wherein each module comprises:

15 a plurality of beams and columns joined together to provide a self-supporting structure;

a plurality of pairs of upper and lower corner castings, each pair is arranged at distal ends of a column,

providing vertical securement between the vertically adjoining modules by:

20 using a plurality of connection rods, penetrating each connection rod through an upper corner casting and a lower corner casting of a respective pair of corner castings of the upper-level module, each connection rod having an internally threaded socket head and an externally threaded tail;

25 threadably engaging the tail with an internally threaded socket head of an other connection rod which is engaged with an upper corner casting of the lower-level module.

16. The method of claim 15, wherein

before stacking at least one upper-level pre-fabricated volumetric construction module on at least one lower-level module to provide vertically adjoining modules, arranging at least one interlocking plate between the upper-level module and the lower-level module, wherein
5 the interlocking plate includes a main plate, at least one interlocking plate opening formed therein and at least one guide projection arranged at least partially around the interlocking plate opening; and

fitting the socket head of the other connection rod within the interlocking plate opening and fitting a lower portion of the guide projection within the upper corner casting of
10 the lower-level module.

17. The method of claim 15, further comprising:

before stacking at least one upper-level pre-fabricated volumetric construction module on at least one lower-level module to provide vertically adjoining modules, providing horizontal securement between horizontally adjoining upper-level modules and further
15 between horizontally adjoining lower-level modules by:

arranging at least one interlocking plate between the horizontally adjoining upper-level modules of the vertically adjoining modules and the horizontally adjoining lower-level modules which vertically adjoin the horizontally adjoining upper-level modules, wherein the interlocking plate includes a main plate, at least one
20 interlocking plate opening formed therein and at least one guide projection arranged at least partially around the interlocking plate opening; and

fitting the socket head of the other connection rod within the interlocking plate opening and fitting a lower portion of the guide projection within the upper corner casting of the lower-level module.

18. The method of claim 16 or 17, wherein stacking at least one upper-level pre-fabricated volumetric construction module on at least one lower-level module to provide vertically adjoining modules further includes:

fitting an upper portion of the guide projection within the lower corner casting of the upper-level module.

19. The method of any one of claims 15 to 18 further comprising: securing at least one of the modules to a core structure which is built on-site.

20. The method of any one of claims 15 to 19, wherein each module further includes:

at least one cross-bracing joining the beams and columns;

5 a plurality of roof purlins joining upper ones of the beams;

at least one roof mounted to the roof purlins;

a plurality of floor joists joining lower ones of the beams; and

at least one floor mounted to the floor joists.

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