

Modular Construction System

Field of Invention

The invention relates to the building construction techniques, and in particular, the use of prefabricated volumetric construction modules in building construction.

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Background

Prefabricated volumetric construction (PPVC) is frequently used in the construction industry to speed up the construction process. Currently, PPVC involves constructing individual modules in factories before transporting these modules on site for assembly.

10 However, the transportation of individual modules from the factories to the construction site tends to be very slow and expensive, particularly for remote sites. In particular, current PPVC systems require expensive handling and erection equipment to transport and erect the prefabricated modules into liveable apartments.

15 It would therefore be desirable to provide a modular construction system which overcomes or alleviates the above disadvantages, or which at least provides a useful alternative.

Summary of Invention

20 In a first aspect of the present invention, there is provided a modular structure, comprising a first module and a second module, said first and second modules moveably coupled to each other by an engagement assembly, wherein the first

module is arranged to be nested within the second module when the modular structure is in an unextended position, and wherein the first and second module are arranged to rotate relative to each other from the unextended position to an extended position.

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In embodiments of the present invention, the engagement assembly further comprises a rotating mechanism arranged to allow rotation of the first module or the second module about at least one principal axis.

10 Accordingly, the collapsible nature of the modular structure allows two units of living space to be shipped as one single module. This facilitates easy transportation from the factory to the construction site, thereby reducing the cost of shipping, transportation and logistics handling, while maximizing living space.

15 As a result, due to its easy deployment, the modular structures of the present invention is applicable for military or civilian projects of short duration, and also for construction of long-term housing in remote areas where on-site construction is uneconomical.

20 In addition, the modular structures of the present invention can also be deployed in copious quantities quickly and efficiently in areas where an urgent need of accommodation may be required. This may include, but is not limited to, disaster areas

or refugee camps, both of which may require large scale accommodation so as to avoid a humanitarian crisis in terms of exposure and disease.

In embodiments of the present invention, the second module further comprises at
5 least one detachable wall arranged to secure the first and second modules in either the unextended position or the extended position.

Accordingly, such an arrangement allows for easy transportation and deployment of the modular structure.

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In embodiments of the present invention, the modular structure further comprises a third module moveably coupled to the second module, the third module is arranged to be nested within the second module when the modular structure is in the unextended position, and rotate relative to the second module from the unextended position to
15 the extended position.

Accordingly, a larger modular structure may be prefabricated at a factory, with their interior fit-outs fully installed and finished for transportation to the construction site. This facilitates the easy construction of large modules on site.

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In embodiments of the present invention, the modular structure further comprises an exterior module moveably coupled to the second module, the second module is

arranged to be nested within the exterior module when the modular structure is in the unextended position.

In another aspect of the present invention, there is provided a building structure,
5 comprising a plurality of modular structures arranged to be adjacent to each other and
at least one binding member arranged to span across and couple adjacent modules,
wherein each of the plurality of modular structures comprises a first module, and a
second module moveably coupled to the first module by an engagement assembly, the
first module is arranged to be nested within the second module when the modular
10 structure is in an unextended position, the first and second module are arranged to
move relative to each other from the unextended position to an extended position,
and wherein at least one edge of one modular structure is aligned with a
corresponding edge of the adjacent modular structure.

15 Accordingly, the present invention allows the easy deployment of modular structures
in copious quantities quickly and efficiently in areas where an urgent need of
accommodation may be required.

Brief Description of Drawings

20 It will be convenient to further describe the present invention with respect to the
accompanying drawings that illustrate possible arrangements of the invention. Other
arrangements of the invention are possible, and consequently the particularity of the

accompanying drawings is not to be understood as superseding the generality of the preceding description of the invention.

Figure 1 shows a perspective view of a structural frame of a modular structure
5 according to one embodiment of the present invention;

Figure 2 shows a perspective view of a structural frame of a first module for the modular structure according to one embodiment of the present invention;

Figure 3 shows a perspective view of a structural frame of a second module for the modular structure according to one embodiment of the present invention;

10 Figures 4A to 4D shows the process of transformation of the modular structure from the unextended position to the extended position according to one embodiment of the present invention;

Figures 5A to 5F shows the process of transformation of the modular structure from the unextended position to the extended position according to one embodiment of the
15 present invention;

Figures 6A and 6B show views of the upper corner casting according to one embodiment of the present invention;

Figures 6C and 6D show views of the lower corner casting according to one embodiment of the present invention;

20 Figures 7A to 7J shows various examples of building structures constructed from more than one modular structures;

Figures 8A to 8D show perspective views of binding members according to one embodiment of the present invention;

Figure 9 shows cross-sectional view of a binding member according to a further embodiment of the invention;

5 Figure 10A shows a perspective view of a structural frame of a module according to one embodiment of the present invention;

Figure 10B shows a perspective view of a structural frame of a module according to one embodiment of the present invention;

10 Figure 11 shows a top view of a structural frame of a modular structure according to one embodiment of the present invention;

Figure 12 shows a perspective view of a structural frame of a modular structure according to one embodiment of the present invention;

Figure 13 shows a perspective view of a structural frame of a module according to one embodiment of the present invention;

15 Figures 14A and 14B shows perspective views of various structural frames of a module according to one embodiment of the present invention; and

Figures 15 to 20 shows perspective views of a module structure according to one embodiment of the present invention.

20 **Detailed Description**

Broadly, embodiments of the present invention generally provide a modular structure having at least one internal occupiable space comprising at least a first module and a

second module, said first and second modules moveably coupled to each other by an engagement assembly. The first module is arranged to be nested within the second module when the modular structure is in an unextended position, and extend out of the second module when the modular structure is in an extended position. To arrive at the extended position from the unextended position, either the first module or the second module is arranged to undergo a transformation.

It will be appreciated that by using the term "transformation", it may mean rotation and/or translation of the first or second module relative to each other.

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It will also be appreciated that embodiments of the present invention as will be described below may be constructed using a variety of accepted construction materials including, but not limited to: (i) masonry materials; (ii) reinforced, prestressed, poststressed and fibre reinforced concrete; (iii) construction metals including steel and aluminum; (iv) non-combustible, non-ferrous materials such as PVC; and (v) plasterboard.

In one embodiment of the present invention as illustrated in Figures 1 to 3, there is provided a modular structure 101 having a first module 105 and a second module 106 rotatably engaged to the first module 105 by an engagement assembly. In this embodiment, the engagement assembly is a rotating mechanism 115 arranged to allow rotation of the first module about one principle axis. The first module 105 is

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smaller than the second module 106, and is nested in the second module 106 when the modular structure 101 is in an unextended position.

As shown in Figures 2 and 3, the first module 105 and the second module 106 each
5 comprises a plurality of columns and beams interjoined to form a self-supporting structure. In particular, Figure 2 shows the structure of the first module 105 in accordance to one embodiment of the present invention. In this embodiment, a first plurality of bottom rails 105B are interconnected to form a base of the first module 105, while a first plurality of top rails 105A are interconnected to form a top of the first
10 module 105. The top and the base of the first module 105 are connected by a first plurality of columns 105C. Cross bracings 105F and top support 105E may also be provided so as to reinforce the structural integrity of the first module 105.

Figure 3 shows a structure of the second module 106. Similar to the first module 105,
15 the second module 106 comprises a second plurality of bottom rails 106B forming a base, and a second plurality of top rails 106A forming a top of the second module 106. Likewise, the base and top are connected by a plurality of columns 106E. Cross bracings 106H and top support 106G may also be provided so as to reinforce the structural integrity of the second module 106.

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As described earlier, the first module 105 and the second module 106 are rotably engaged by the rotating mechanism 115. In the illustrated embodiment as shown in

Figure 3, the rotating mechanism 115 comprises ball bearings positioned in the structural frame 106F of the second module 106. The ball bearings may be ball transfer units, transfer bearings, or any other mechanisms that allow smooth rotation of the first module 105 relative to the second module 106. As shown in Figure 2, at least one
5 steel base plate 105D is further provided on the first module 105, and arranged to be positioned directly over the ball bearings once the first and second modules are coupled together (as shown in Figure 1). In an embodiment as shown in Figure 2, one steel base plate 105D is positioned over each ball bearings. In this illustrated embodiment, the rotating mechanism 115 has a center of rotation 110 once it is
10 assembled.

Referring now to Figure 4A, the second module 106 may further comprise at least one detachable wall 107. As will be further described later, the detachable wall 107 is arranged to enclose the first module 105 when the modular structure 101 is in an
15 unextended position, and act as an opening for the first module 105 to rotate outwards and extend out of the second module 106 when the modular structure 101 is being moved to an extended position.

Figures 4A to 4D depicts the operation of the modular structure 101 in further detail.
20 As shown in Figure 4A, the first module 105 is nested in the second module 106 when the modular structure 101 is in an unextended position. At this position, the detachable wall 107 is closed, thereby enclosing the first module 105 within the

second module 106. Once the modular structure 101 is on site and in position, the detachable walls 107 of the second module 106 will be opened, thereby exposing the first module 105. The first module 105 can then rotate about the center of rotation 110 of the rotating mechanism 115. Once the first module 105 reaches to the
5 extended position, the detachable walls 107 will then be closed, thereby securing the first module 105 in place (as shown in Figure 4D).

Accordingly, such an arrangement reduces the time required to erect a multi-room apartment. Specifically, the modular structure 101 of the present invention allows two
10 units of living space to be shipped and transported to site as a single module, wherein the first module is encapsulated in the second module during transportation. This greatly reduces the shipping and transportation costs. Furthermore, with the rotating mechanism of this embodiment, the modular structure 101 can be erected rapidly with minimal manpower once the modules arrive on site.

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To this end, due to its easy deployment, the modular structure 101 of the present invention has several applications, such as erecting temporary structures for military or commercial purposes, or even for construction of long-term housing in remote areas where on-site construction is uneconomical.

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Furthermore, the present invention also allows the modular structure 101 to be secured when it is in the unextended position. Specifically, when the modular structure

101 is in the unextended position as shown in Figure 4A, the detachable walls 107 are closed, thereby nesting the first module 105 in the second module 106. This further increases the ease of transportation of the modular structure 101 while it is in the unextended position.

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In addition, rotational bearings such as ball bearings are able to withstand the static and dynamic force exerted by the rotating module. Hence, the use of ball bearings as part of the rotating mechanism provides a smooth rotation and increases the lifespan of the rotating mechanism.

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Whilst the modular structure 101 of Figures 4A to 4D are illustrated as having only two sets of detachable walls 107, it will be appreciated that the detachable walls may be of various configurations, such as the configuration as shown in Figures 5A to 5F, wherein there are more than two sets of detachable walls on the second module 156. In this regard, Figure 5E shows a top view of the completed and furnished modular structure 151, with the first and second modules 155, 156 fully extended out.

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Accordingly, such an arrangement allows the modular structure to be modified based on the design requirements. For example, should a larger module be required, the size of the first and second module could be enlarged and more detachable walls could be added so as to meet the geometric requirements without comprising on the structural integrity of the modular structure.

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Referring back to Figure 2 and 3, in further embodiments of the present invention, the second module 106 may further comprise a plurality of pairs of corner castings arranged at distal ends of each column 106E. Each pair of corner casting comprises a lower corner casting 106D and an upper corner casting 106C. In this embodiment, the columns 106E are hollow so as to provide a passageway therethrough.

An embodiment of the upper corner casting 106C is shown in Figures 6A and 6B. In this embodiment, the upper corner casting 106C comprises a first top plate, a first bottom plate and four first side plates interjoined or casted together to form the upper corner casting 106C. A first top opening 118, a first bottom opening 119 and four first side openings 120 are provided on the first top plate, the first bottom plate and the four first side plates, respectively. As shown in Figure 6A, the first top opening 118 is arranged to be larger than the first bottom opening 119.

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Figures 6C and 6D further show an embodiment of the lower corner casting 106D in further detail. Like the upper corner casting 106C, the lower corner casting 106D comprises a second top plate, a second bottom plate and four second side plates interjoined or casted together to form the lower corner casting 106D. A second top opening 122, a second bottom opening 123 and four second side openings 124 are provided on the second top plate, the second bottom plate and the four second side

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plates, respectively. As shown in Figure 6C, the second top opening 122 is arranged to be smaller than the second bottom opening 123.

Accordingly, such an arrangement allows two or more modular structures to be

5 stacked on top of or positioned adjacent to each other, thereby forming apartments as shown in Figures 7A to 7J. In particular, for securing vertically adjoining modules, at least one binding member could be inserted through the corner castings 106C, 106D and the hollow columns 106E of adjacent modules.

10 One such binding member that can be used according to this embodiment is the connection rod as shown in Figures 8A to 8C. In this embodiment, the connection rod 130 comprises an internally threaded socket head 132 and an externally threaded tail 135, the threads of the externally threaded tail 135 and the internally threaded socket head 132 are complementary. The socket head 132 is arranged to have a larger
15 external diameter than the diameter of the shaft 140, the first top opening 118 of the upper corner casting 106C and the second bottom opening 123 of the lower corner casting 106D. Further, the socket head 132 is also arranged to have a smaller external diameter than the first bottom opening 119 of the upper corner casting 106C.

20 In operation, a first connection rod 130 will be inserted into the corner castings and the hollow column of the second module of a first modular structure. The socket head will go through the first top opening 118 of the upper corner casting and abut the first

bottom plate of the upper corner casting, therefore securing the first modular structure. A second modular structure is then stacked on top of the first modular structure, and a second connection rod 130 is inserted into the corner castings and the hollow column of the second module of the second modular structure. As with the first connection rod, the socket head of the second connection rod will also abut the first bottom plate of the upper corner casting of the second modular structure. At the same time, the externally threaded tail of the second connection rod 130 will penetrate through the first bottom opening 119 of the upper corner casting and second top opening 122 of the lower corner casting so as to engage with the internally threaded socket head of the first connection rod, thereby securing the second modular structure to the first modular structure.

As for the horizontally adjoining modules, a horizontal binding member could also be used to secure the modules in place. An example of the horizontal binding member that can be used according to this embodiment is the interlocking plate as shown in Figure 8D. In this embodiment, the interlocking plate 212 is placed over the upper corner castings of adjacent second modules such that each of the plate apertures 214 is aligned with the opening of the upper corner casting 106C of the second module. The plate apertures 214 are arranged to allow vertical binding members, such as the binding members shown in Figures 8A to 8C, to penetrate through so as to secure the interlocking plate 212 and the modular structures in place.

Other types of binding members may also be used to secure adjacent modular structures together. This will include, but is not limited to, at least one tension cable and at least a pair of anchors.

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As an alternative arrangement the binding member may comprise a series of anchor blocks and post-stressing cables locating at the peripheral edges of the modules, with anchor blocks positioned at the connections portions of the modules. For instance the corner castings may comprise end anchors arranged to resist a post-stressed cable

10 connecting adjacent modules and binding said modules into a building structure. Such an arrangement is shown in Figure 9, which is alternative to the use of connecting rods as the binding member, as shown in Figures 8A to 8C. For this alternative embodiment, the end connections 322 are modified to receive an anchor 321, which act to resist the post-stressing of the cable 320. Thus when the various modules have been placed and

15 aligned, the cable is stressed so as to couple the placed discrete modules to form a unitary building structure.

Accordingly, such an arrangement allows a multi-room or multi-storey apartment block to be constructed quickly and efficiently, thereby increasing construction productivity

20 and as a result, reduces the cost of construction.

Whist the second module of the present invention is described to comprise corner castings, it will be appreciated that the corner castings are not required for the invention to work. In particular, as described earlier, one of the main functions of the corner castings is to aid in the securement of the modules using the binding members of Figures 8A to 8C. Hence, a skilled person will understand that any mechanism that allows any binding members to secure the modules may be used for the purposes of this invention.

It is to be appreciated that the first module 105 may also be rotated relative to the second module 106 without departing from the scope of the invention in order to meet the design requirements of the building.

It is also to be appreciated that the modular structure 101 may be prefinished at a factory, with their interior fit-outs fully installed and finished for transportation to the construction site.

Accordingly, this facilitates efficient construction on-site, and ensures that all gaps are accounted for and water-sealed before transporting the completed modular structure to the construction site. As a result, defects arising from on-site construction will also be minimized.

In further embodiments of the present invention as shown in Figures 10A and 10B, instead of ball bearings as described earlier, the rotating mechanism 1115 may be a ball bearing swivel plate 1106J positioned on top of the base structural frame 1106F of the second module 1106. Transfer bearings (not shown) may be positioned in between
5 the ball bearing swivel plate 1106J and the base structural frame 1106F so as to effect rotation. The ball bearing swivel plate 1106J is arranged to engage with a base plate 1105G on the first module 1105 via an aperture 1105H, wherein the base plate 1105G is positioned adjacent to the bottom rails 1105B (as shown in Figure 10B). In the illustrated embodiment, a pivot 1106K is also positioned on the top support 1106G and
10 in line with the center of rotation 1110. The pivot 1106K is arranged to engage a top plate 1105J on the top support 1105E of the first module 1105 (as shown in Figure 10B).

As a result, once the first and second modules 1105, 1106 are assembled, the first
15 module 1105 will be able to rotate about the center of rotation 1110, from an unextended position to an extended position, and vice versa.

In further embodiments of the present invention, the first and second modules may further comprise at least one of wall panels, roof panels or floor panels coupled to the
20 sides, top or base of the first and/or second modules respectively. These panels may be assembled in the factory, before transporting to the construction site for assembly. As a result, the time required for construction will be further reduced.

In yet another embodiment of the present invention as shown in Figures 11 to 14B, there is provided a first and third module 2105, 2107 (as shown in Figures 14A and 14B, respectively) rotatably engaged to a second module 2106 (as shown in Figure 13). The
5 first and third modules 2105, 2107 are arranged to be smaller than the second module 2106, and are nested in the second module 2106 when the modular structure 2101 is in an unextended position.

In this embodiment as shown in Figures 11 and 14B, the first and third module 2105,
10 2107 rotatably engaged to the second module 2106 by two sets of rotating mechanisms 2105A, 2107A, respectively, wherein the rotating mechanisms 2105A, 2107A are similar to the various rotating mechanisms described in this specification. Specifically, the rotating mechanisms 2105A, 2107A may include ball bearings, ball transfer units, or a ball bearing swivel plate as described earlier. However, it will be
15 appreciated that the rotating mechanisms 2105A, 2107A may also be any form of mechanisms that allow smooth rotation of the first and third modules 2105, 2107 relative to the second module 2106.

Accordingly, a larger modular structure 2101 may be prefinished at a factory, with
20 their interior fit-outs fully installed and finished for transportation to the construction site. This facilitates the easy construction of large modules on site.

It will be appreciated that more than two modules may be rotatably engaged to the second module, and arranged to be nested in the second module when the modular structure is in the unextended position. In this case, the number of rotating mechanisms is equal to the number of modules rotatably coupled to the second
5 module.

In embodiments of the present invention, the modular structures of the present invention may be stacked up to a height of 10 storeys. Nevertheless, it will be appreciated that depending on the building codes and regulations, the modular
10 structures may be stacked to a height of more than 10 storeys.

In embodiments of the present invention, the modular structure has dimensions equal to that of a standard shipping container when it is in the unextended position. For example, the modular structure may have the same dimensions as a standard 20-
15 footer or 40-footer shipping container. In other embodiments, the modular structure of the present invention may have dimensions corresponding to the requirements of the construction site.

Accordingly, such an arrangement is advantageous for transportation to the
20 construction site. In particular, the modular structure may be transported through normal shipping methods, such as cranes and forklifts using twistlock devices to engage, lift and disengage the modular structure. Furthermore, if transportation to a

remote location is required, shipping carriers and/or international ports can also use standard equipment and trailers to lift, shift, load and transport these modules. All these will lead to a reduction in transportation costs, thereby reducing the overall building costs.

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In yet another embodiment of the present invention as shown in Figures 15 to 20, the modular structure 3101 further comprises an exterior module 3108 moveably engaged to the second module 3106, wherein the first module 3105 is nested within the second module 3106. Furthermore, the first and/or second modules 3105, 3106 are arranged
10 to be nested within the exterior module 3108 when the modular structure is in an unextended position, and extend out of the second module when the modular structure is in an extended position. To arrive at the extended position from the unextended position, either the second module 3106 or the exterior module 3108 is arranged to undergo a translation relative to each other.

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The method of setting up the modular structure 3101 will now be described. In an embodiment, the exterior module 3108 of the modular structure 3101 is first lifted from an unextended position as shown in Figure 15 to an extended position as shown in Figure 16. This can be done using a crane or forklift or any other standard lifting
20 equipment. The detachable walls 3106A of the second module 3106 will then be opened (as shown in Figure 17), thereby exposing the first module 3105 that is nested within the second module 3106. As shown in Figures 18 and 19, the first module 3105

can then rotate out of the second module 3106 so as to reach the extended position.

Once the first module 3105 is in the extended position, the detachable walls 3106A can then be closed, thereby securing the modular structure 3101 in place (as shown in Figure 20).

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Accordingly, one modular structure will have more internal occupiable space available.

This allows a large multi-storey building to be prefabricated and prefinished in the factory, before being transported out to the construction site for assembly.

- 10 Although the illustrated embodiment only shows one module being nested in the second module when the modular structure is in the unextended position, it will be appreciated that two or more modules may be nested in the second module as well.

While the invention has been described with reference to specific embodiments,

- 15 modifications and variations in design and/or detail may be made without departing from the spirit and scope of the invention.

Claims

1. A modular structure, comprising:
 - a first module; and
 - 5 a second module, said first and second modules moveably coupled to each other by an engagement assembly, said engagement assembly including a swivel plate positioned on the second module and a base plate on the first module;
 - wherein the first module is arranged to be nested within the second
 - 10 module when the modular structure is in an unextended position, and
 - wherein the first and second module are arranged to rotate relative to each other from the unextended position to an extended position.
2. The modular structure according to claim 1, wherein the first module is
- 15 arranged to extend out of the second module when the modular structure is in the extended position.
3. The modular structure according to claim 1, wherein the second module is
- arranged to extend out of the first module when the modular structure is in the
- 20 extended position.
4. The modular structure according to any one of the preceding claims, wherein the engagement assembly further comprises a rotating mechanism arranged to

allow rotation of the first module or the second module about at least one principal axis.

5. The modular structure according to any of the preceding claims, wherein the second module further comprises at least one detachable wall arranged to secure the first and second modules in either the unextended position or the extended position.
6. The modular structure according to any of the preceding claims, wherein the second module further comprises a plurality of pairs of corner castings.
7. The modular structure according to any of the preceding claims, wherein the second module is arranged to be of the same dimensions as a standard shipping container.
8. The modular structure according to any of the preceding claims, further comprising a third module moveably coupled to the second module, the third module is arranged to be nested within the second module when the modular structure is in the unextended position, and rotate relative to the second module from the unextended position to the extended position.
9. The modular structure according to any of the preceding claims, further comprising an exterior module moveably coupled to the second module, the

second module is arranged to be nested within the exterior module when the modular structure is in the unextended position.

10. The modular structure according to claim 9, wherein the exterior module is
5 arranged to translate relative to the second module.

11. A building structure, comprising:

a plurality of modular structures arranged to be adjacent to each other;

and

10 at least one binding member arranged to span across and couple adjacent modules,

wherein each of the plurality of modular structures comprises a first module, and a second module moveably coupled to the first module by an engagement assembly, the first module is arranged to be nested within the
15 second module when the modular structure is in an unextended position, the first and second module are arranged to move relative to each other from the unextended position to an extended position, and

wherein at least one edge of one modular structure is aligned with a corresponding edge of the adjacent modular structure;

20 wherein the engagement assembly comprises a rotating mechanism arranged to allow rotation of the first or the second module about at least one principal axis.

12. The building structure according to claim 11, wherein the first module is arranged to extend out of the second module when the modular structure is in the extended position.
- 5 13. The building structure according to claim 11, the second module is arranged to extend out of the first module when the modular structure is in the extended position.
- 10 14. The building structure according to any one of claims 11 to 13, wherein the binding member comprises at least one connection rod arranged to be inserted through at least one edge of the second module, the connection rod comprises an internally threaded end and an externally threaded end, the externally threaded end of at least one connection rod is arranged to be secured to a base
- 15 of an adjacent second module.
15. The binding structure according to claims 11 to 13, wherein the binding member comprises an assembly of at least one tension cable and at least one pair of end anchors.
- 20 16. The building structure according to any one of claims 11 to 15, further comprising a third module moveably coupled to the second module, the third module is arranged to be nested within the second module when the modular

structure is in the unextended position, and rotate relative to each other from the unextended position to the extended position.

17. The building structure according to any one of claims 11 to 16, further
5 comprising an exterior module moveably coupled to the second module, the second module is arranged to be nested within the exterior module when the modular structure is in the unextended position.
18. The building structure according to claim 17, wherein the exterior module is
10 arranged to translate relative to the second module.