

# APPARATUS, SYSTEM AND METHOD FOR PREFABRICATED MODULAR HOUSING

## Field of Invention

5 The present invention relates to an apparatus, system and method for prefabricated modular housing. In particular, this apparatus, system and method is suitable for, but not limited to, concrete-based prefabricated modular housing.

## Background Art

10 The following discussion of the background to the invention is intended to facilitate an understanding of the present invention only. It should be appreciated that the discussion is not an acknowledgement or admission that any of the material referred to was published, known or part of the common general knowledge of the person skilled in the art in any jurisdiction as at the priority date of the invention.

15 To achieve higher construction productivity, precast or prefabrication industry has been evolving from using two-dimensional (2D) components to larger three-dimensional volumetric precast components (also known as 3D precast modules or 3D prefabricated component). Further productivity gain can be achieved through integration of architectural finishes, such as incorporating tiles and window frames, and precasting 3D precast modules that are of a larger size. However, one challenge is that the size (height and width) of each 3D precast modules has to be constrained so as to be transportable by trucks along public roads. An apartment unit may be too large to prefabricate as a single element. As a consequence, a feasible solution is to produce 3D precast modules that have a size of a room, kitchen or bathroom unit before assembling them in a modular manner to form a building block on-site.

25 There are several challenges relating to the modular system of assembling a building from 3D precast modules (also known as a prefabricated building system). One challenge is to ensure that the structural performance of the modularly assembled building is able to fulfil building codes and regulatory standard, including being able to support and resist external forces acting on building and ultimately transfer the load to the building's foundation. Furthermore, crack formation within each 3D precast modules and joint connection has to be controlled when exposed to external forces.

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There is also a need to ensure water-tightness to minimize or prevent water leaking between the interconnected 3D precast modules which may result in discomfort for the resident as well as degrade overall structural performance of the building. Additionally, the assembly of 3D precast modules has to be efficient in space utilization and at the same time, achieve aesthetic both in the interior and exterior of the building.

As shown in Fig. 1, a present solution 100 for interconnecting or interlocking 3D precast modules involves the use of bolted connections 102 (or other structural connector system available in the market) between adjacent 3D precast modules. These bolted connections 102 require a double-wall architecture 104 in which opposing vertical wall sections (106 and 108) of two adjacent 3D precast modules abuts so as to allow for a bolt 102 to be threaded laterally across the two wall sections (106 and 108) to secure the two adjacent 3D modules together. A disadvantage associated with this solution is that water can easily seep through bolted connections 102 into the space or gap 104 between the double-wall, resulting in long term structural degradation and water leakages. Further, the space between two abutting walls is not easily accessible to locate the gap 104 for repairs. A further disadvantage of the double-wall architecture (106 and 108) is reduction in interior floor space without significant increase in structural performance of the building. A further disadvantage of the present solution 100 is that adjacent modules typically have to be the same type for easy integration, i.e. N-shape module with N-shape module (Fig. 1 (a)) or U-shape module with U-shape module (Fig. 1 (b) and (c)). In this case, the N-shape module is defined as a 3D precast module that has a roof with at least one downward extending wall section and the U-shape module is defined as a 3D precast module that has a floor with at least one upward extending wall section. Consequently, this prevents the flexibility of having interior architectural floor finishing in some modules and interior architectural ceiling finishing in other modules.

Another disadvantage of existing solutions is the adoption of dry method of connection between inter-modules joints which usually does not provide a strong enough counter or restraint forces against cracks formation associated with thermal effect or differential building movements, thus causing potential water seepage

through such cracks. Also, the performance of these connection method used by the conventional solutions such as those in Fig. 1 are very dependent on workmanship, material durability and it is less resilient against damage due to tempering, renovation and the worst scenario is by fire. Defect associated with construction  
5 imperfection of the prior art is also difficult to detect or access for repair.

Therefore, there exists a need for a better solution to ameliorate one or more of the aforementioned problems in a prefabricated modular housing system.

## **Summary of the Invention**

One or more of the aforementioned problems may at least be solved through the  
10 provision of a coupling portion along an edge of a body portion of each 3D precast module to facilitate the formation of in-filled concrete joints when connecting adjacent 3D precast modules.

In accordance with one aspect of the invention, there is a prefabricated component for use in a prefabricated building system, comprising a first body portion having an  
15 edge, the edge comprises a coupling portion, wherein when the prefabricated component is arranged adjacent to a second component along the edge to form a composite module, the coupling portion and a part of the second component define a groove for a casting material to be in-filled to join the first body portion to the second component. Advantageously, the prefabricated component and the second  
20 component may be fabricated or precast off-site and connected or secured together on-site upon curing of a casting material.

Preferably, the first body portion is three-dimensional and comprises at least one vertical element extending from a slab. Advantageously, the construction time may be reduced as the joint between the slab and the at least one vertical element is  
25 prefabricated off-site.

Preferably, the at least one vertical element extends downwardly from the slab when the first body portion is placed adjacent to the second component. Advantageously, a N-shape module allows architectural finishes to be applied to the walls and ceiling off-site.

30 Preferably, the at least one vertical element extends upwardly from the slab when the first body portion is placed adjacent to the second component. Advantageously,

a U-shape module offers better water-tightness performance as the floor and side walls are precast integrally or integrally moulded. Furthermore, architectural finishes may be applied to the floor and walls to provide continuity in the architectural finishes and further improve water-tightness performance. More preferably, the second component is three-dimensional and comprises at least one vertical element extending from a second slab, wherein the at least one vertical element extends downwardly from the second slab when the first body portion is placed adjacent to the second component. Advantageously, the interconnection of U-shape and N-shape modules enables the abutting joints between modules to be accessed, cast and treated prior to the concealment caused by the installation subsequent modules thus enable better water-tightness of the internal space and use of interior space to be more optimal.

Preferably, the coupling portion is a recess on the slab. More preferably, the part of the second component is a beam with a recess.

Preferably, the coupling portion is a beam protruding from the slab.

Preferably, the beam is Z-shape.

Preferably, the coupling portion is the at least one vertical element with thickness dimensioned such that the groove is defined for the casting material to be in-filled when the first body portion is placed adjacent to the second component.

Preferably, the first body portion is precast from concrete.

Preferably, the casting material is concrete or structural grout.

Preferably, the first body portion and the coupling portion are integrally moulded.

In accordance to a second aspect of the invention, there is a method of interconnecting a prefabricated component and a second component, comprising the steps of positioning a first body portion of the prefabricated component next to the second component such that a coupling portion of the prefabricated component and a part of the second component define a groove; and filling the groove with a casting material to join the first body portion to the second component.

Preferably, the first body portion is three-dimensional and comprises at least one vertical element extending from a slab.

Preferably, the at least one vertical element extends downwardly from the slab when the first body portion is placed adjacent to the second component. Preferably, the at least one vertical element extends upwardly from the slab when the first body portion is placed adjacent to the second component. More preferably, the second component is three-dimensional and comprises at least one vertical element extending from a second slab, wherein the at least one vertical element extends downwardly from the second slab when the first body portion is placed adjacent to the second component.

Preferably, the coupling portion is a recess on the slab. More preferably, the part of the second component is a beam with a recess.

Preferably, the coupling portion is a beam protruding from the slab.

Preferably, the beam is Z-shape.

Preferably, the coupling portion is the at least one vertical element with thickness dimensioned such that a groove is defined for the casting material to be in-filled when the first body portion is placed adjacent to the second component.

Preferably, the first body portion is precast from concrete.

Preferably, the casting material is concrete or structural grout.

Preferably, the first body portion and the coupling portion are integrally moulded.

In a third aspect of the invention, there is a prefabricated building system comprising a prefabricated component having a first body portion having an edge, the edge comprises a coupling portion; and a second component, wherein when the prefabricated component is arranged adjacent to the second component along the edge to form a composite module, the coupling portion and a part of the second component define a groove for a casting material to be in-filled to join the first body portion to the second component to form as an integral building element.

## **Brief Description of the Drawings**

The present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Fig. 1 shows a present solution used in the prior art in connecting adjacent 3D precast modules.

Fig. 2 shows the two types of concrete in-filled joints (type T1 and T2) that may be used to interconnect adjacent modules.

- 5 Fig. 3 shows the two types of concrete in-filled joints (type T3 and T4) that may be used to interconnect adjacent modules.

Fig.4 shows the two types of concrete in-filled joints (type T3 and T5) that may be used to interconnect adjacent modules.

- 10 Fig. 5 shows an overall layout plan of a typical residential building comprising of flats with two different layouts (unit 1 and unit 2) and perspective views of the building of each layout.

Fig. 6 shows layout plan for type-1 units (also known as type-1 unit layout) wherein each flat comprises three modules (M1+M2+M3 or M1a+M2a+M3a).

- 15 Fig. 7 shows individual perspective views of (a) module 1a, (b) module 2a and (c) module 3a.

Fig. 8 a partial exploded view illustrating the integration of various individual 3D precast modules into composite modules for type-1 units. The position of the five types of joints used for interconnection also indicated.

- 20 Fig. 9 shows a layout plan for type-2 units (also known as type-2 unit layout) wherein each flat comprises three modules (M4+M5+M6 or M4a+M5a+M6a).

Fig. 10 shows individual perspective views of (a) module 4a, (b) module 5a and (c) module 6a.

Fig. 11 shows a cross-section view of (a) T1 joint and (b) T2 joint.

- 25 Fig. 12 shows (a) a plan view of a T3 joint and (b) a cross-section view of the T3 joint.

Fig. 13 shows (a) a cross-section view of a T4 joint and (b) a cross-section view of a T5 joint.

Fig. 14 shows cross-section views of two different design options for T4 joint.

## Description of Embodiments of the Invention

Throughout the specification, unless the context requires otherwise, the word “comprise” or variations such as “comprises” or “comprising”, will be understood to imply the inclusion of a stated integer or group of integers but not the exclusion of any other integer or group of integers.

Furthermore, throughout the specification, unless the context requires otherwise, the word “include” or variations such as “includes” or “including” will be understood to imply the inclusion of a stated integer or group of integers but not the exclusion of any other integer or group of integers.

10 In accordance with various embodiments of the invention as shown in Fig. 2, there is a prefabricated modular housing system 200 for assembling a structure, such as a building (also known as a “prefabricated building system 200”). The prefabricated modular housing system 200 comprises a plurality of 3D precast modules that may be assembled to form the building. The 3D precast modules may include an N-shaped module and a U-shape module. An N-shaped module is defined as 3D precast module having a roof with at least one element extending perpendicular from an edge of the roof (hereinafter also known as a vertical element) and the U-shape module is defined as a 3D precast module that has a floor with at least one upward extending vertical element. In various embodiments, the vertical element may be any one of the following: a wall, a column or a beam. A module may also be interchangeably referred to as a “component”. The prefabricated modular housing system 200 may comprise joints to interconnect N-shape modules with U-shape modules (see Fig. 2) and joints to interconnect N-shape modules with N-shape modules (see Fig. 3 and Fig. 4). In particular, interconnecting N-shape modules with U-shape modules allows the flexibility to selectively provide interior architectural finishing on either the floor (for U-shape modules) and ceiling (for N-shape modules). It is to be appreciated that U-shape modules are considered to have better water-tightness property or performance since that floor and upward extending wall-sections are precast integrally and further off-site architectural finishes may be applied to the interior to provide continuity of the wall and floor finishes of the U-shape module and to further enhance water-tightness prior to on-site assembly. As such, U-shape modules may typically be well-suited to be used for bathroom or

kitchen units. However, for living room or bedroom units, it may be more advantageous to have off-site architectural finishes on the ceiling and walls instead. Furthermore, the concept to integrate an N-shape module with the U-shape module (N-U configuration) is also to allow accessibility to reinforce and cast the abutting joint, which otherwise may not be full accessible for treatment if it is assembled as a U-shape module and U-shape module (U-U configuration). In other words, the N-U and N-N configurations allow the joints in a first floor to be accessed even after additional 3D precast modules are stacked on top of the first floor to form a second floor. This is in contrast to a U-U configuration as shown partly by Fig. 1, in which the in-filled joint in place of the bolted connection 102 between two U-U modules at the top edge would become inaccessible because it would be concealed by the horizontal slabs of the U-shape modules making up the second floor after stacking. Consequently, it is advantageous to provide a prefabricated modular housing system 200 that can cater to both types of modules.

Referring to Fig. 7, it may be observed that a N-shape or U-shape module has a body portion comprising at least one vertical element and a horizontal slab section, arranged such that the at least one vertical element extends either downwardly or upwardly from the horizontal slab section. The body portion defines an interior space of the building and may be self-supporting such that the 3D modules may be able to stand upright (on the vertical walls for N-shape module and on the horizontal slab for U-shape module) for easy transportation. In various embodiments, if the 3D modules are not self-supporting, external temporary supports may be provided during transportation and prior to its assembly. It may be appreciated that the cross-section structure of the modules at different lateral positions may be varying, i.e. for N-shape module, possible cross-sections are N-shape with two opposing side walls or inverted L. Consequently, different joints are required to cater to different cross-section for connection with an adjacent module. To this end, different cross-section of the 3D precast module comprises a coupling portion along a corresponding edge shaped to facilitate the formation of an appropriate in-filled concrete joint. In some embodiments, the coupling portion may be in the form of a flange along an edge of the body portion. The edge may be a corner, a length or a portion of length along a side wall, or a combination of the above.

As shown in Fig. 2 to 4, the prefabricated modular housing system 200 illustrates the use of at least five different types of in-filled concrete joints for interconnecting 3D precast modules representing the connection between two 3D precast modules at different lateral positions with different cross-sections. These joint connections may  
5 allow a horizontal concrete element (such as a slab and beam) or a vertical element (such as column and wall) that is part of the first body portion of a first 3D precast module (first or prefabricated component) to be correspondingly connected to either a horizontal element or a vertical element that is part of the second body portion of a laterally or vertically adjacent second 3D precast module (second component). In  
10 various embodiments, a horizontal element or a vertical element of a laterally or vertically adjacent third 3D precast module (third component) may also be connected to the first and second 3D precast modules. Having a variety of joint connections enables the use of interior space to be near optimal by eliminating double-wall configuration at certain sections. Furthermore, interconnectivity between adjacent  
15 modules is also not restricted to a double-wall or double column architecture 104 that is required for a bolted connection 102 or other structural connector system available in the market as compared to the present solution 100 as described above.

Referring to Fig. 2 at section A-A, a type-1 (T1) in-filled concrete joint 202 may comprise two parts. A first part is a sandwiched wall or column that is formed at an  
20 interface between a vertical wall section or column section 210 of an N-shape module 206 and a corresponding vertical wall section or column section 212 of a first U-shape module 208. The opposing vertical wall or column sections 210 and 212 are dimensioned such that a gap 222 is defined for the in-filling of concrete (or other structural grout infill materials) to form the sandwiched column or wall when both  
25 modules are stacked on top of the bottom set of modules. In various embodiments, the stacking of two modules involve connecting the column of the upper module to the column of the lower module by a structural connector. In other words, the opposing vertical wall or column sections 210 and 212 may be regarded as a first and second coupling portions respectively to facilitate the formation of the T1 joint  
30 202 (also known as a coupling) which serves to connect the N-shape module 206 with the first U-shape module 208.

A second part is a sandwiched slab or beam of the T-1 joint 202 is formed at an interface between a horizontal slab section 214 of the N-shape module 206 and a

horizontal slab section 216 of a second U-shape module 220, wherein the second U-shape 220 is stacked on top of the first U-shape module 208. In various embodiments, a horizontal recess 218 is formed at a top portion and along an edge of the horizontal slab section 214 of the N-shape module 206 so as to allow in-filled concrete to form a horizontal sandwiched slab or beam between a step-edge of the horizontal recess 218 and an outer bottom edge of the second U-shape module 220. Similarly, the horizontal recess 218 and the outer bottom edge of the second U-shape module 220 may also be considered to be coupling portions which serves to connect the N-shape module 206 with the second U-shape module. Consequently, the T1 joint 202 with the first and second parts has a substantially L-shaped cross-section comprising of the sandwiched concrete column or wall and the sandwiched concrete slab or beam. Therefore, the T1 joint 202 reinforces the structural integrity of the building in both the vertical and lateral or shearing directions.

Referring to Fig. 2 at section B-B, a type-2 (T2) in-filled concrete joint 204 may be formed to connect three 3D precast modules at an intersection comprising: 1) a horizontal slab section 228 of a N-shape module 224, 2) a vertical wall or column section 238 of a first U-shape module 226 and 3) a horizontal slab section 232 of a second U-shape module 236. In various embodiments, the first coupling portion 230 along an edge of the N-shape module 224 and the second coupling portion 234 along an edge of the first U-shape module 226 are shaped such that a groove or pocket of space is formed at the intersection to allow concrete to be filled to form the T2 joint. In this case, the coupling portion along an edge of the N-shape module 224 comprises a beam that is Z-shape beam or Z-shape protrusion 230 extending laterally from the horizontal slab 228 and the coupling portion along an edge of the first U-shape module 226 comprises a projection 234 extending laterally outwards from the vertical wall or column section 238 of the first U-shape module 226 towards the N-shape module. When the N-shape module is arranged or placed next to the U-shape module during the modular assembling of the building, the Z-shape beam 230 couples with projection 234 and a bottom edge of the second U-shape module 236 to define a pocket of space or groove. Concrete may then be in-filled into the groove to form the T2 joint at the intersection, connecting the three modules together. In various embodiments, the first coupling portion 230 and second coupling portion 234 may be a first half-beam protruding laterally from the horizontal slab 228 and a

second half-beam protruding laterally from the vertical wall 238 respectively. Subsequently, the connection of both the first coupling portion 230 and second coupling portion 234 forms a sandwiched or integrated beam which becomes the base of the groove for concrete to be in-filled to form the T2 joint. In other words, the first half-beam and second half-beam are connected to form the sandwiched or integrated beam. The T2 joint 204 enhances the structural performance of the building in handling shear forces without requiring the double-wall architecture which would compromise interior space efficiency.

In various embodiments not shown in Fig. 2, the coupling portion of the N-shape module 224 may be a horizontal recess and a vertical recess formed along an upper edge of the horizontal slab 228. The horizontal recess and vertical recess may be arranged in a substantially perpendicular manner to form a step or Z-shape like structure that is capable to function like the Z-shape beam 230 as described above.

A type-3 (T3) in-filled concrete joint 302 may comprise of two part. A first part is sandwiched column or wall that may be formed at an interface between a vertical wall section or column section 310 of a first N-shape module 306 and a corresponding vertical wall section or column section 312 of a second N-shape module 308, wherein the first N-shape module 306 is position laterally adjacent to the second N-shape module 308. The opposing vertical wall or column sections 310 and 312 are dimensioned such that a gap 338 is defined for the in-filling of concrete or structural grout to form the sandwiched wall or column when both modules laterally adjacent to each other. In other words, the opposing vertical wall or column sections 310 and 312 are a first and second coupling portions respectively to facilitate the formation of the T3 joint 302 (also known as a coupling) which serves to connect the first N-shape module 306 with the second N-shape module 308.

The second part of the T3 in-filled concrete joint 302 is a sandwich beam or slab formed by in-filled concrete in the space or groove defined by a first horizontal recess 318 that is formed at a top portion of the horizontal slab section 314 of the first N-shape module 306 and a second horizontal recess 320 formed at a top portion of the horizontal slab section 316 of the second N-shape module 308. Consequently, the T3 joint 302 has a substantially T-shaped cross-section comprising of a sandwiched concrete column and a sandwiched concrete beam. In various

embodiments as shown in Fig. 12, the T3 joint may also comprise of only the sandwiched vertical column or wall without the horizontal sandwich beam or slab. The T3 joint 302, by virtue of the sandwiched vertical column and horizontal beam, reinforces the structural integrity of the building in both the vertical and lateral or shearing directions.

A type-4 (T4) in-filled concrete joint 304 may be formed at an interface between a horizontal slab section 328 of a first N-shape module 322 and a corresponding vertical wall section or column section 326 of a second N-shape module 324, wherein the first N-shape module 322 is position laterally adjacent to the second N-shape module 324. In this case, the coupling portion of the first N-shape module 322 comprises a Z-shape beam or Z-shape protrusion 330 extending laterally from the horizontal slab 328 and the coupling portion of the second N-shape module 324 comprises a horizontal recess 336. Subsequently, the Z-shape beam or Z-shape protrusion 330 couples with a top edge 334 of the second N-shape module 324 to form a T-shape groove. Concrete may then be in-filled into the T-shape groove to form the T4 joint. The T4 joint 304 enhances the structural performance of the building in handling shear forces without requiring the double-wall or double column architecture which would compromise interior space efficiency.

In various embodiments, the vertical wall section or column section may be a non-structural partition wall integrated with a protrusion 338 hidden along the wall at the top edge of the second N-shape module. The Z-shape beam 340 may then couple with the protrusion 338 to form a sandwich beam. The groove that is formed between the Z-shape protrusion 340 and protrusion 338 allows concrete or structural grout to be in-filled to form the T4 joint.

A type-5 (T5) in-filled concrete joint 402 may at an interface between a horizontal slab section 408 of a first N-shape module 404 and a corresponding horizontal slab section 410 of a second N-shape module 406, wherein the first N-shape module 404 is position laterally adjacent to the second N-shape module 406. Likewise, the first coupling portion 412 (or first beam portion 412) of the first N-shape module 404 and the second coupling portion 414 (or second beam portion 414) of the second U-shape module 406 are shaped such that a pocket of space is formed at the intersection which allows concrete to be filled to form the T5 joint 402. In this case,

the first coupling portion 412 comprises a Z-shape protrusion 412 extending laterally from the horizontal slab 408 and the coupling portion 414 of the second N-shape module 406 comprises an angled-bar protrusion 414 extending laterally from the horizontal slab 410 towards the first N-shape module 404. Subsequently, the Z-shape beam 412 couples with the angled-bar protrusion 414 to form a T-shape groove. Concrete may then be in-filled into the T-shape groove to form the T5 joint 402. The T5 joint 402 enhances the structural performance of the building in handling shear forces without requiring the double-wall or double column architecture which would compromise interior space efficiency.

The modular assembly system will now be described in more details in the context of its application to a residential construction project. Fig. 5 shows an overall layout plan of a residential building comprising units or flats with two different layout plans (type-1 and type-2 units). Fig. 6 and Fig. 9 show the expanded view of the layout plan for both type-1 and type-2 units respectively. Both units may be assembled from 3D precast modules with different structural designs as illustrated in Fig. 7 and 10. For example, type-1 units may be assembled from 3D precast modules M1, M2, M3, M1a, M2a and M3a whereas type-2 units may be assembled from 3D precast modules M4, M5, M6, M4a, M5a and M6a. In this case, the suffix “a” denotes that the corresponding modules are related. For example, module M1a is a mirror image of module M1 and comprises an additional vertical wall 702. Similarly, module 3a is mirror image of module M3 and comprises an additional vertical wall 704. Module M2a is a mirror image of module M2. Assembling modules M1, M2, M3, M1a, M2a and M3a in a manner illustrated in Fig. 6 results in two adjacent type-1 units which are mirror images of each other (P1 and P1a). Furthermore, the use of complementary modules M1a and M3a allows the two laterally adjacent type-1 units (P1 and P1a) be partitioned by a single wall substantially along the separation axis 602, thus eliminating the use of a double-wall architecture and improving interior space efficiency. Fig. 7 also shows, non-exhaustively, a Z-shape beam or Z-shape protrusion 706 located along an edge of module M3a, a projection 708 extending laterally from an edge of module M2a, a horizontal recess 710 along an edge of module M3a and a vertical recess 712 located along an edge of module M1a.

Fig. 8 shows a partial exploded view of two adjacent type-1 units (P1 and P1a) disassembled along the separation axis 602. In this case, each unit is a composite

module assembled from three individual 3D precast modules. It may be observed that the partition between the two adjacent P1 and P1a units may be achieved by either vertical wall 702 or 704 located in modules M1a and M3a respectively.

Fig. 8 further illustrates, non-exhaustively, the use of the five types of concrete in-filled joints (denoted by five different shapes) for interconnecting 3D precast U-shape modules (module M2 and M2a) and N-shape modules (M1, M1a, M3 and M3a) to assemble a residential building in a modular manner. As observed in Fig. 8 cross-referencing with Fig. 11 (a), a T2 joint may be formed to interconnect a vertical wall-section of a M2 module at a first section or cross-section 1102 with a horizontal slab section of module M3 when module M2 is arranged adjacent next to module M3 along an edge 1106 of module M2. Cross-referencing Fig. 8 with Fig. 11 (b), a T1 joint may be formed to interconnect module M2 (U-shape module) at a second section 1104 with module M3 (N-shape module)). In this case, module M2 is a bathroom unit that requires water-tightness provided by the U-shape module. Further, the U-shape module allows integration of floor with wall(s) and allow continuity of finishes, whereas N-N configuration does not allow continuity of the finishes and there may be a visible joint at floor level which is not desirable, especially at kitchen and bathroom where there are wall and floor tiles finished.

Cross-referencing Fig. 8 with Fig. 12, a T3 joint may be formed to interconnect a vertical wall section of module M1a at a first section 1202 with a vertical wall section of module M1 whereby the sandwiched column serves as a connection as well as enhances structural integrity. Further, reinforcing bars 1204 (re-bars) may be also used to reinforce the sandwiched column. In various embodiments, the re-bars may be made of steel. Referring to Fig. 13 (a), a T4 joint may also be formed to interconnect a vertical wall section of module M1a at a second section 1302 with a horizontal slab section of module M1. Cross-referencing Fig. 8 with Fig. 13 (b), a T5 joint may be formed to interconnect a horizontal slab section of module M1a at a third section 1304 with a horizontal slab section of module M3a. In this case, the joints at the first, second and third sections of module M1a serves to interconnect the module M1a with adjacent modules M1 and M3a. Similarly, module M1a may also be connected at other sections (not described here) to module M2a and other modules not shown.

Consequently, it may be observed above that the variety of joints available provide the technical advantages of: 1) allowing more complex interior layout since 3D precast modules of different lateral dimensions may be integrated, 2) increasing space efficiency by eliminating double-wall substantially and 3) improving water-tightness and better building performance by enabling the integration of U-shape modules with N-shape modules.

It should be further appreciated by the person skilled in the art that variations and combinations of features described above, not being alternatives or substitutes, may be combined to form yet further embodiments falling within the intended scope of the invention. In particular,

- It may be appreciated that the interconnection of a first and second adjacent 3D precast modules may be achieved in which only the first 3D precast module has a coupling portion for coupling to a body portion or element (such as a column, wall, beam or slab) of the second 3D precast module as long as a groove is formed at the interconnection for the filing of casting material for forming a joint. Furthermore, a 3D precast module may also be interconnected to an existing building component as part of a building renovation or refurbishment project. As such, the coupling portion on the 3D precast module may enable coupling to a vertical wall or column or horizontal slab of an existing building component (second component), wherein the existing building component may or may not be precast or prefabricated.
- For coupling to a slab in a first 3D precast module, a beam with recess may be used in the adjacent second 3D precast module to couple with the slab with a recess in the first 3D precast module.
- It may be appreciated that an in-filled concrete or structural grouted joint may also be formed for connecting a first U-shape module and a second U-shape module through the use of coupling portions as illustrated in Fig. 2, 3 and 4.
- Reinforcing bars may be used to enhance the connection for each of the T1-T5 joints. In various embodiments, the reinforcing bars may be made of steel or connectors.
- The application of joining two adjacent precast or prefabricated components is not limited to only concrete components and may similarly be applied to

structures that are precast in other types of materials such as resin or plastic. In various embodiments, it may also be applied to structures or components that are made or prefabricated using additive manufacturing methods such as 3D-printing or subtractive manufacturing methods such as milling or carving.

- 5       • While the joints are described above to be formed by in-filled concrete or structural grout, it may be appreciated that other types of casting material may be used for the formation of the joint to connect two adjacent components. These material are, but not limited to, plaster, clay, metals and wax.
- 10       • While the Fig. 5, 6 and 9 illustrate that the 3D precast modules are substantially cuboid in nature with perpendicular side walls, it may be appreciated the adjacent side walls may be arranged at other angles. Consequently, the 3D precast modules may be interconnected at angles apart from 90 degrees.
- 15       • It may be appreciated that to achieve good design and functionality, it is important to have efficiency of space utilization and at the same time, achieve aesthetic. As such, the size and placement of each structural elements (such as beams, column, walls, and partition) of each 3D precast modules may be optimized to suit specific needs.
- 20       • Further, the design of each 3D modules should enable maximum repetition and utilization of the moulds used for fabrication.
- In addition, the modular building has to be segmented and the joints has to be positioned along the right location to facilitate assembly as well as conceal the joint treatment, such as sealants material.
- 25       • The interconnection concept and detail can be applied to other precast design system for connection of two separated precast elements together (not limited to only 3D), such as beam to beam, column to column, column to walls etc. in order to achieve the structural performance required.
- 30       • Further, modification or changes may be developed from the invention by changing the configuration and arrangement of the 3D volumetric units, lap length of reinforcement, depth and size of the beams or columns, the profile of the sandwich beam, shape of interlocking reinforcement used in the sandwich beam/column etc.

- It is to be appreciated the number of modules used for a building project depends on layout and hence is not limited to the example as illustrated in Fig. 5.
- As shown in Fig. 14, the T4 and T5 joints may have different dimensions to cater to different design layouts.

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**Claims:**

1. A prefabricated component for use in a prefabricated building system, comprising  
a first body portion having an edge, the edge comprises a coupling portion,  
wherein when the prefabricated component is arranged adjacent to a second component along the edge to form a composite module, the coupling portion and a part of the second component define a groove for a casting material to be in-filled to join the first body portion to the second component.
2. The prefabricated component according to claim 1, wherein the first body portion is three-dimensional and comprises at least one vertical element extending from a slab.
3. The prefabricated component according to claim 2, wherein the at least one vertical element extends downwardly from the slab when the first body portion is placed adjacent to the second component.
4. The prefabricated component according to claim 2, wherein the one vertical element extends upwardly from the slab when the first body portion is placed adjacent to the second component.
5. The prefabricated component according to claim 4, wherein the second component is three-dimensional and comprises at least one vertical element extending from a second slab, wherein the at least one vertical element extends downwardly from the second slab when the first body portion is placed adjacent to the second component.
6. The prefabricated component according to any one of the claims 2 to 5, wherein the coupling portion is a recess on the slab.
7. The prefabricated component according to claim 6, wherein the part of the second component is a beam with a recess.

8. The prefabricated component according to any one of the claims 2 to 5, wherein the coupling portion is a beam protruding from the slab.
9. The prefabricated component according to claim 8, wherein the beam is Z-shape.
10. The prefabricated component according to claim 2, wherein the coupling portion is the at least one vertical element with thickness dimensioned such that the groove is defined for the casting material to be in-filled when the first body portion is placed adjacent to the second component.
11. The prefabricated component according to any one of the preceding claims, wherein the first body portion is precast from concrete.
12. The prefabricated component according to any one of the preceding claims, wherein the casting material is concrete or structural grout.
13. The prefabricated component according to any one of the preceding claims, wherein the first body portion and the coupling portion are integrally moulded.
14. A method of interconnecting a prefabricated component and a second component comprising the steps of:  
positioning a first body portion of the prefabricated component next to the second component such that a coupling portion of the prefabricated component and a part of the second component define a groove; and  
filling the groove with a casting material to join the first body portion to the second component.
15. The method according to claim 14, wherein the first body portion is three-dimensional and comprises at least one vertical element extending from a slab.

16. The method according to claim 15, wherein the at least one vertical element extends downwardly from the slab when the first body portion is placed adjacent to the second component.
17. The method according to claim 15, wherein the at least one vertical element extends upwardly from the slab when the first body portion is placed adjacent to the second component.
18. The method according to claim 17, wherein the second component is three-dimensional and comprises at least one vertical element extending from a second slab, wherein the at least one vertical element extends downwardly from the second slab when the first body portion is placed adjacent to the second component.
19. The method according to any one of the claims 14 to 18, wherein the coupling portion is a recess on the slab.
20. The method according to claim 19, wherein the part of the second component is a beam with a recess.
21. The method according to any one of the claims 14 to 18, wherein the coupling portion is a beam protruding from the slab.
22. The method according to claim 21, wherein the beam is Z-shape.
23. The method according to claim 15, wherein the coupling portion is the at least one vertical element with thickness dimensioned such that a groove is defined for the casting material to be in-filled when the first body portion is placed adjacent to the second component.
24. The method according to any one of claims 14 to 23, wherein the first body portion is precast from concrete.

25. The method according to any one of claims 14 to 24, wherein the casting material is concrete or structural grout.

26. The method according to any one of claims 14 to 25, wherein the first body portion and the coupling portion are integrally moulded.

27. A prefabricated building system, comprising  
a prefabricated component having a first body portion having an edge, the edge comprises a coupling portion; and  
a second component,  
wherein when the prefabricated component is arranged adjacent to the second component along the edge to form a composite module, the coupling portion and a part of the second component define a groove for a casting material to be in-filled to join the first body portion to the second component.