

PREFABRICATED PREFINISHED VOLUMETRIC CONSTRUCTION MODULES AND CONNECTORS FOR JOINING SAME

Field of Invention

The present invention relates to prefabricated prefinished volumetric construction (PPVC) modules and connectors for joining two or more PPVC modules. In particular, the PPVC modules are suitable for deployment in a concrete-based PPVC system.

Background Art

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.

Prefabricated Prefinished Volumetric Construction (PPVC) refers to a construction method whereby free-standing volumetric modules (complete with finishes for walls, floors and ceilings) are constructed, manufactured and assembled. PPVC methodology is increasingly deployed as part of a "Design for Manufacturing and Assembly (DfMA)" concept, where construction is designed such that as much work as possible may be performed off-site in a controlled manufacturing of fabrication facility and efficiency of on-site assembly. Specifically, concrete-based PPVC system are concrete modules prefabricated in factories and completed with finishes before being transported to site for installation for boosting construction productivity.

With the increased use of the construction sector towards design for manufacturing and assembly (DfMA) concept, PPVC modules can yield more significant manpower and time savings, achieving higher productivity. PPVC can also bring about intangible benefits such as less noise and dust at the construction site, safer workplaces and better quality homes.

Although the PPVC modules can be constructed or manufactured off-site to achieve the desired advantages, assembly of the PPVC modules would still have to be performed on-site. Traditionally, assembly of multiple PPVC modules require workmen, use of bolts or other fastening means, wet pour at joints, etc. Conventionally,

the water-tightness of a joint or connection is dependent on the skill of the workmen and whether the workmen follow the proper sequence in forming the joints as part of the assembly process.

5 In addition, some PPVC systems adopt a double floor or double partition wall system. This results in wastage in internal built-up space.

Therefore there exist needs to, *inter alia*,

- i. reduce the time required for assembly at the construction site;
- ii. reduce wastage of materials at joints;
- 10 iii. ensure that the joints between PPVC modules are water tight and achieve an acceptable level of structural integrity; and
- iv. maximize internal built-up space.

The invention seeks to meet one or more of the aforementioned needs.

Summary of the Invention

15 The invention seeks to provide one or more PPVC components which achieves ease of delivery, installation and water-tightness. In particular, the PPVC components achieve a minimum level of finishing and fittings to be completed off-site as stipulated in regulatory code, such as Building and Construction Authority (BCA) Code of Practice.

20 In accordance with an aspect of the invention there is a prefabricated prefinished volumetric construction (PPVC) component comprising a coupling interface for joining another PPVC component, the coupling interface comprises at least one mating groove shaped and dimensioned to couple with the another PPVC component, the at least one mating groove comprises a plurality of metal elements arranged to provide structural reinforcement to the PPVC module and reduce the amount of casting
25 material to be in-filled; wherein when joined, each of the plurality of metal elements is secured with a corresponding metal element of the another PPVC component.

In some embodiments, the PPVC component is a column component.

In some embodiments, the at least one mating groove comprises a plurality of connector loop boxes disposed at various positions along the mating groove.

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In some embodiments, each of the plurality of connector loop boxes comprises a steel wire rope arranged to protrude from the base of the mating groove to form loops having planes substantially perpendicular to the plane of the base of the mating groove.

5 In some embodiments, when the column component is mated with another column component, the mated grooves define a first channel, and a second channel, wherein the first channel and the second channel are each adapted to receive a reinforcement bar.

10 In some embodiments, the PPVC component comprises at least one edge surface having a plurality of steel brackets disposed at regular intervals along the edge surface.

In some embodiments, the PPVC component further comprise a plurality of protruding rods precast and protruding from the edge surface, wherein each protruding rod is shaped and dimensioned to receive a steel plate and/or a spiral connector.

15 In some embodiments, the PPVC component is a beam component.

In some embodiments, the at least one mating groove of the beam component comprises an L-shaped ledge formed for mating with a corresponding beam component. In some embodiments, the two L-shaped ledges define a U-shaped channel when mated.

20 In some embodiments, the PPVC component further comprises one or more steel elements arranged to extend from an inner surface of the U-shaped channel to the base of the U-shaped channel.

In some embodiments, the PPVC component further comprises a plurality of protrusions for receiving other PPVC components.

25 In some embodiments, the PPVC component is a slab component.

In some embodiments, the at least one mating groove comprises a depressed region/recess located proximate an edge of the slab component.

30 In accordance with another aspect of the invention there is a method of connecting a first prefabricated prefinished volumetric construction (PPVC) component with a second PPVC component comprising the steps of:

- (a) positioning a first coupling interface of the first PPVC component adjoining a second coupling interface of the second PPVC component;

(b) aligning the mating grooves such that the mating grooves of the first PPVC component and second PPVC component defines a channel;
(c) positioning at least one metal element across the channel; and
filling the channel with a casting material to join the first PPVC component to the
5 second PPVC component.

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 illustrates a prefabricated prefinished volumetric construction (PPVC) module in
10 accordance with an embodiment;

Fig. 2a to Fig. 2e illustrate a PPVC column component and a PPVC beam component, as well as the coupling interface of the PPVC component;

Fig. 3a to Fig. 3f illustrate joints between a PPVC slab component and PPVC beam component, joints between a PPVC slab component to a PPVC composite component, and joints to a PPVC beam component arranged below the slab and composite
15 component.

Fig. 4a to Fig. 4c illustrate a joint between a PPVC slab component and another PPVC slab component.

Fig. 5 illustrate a joint for a floor component.

20 Fig. 6 shows a flow chart of a method of connecting one PPVC component with another PPVC component.

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
25 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.

In an embodiment of the invention as shown in Fig. 1a and 1b there is a prefabricated prefinished volumetric construction (PPVC) module 10. The PPVC module 10 may be a concrete module comprising prefabricated and prefinished elements (not shown) meeting one or more regulatory requirements. Examples of such PPVC module 10 includes a room, a bathroom, a toilet, a kitchen, etc. Non-limiting examples of prefinished elements may include window(s), floor finishes, and electrical conduits.

The PPVC module 10 is formed using one or more PPVC components such as column components, beam components, and slab components. Each of the PPVC components comprise at least one coupling interface 12 for coupling with one or more other PPVC components. The coupling interface 12 comprises at least one mating groove arranged to couple with the another PPVC component, the at least one mating groove comprises a plurality of metal elements arranged to provide structural reinforcement to the PPVC module and reduce the amount of casting material to be in-filled; wherein when joined, each of the plurality of metal elements is secured with a corresponding metal element of the another PPVC module. The PPVC module 10 may be rested on a slab mould/formwork 16.

The coupling interface 12 may form part or whole of a connector for joining two or more PPVC components/modules. As shown in Fig. 1b, the coupling interface 12 may be for joining PPVC components such as column to column component, slab to slab component, column to beam component, beam to beam component etc.

In some embodiments, the PPVC module 10 comprises coupling interface 12 for coupling or mating two column components and two beam components. Fig. 2a to Fig. 2c show close-up views of part of a PPVC module 10 comprising the coupling interface 12 of a column component 202 and a beam component 204. Column component 202 may comprise at least one, but as illustrated comprises a plurality of mating grooves 206a, 206b shaped and dimensioned to couple with another column component 202' and corresponding mating grooves 206a', 206b'. A plurality of connector loop boxes 208, each connector loop box 208 comprising a high-strength steel wire rope and a metal box made of galvanized steel, are disposed at various positions along the mating grooves 206a, 206b. The steel wire ropes are arranged to protrude from the base of

the grooves 206a, 206b, forming loops 208a, 208b, 208c, 208d, 208e, 208f having planes substantially perpendicular to the plane of the base of the grooves 206a, 206b. Correspondingly, connector loop boxes 208' are disposed at various positions along the mating groove 206a', 206b' with the steel wire ropes arranged to protrude from the base of the grooves 206a', 206b', forming loops 208a', 208b', 208c' having planes substantially perpendicular to the plane of the base of the grooves 206a', 206b'.

When the column component 202 and 202' are properly mated, the mated grooves 206a, 206a' define a first channel, and mated grooves 206b, 206b' define a second channel. Loops 208a, 208a' forms a first overlapping loop. Loops 208b, 208b' forms a second overlapping loop, and loops 208c, 208c' forms a third overlapping loop. Each of the first and second channel is shaped and dimensioned to receive a reinforcement element, such as a steel bar/rod. When the steel bar/rod is inserted correctly, it sits within the channel with the overlapping loops positioned around the steel bar/rod. The steel bars/rods are arranged to be slotted through the overlapping loops and are secured in place before grouting.

At least one edge surface 210, 210' of the column component 202, 202' is shaped and dimensioned for another PPVC component to rest thereon. The edge surface 210, 210' comprises a plurality of steel brackets 212, 212' precast on the edge surface 210, 210'. The steel brackets 212, 212' may be disposed at regular intervals along the edge surface 210, 210'. There is preferably a minimum and/or maximum spacing between the each of the steel brackets 212, 212'. Such spacing(s) should preferably comply with regulatory requirements. There further comprise a plurality of protruding rods 214, 214' precast and protruding from the edge surface 210, 210'. Each protruding rods 214, 214' are shaped and dimensioned to receive respective steel plates 216, (when mated) and spiral connectors 218. Each steel bracket pair 212, 212' may be secured by a steel tie 213 when mated. The protruding rods 214, 214' may be positioned proximate the edges or ends of the column components 202, 202'.

As illustrated in Fig. 2a to Fig. 2c, the mating groove of the beam component 204 comprises an L-shaped ledge 220 formed for mating with a corresponding L-shaped ledge 220' of a corresponding beam component 204'. When mated, the two L-shaped ledges 220, 220' define a U-shaped channel. One or more steel elements 222, 222' are arranged to extend from an inner surface of the U-shaped channel to the base of

the U-shaped channel. The number of steel elements is preferably based on design requirement such as shear link provision. The shape of the steel element is important. It must be shaped to provide effective shear resistance and make the combined beam elements as monolithic as possible. There comprise protrusions 224, 224' for receiving other PPVC components (e.g. slabs) to be positioned on the beam component 204.

To improve or maximize the water-tightness of the joint(s) between two or more PPVC modules, self-adhesive compressible waterproofing strip 230 may be positioned at one or more corner regions of the column components 202, 202' and beam components 204, 204'.

Once the column components 202, 202' and/or beam components 204, 204' are mated, the resulting joint interface/region may be filled up with concrete and/or grout.

Fig. 2d illustrates the coupling interface 12 filled up with grout. The grout is preferably non-shrink grout. Once the coupling interface 12 is filled appropriately with non-shrink grout, the various metallic, steel and connection portions will not be visible except for the protrusions 214, 214', 224, 224' for receiving spiral connectors 218 to join other PPVC components. In some embodiments, spiral connectors 218 may not be necessary. In general spiral connectors 218 are required for joining column to column components. As alternative or in addition, the spiral connectors 218 can be replaced or complemented by mechanical splice sleeves such as NMB splice sleeveTM. For joining at protrusions 224, 224' between beam components, it can be performed without the need of spiral connectors 218. As shown in Fig. 2e, the beam components 204, 204' may be mated with other column components, beam components, or slab components. This may be facilitated using one or more spiral connectors 218 that can be positioned or installed on protrusion 214, 214' for joining at 224, 224' respectively, without the need of spiral connectors.

Fig. 3a shows a slab component 304 installed onto protrusion 224 of the beam component 204. The slab component 304 comprises a depressed region 306 or recess and an aperture (not shown) formed around a central part in the depressed region 306. The recess 306 is preferably located around an edge of the slab component 304 and preferably the corner of the slab component 304. The recess 306 may be referred to as a slab pocket. The recess 306 may be, but is not limited to, a square or a rectangle shaped region having an open end 310. The aperture is shaped

and dimensioned for insertion by the protrusion 224. A corresponding slab component 304' may be installed onto protrusion 224'. When the two slab components 304, 304' are installed, the open ends 310, 310' are aligned such that the two slab components 304, 304' form a resultant contiguous rectangular depressed region. A steel plate 312
5 may then be inserted onto the protrusions 224, 224'. The resultant contiguous rectangular depressed region may then be covered with grout, preferably non-shrink grout.

In some embodiments as shown in Fig. 3b to Fig. 3f, the slab component 304' may be installed with or mated with a composite component 314' comprising a slab and a
10 partition wall component. The composite component 314' may comprise a coupling interface 320' having depressed region/open end 310' for mating with the slab component 304, and an aperture 322' to enable an on-site worker to install or position the steel plate 312 onto the protrusion 224'.

Once the steel plate 312 is installed, it may be fastened by fastening mechanisms 316
15 such as bolts and nuts. In some embodiments, the protrusion 224 is threaded. The fastening mechanism 316 may be in the form of a nut to fasten the steel plate 312 in place.

The contiguous rectangular depressed region is then covered by casting material such as non-shrink grout. The aperture 322 can then be covered by concrete and/or non-
20 shrink grout or cement board/ dry wall method, as shown in Fig. 3e and Fig. 3f.

Fig. 4a and Fig. 4b illustrate another embodiment where slab or floor components 402, 402' are joined or mated together. Such slab components 402, 402' may be laid by criss-crossing lapping steel elements 404, 404' and filled with casting material such as normal wet pour concrete material.

Fig. 5 illustrate another embodiment where floor components 502, 502' are joined or mated together. The floor components may be slab components having similar arrangement as illustrated in Fig. 3c or Fig. 3d, having depressed region/open end 510/510' with protrusions 524, 524' arranged for a steel plate 512 to be fastened thereto.

In another embodiment, there is a method 600 of connecting a first prefabricated prefinished volumetric construction (PPVC) component with a second PPVC

component, each of the first and second PPVC components having at least one mating groove, comprising the steps of:

(a.) positioning a first coupling interface of the first PPVC component adjoining a second coupling interface of the second PPVC component (step s602);

5 (b.) aligning the mating grooves such that the mating grooves of the first PPVC component and second PPVC component defines a channel (step s604);

(c.) positioning at least one metal element across the channel to join the first PPVC component to the second PPVC component (step s606); and

(d.) filling the channel with a casting material (step s608).

10 In another embodiment, there is a PPVC concrete system formed using a plurality of PPVC modules. Each PPVC module is prefabricated and prefinished in a precast facility and comprises at least one coupling interface for joining or mating with another PPVC module. Each PPVC module is then transported to a site, and may be joined to another PPVC module using the connectors (coupling interface) and method as
15 described.

It is to be appreciated that the embodiments described are non-exhaustive. In particular, different PPVC modules formed using the different PPVC components may be used to join different PPVC components to one another. For example, column to column components, column to slab, beam to beam, beam to slab, slab to slab. The
20 introduction of steel elements and/or steel brackets in the coupling interface reduce the amount of casting material to be in-filled at the actual construction site.

The various embodiments of the PPVC modules are advantageous in at least the following ways.

In the connections for the slab components, the slab pockets (i.e. the depressed
25 region) are strategically placed to minimize the area of wet pour joint to be carried out on-site and maximize level of finishing and fittings to be completed off-site in the factory control environment, thus meeting regulatory requirements.

The arrangement of the first and second channels of the column components (when mated or coupled) enable two PPVC column components to be interlocked and
30 behave monolithically as a single integral element. The steel plate connection at column pockets reduce the area of filling, e.g. wet pour (grout) to be carried out at work site.

The steel plate connectors at slab pockets minimize the area of wet pour joint to be carried out on-site and maximize level of finishing and fittings to be completed off-site in the factory control environment. Such an arrangement overcomes the difficulty in achieving the minimum level of 80% floor finishes to be completed off-site as stipulated

5 in Code of Practice on Buildability 2015 Edition on PPVC.

The improved connectors are arranged to take care concern over water seepage and prevention of corrosion where steel is used as a structural materials in PPVC system.

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
10 be combined to form yet further embodiments falling within the intended scope of the invention.

CLAIMS

1. A prefabricated prefinished volumetric construction (PPVC) module manufactured off-site, the PPVC module having at least one component comprising a column, beam and/or slab component for joining another PPVC module on-site, the at least one component comprising
a coupling interface for joining the another PPVC module, the coupling interface comprising at least one mating groove shaped and dimensioned to couple with the another PPVC module, the at least one mating groove comprising a plurality of metal elements arranged to provide structural reinforcement to the PPVC module and reduce the amount of casting material to be in-filled; wherein when joined, each of the plurality of metal elements is secured with a corresponding metal element of the another PPVC module.
2. The PPVC module according to claim 1, wherein the at least one component comprises a said column component.
3. The PPVC module according to claim 2, wherein the at least one mating groove comprises a plurality of connector loop boxes disposed at various positions along the mating groove.
4. The PPVC module according to claim 3, wherein each of the plurality of connector loop boxes comprises a steel wire rope arranged to protrude from the base of the mating groove to form loops having planes substantially perpendicular to the plane of the base of the mating groove.
5. The PPVC module according to claim 4, wherein when the column component is mated with another column component, the mated grooves define a first channel, and a second channel, wherein the first channel and the second channel are each adapted to receive a reinforcement bar.
6. The PPVC module according to any one of the preceding claims, comprising at least one edge surface having a plurality of steel brackets disposed at regular intervals along the edge surface.

7. The PPVC module according to claim 6, further comprising a plurality of protruding rods precast and protruding from the edge surface, wherein each protruding rod is shaped and dimensioned to receive a steel plate and/or a spiral connector.
8. The PPVC module according to claim 1, wherein the at least one PPVC component comprises a said beam component.
9. The PPVC module according to claim 8, wherein the at least one mating groove of the beam component comprises an L-shaped ledge formed for mating with a corresponding beam component.
10. The PPVC module according to claim 9, wherein when mated, the two L-shaped ledges define a U-shaped channel.
11. The PPVC module according to claim 10, further comprises one or more steel elements arranged to extend from an inner surface of the U-shaped channel to the base of the U-shape channel.
12. The PPVC module according to claim 11, further comprises a plurality of protrusions for interfacing with PPVC components.
13. The PPVC module according to claim 1, wherein the at least one PPVC component comprises a said slab component.
14. The PPVC module according to claim 13, wherein the at least one mating groove comprises a depressed region/recess located proximate an edge of the slab component.

15. A method of connecting a first prefabricated prefinished volumetric construction (PPVC) module with a second PPVC module, each of the first and second PPVC modules comprising at least one component having at least one mating groove, comprising the steps of:

- (a) manufacturing the first PPVC module and the second PPVC module off-site;
- (b) positioning a first coupling interface of the first PPVC module adjoining a second coupling interface of the second PPVC module;
- (c) aligning the mating grooves such that the mating grooves of the first PPVC module and second PPVC module defines a channel;
- (d) positioning at least one metal element across the channel to join the first PPVC module to the second PPVC module; and

filling the channel with a casting material;

wherein the steps (b), (c) and (d) are performed on-site, and wherein the at least one component comprises a column, beam and/or slab component.