

PREFABRICATED CONSTRUCTION STRUCTURE

Technical Field

- 5 The present disclosure generally relates to prefabricated construction structures. More particularly, the present disclosure describes various embodiments of a prefabricated construction module, a construction structure comprising the prefabricated construction modules, and method for constructing the construction structure.

10 Background

In-situ construction methods such as casting of concrete on-site are known and commonly used in the construction industry, but these methods tend to be more labour-intensive and time-consuming. Prefabricated or precast concrete structures
15 that are formed off-site is increasingly being used as this reduces construction time at the construction site. Precast structures are joined in-situ using connection members anchored between them. More recently, Prefabricated Prefinished Volumetric Construction (PPVC) is being adopted in the construction industry and this is a new approach that has been developed to significantly speed up construction. In PPVC,
20 construction modules with precast structures, e.g. whole rooms, are prefabricated in an off-site fabrication facility before they are delivered to site. At the construction site, the prefabricated construction modules are joined and assembled to construct a construction structure such as a building. The prefabricated construction modules are formed with joints so that they can be joined and assembled via the joints.

25 Singapore patent 10201703972W describes a prefabricated construction module comprising a panel body and guides, such as steel wire loops, partially embedded into the panel body. The guides need to be accurately positioned in the prefabricated construction module for proper alignment and joining to another prefabricated
30 construction module. More time is required in prefabricating the construction modules to ensure the guides are properly placed, thus slowing down fabrication and the overall construction productivity. The steel guides which protrude out of the panel bodies can

cause obstruction during site assembly and can be hazardous or dangerous to the on-site workers, especially if the workers accidentally fall or knock onto the steel guides.

Therefore, in order to address or alleviate at least one of the aforementioned problems
5 and/or disadvantages, there is a need to provide an improved prefabricated construction module, a construction structure comprising the prefabricated construction modules, and method for constructing the construction structure.

Summary

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According to a first aspect of the present disclosure, there is a prefabricated construction module comprising a structural body and a groove formed longitudinally along a grooved surface of the structural body and arranged to receive a connection member for joining to another prefabricated construction module. A lateral cross-
15 section of the groove comprises a first groove section and a second groove section, the first groove section formed between the grooved surface and the second groove section, the first groove section being narrower than the second groove section.

According to a second aspect of the present disclosure, there is a construction
20 structure comprising a first prefabricated construction module and a second prefabricated construction module arranged adjacent to each other. Each prefabricated construction module comprises a structural body and a groove formed longitudinally along a grooved surface of the respective structural body. The prefabricated construction modules are arranged such that the respective grooves
25 face each other and a joint gap including the grooves is formed between the respective grooved surfaces. The construction structure further comprises a connection member inserted into the joint gap and a joint filler material filling the joint gap and joining the prefabricated construction modules together. For each prefabricated construction module, a lateral cross-section of the respective groove comprises a first groove
30 section and a second groove section, the first groove section formed between the respective grooved surface and the second groove section, the first groove section being narrower than the second groove section.

According to a third aspect of the present disclosure, there is a method for constructing a construction structure. The method comprises providing a plurality of prefabricated construction modules, each prefabricated construction module comprising a structural body and a groove formed longitudinally along a grooved surface of the respective structural body; arranging a first pair of prefabricated construction modules adjacent to each other such that the respective grooves face each other and a first joint gap including the grooves is formed between the respective grooved surfaces; inserting a first connection member into the first joint gap; filling the first joint gap with a joint filler material to join the first pair of prefabricated construction modules together; and curing the joint filler material to thereby construct the construction structure comprising the joined prefabricated construction modules. For each prefabricated construction module, a lateral cross-section of the respective groove comprising a first groove section and a second groove section, the first groove section formed between the respective grooved surface and the second groove section, the first groove section being narrower than the second groove section.

A prefabricated construction module, a construction structure comprising the prefabricated construction modules, and method for constructing the construction structure according to the present disclosure is thus disclosed herein. Various features, aspects, and advantages of the present disclosure will become more apparent from the following detailed description of the embodiments of the present disclosure, by way of non-limiting examples only, along with the accompanying drawings.

Brief Description of the Drawings

Figures 1A and 1B are illustrations of a construction structure comprising a pair of prefabricated construction modules, in accordance with some embodiments of the present disclosure.

Figures 2A and 2B are illustrations of another construction structure comprising a pair of prefabricated construction modules, in accordance with some embodiments of the present disclosure.

Figures 3A, 4A, 5A, and 6A are various illustrations of a groove lateral cross-section of a prefabricated construction module, in accordance with some embodiments of the present disclosure.

- 5 Figures 3B, 4B, 5B, and 6B are various illustrations of a groove lateral cross-section of another prefabricated construction module, in accordance with some embodiments of the present disclosure.

- 10 Figures 7A to 7H are various illustrations of a connection member of a construction structure for joining a pair of prefabricated construction modules, in accordance with some embodiments of the present disclosure.

- 15 Figure 8 is a flowchart illustration of a method for constructing a construction structure, in accordance with some embodiments of the present disclosure.

Figures 9A to Figure 9E are various illustrations a construction structure comprising a pair of prefabricated construction modules joined in various arrangements, in accordance with some embodiments of the present disclosure.

20 **Detailed Description**

- For purposes of brevity and clarity, descriptions of embodiments of the present disclosure are directed to a prefabricated construction module, a construction structure comprising the prefabricated construction modules, and method for constructing the construction structure, in accordance with the drawings. While aspects of the present disclosure will be described in conjunction with the embodiments provided herein, it will be understood that they are not intended to limit the present disclosure to these embodiments. On the contrary, the present disclosure is intended to cover alternatives, modifications and equivalents to the embodiments described herein, which are included within the scope of the present disclosure as defined by the appended claims. Furthermore, in the following detailed description, specific details are set forth in order to provide a thorough understanding of the present disclosure. However, it will be recognized by an individual having ordinary skill in the art, i.e. a skilled person, that
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the present disclosure may be practiced without specific details, and/or with multiple details arising from combinations of aspects of particular embodiments. In a number of instances, known systems, methods, procedures, and components have not been described in detail so as to not unnecessarily obscure aspects of the embodiments of
5 the present disclosure.

In embodiments of the present disclosure, depiction of a given element or consideration or use of a particular element number in a particular figure or a reference thereto in corresponding descriptive material can encompass the same, an equivalent,
10 or an analogous element or element number identified in another figure or descriptive material associated therewith.

References to “an embodiment / example”, “another embodiment / example”, “some embodiments / examples”, “some other embodiments / examples”, and so on, indicate
15 that the embodiment(s) / example(s) so described may include a particular feature, structure, characteristic, property, element, or limitation, but that not every embodiment / example necessarily includes that particular feature, structure, characteristic, property, element or limitation. Furthermore, repeated use of the phrase “in an embodiment / example” or “in another embodiment / example” does not
20 necessarily refer to the same embodiment / example.

The terms “comprising”, “including”, “having”, and the like do not exclude the presence of other features / elements / steps than those listed in an embodiment. Recitation of certain features / elements / steps in mutually different embodiments does not indicate
25 that a combination of these features / elements / steps cannot be used in an embodiment.

As used herein, the terms “a” and “an” are defined as one or more than one. The use of “/” in a figure or associated text is understood to mean “and/or” unless otherwise
30 indicated. The recitation of a particular numerical value or value range herein is understood to include or be a recitation of an approximate numerical value or value range. The term “set” is defined as a non-empty finite organization of elements that mathematically exhibits a cardinality of at least one (e.g. a set as defined herein can

correspond to a unit, singlet, or single-element set, or a multiple-element set), in accordance with known mathematical definitions. The terms “first”, “second”, “third”, etc. are used merely as labels or identifiers and are not intended to impose numerical requirements on their associated terms. The term “each other” represents a reciprocal
5 relation between two or more elements.

Representative or exemplary embodiments of the present disclosure describe a prefabricated construction module 100 and a construction structure 50 comprising a plurality of prefabricated construction modules 100. Figure 1A and Figure 2A illustrate
10 some embodiments of the construction structure 50 which comprises a first prefabricated construction module 100a and a second prefabricated construction module 100b arranged adjacent to each other.

In one embodiment, the construction structure 50 is a wall, floor, or ceiling structure
15 (and the like) comprising a plurality of prefabricated construction modules 100 joined together, including by stacking on each other. In another embodiment, the construction structure 50 forms the structural frame of a habitable unit or an apartment (or part thereof), the construction structure 50 comprising a plurality of prefabricated construction modules 100 joined together, wherein each prefabricated construction
20 module 100 forms a room or compartment of the apartment, such as the living room, bedroom, or kitchen. For example, the prefabricated construction modules 100 may be joined to form the four walls, floor, and ceiling of a room. In another embodiment, the construction structure 50 is a building comprising multiple joined prefabricated construction modules 100, like rooms joining to form an apartment and apartments
25 joining to form a building floor / storey. The construction structure 50 may be a single-storey or multi-storey building with various prefabricated construction modules 100. The aforementioned examples are non-limiting and it will be appreciated that there can be various types of prefabricated construction modules 100 and construction structures 50 used in the PPVC industry.

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Each prefabricated construction module 100 comprises a structural body 102 formed from a suitable material for PPVC, such as precast concrete. The terms “prefabricated” and “precast” may be used interchangeably in the present disclosure. The structural

body 102 may be fabricated in the form of a beam, column, wall, panel, pillar, or slab. In one embodiment, the structural body 102 is a corner structural column or pillar for joining to another prefabricated construction module 100, such as another room. In another embodiment, the structural body 102 is a wall panel for joining to another prefabricated construction module 100, such as a floor / ceiling construction module or another wall. The structural body 102 comprises a plurality of surfaces including a pair of opposing end surfaces 104.

The prefabricated construction module 100 comprises a set of one or more grooves 106 formed longitudinally along one of the side surfaces of the structural body 102. In many embodiments, the prefabricated construction module 100 comprises a groove 106 is formed longitudinally, i.e. along the z-axis, and the groove 106 extends along a grooved surface 108 of the structural body 102. The grooved surface 108 may be referred to as a joint surface it is arranged to face the corresponding grooved surface 108 of another prefabricated construction module 100 to be joined together. In some other embodiments, the prefabricated construction module 100 can comprise two or more grooves 106 and various aspects of the present disclosure relating to the prefabricated construction module 100 comprising a groove 106 will apply similarly or analogously to prefabricated construction modules 100 comprising two or more grooves 106.

The groove 106 is arranged to receive a connection member 110 for joining to another prefabricated construction module 100. The connection member 110 forms the connection between the prefabricated construction modules 100 and distributes forces and loads across the prefabricated construction modules 100. The connection member 110 functions as a bridge for the transfer of various types of forces, including direct tensile, interface shear friction, and dowel forces across the prefabricated construction modules 100. The grooved surface 108 including the groove 106 itself may be roughened, such as by a blasting process, to increase surface roughness and improve interface shear transfer or the transfer of shear forces by friction. The joined prefabricated construction modules 100 form the construction structure 50 as an integral structural unit that has increased load bearing capacity to resist the designed

expected forces like a monolithic construction structure, comparable to a similar structure constructed using conventional in-situ construction methods.

5 In one embodiment, the groove 106 extends through both end surfaces 104 of the structural body 102. The connection member 110 may be inserted into the groove 106 from either end surface 104. The longitudinal length of the connection member 110 is at least the longitudinal length of the grooves 106, such that the connection member 110 may extend beyond one or both end surfaces 104 of the structural body 102. The extended portion may be used for joining to another prefabricated construction module
10 100 above or below.

In another embodiment, the groove 106 extends from one end surface 104 and partially through the structural body 102 to a desired length and ending before the other end surface 104. For example, the connection member 110 may be inserted into
15 the groove 106 from the top end surface 104 but the groove 106 ends before the bottom end surface 104, such as if the prefabricated construction module 100 is for joining to a floor construction module. Conversely, the connection member 110 may be inserted into the groove 106 from the bottom end surface 104 but the groove 106 ends before the top end surface 104, such as if the prefabricated construction module
20 100 is for joining to a ceiling construction module.

In many embodiments, the groove 106 has a uniform lateral cross-section (on the xy-plane) across its length (along the z-axis). Further with reference to Figure 1B and Figure 2B, the lateral cross-section of the groove 106 comprises a first groove section
25 112 and a second groove section 114. The second groove section 114 is preferably the innermost section of the groove 106 formed inside the structural body 102. The first groove section 112 is an outer section formed between the grooved surface 108 and the second groove section 114. The first groove section 112 is preferably the outermost section of the groove 106 that is recessed from the grooved surface 108
30 into the structural body 102.

The first groove section 112 has a first depth (along the x-axis) and a first width (along the y-axis), and similarly the second groove section 114 has a second depth (along

the x-axis) and a second width (along the y-axis). Depending on the profile or geometrical shape of the first and second groove sections 112,114, the first and second widths may refer to the maximum widths of the respective first and second groove sections 112,114.

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The first groove section 112 is narrower than the second groove section 114. This may be defined as the first width being smaller than the second width, i.e. the maximum width of the first groove section 112 is smaller than the maximum width of the second groove section 114. The first groove section 112 and second groove section 114 are
10 joined to each other at a groove section interface 116 along the y-axis. The first groove section 112 is narrower than the second groove section 114, such that the width of the first groove section 112 immediately adjacent to the interface 116 is less than the width of the second groove section 114 immediately adjacent to the interface 116. The groove 106 thus has a lateral cross-section profile that narrows from the second
15 groove section 114 to the first groove section 112. This profile may narrow gradually across the interface 116 like a tapered slope or may narrow abruptly like a distinct step.

In fabricating the prefabricated construction module 100, the prefabricated construction module 100 may comprise a reinforcement elements or structure
20 embedded in the structural body 102 to provide structural strength, especially tensile strength, to the prefabricated construction module 100. The groove 106 may be formed in the structural body 102 using a mould structure embedded into the grooved surface 108 of the structural body 102. The mould structure is then removed after the structural body 102 is casted, thereby forming the groove 106. The mould structure
25 may be formed from one or more thin wall steel sections and/or corrugated pipes having the desired lateral cross-section of the groove 106. For example, in forming the groove 106 as shown in Figure 1B, a small rectangular thin wall steel section and a large small rectangular thin wall steel section are used to form the first and groove sections 112,114, respectively.

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In constructing the construction structure 50, a pair of prefabricated construction modules 100 are arranged adjacent to each other such that the respective grooves 106 face each other and a joint gap 118 is formed between the respective grooved

surfaces 108. The joint gap 118 includes the opposing grooves 106 recessed into the respective grooved surfaces 108 as well as the space between the non-grooved portions of the grooved surfaces 108. The joint gap has a depth (along the x-axis) dimensioned between the respective grooved surfaces 108.

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Some exemplary dimensional relations are described as follows. The depth of the joint gap 118 may be around 3 times that of the thickness of the connection member 110. The first width of the first groove section 112 may be around 1.5 times that of the depth of the joint gap 118. Consequently, the first width of the first groove section 112 may be around 4.5 times that of the thickness of the connection member 110.

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In this arrangement of the prefabricated construction modules 100 are joined, the grooves 106 that form the joint gap 118 are large enough with suitable tolerance for insertion of the connection member 110, reducing errors that may occur during construction. The grooves 106 also serve as a constriction in the modules 100 that prevent a shear cone to be fully developed, which would result in concrete cone failure. Concrete cone is a failure mode in concrete loaded by a tensile force and is usually caused by crack growth in concrete. The grooves 106 prevent cracks from propagating entirely through the structural bodies 102, thus preventing the shear cone from developing completely.

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Additionally, the first groove sections 112 of both grooves 106 form a constricted or narrowed pathway across the joint gap 118 for insertion of the connection member 110 into the joint gap 118. The narrowed pathway reduces the tolerance between the connection member 110 and sides of the first groove sections 112. This results in restricting movement of the connection member 110 within the joint gap 118 and improving the structural stability of the connection between the prefabricated construction modules 100.

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In some embodiments as shown in Figure 1A and Figure 1B, each prefabricated construction module 100 has a lateral cross-section wherein the overall depth is minimally 90 mm and the first depth of the first groove section 112 may be at least half of or approximately equal to the second depth of the second groove section 114.

Additionally, the first depth may be more than the joint gap depth. As an example, each prefabricated construction module 100 has a lateral cross-section with an overall depth of 125 mm. Further, the first depth is around 35 mm to 40 mm, the second depth is around 45 mm, and the joint gap depth is around 20 mm.

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In some embodiments as shown in Figure 2A and Figure 2B, each prefabricated construction modules 100 has a lateral cross-section wherein the overall depth is minimally 90 mm and the first depth of the first groove section 112 may be less than half of the second depth of the second groove section 114. For example, the first depth of the first groove section 112 may be the thickness of the structural material forming the groove 106. Additionally, the first depth may be less than the joint gap depth. As an example, each prefabricated construction module 100 has a lateral cross-section with an overall depth of 100 mm. Further, the first depth is around 5 mm to 8 mm, the second depth is around 45 mm, and the joint gap depth is around 20 mm.

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In the embodiments of the prefabricated construction module 100 as shown in Figure 1A and Figure 2A, each of the first and second groove sections 112,114 has a quadrilateral profile, such as a square or rectangular profile. The quadrilateral profile may have right-angled or sharp corners as shown but may optionally have rounded / filleted / chamfered corners. Further with reference to Figure 3A, the centroid of the second groove section 114 approximately coincides with the geometric centre of the structural body 102. Similarly, in the embodiments of the prefabricated construction module 100 as shown in Figure 1B and Figure 2B, each of the first and second groove sections 112,114 has a quadrilateral, e.g. square or rectangular, profile. However, with reference to Figure 3B, although the groove 106 is centred along the y-axis to the structural body 102, the centroid of the second groove section 114 may not coincide with the geometric centre of the structural body 102.

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Figure 3A and Figure 3B illustrate the groove sections 112,114 having quadrilateral profiles. In some other embodiments, the groove sections 112,114 may have other profiles or geometrical shapes, such as but not limited to circular, trapezoidal, and elliptical. Some examples of various profiles of the first and second groove sections 112,114 of a prefabricated construction module 100 are shown in Figure 4A, Figure

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5A, and Figure 6A. Some examples of various profiles of the first and second groove sections 112,114 of a prefabricated construction module 100 are shown in Figure 4B, Figure 5B, and Figure 6B. The first groove sections 112 may have thin first depths and due to this thinness, the first groove sections 112 may be referred to as an entry slot or aperture leading into the second groove sections 114. The aforementioned examples are non-limiting and it will be appreciated that there can be various profiles or geometrical shapes of the groove sections 112,114.

After the prefabricated construction modules 100 are arranged and the joint gap 118 is formed, the connection member 110 is inserted into the joint gap 118. The connection member 110 can thus be easily inserted into the joint gap 118 from an end surface 104 of the structural body 102, especially in situations wherein access to the joint gap 118 is restricted to only the end surfaces 104.

In some embodiments, the construction structure 50 includes a single connection member 110 inserted into the joint gap 118. In some embodiments, the construction structure 50 may include two or more connection members 110 inserted into the joint gap 118. The structure of each connection member 110 is described below. It will be appreciated that the two or more connection members 110 inserted between prefabricated construction modules 100 may be the same or different from each other.

As shown in Figure 7A, the connection member 110 comprises a plurality of longitudinal bars 120 and a set of one or more lateral connector elements 122 joining the longitudinal bars 120. For example, the connection member 110 has a pair of longitudinal bars 120 and the lateral connector elements 122 are joined to both bars 120. In some embodiments, the connection member 110 may have three or even more longitudinal bars 120 and the lateral connector elements join 122 across all the bars 120. When the connection member 110 is inserted into the joint gap 118, the longitudinal bars 120 are arranged such that they extend through the respective grooves 106. More specifically, each longitudinal bar 120 extends through the respective second groove sections 114 and the lateral connector elements 122 extend across the joint gap 118.

The longitudinal bars 120 are reinforcing bars that are subject to axial loading along the longitudinal length of the bars 120. When the prefabricated construction modules 100 are arranged vertically, the longitudinal bars 120 are likewise arranged vertically and subject to vertical loads, such as coming from other prefabricated construction modules 100 stacked above. The lateral connector elements 122 are joined to both longitudinal bars 120 by various mechanical means, such as welding or tying as will be readily known to the skilled person, so that the connection member 110 is formed as an integral structure. Alternatively, the connection member 110 may be formed from a single structural material. The lateral connector elements 122 are the main elements that transfer the forces and loads across the longitudinal bars 120, enabling the construction structure 50 to behave like a monolithic construction structure. The longitudinal bars 120 and lateral connector elements 122 are formed of a structural steel material, such as carbon steel or high strength / low alloy steel, although other construction materials may be possible.

In some embodiments, the set of lateral connector elements 122 is disposed at a number of discrete positions along the longitudinal length of the bars 120. As shown in Figure 7A, there are three lateral connector elements 122 disposed at discrete positions along the longitudinal bars 120. As shown in Figure 7B, there are two pairs of lateral connector elements 122 disposed at discrete positions along the longitudinal bars 120. The lateral connector elements 122 may comprise one or more of reinforcement bars, loop elements, mesh, shear studs, and strip elements.

In some embodiments as shown in Figure 7A and Figure 7B, each lateral connector element 122 comprises a steel bar or wire that is welded to the longitudinal bars 120, such that the connection member 110 has a mesh structure. In one embodiment as shown in Figure 7C, each lateral connector element 122 comprises a bolt tied to the longitudinal bars 120 by end nuts. One example of such lateral connector elements 122 are Grade 4.6 hex head steel bolts and nuts. In one embodiment as shown in Figure 7D, each lateral connector element 122 comprises a high strength wire loop joined to the longitudinal bars 120. Each wire loop may include a tie or clip at its centre intersection. In one embodiment as shown in Figure 7E, each lateral connector element 122 comprises a pair of shear studs joined to each other and to the

longitudinal bars 120. In one embodiment as shown in Figure 7F, each lateral connector element 122 comprises a loop reinforcing bar joined to the longitudinal bars 120. In one embodiment as shown in Figure 7G, each lateral connector element 122 comprises a strip element tied to the longitudinal bars 120 by end anchor plates.

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In some embodiments, the set of lateral connector elements 122 spans continuously along the longitudinal length of the bars 120. In one embodiment as shown in Figure 7H, the set of lateral connector elements 122 comprises a lattice girder element or reinforcing bar joined to the longitudinal bars 120. The lattice girder element spans
10 continuously along the longitudinal bars 120 in a serpentine / sinusoidal arrangement, joining to the longitudinal bars 120 at respective peaks of the serpentine / sinusoidal arrangement. In this embodiment, the connection member 110 has a structure similar to a lattice girder.

15 After the connection member 110 is inserted into the joint gap 118, a joint filler material is dispensed to fill the joint gap 118 and join the prefabricated construction modules 100 together. The joint filler material may comprise a cementitious mixture, epoxy, or a combination thereof. The cementitious mixture is a mixture of water, cement, and sand. One example of the cementitious mixture is grout, such as high-strength or high-
20 grade grout. The joint gap 118 is filled with the grout in a process such as pressure or jet grouting, or by pouring the grout under the influence of gravity. The grout is preferably a high strength / non-shrink grout that contain other compounds like graded fillers and chemical additives. The joint filler material may include epoxy resin which may be combined with other filler materials such as silica fillers, pigments, and a
25 hardener. It will be appreciated that there may be other compositions of the joint filler material. The curing / hardening of the joint filler material adheres the prefabricated construction modules 100 together and forms a sealant between them, preventing seepage of external agents or contaminants, such as rainwater, into the joint gap 118.

30 The prefabricated construction modules 100 are joined together and supported by each other via the connection member 110 while the joint gap 118 is being filled with the joint filler material. The connection member 110 thus stabilizes the prefabricated construction modules 100 and reduces errors during filling of the joint gap 118, such

as inaccurate dispensing of the joint filler material. This reduces the time and labour required, enabling the construction structure 50 to be constructed quicker and more efficiently.

- 5 The construction structure 50 is thus constructed from the modules 100 that are prefabricated in an off-site facility or factory and delivered to the construction site. Productivity can be increased by scaling up fabrication of the modules 100. The facility also provides an environment that controls various factors to improve the quality of the precast material (e.g. concrete) of the modules 100, as compared to on-site casting of
- 10 concrete which can be adversely affected by weather conditions. The modules 100 can be fabricated in the facility at the same time as continuing formworks at the construction site, thus reducing construction time and increasing productivity.

- Another advantage of the construction structure 50 is that the connection member 110
- 15 is easily inserted into the joint gap 118 formed between the prefabricated construction modules 100, without passing through any guides embedded in the respective structural bodies 102. Formworks in forming the joint connection is significantly reduced at the construction site. On the contrary and as described in the background, the presence of guides, such as protruding steel loops / bars / rods, would require
- 20 proper alignment thereof which decreases productivity. The absence of guides in the prefabricated construction modules 100 makes fabrication of the modules 100 easier, such as through use of standardized moulds. This results in increased work productivity of the modules 100 in the prefabrication stage and on-site construction of the construction structure 50. The absence of guides also eliminates a hazardous risk
- 25 and improves safety at the construction site.

- Additionally, the production of the prefabricated construction modules 100, due to its less complex design without the guides, may potentially be automated to further increase productivity. Without protruding guides, the modules 100 are designed to be
- 30 easily fabricated are thus suitable for constructions using the Design for Manufacturing and Assembly (DfMA) approach. DfMA is a design approach that focuses on ease of manufacture and efficiency of assembly to achieve advantages like increased construction speed and productivity, reduction in construction costs, and improved

quality and reliability. Countries are increasingly adopting DfMA in the construction industry. For example, the Building and Construction Authority (BCA) in Singapore has identified the DfMA approach as a key strategic thrust to raise the construction productivity. It will be appreciated that the increased productivity will result in economic
5 benefits not limited to lower construction costs.

In various embodiments of the present disclosure as shown in Figure 8, there is a method 200 of constructing the construction structure 50. The design and construction of the construction structure 50, including the fabrications and materials of its
10 respective prefabricated construction modules 100 including their respective parts like the structural bodies 102 and connection members 110, may be governed by various building, construction, and material codes / standards known to the skilled person. One example in Singapore is the Eurocode EN 1992-1-1 governing structural use of concrete. It will be appreciated that these codes / standards may differ across various
15 regions around the world.

The method 200 comprises a step 202 of providing a plurality of the prefabricated construction modules 100. In many embodiments, the step 202 provides a first pair of prefabricated construction modules 100 including a first and a second module 100.
20 The method 200 further comprises a step 204 of arranging the first pair of prefabricated construction modules 100 adjacent to each other such that the respective grooves 106 face each other and a first joint gap 118 including the grooves 106 is formed between the respective grooved surfaces 108.

25 The method 200 further comprises a step 206 of inserting a first connection member 110 into the first joint gap 118. For example, the first connection member 110 is inserted into the first joint gap 118 via one pair of the end surfaces 104. The method 200 further comprises a step 208 of filling the first joint gap 118 with the joint filler material to join the first pair of prefabricated construction modules 100 together. The
30 method 200 further comprises a step 210 of curing (e.g. for hardening) the joint filler material to thereby construct the construction structure 50 comprising the joined prefabricated construction modules 100.

In the embodiment as shown in Figure 2A, a first prefabricated construction module 100a and a second prefabricated construction module 100b are arranged vertically and parallel to each other. The grooved surfaces 108 are on the longer sides of the respective structural bodies 102 and the respective grooves 106 opposingly face each other. In some other embodiments, the prefabricated construction modules 100 may be arranged differently, such as horizontally, vertically, perpendicularly, and/or in parallel.

In one embodiment as shown in Figure 9A, a first prefabricated construction module 100a and a second prefabricated construction module 100b are arranged vertically and perpendicular to each other. The grooved surface 108 of the first prefabricated construction module 100a is on the longer side of the respective structural body 102, and the grooved surface 108 of the second prefabricated construction module 100b is on the shorter side of the respective structural body 102. The respective grooves 106 opposingly face each other to form the first joint gap 118 and the first connection member 110 is inserted into the first joint gap 118. The first joint gap 118 is filled with the joint filler material and after curing, the second prefabricated construction module 100b is joined to the first prefabricated construction module 100a, such as to construct an internal wall of the construction structure 50.

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In one embodiment as shown in Figure 9B, a first prefabricated construction module 100a and a second prefabricated construction module 100b are arranged vertically and perpendicular to each other. This embodiment is similar to that as shown in Figure 9A and various aspects described above apply similarly. In this embodiment, the second prefabricated construction module 100b is joined to the first prefabricated construction module 100a, such as to construct an edge wall of the construction structure 50.

In one embodiment as shown in Figure 9C, a first prefabricated construction module 100a and a second prefabricated construction module 100b are arranged horizontally and parallel to each other on the same horizontal plane. The grooved surfaces 108 are on the shorter sides of the respective structural bodies 102 and the respective grooves 106 opposingly face each other to form the first joint gap 118. The first

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connection member 110 is inserted into the first joint gap 118 which is then filled with the joint filler material and cured. The prefabricated construction modules 100 are joined to form a precast slab, such as a floor or ceiling slab of the construction structure 50.

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In one embodiment as shown in Figure 9D, a first prefabricated construction module 100a and a second prefabricated construction module 100b are arranged horizontally and parallel to each other on the same horizontal plane. The grooved surfaces 108 are on the shorter sides of the respective structural bodies 102. Each prefabricated construction module 100 comprises two grooves 106 formed adjacent to each other. Specifically, the first prefabricated construction module 100a has a first groove 106a and a second groove 106a' adjacent to each other. Similarly, the second prefabricated construction module 100b has a first groove 106b and a second groove 106b' adjacent to each other. The pair of first grooves 106a, 106b opposingly face each other and the pair of second grooves 106a', 106b' opposingly face each other, collectively forming the first joint gap 118.

A first connection member 110a and a second connection member 110b are inserted into the first joint gap 118 and through the grooves 106. Specifically, the first connection member 110a is inserted through the pair of first grooves 106a, 106b and the second connection member 110b is inserted through the pair of second grooves 106a', 106b'. The first joint gap 118 is filled with the joint filler material and after curing, the prefabricated construction modules 100 are joined to form a precast slab, such as a floor or ceiling slab of the construction structure 50.

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In one embodiment as shown in Figure 9E, a first prefabricated construction module 100a and a second prefabricated construction module 100b are arranged vertically and parallel to each other. The grooved surfaces 108 are on the longer sides of the respective structural bodies 102. Each prefabricated construction module 100 comprises three grooves 106 formed adjacent to each other. Specifically, the first prefabricated construction module 100a has a first groove 106a, a second groove 106a', and a third groove 106a'' adjacent to each other. Similarly, the second prefabricated construction module 100b has a first groove 106b, a second groove

106b', and a third groove 106b'' adjacent to each other. The pair of first grooves 106a,106b opposingly face each other, the pair of second grooves 106a',106b' opposingly face each other, and the pair of third grooves 106a'',106b'' opposingly face each other, collectively forming the first joint gap 118.

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A first connection member 110a, a second connection member 110b, and a third connection member 110c are inserted into the first joint gap 118 and through the grooves 106. Specifically, the first connection member 110a is inserted through the pair of first grooves 106a,106b, the second connection member 110b is inserted
10 through the pair of second grooves 106a',106b', and the third connection member 110c is inserted through the pair of third grooves 106a'',106b''. The first joint gap 118 is filled with the joint filler material and after curing, the prefabricated construction modules 100 are joined to form a precast slab, such as a wall of the construction structure 50.

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Although the embodiments as shown in Figure 9D and Figure 9E show the prefabricated construction modules 100 having two and three grooves 106, respectively, it will be appreciated that the prefabricated construction module 100 can have a plurality (e.g. two, three, four, or more) of grooves 106 formed adjacent to each
20 other, as well as a corresponding number of connection members 110 (e.g. one, two, or more connection members 110 for each joint gap 118). It will also be appreciated that the prefabricated construction modules 100 need not be identical, i.e. having identical shape and dimensions.

25 In some embodiments, there is a second pair of prefabricated construction modules 100 including a third and a fourth module 100. The second pair of prefabricated construction modules 100 are arranged to form a second joint gap 118 including the respective grooves 106, wherein a second connection member 110 is inserted into the second joint gap 118. It will be appreciated that various steps of the method 200 for
30 joining the first pair of prefabricated construction modules 100 apply similarly or analogously to the second pair of prefabricated construction modules 100, and are not further elaborated upon for purpose of brevity. The method 200 comprises joining the second pair of prefabricated construction modules 100 arranged relative to the first

pair of prefabricated construction modules 100, wherein the arrangement may be horizontally, vertically, perpendicularly, and/or in parallel.

- In one embodiment, the first and second pairs of prefabricated construction modules 100 are arranged vertically by stacking the second pair of prefabricated construction modules 100 onto the first pair of prefabricated construction modules 100, such as to form the construction structure 50 having a taller wall. In another embodiment, the first and second pairs of prefabricated construction modules 100 are arranged horizontally and parallel to each other on the same horizontal plane, such as to form the construction structure 50 having a large floor or ceiling slab. In another embodiment, the first and second pairs of prefabricated construction modules 100 are arranged perpendicularly to each other. For example, the first pair may form a centre wall and the second pair may form a floor or ceiling of the construction structure.
- In some embodiments, the method 200 comprises arranging the second pair of prefabricated construction modules 100 relative to the first pair of prefabricated construction modules 100, such that the first or second connection member 110 extends at least partially into the second or first joint gap 118, respectively. This extended or overlapping portion may be partial or the whole longitudinal length of the respective joint gap 118. The longitudinal bars 120 of one connection member 110 may be steel bars or rods and the longitudinal bars 120 of the other connection member 110 may be corrugated pipes, such that the steel bars can be inserted into the corrugated pipes to extend into the respective joint gap 118.
- The method 200 may further comprise inserting a stacking connector into the first and second joint gaps 118. The stacking connector is a structural element such as a steel bar or rod that strengthens the connection between the pairs of prefabricated construction modules 100.
- The respective connection member 110 or stacking connector extends at least partially into the respective joint gap 118, and possibly the whole longitudinal length of the joint gap 118. This extended portion which allows for vertical or horizontal loads, depending

on the arrangement of the prefabricated construction modules 100, to be transferred to the connection members 110.

In one embodiment, the second pair of prefabricated construction modules 100 is vertically stacked onto the first pair of prefabricated construction modules 100. The second connection member 110 extends into the first joint gap 118 along the extended portion. The second connection member 110 may be inserted into the first joint gap 118 before filling the first joint gap 118 with the joint filler material or before the joint filler material has cured completely. Alternatively, the first joint gap 118 may be partially filled with the joint filler material to a level below the extended portion. The second connection member 110 may then be inserted into the first joint gap 118 after the partial-filling joint filler material has cured. Partially filling the first joint gap 118 with the joint filler material stabilizes the first pair of prefabricated construction modules 100 for stacking of the second pair of prefabricated construction modules 100.

After stacking both pairs of prefabricated construction modules 100 and inserting the second connection member 110 into the first joint gap 118, the joint filler material is dispensed to fill the first and second joint gaps 118. The joint filler material also fills a horizontal joint gap formed between both pairs of prefabricated construction modules 100. The joint filler material is cured to thereby construct the construction structure 50 comprising the joined pairs of prefabricated construction modules 100. Spacer elements may be disposed between both pairs of prefabricated construction modules 100. The spacer elements form an enclosed horizontal space in between for filling of the joint filler material and mitigate risk of leakage during curing.

Additional pairs of prefabricated construction modules 100 may be vertically stacked onto the second pair of prefabricated construction modules 100 and joined in a similar manner as described above for joining the second pair to the first pair. Specifically, the third pair is joined to the second pair, the fourth pair is joined to the third pair, and so forth. Stacking multiple pairs of prefabricated construction modules 100 vertically may be done to increase the overall height of the construction structure 50. Similarly, additional pairs may be arranged adjacently / horizontally to widen the construction structure 50.

It will be appreciated that the aforementioned aspects of the second connection member 110 and the corresponding extended portion apply similarly or analogously to the first connection member 110 and stacking connector where applicable and are not further elaborated upon for purpose of brevity. It will also be appreciated that the
5 aforementioned aspects of vertically stacking and joining the pair of prefabricated construction modules 100 apply similarly or analogously to other arrangements and are not further elaborated upon for purpose of brevity.

10 After completion of the construction structure 50, various checks and tests may be performed to assess various conditions, especially structural integrity, of the construction structure 50 and parts thereof, including the prefabricated construction modules 100 and connection formed by the connection member 110 in the joint gap 118. These checks and tests may be governed by various codes / standards known
15 to the skilled person, although it will be appreciated that these codes / standards may differ globally. One example is a sampling test that checks the material strength of the connection member 110. Another test is the grout strength test that checks whether the joint filler material (e.g. grout or epoxy) is properly cured and structurally sound.

20 In the foregoing detailed description, embodiments of the present disclosure in relation to a prefabricated construction module, a construction structure comprising the prefabricated construction modules, and method for constructing the construction structure are described with reference to the provided figures. The description of the various embodiments herein is not intended to call out or be limited only to specific or
25 particular representations of the present disclosure, but merely to illustrate non-limiting examples of the present disclosure.

The present disclosure serves to address at least one of the mentioned problems and issues associated with the prior art. Although only some embodiments of the present
30 disclosure are disclosed herein, it will be apparent to a person having ordinary skill in the art in view of this disclosure that a variety of changes and/or modifications can be made to the disclosed embodiments without departing from the scope of the present

disclosure. Therefore, the scope of the disclosure as well as the scope of the following claims is not limited to embodiments described herein.

Claims

1. A prefabricated construction module comprising:
a structural body; and
5 a groove formed longitudinally along a grooved surface of the structural body and arranged to receive a connection member for joining to another prefabricated construction module,
wherein a lateral cross-section of the groove comprises a first groove section and a second groove section, the first groove section formed between
10 the grooved surface and the second groove section, the first groove section being narrower than the second groove section.
2. The prefabricated construction module according to claim 1, wherein a depth of the first groove section is approximately equal to a depth of the second groove
15 section.
3. The prefabricated construction module according to claim 1 or 2, wherein a centroid of the second groove section approximately coincides with a geometric centre of the structural body.
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4. The prefabricated construction module according to claim 1, wherein a depth of the first groove section is less than half of a depth of the second groove section.
5. The prefabricated construction module according to any one of claims 1 to 4,
25 wherein each groove section has a quadrilateral profile.
6. The prefabricated construction module according to any one of claims 1 to 5, comprising a plurality of the grooves formed adjacent to each other.
- 30 7. A construction structure comprising:
a first prefabricated construction module and a second prefabricated construction module arranged adjacent to each other, each prefabricated

construction module comprising a structural body and a groove formed longitudinally along a grooved surface of the respective structural body;

the prefabricated construction modules arranged such that the respective grooves face each other and a joint gap including the grooves is formed between the respective grooved surfaces;

a connection member inserted into the joint gap; and

a joint filler material filling the joint gap and joining the prefabricated construction modules together,

wherein for each prefabricated construction module, a lateral cross-section of the respective groove comprises a first groove section and a second groove section, the first groove section formed between the respective grooved surface and the second groove section, the first groove section being narrower than the second groove section.

8. The construction structure according to claim 7, wherein a depth of the first groove section is approximately equal to a depth of the second groove section and is more than a depth of the joint gap.

9. The construction structure according to claim 7, wherein a depth of the first groove section is less than half of a depth of the second groove section and is less than a depth of the joint gap.

10. The construction structure according to any one of claims 7 to 9, wherein the connection member comprises:

a plurality of longitudinal bars each extending through the respective second groove section; and

a set of lateral connector elements joining the longitudinal bars, the lateral connector elements extending across the joint gap.

11. The construction structure according to claim 10, wherein the set of lateral connector elements comprises multiple lateral connector elements disposed at discrete positions along the longitudinal bars.

12. The construction structure according to claim 11, wherein the lateral connector elements comprise one or more of reinforcement bars, loop elements, mesh, shear studs, and strip elements.
- 5 13. The construction structure according to claim 10, wherein the set of lateral connector elements comprises a single lateral connector element spanning along the longitudinal bars.
14. The construction structure according to claim 13, wherein the lateral connector
10 element comprises a lattice girder element.
15. The construction structure according to any one of claims 7 to 14, wherein the joint filler material comprises grout, epoxy, or a combination thereof.
- 15 16. A method for constructing a construction structure, the method comprising:
providing a plurality of prefabricated construction modules, each
prefabricated construction module comprising a structural body and a groove
formed longitudinally along a grooved surface of the respective structural body;
arranging a first pair of prefabricated construction modules adjacent to
20 each other such that the respective grooves face each other and a first joint
gap including the grooves is formed between the respective grooved surfaces;
inserting a first connection member into the first joint gap;
filling the first joint gap with a joint filler material to join the first pair of
prefabricated construction modules together; and
25 curing the joint filler material to thereby construct the construction
structure comprising the joined prefabricated construction modules,
wherein for each prefabricated construction module, a lateral cross-
section of the respective groove comprising a first groove section and a second
groove section, the first groove section formed between the respective grooved
30 surface and the second groove section, the first groove section being narrower
than the second groove section.

17. The method according to claim 16, further comprising joining a second pair of prefabricated construction modules arranged relative to the first pair of prefabricated construction modules.

5 18. The method according to claim 17, further comprising arranging the second pair of prefabricated construction modules relative to the first pair of prefabricated construction modules, such that the first connection member extends at least partially into a second joint gap formed between the second pair of prefabricated construction modules.

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19. The method according to claim 17, further comprising arranging the second pair of prefabricated construction modules relative to the first pair of prefabricated construction modules, such that a second connection member of the second pair of prefabricated construction modules extends at least partially into the first joint gap.

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20. The method according to any one of claims 17 to 19, further comprising inserting a stacking connector into the first joint gap and a second joint gap formed between the second pair of prefabricated construction modules.

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