

PRECAST BUILDING

The present application relates to a prefabricated building. In particular, the present application relates to a multi-storey building that is constructed with prefabricated prefinished volumetric construction (PPVC) modules.

To raise construction productivity, the construction industry has embraced the idea of Design for Manufacturing and Assembly (DfMA), where construction is designed and configured such that a substantial portion of the construction work is done off-site in a controlled manufacturing environment. By doing this, manpower and time needed to construct buildings at a work site are reduced, while ensuring the work site is safe with minimal impact on the surrounding living environment.

Prefabricated Prefinished Volumetric Construction (PPVC) is a construction method that support the DfMA idea to significantly speed up the construction. The PPVC method facilitates manufacturing of precast unit modules at an off-site location. The manufactured precast unit modules with internal finishes, fixtures and fittings are then transported to the work site for installation.

WO2018067067A1 discloses a prefabricated prefinished volumetric construction (PPVC) module. The PPVC module forms a five-sided or a six-sided polygonal unit, which includes a slab, a plurality of combined walls, at least a facade, and a wall. The PPVC module is constructed in a manufacturing plant and assembled at a remote site. The PPVC module is equipped with internal fittings that include partition walls, bathroom fittings with other architectural finishes, electrical wiring

conduits, water piping, and other mechanical and electrical services.

EP3263795A1 discloses a building structure, which is constructed
5 from multiple prefabricated construction modules. Each
prefabricated construction module includes one or more walls.
Each wall includes one or more guides for overlapping with an
adjacent guide of an adjacently-arranged wall of an adjacently-
arranged prefabricated construction module. The overlapping
10 guides provide a channel for receiving a linking rod. The wall
is adapted to join to the adjacently-arranged wall by grouting a
gap that includes the channel, wherein the gap is located
between the wall and the adjacently-arranged wall.

15 WO2018101891A1 discloses a prefabricated volumetric construction
module, which has a connection mechanism for securing the module
to other similar modules. The prefabricated volumetric
construction module includes a self-supporting structure and
pairs of corner castings, which are arranged at least at the
20 corners of the structure. During building construction, the
modules are assembled and secured together using connection rods
and interlocking plates to provide vertical securement between
vertically adjoining modules and horizontal securement between
horizontally adjoining modules.

25 It is an objective of the application to provide an improved
precast unit module.

The application provides an improved precast construction module
30 for constructing a building. The precast construction module
refers to a construction unit that is produced by casting
concrete in a reusable mould or formwork at a precast plant. The

casted concrete is then cured in a controlled environment and later transported to a construction site for assembling into a building of multiple storeys. The precast construction module is also called prefabricated prefinished volumetric construction (PPVC) module or precast unit module.

The precast construction module comprises a horizontal concrete slab and a group of walls consisting of a first concrete wall, a second concrete wall, a third concrete wall, and a fourth concrete wall. The slab comprises a first edge portion that is integrally connected to a lower end of the first wall, and a second edge portion that is integrally connected to a lower end of the second wall. The slab also comprises a third edge portion that is integrally connected to a lower end of the third wall, and a fourth edge portion that is integrally connected to a lower end of the fourth wall. A first vertical edge of the first wall is integrally connected to a first vertical edge of the second wall, and a second vertical edge of the second wall is integrally connected to a first vertical edge of the third wall. A second vertical edge of the third wall is integrally connected to a first vertical edge of the fourth wall, and a second vertical edge of the fourth wall is integrally connected to a second vertical edge of the first wall. In other words, the precast construction module has a shape of a cuboid having one side that is open.

The precast construction module further comprises a plurality of corrugated ducts. Each corrugated duct has an inner surface that can be roughened to become uneven. The corrugated ducts are provided vertically in one or more walls that are selected from the group of walls. A wall of the precast construction module, which is arranged to be adjacent to a wall of an adjacent

precast construction module, is often provided with corrugated ducts. Each corrugated duct is adapted or sized to receive a plurality of connecting bars, but not just only one single connecting bar. The corrugated duct is also adapted to receive
5 grout to fill the corrugated duct to form a grout column. The grout column surrounds the connecting bars that are inserted into the corrugated duct and binds them to each other, to the inner surface of the corrugated duct. The grout column that is reinforced by the connecting bars can improve the structural
10 strength of the precast construction module.

Each corrugated duct can extend from an upper end of the wall to a lower end of the wall, and to a bottom side of the slab.

15 The wall can also be provided with one or more grooves or recesses, which are often provided on an exterior surface of the wall.

In one implementation, each groove includes a top portion and a
20 body portion. An upper end of the body portion is attached to a lower end of the top portion. The top portion has a horizontal cross-sectional area that is larger than a horizontal cross-sectional area of the body portion. The top portion is also called pocket portion.

25 The groove can include a plurality of mechanical connection elements for connecting a wall of the precast construction module to a wall of an adjacent precast construction module, wherein the adjacently arranged precast construction modules are
30 positioned on a same horizontal plane such that the walls face each other.

Each mechanical connection element can include a portion that is embedded within the wall and a remaining portion that protrudes from a major surface of the groove of the wall. The major surface of the groove often faces towards a direction that is substantially perpendicular to the exterior surface of the wall.

The mechanical connection elements can include one or more rectangular reinforcement links. The reinforcement link is often formed by bending an elongated steel bar such that the steel bar forms a rectangle.

The mechanical connection element can also include one or more loop parts. In one implementation, the loop part comprises a metal wire loop. In another implementation, the loop part comprises a metal ring.

The application also provides an improved building structure. The building structure refers to a concrete structure, which includes a plurality of concrete parts. The concrete parts are arranged and organized to form a structure of a building of two or more storeys. The improved building structure includes two or more precast construction modules that are described above.

The precast construction modules can include a first lower precast construction module and a second lower precast construction module that is arranged adjacent to the first lower precast construction module such that a first wall of the first lower precast construction module is adjacent to a third wall of the second lower precast construction module. A first wall of a precast construction module is opposite its third wall.

The building structure further includes a first lower connection device for connecting the first wall of the first lower precast construction module to the third wall of the second lower precast construction module. The first lower connection device is located between the first wall of the first lower precast construction module and the third wall of the second lower precast construction module. The first lower connection device is also called shear connection unit.

- 10 The first lower connection device includes one or more first mechanical connection elements of the first wall of the first lower precast construction module. The first mechanical connection element has a portion that protrudes from a major surface of the first wall. The first lower connection device
- 15 also includes one or more second mechanical connection elements of the third wall of the second lower precast construction module. The second mechanical connection element also has a portion that protrudes from a major surface of the third wall. The first lower connection device further includes a horizontal
- 20 metal plate, at least one first connecting rod that is vertically attached to a first part of a bottom surface of the metal plate, and at least one second connecting rod that is also vertically attached to a second part of the bottom surface of the metal plate. The first part and the second part are
- 25 positioned such that the first connecting rod is disposed vertically in a protruding portion of the first mechanical connection element, and the second connecting rod is vertically disposed in a protruding portion of the second mechanical connection element. The first connecting rod, the first
- 30 mechanical connection element, the second connecting rod, and the second mechanical connection element together form a coupling device that connects the first wall to the third wall.

The first lower connection device also includes a first non-shrink grouting that is disposed between the first wall of the first lower precast construction module and the third wall of the second lower precast construction module. The first grouting acts to bind or securely join the first mechanical connection element to the first connecting rod, to the second mechanical connection element, to the second connecting rod, to the metal plate, to the first wall, and to the third wall. This allows the elements of the coupling device to be secured at fixed positions, thereby preventing the first lower precast construction module and the second lower precast construction module from shifting with respect to each other in a lateral direction.

The first mechanical connection element can include a reinforcement link and the second mechanical connection element can also include a reinforcement link.

The first connecting rod can include a steel J-bolt or a steel U-shaped bar, and the second connecting rod can also include a steel J-bolt or a steel U-shaped bar.

The first lower connection device is often provided at an upper portion of the first wall of the first lower precast construction module. Put differently, the first lower connection device can be placed in a top portion of a groove of the first wall of the first lower precast construction module as well as in a top portion of a corresponding groove of the third wall of the second lower precast construction module.

The building structure can further include a second lower connection device for connecting the first wall of the first lower precast construction module to the third wall of the second lower precast construction module. The second lower connection device includes at least one first loop part of the first wall of the first lower precast construction module and at least one second loop part of the third wall of the second lower precast construction module. A portion of the second loop part of the third wall overlaps a portion of the first loop part of the first wall. The second lower connection device also includes a linking bar that is disposed within the overlapping portion of the first loop part and within the overlapping portion of the second loop part. The second lower connection device further includes a second grouting that is disposed between the first wall of the first lower precast construction module and the third wall of the second lower precast construction module. The second grouting binds the first loop part to the second loop part, to the linking bar, to the first grouting, to the first wall, and to the third wall.

In one implementation, the second lower connection device is provided below the first lower connection device.

The precast construction modules of the building structure can further comprise a first upper precast construction module that is stacked above the first lower precast construction module. The first upper precast construction module includes a first upper corrugated duct and a first upper connecting bar, which is provided in the first upper corrugated duct. The first lower precast construction module includes a first lower corrugated duct that corresponds to the first upper corrugated duct, wherein a part of the first upper connecting bar extends into

the first lower corrugated duct. The first lower precast construction module also includes a first lower connecting bar, which is provided in the first lower corrugated duct such that a part of the first lower connecting bar overlaps a part of the first upper connecting bar. The building structure further comprises a third grouting, which is disposed in the first lower corrugated duct and in the first upper corrugated duct. The third grouting acts to bind the first lower connecting bar to the first upper connecting bar, to the first lower corrugated duct, and to the first upper corrugated duct. Put differently, the third grouting is formed as a grouting column, which extends from the first upper corrugated duct to the first lower corrugated duct. The grouting column is reinforced by the connecting bars to provide a vertical connection that binds the first upper precast construction module to the first lower precast construction module. The third grouting is also called a grout column.

The building structure can further include a plurality of metal shim plates that are provided between the first upper precast construction module and the first lower precast construction module. The metal shim plate refers to a thin and often tapered piece of metal, which is used to fill a gap between the first upper precast construction module and the first lower precast construction module. The shim plate can be pre-adjusted to provide a level surface for placing the first upper precast construction module. The building structure also includes a fourth grouting that is disposed between the first upper precast construction module and the first lower precast construction module to bind the metal shim plates to the first upper precast construction module, and to the first lower precast construction module.

The application also provides a method for constructing a building structure at a site. The method includes a step of positioning a first lower precast construction module and a second lower precast construction module in a side-by-side arrangement. The lower precast construction modules are described above. A first wall of the first lower precast construction module and a third wall of the second lower precast construction module are adjacently arranged such that they are separated by a predetermined gap. Prior to the positioning of the first and second lower precast construction modules, the first and second lower precast construction modules are respectively marked with reference lines, level lines, and offset lines off site. The reference lines, the level lines, and the offset lines of the first and second lower precast construction modules are then marked on the site for indicating positions of the first and second lower precast construction modules. These lines are also used to guide the positioning the lower precast construction modules. A horizontal metal plate with at least one first connecting rod and with at least one second connecting rod is positioned vertically. The first connecting rod and the second connecting rod, which are attached to a bottom of the metal plate, are placed such that the first connecting rod is disposed in at least one first mechanical connection element of the first wall of the first lower precast construction module, and the second connecting rod is disposed in at least one second mechanical connection element of the third wall of the second lower precast construction module. A first grout is later provided between the gap to bind the metal plate to the first connecting rod, to the first mechanical connection element, to the second connecting rod, to the second

mechanical connection element, to the first wall, and to the third wall.

The method can further include a step of inserting a linking bar into at least one first loop part of the first wall of the first lower precast construction module and into at least one second loop part of the third wall of the second lower precast construction module, and a step of providing a second grout in the gap to bind the linking bar to the first loop part, to the second loop part, to the first grout, to the first wall, and to the third wall.

The method can also include another step of positioning a first upper precast construction module above the first lower precast construction module, followed by a step of inserting a first lower connecting bar into a first lower corrugated duct of the first lower precast construction module. A third grout is then provided into the first lower corrugated duct until the third grout reaches a lapping length of the first lower connecting bar. A first upper connecting bar is later inserted into a first upper corrugated duct of the first upper precast construction module such that a part of the first upper connecting bar overlaps a part of the first lower connecting bar. The third grout is further provided into the first upper corrugated duct and into the first lower corrugated duct to bind the first lower connecting bar to the first upper connecting bar, to the first lower corrugated duct, and to the first upper corrugated duct.

The first grout, the second grout, and the third grout can be provided in different order or sequence. In other words, the third grout can be provided before the second grout, which can be provided before the first grout. Alternatively, the second

grout can be provided before the first grout, which can be provided before the third grout.

The application also provides a connection assembly for
5 connecting a first wall to a second wall that is arranged
adjacent to the first wall. The connection assembly includes one
or more first connection elements of the first wall, one or more
second connection elements of the second wall, a horizontal
plate, one or more first connecting rods that are vertically
10 attached to a first part of a bottom surface of the horizontal
plate, and one or more second connecting rods that are
vertically attached to a second part of the bottom surface of
the horizontal plate. The first part and the second part of the
bottom surface are positioned such that the first connecting rod
15 is disposed vertically in the first connection element, and the
second connecting rod is vertically disposed in the second
connection element. The connection assembly also includes a
first grouting, which is disposed between the first wall and the
second wall. The first grouting binds the first connection
20 element to the first connecting rod, to the second connection
element, to the second connecting rod, to the horizontal plate,
to the first wall, and to the second wall.

The first connection element can include a reinforcement link
25 and the second connection element can also include a
reinforcement link.

The first connecting rod can include a steel J-bolt or a steel
U-shaped bar, and the second connecting rod can also include a
30 steel J-bolt or a steel U-shaped bar.

The connection assembly can further include one or more first loop parts of the first wall, one or more second loop parts of the second wall, a linking bar that is disposed within the first loop part and within the second loop part, and a second grouting that is disposed between the first wall and the second wall. The second grouting binds the first loop part to the second loop part, to the linking bar, to the first grouting, to the first wall, and to the second wall.

- 10 Each first loop part can include a metal wire loop and each second first loop part can also include a metal wire loop.

The first wall and the second wall can be provided by separate prefabricated construction modules, wherein the first wall is a part of a prefabricated construction module and the second wall is a part of another prefabricated construction module.

The prefabricated construction modules can include precast construction modules that are described above.

20

Fig. 1 illustrates a perspective view of a two-storey housing unit comprising two precast unit modules,

Fig. 2 illustrates a cross section view of two vertically arrange corrugated ducts of the housing unit of Fig.

25 1,

Fig. 3 illustrates a perspective view of a building comprising the multiple two-storey housing units of Fig. 1, each two-storey housing unit being connected to an adjacent housing unit,

30 Fig. 4 illustrates a cross-sectional view of walls of the building of Fig. 3, the walls being placed adjacent to

each other, wherein each wall comprises a first connection device and a second connection device,

Fig. 5 illustrates a top view of the first connection device and of the second connection device of Fig. 4,

5 Fig. 6 illustrate a perspective view of an upper part of the wall of Fig. 4,

Fig. 7 illustrates a side view of the second connection devices of Fig. 4,

Fig. 8 illustrates a top view of the second connection device of Fig. 7 for connecting the adjacent walls of Fig. 4,

10 Fig. 9 illustrates an elevated cross-sectional view of the first connection device of Fig. 4,

Fig. 10 illustrates a perspective view of the first connection device of Fig. 9,

15 Fig. 11 illustrates a top view of the first connection device of Fig. 10,

Fig. 12 illustrates a side view the first connection device of Fig. 10,

Fig. 13 illustrates a top view of the first connection device of Fig. 10 for connecting the adjacent walls of Fig. 4,

20 Fig. 14 illustrates a perspective view of a prefabricated precast unit module of the housing unit of Fig. 1,

Fig. 15 illustrates a cross-sectional view of a steel formwork for fabricating the precast unit module of Fig. 14,

25 Fig. 16 illustrates a perspective view of the prefabricated precast unit module of Fig. 14, which is placed in an inverted position,

Fig. 17 illustrates a flow chart of a method for constructing the building of Fig. 3,

30

- Fig. 18 illustrates a perspective view of another connection device, which is a variant of the first connection device of Fig. 10,
- Fig. 19 illustrates a top view of the connection device of Fig. 18,
- Fig. 20 illustrates a side view the connection device of Fig. 18,
- Fig. 21 illustrates an elevated cross section view of an alternative connection device for connecting the adjacent walls of Fig. 4, and
- Fig. 22 illustrates a top view of the alternative connection device of Fig. 21.

In the following description, details are provided to describe the embodiments of the present specification. It shall be apparent to one skilled in the art, however, that the embodiments may be practised without such details.

The embodiments below have similar parts. The similar parts may have the same names or similar part numbers. The description of one part applies by reference to another similar part, where appropriate, thereby reducing repetition of text without limiting the disclosure.

Fig. 1 shows a two-storey housing unit 1. The housing unit 1 includes an improved upper precast unit module 3, an improved lower precast unit module 3', a module connecting unit 9, and a wall structure 33. The upper precast unit module 3 is placed above the lower precast unit module 3', which is placed above the wall structure 33. The module connecting unit 9 is placed between the upper precast unit module 3 and the lower precast unit module 3', wherein the module connecting unit 9 is

connected to the upper precast unit module 3 and to the lower precast unit module 3'.

The upper precast unit module 3, which is prefabricated at a precast plant, includes a rectangular upper concrete floor slab 12, a rectangular upper right concrete wall 15, a rectangular upper rear concrete wall 23, a rectangular upper left concrete wall 18 with a window opening 21, a rectangular upper front concrete wall 26 with a door opening 29, and a plurality of upper corrugated ducts 72. The upper floor slab 12 is placed horizontally while the walls 15, 18, 23, and 26 are placed vertically. The upper corrugated ducts 72 are provided vertically in at least one of the walls 15, 18, 23, and 26. In this embodiment, the upper corrugated ducts 72 are provided in the walls 15 and 18.

The upper floor slab 12 includes an elongated first edge portion, an elongated second edge portion, an elongated third edge portion, and an elongated fourth edge portion. A first end of the first edge portion is connected to a first end of the second edge portion. A second end of the second edge portion, which is opposite the first end of the second edge portion, is connected to a first end of the third edge portion. A second end of the third edge portion, which is opposite the first end of the third edge portion, is connected to a first end of the fourth edge portion. A second end of the fourth edge portion, which is opposite the first end of the fourth edge portion, is connected to a second end of the first edge portion, wherein the second end of the first edge portion is opposite the first end of the first edge portion. In other words, the first edge portion is opposite the third edge portion while the second edge portion is opposite the fourth edge portion.

The first edge portion of the upper floor slab 12 is integrally connected to a lower end of the upper right sidewall 15. The second edge portion of the upper floor slab 12 is integrally connected to a lower end of the upper rear wall 23. The third edge portion of the upper floor slab 12 is integrally connected to a lower end of the upper left sidewall 18, and the fourth edge portion of the upper floor slab 12 is integrally connected to a lower end of the upper front wall 26.

10

The first vertical edge of the upper right wall 15 is integrally connected to a first vertical edge of the upper rear wall 23. A second vertical edge of the upper rear wall 23, which is opposite the first vertical edge of the upper rear wall 23, is integrally connected to a first vertical edge of the upper left wall 18. A second vertical edge of the upper left wall 18, which is opposite the first vertical edge of the upper left wall 18, is integrally connected to a first vertical edge of the upper front wall 26. A second vertical edge of the upper front wall 26, which is opposite the first vertical edge of the upper front wall 26, is integrally connected to a second vertical edge of the upper right wall 15, wherein the second vertical edge of the upper right wall 15 is opposite the first vertical edge of the upper right wall 15.

25

Referring to the upper corrugated ducts 72, each corrugated duct 72 has an upper end opening that is located at a predetermined position on an upper edge of the walls 15 and 18. The corrugated duct 72 also has a lower end opening that is located at a bottom surface of a corresponding edge portion of the upper concrete floor slab 12. The corrugated duct 72 has an upper continuity bar 80, which is shown in Fig. 2. The upper continuity bar 80

30

has a predetermined length. The continuity bar 80 has a lower part that extends to a part of the lower precast unit module 3'. The continuity bar 80 is also called a connecting bar.

5 Referring to the lower precast unit module 3', it is prefabricated at a precast plant. The lower precast unit module 3' and the upper precast unit module 3 have similar parts that are arranged similarly. The lower precast unit module 3' also includes a rectangular lower concrete floor slab 12', a
10 rectangular lower right concrete wall 15', a rectangular lower rear concrete wall 23', a rectangular lower left concrete wall 18' with a window opening 21', a rectangular lower front concrete wall 26' with a door opening 29', and a plurality of lower corrugated ducts 72'.

15

The lower precast unit module 3' is placed below the upper precast unit module 3 such that an exterior vertical surface of the lower right wall 15' and an exterior vertical surface of the upper right wall 15 lie on a same vertical plane and an exterior
20 vertical surface of the lower rear wall 23' and an exterior vertical surface of the upper rear wall 23 lie on another vertical plane.

Each lower corrugated duct 72' has an upper end opening that is
25 located at a predetermined position on an upper edge of the walls 15' and 18'. The lower corrugated duct 72' also has a lower end opening that is located at a bottom surface of a corresponding edge portion of the lower concrete floor slab 12'. The lower corrugated duct 72' and the upper corrugated duct 72
30 are arranged such that they have a common vertical axis. In other words, the lower corrugated duct 72' and the upper corrugated duct 72 provide a vertical passageway.

The lower corrugated duct 72' has a lower continuity bar 80', which is shown in Fig. 2. The continuity bar 80' has a lower part that extends to a part of the wall structure 33. The lower
5 corrugated duct 72' also receives the lower part of the upper continuity bar 80 that extends to an upper portion of the lower corrugated duct 72'. The lower part of the upper continuity bar 80 is placed adjacent to an upper part of the lower continuity bar 80' such that they overlap each other with a lapping length.

10

The lower corrugated duct 72' and the upper corrugated duct 72 are both filled with non-shrink grout. The grout surrounds the continuity bars 80 and 80' and connects the lower continuity bar 80' to the upper continuity bar 80 to form a grout column that
15 is reinforced with an extended connecting bar that is formed by the continuity bars 80 and 80'. The grout column with the reinforcement bar acts to connect the lower corrugated duct 72' to the upper corrugated duct 72.

20 In short, the grout column is formed by filling the corrugated duct 72' with non-shrink grout until the grout reaches a vertical level that corresponds to the lapping length of the lower continuity bar 80'. This is to allow a part of the upper continuity bar 80 to be inserted later into the lower corrugated
25 duct 72'. After placing the upper continuity bar 80, the non-shrink grout is further added into the upper corrugated duct 72 until the grout reaches the vertical level that corresponds to the lapping length of the upper continuity bar 80. A vertical space with the lapping length is required for placing a next
30 continuity bar from another precast unit module that can be placed above the upper precast unit module 3.

Referring to the wall structure 33, which is casted on site, includes a left concrete wall 34 and a right concrete wall 35. The right wall 35 is opposite the left wall 34. A major surface of the right wall 35 faces a major surface of the left wall 34 and the major surfaces of the walls 34 and 35 are separated by a predetermined distance. The left wall 34 is placed below the lower left wall 18' such that an exterior vertical surface of the left wall 34 and an exterior vertical surface of the lower left wall 18' lie on a same vertical plane. The right wall 35 is placed below the lower right wall 15' such that an exterior vertical surface of the right wall 35 and an exterior vertical surface of the lower right wall 15' lie on a same vertical plane.

Each wall 34 and 35 includes a plurality of corrugated ducts that are embedded in the wall 34 and 35. Each corrugated duct receives a lower part of a corresponding lower continuity bar 80' and the corrugated duct is filled with non-shrink grout.

Referring to the module connecting unit 9, it includes a plurality of metal shim plates 36 with layers of grout bedding 39. The metal shim plates are made of, for example, steel.

Bottom surfaces of the shim plates 36 contact with predetermined areas of top surfaces of the lower walls 15', 18', 23', and 26' of the lower precast unit module 3'. Top surfaces of the shim plates 36 contact with a bottom surface of the upper floor slab 12 of the upper precast unit module 3. A lateral gap is formed between the bottom surface of the upper floor slab 12 and the top surfaces of the lower walls 15', 18', 23', and 26'.

The grout bedding 39 is provided in the lateral gap. The grout bedding 39 surrounds the steel shim plates 36 and binds the steel shim plates 36 to the top surfaces of the lower walls 15', 18', 23', and 26', and to the bottom surface of the upper
5 concrete floor slab 12. This is done such that the upper concrete floor slab 12' also serves as a ceiling slab for the lower precast unit module 3'.

Forming of the grout bedding 39 is described below.

10

Some shim plates 36 are placed at the predetermined areas on top surfaces of the lower walls 15', 18', 23', and 26'. A compressive bituminous strip 38 is then arranged to surround a space that encloses the shim plates 36. The space is later
15 filled with non-shrink grout, which often comprises a wet or unhardened concrete mixture in the form of a paste, such that the grout covers partially or fully the shim plates 36. The upper precast unit module 3 is afterward lifted and placed on the shim plates 36 such that the upper floor slab 12 contacts the top
20 surfaces of the shim plates 36. This also acts to compress the grout. The compressive bituminous strip 38 prevents the grout from flowing out from the space defined by the compressive bituminous strip 38 when the grout is being compressed. The grout is then cured and hardened to form the grout bedding 39.

25

Fig. 3 shows an improved building 10. The building 10 includes a first two-storey housing unit 1, a second two-storey housing unit 1'', an upper lateral connection device 70, and a lower lateral connection device 70', wherein the upper lateral
30 connection device 70 and the lower lateral connection device 70' are shown in Figs. 4 and 5. The first two-storey housing unit 1 is placed adjacent to the second two-storey housing unit 1''. The

upper lateral connection device 70 and the lower lateral connection device 70' are located between the housing units 1 and 1". The upper lateral connection device 70 is placed above the lower lateral connection device 70'.

5

The first housing unit 1 and the second housing unit 1" have the same configuration, which is described above.

Briefly, each housing unit 1 and 1" includes an upper precast unit module 3 and a lower precast unit module 3'. The upper precast unit module 3 includes a right wall 15 and a left wall 18. Similarly, the lower precast unit module 3' includes a right wall 15' and a left wall 18'.

15 The left walls 18 and 18' of the second housing unit 1" are placed adjacent to the right walls 15 and 15' of the first housing unit 1 such that they face each other, and they are separated by a predetermined gap 73. The predetermined gap 73 has a width of, for example, 20 millimetres (mm).

20

The upper right wall 15 further includes one or more vertical recesses or grooves 63. As better seen in Figs. 4 and 6, the grooves 63 are provided on an exterior surface of the upper right wall 15. Each groove 63 extends from an upper end of the upper right wall 15 to a lower end of the upper right wall 15.

Each groove 63 includes a pocket portion 67 and an elongated body portion 77. The pocket portion 67 is located at an upper part of the groove 63. A lower end of the pocket portion 67 is connected to an upper end of the body portion 77. A horizontal cross-sectional area of the pocket portion 67 is larger than a horizontal cross-section area of the body portion 67.

30

The pocket portion 67 has a U-shaped recess, which includes a vertical major surface 200, a first vertical side surface 203, and a second vertical side surface 206. A vertical edge of the first side surface 203 is integrally connected to a first vertical edge of the major surface 200 such that the first side surface 203 is substantially perpendicular to the major surface 200. A vertical edge of the second side surface 206 is integrally connected to a second vertical edge of the major surface 200 such that the second side surface 206 is substantially perpendicular to the major surface 200.

The body portion 77 has a trapezoidal recess. The trapezoidal recess includes a vertical flat surface 210, a first vertical inclined surface 213, and a second vertical inclined surface 216. A vertical edge of the first inclined surface 213 is integrally connected to a first vertical edge of the flat surface 210 such that the first inclined surface 213 is inclined at an obtuse angle with respect to the flat surface 210. A vertical edge of the second inclined surface 216 is integrally connected to a second vertical edge of the flat surface 210 such that the second inclined surface 216 is inclined at an obtuse angle with respect to the flat surface 210.

The body portion 77 and the pocket portion 67 are arranged such that the flat surface 210 of the body portion 77 is substantially parallel to the major surface 200 of the pocket portion 67.

Each groove 63 further includes a plurality of rectangular reinforcement links 82, a first mechanical connector set 75, and a second mechanical connector set 76. The reinforcement links 82

are connect to the major surface 200 of the pocket portion 67. The first connector set 75 and the second connector set 76 are connected to the flat surface 210 of the body portion 77 such that the first connector set 75 is placed between the
5 reinforcement links 82 and the second connector set 76.

Each rectangular reinforcement link 82 includes a first link portion, a second link portion, a third link portion, and a fourth link portion. A first end the first link portion is
10 integrally connected to a first end of the second link portion, a second end of the second link is integrally connected to a first end of the third link portion, a second end of the third link portion is integrally connected to a first end of the fourth link portion, and a second end of the fourth link portion
15 is placed near a second end of the first link portion.

A part of the reinforcement link 82 is embedded within the upper right wall 15 while the remaining part of the reinforcement link 82 protrudes from the major surface 200 of the pocket portion
20 67. The protruding part of the reinforcement link 82 can include a part of the second link portion, the third link portion, and a part of the fourth link portion, wherein the part of the second link portion and the part of the fourth link portion are substantially perpendicular to the major surface 200.

25 The reinforcement links 82 are arranged such that the adjacent reinforcement links 82 are separated by a vertical distance and are aligned to provide a vertical passageway.

30 The first connector set 75 includes one or more wire loop boxes 79. As shown in Figs. 7 and 8, the wire loop box 79 includes a perforated housing 81 and two flexible steel wire loops 83. The

housing 81 is fixed within the upper right wall 15 at a position that is next to the flat surface 210 of the body portion 77. Each of the wire loops 83 passes through the housing 81 by a hole of the housing 81 so that the wire loop 83 forms a grip loop. The grip loop extends from the housing 81 and protrudes from the flat surface 210 of the body portion 77. Two straight sections of the grip loop are fastened to each other with a sleeve 87 and they are embedded within the upper right wall 15. The two grip loops are arranged such that a bar can pass through the wire loops 83 vertically. In one implementation, the wire loop 83 has a diameter of 6 millimetres (mm).

The second connector set 76 includes one or more wire loop boxes 89. The wire loop box 89 and the wire loop box 79 have similar parts, which are arranged similarly.

The wire loop boxes 79 and 89 are placed such that they are separated by a predetermined vertical distance. The wire loops 83 of the wire loop boxes 79 and 89 are positioned such that a vertical axis passes through the wire loops 83.

The upper right wall 15 further includes one or more reinforcement cages, which are embedded in the wall 15. The reinforcement cage includes, for examples, a mesh of reinforcing steel bars. The reinforcement cage acts to provide structural strength to the wall 15 and it also serves as an attachment or anchoring point for the reinforcement link 82 and for the wire loop boxes 79 and 89.

Referring to the upper left wall 18 of the second housing unit 1", which is shown in Figs. 3 and 4, the upper left wall 18 further includes one or more vertical recesses or grooves 63.

The groove 63 of the upper left wall 18 faces a corresponding groove 63 of the upper right wall 15 of the first housing unit 1 such that the vertical grooves 63 face each other to form a vertical channel 69.

5

Each groove 63 of the upper left wall 18 of the second housing unit 1" and the groove 63 of the upper right wall 15 of the first housing unit 1 have similar parts, which are arranged similarly.

10

Briefly, the groove 63 of the upper left wall 18 includes a plurality of reinforcement links 82, a third mechanical connector set 85, and a fourth mechanical connector set 86. The third connector set 85 is located between the reinforcement links 82 and the fourth connector set 86.

15

The third connector set 85 and the first connector set 75 have similar parts, which are arranged similarly. The third connector set 85 is arranged such that each wire loop 83 of the third connector set 85 and a corresponding wire loop 83 of the first connector set 75 of the first housing unit 1 overlaps each other to provide a first vertical passage.

20

The fourth connector set 86 and the second connector set 76 have similar parts, which are arranged similarly. The fourth connector set 86 is arranged such that each wire loop 83 of the fourth connector set 86 and a corresponding wire loop 83 of the second connector set 76 of the first housing unit 1 overlaps each other to provide a second vertical passage. The second vertical passage is located vertically below the first vertical passage such that they have a common vertical axis.

30

Referring to the upper lateral connection device 70, which is shown in Figs. 4 and 9, the upper lateral connection device 70 includes a shear connection unit 92 and a wall connection unit 97. The shear connection unit 92 is placed in the pocket portion 67 while the wall connection unit 97 is placed in the body portion 77. The wall connection unit 97 is bound or integrally connected to the shear connection unit 92.

As better seen in Figs. 10, 11, and 12, the shear connection unit 92 includes a horizontal rectangular metal plate 93 with two pairs of metal J-bolts 95, and first non-shrink grouting. The metal plate 93 and the J-bolts 95 are often made of steel.

The metal plate 93 has a rectangular size that corresponds to a size of an end opening of an upper portion of the vertical channel 69, wherein the upper portion of the vertical channel 69 is formed by the pocket portion 67 of the right wall 15 of the first housing unit 1, by the pocket portion 67 of the left wall 18 of the second housing unit 1", and by an upper part of the gap 73. The metal plate 93 includes four through holes 94, which are located at respective corner portions of the metal plate 93.

Each J-bolt 95 has a straight part and a bent part. A first end of the straight part is integrally connected to an end of the bent part. A second end of the straight part is vertically inserted into one of the holes 94 and is welded to the metal plate 93 with a full welded portion 101 and with a fillet welded portion 102. The full welded portion 101 is located near a top surface of the metal plate 93 while the fillet welded portion 102 is located near a bottom surface of the metal plate 93.

The J-bolts 95 are connected to the metal plate 93 such that a first pair of the J-bolts 95 are positioned on a first vertical plane and their bent parts are placed near to each other, and such that a second pair of the J-bolts 95 are positioned on a second vertical plane and their bent parts are placed near to each other. The first vertical plane and the second vertical plane are substantially parallel to each other.

In one implementation, the metal plate 93 is made of a steel plate with a thickness of 16 mm. The steel plate has a length of about 310 mm and a width of about 180 mm. The steel plate has four through holes 94, each of which is located at a position that is about 40mm from two adjacent edges of the steel plate. The J-bolts 95 are made of high yield steel reinforcing bars. The full welded portion 101 has a thickness of about 6mm and the fillet welded portion 102 has a thickness of 8mm.

As better seen in Fig. 13, the first pair of the J-bolts 95 are inserted into a vertical passageway of the reinforcement links 82 of the upper right wall 15 of the first housing unit 1 while the second pair of the J-bolts 95 are inserted into a vertical passageway of the reinforcement links 82 of the upper left wall 18 of the second housing unit 1".

The first non-shrink grouting occupies essentially a whole space of the upper portion of the vertical channel 69. The first grouting surrounds the J-bolt 95 and the reinforcement links 82, as well as covers the bottom surface of the metal plate 93. The first grouting binds these parts to each other, to the right wall 15, and to the left wall 18 for preventing the upper precast module 3 of the first housing unit 1 from moving or

shifting laterally away from the upper precast module 3 of the second housing unit 1".

Referring to the wall connection unit 97, which is shown in
5 Figs. 4 and 5, it includes a cottering bar 90 and second non-shrink grouting. The cottering bar 90 is also called linking bar or reinforcement bar.

The cottering bar 90 is vertically inserted into the first
10 vertical passage of the connector sets 75 and 85 and into the second vertical passage of the connector sets 76 and 86. The cottering bar 90 extends from an upper end of the body portion 77 to a lower end of the body portion 77.

15 The second non-shrink grouting occupies essentially a whole space that is formed by the body portion 77 of the right wall 15 of the first housing unit 1, by the body portion 77 of the left wall 18 of the second housing unit 1", and a part of the gap 73 that is between these body portions 77. The second grouting
20 surrounds the cottering bar 90, the connector sets 75, 76, 85, and 86 and binds these parts to each other, to the right wall 15, to the left wall 18, and to the first grouting. This can further strengthen the connection between the walls 15 and 18 and prevent the upper precast module 3 of the first housing unit
25 1 from moving or shifting laterally away from the upper precast module 3 of the second housing unit 1".

Referring to the lower lateral connection device 70', it has parts that are similar to the parts of the upper lateral
30 connection device 70. The parts are also arranged similarly.

The building 10 further includes a thin mortar, which refers to a non-shrink grouting. The mortar essentially fills the gaps 73 such that the mortar is bound to the first grouting, to the second grouting, to the upper right wall 15, to the upper left wall 18, to the lower right wall 15', and to the lower left wall 18'.

Fig. 14 shows a precast unit module 3, which is placed in a U-shape position. In this position, a floor slab 12 of the precast unit module 3 is below walls 12, 18, 23, and 26 of the precast unit module 3.

A method for manufacturing the precast unit module 3 using reusable steel formworks or moulds at a precast plant is described below.

The method includes a step of placing a horizontal base steel plate 65 on the ground of the precast plant, as seen in Fig. 15.

This is followed by a step of constructing a steel formwork 45, as seen in Fig. 16. In detail, a steel inner core structure 50 is formed by providing a rectangular ceiling slab portion 56 and four rectangular wall portions 59 on the base steel plate 65. The four wall portions 59 are placed such that a first set of two opposite wall portions 59 are essentially parallel to each other while a second set of another two opposite wall portions 59 are essentially parallel to each other. The first set of the wall portions 59 are essentially perpendicular to the second set of the wall portions 59. Upper ends of the respective wall portions 59 are then connected to respective edge portions of the ceiling slab portion 56 such that the ceiling slab portion

56 and the wall portions 59 form the steel inner core structure 50.

The method further includes a step of placing an adjustable
5 system 66 for supporting the steel inner core structure 50. In
detail, a plurality of adjustable vertical props 68 is placed
between the steel plate 65 and the ceiling slab portion 56 such
that upper ends of the adjustable props 68 touch and contact
with the ceiling slab portion 56 while lower ends of the
10 adjustable props 68 touch and contact with the steel plate 65. A
plurality of adjustable horizontal props 68 is also placed
between the wall portions 59 such that first ends of the
adjustable props 68 touch and contact with one wall portion 59
and second ends of the adjustable props 68 touch and contact
15 with another opposite wall portion 59.

The steel inner core structure 50 is then surrounded by a
plurality of rectangular steel side formwork panels 53, wherein
upper end of each of the steel side formwork panels 53 is
20 provided with a rectangular standing platform. The steel side
formwork panels 53 are arranged such that an empty space is
formed between the steel inner core structure 50 and the steel
side formwork panels 53, wherein the empty space corresponds
with the structure of the precast unit module 3 that is placed
25 in an inverted U-shaped position, wherein the floor slab 12 of
the precast unit module 3 is above walls 15, 18, 23, and 26 of
the precast unit module 3. The standing platforms of the steel
side formwork panels 53 are also arranged to form a steel top
frame 62 that surrounds a space above the steel inner core
30 structure 50.

Subsequently, a step of placing one or more reinforcement cages that are made of reinforcing steel inside the empty space is performed.

- 5 Cast-in items are later placed inside the empty space at predetermined positions. These cast-in items include, for example, corrugated ducts, mechanical connections such as wire loop boxes, curtain wall brackets, mechanical, electrical, and plumbing (MEP) fittings.

10

After this, the empty space of the formwork 45 is filled with a wet concrete mixture until the concrete mixture fills the empty space up to a predetermined volume.

- 15 The method also includes a step of curing the concrete mixture in a controlled environment to form a harden or solid concrete unit module 3, as seen in Fig. 16, wherein the concrete unit module 3 is placed in the inverted U-shape position.

- 20 The steel formwork 45 is later released and demoulded.

The precast unit module 3 is then rotated with a turning device such that the precast unit module 3 is placed in the U-shape position.

25

After this, lightweight panels, waterproofing, fittings, and building finishing works are provided. The building finishing works include glazing, tiling, MEP works, and painting.

- 30 Fig. 17 shows a flow chart 100 of a method for using the fabricated precast unit modules for constructing a building 10.

The construction method 100 includes a pre-assembly procedure 105 performed at a fit-out factory for preparing precast unit modules for assembly and an assembling procedure 110 performed at a construction site for assembling the prepared precast unit
5 modules to form the building 10.

The precast unit module pre-assembly procedure 105 includes a platform levelling step 115 of providing a plurality of I-beam platforms. Each platform is dimensioned according to an outline
10 or profile of a precast unit module. The platforms are then placed on a firm flat ground according to a design layout of a selected level of the building 10. The platforms are later levelled such that top surfaces of the platforms are essentially on a same horizontal plane.

15 In a next step 120, the precast unit modules are placed on predetermined positions of the levelled platforms and are arranged according to a layout of a selected level of the building 10. The adjacent precast unit modules are separated
20 from each other by a predetermined gap 73.

In a subsequent step 125, levelling of the precast unit modules is performed. Herein, all parts of the precast unit module are checked using a laser self-levelling device according to layout
25 requirements relating to position, verticality, and level. If the parts do not meet the requirements, rectification, such as re-alignment and re-orientation, of these parts are done. The rectifications are done without disturbing or moving the precast unit module from its respective predetermined positions. In
30 other words, the rectification does not change the predetermined gap 73 between the precast unit modules.

After the levelling of the precast unit modules is completed, reference lines, level lines, and offset lines are measured and marked on each precast unit module according to its position in the layout, in a step 130. The reference lines can refer to multiple reference lines in a longitudinal or vertical direction of the precast unit modules for aligning the precast unit modules at different vertical levels. The reference lines can also refer to a walkway or corridor centre line, and a grid centre line, which is a straight line in the middle of the predetermined gap 73 between the precast unit modules. The level lines refer to a 1m datum level line, which is 1 meter above the levelled platforms and is often marked on an exterior of the precast unit module. An offset or separation distance of the exterior wall of the precast unit module from the grid centre line is also measured and its corresponding offset line is marked on the precast unit module.

After this, the precast unit modules are removed from the platforms and are packed, in a step 135. The packed precast unit modules are then delivered to a construction site for assembly of the precast unit modules into a multi-storey building.

The precast unit module assembly procedure 110 includes a step 140 of a land surveyor establishing or marking survey points on a work site or construction site. This step includes preparing a clean and levelled concrete surface. The surface is then marked with reference lines, level lines, and offset lines according to the layout of the selected level of the building 10 and according to the measurements of the precast unit modules. These marked reference lines, level lines, and offset lines indicate positions for placement of the precast unit modules. This allows

quick placement of the precast unit modules at the predetermined positions and this saves construction time.

In a next step 145, the housing units 1 and 1" and corresponding precast unit modules 3 and 3' are moved to the work site. Levels and verticality of the housing units 1 and 1", and of the corresponding precast unit modules 3 and 3' are then checked again. Measurements of the housing units 1 and 1", and of the precast unit modules 3 and 3' with respect to locations of the corresponding shim plates 36 are also taken for pre-adjusting the shim plates 36 to achieve a predetermined level for aligning the precast unit modules 3 and 3' such that they are essentially vertical.

Some shim plates 36 are then placed on top surfaces of walls 34 and 35 of a wall structure 33 at predetermined positions. The levels of the shim plates 36 are checked using a shim plate level indicator and pre-adjusted accordingly to achieve the predetermined level, in a step of 150.

The lower precast unit modules 3' are then hoisted and placed on the shim plates 36 such that the reference lines, level lines, and offset lines that are marked on the lower precast unit module 3' are checked to match with the corresponding reference lines, level lines, and offset lines marked on the corresponding positions of the levelled concrete surface.

The lateral gaps between lower ends of the lower precast unit modules 3' and the levelled concrete surface are then filled with wet concrete mixture. The concrete mixture is then cured to form a solid concrete that binds the lower precast unit modules 3' to the concrete surface, in a step 155.

In a next step 160, vertical connection devices 78 are provided in lower corrugated ducts 72' of the lower precast unit modules 3' of the first housing unit 1. Vertical connection devices 78 are also provided in corrugated ducts 72' of the lower precast unit modules 3' of the second housing unit 1". In detail, a lower continuity bar 80' is placed vertically inside a lower corrugated duct 72' of the lower precast unit module 3'. The lower continuity bar 80' extends from an upper end of the lower corrugated duct 72' to a lower end of the lower corrugated duct 72', and to a part of a corresponding corrugated duct of the walls 34 and 35 of the wall structure 33. The lower corrugated duct 72' and the corresponding corrugated duct of the walls 34 and 35 are then in-filled with non-shrink grout until the non-shrink grout reaches a predetermined height of the lower corrugated ducts 72', which corresponds to a lapping length of the lower continuity bar 80'.

In a subsequent step 165, lower lateral connection devices 70' are provided in the vertical channels 69 for connecting an exterior surface of the lower precast unit module 3' of the first housing unit 1 to an exterior surface of the lower precast unit module 3' of the second housing unit 1". In detail, a cottering bar 90 is inserted into wire loops 83 of a first connector set 75 of the first housing unit 1 and into wire loops of a third connector set 85 of the second housing unit 1". The cottering bar 90 is also further inserted into wire loops 83 of a second connector set 76 of the first housing unit 1 and into wire loops 83 of a fourth connector set 86 of the second housing unit 1".

After this, non-shrink grout is poured into the vertical channels 69. The non-shrink grout flows and fills each of the vertical channels 69 and the gap 73 that is between the lower precast unit module 3' of the first housing unit 1 and the lower precast unit module 3' of the second housing unit 1". The non-shrink grout is further poured until the grout reaches a vertical level, at which about three quarter of the upper portion of the channel 69 is filled. A horizontal metal plate 93 that is attached with multiple steel J-bolts 95 is later placed into the upper portion of the channel 69. The J-bolts 95 are then embedded into the grout. The grout is further filled until the metal plate 93 with the J-bolts 95 is properly embedded, in a step 170. The non-shrink grout is then cured and becomes harden. The harden grout binds the connector sets 75, 76, 85, and 86 to the cottering bar 90, to the J-bolts 95, to the metal plate 93, to the walls 15 and 18, thereby binding the lower precast unit module 3' of the first housing unit 1 to the lower precast unit module 3' of the second housing unit 1".

In a next step 175, some shim plates 36 are placed on upper surfaces of the lower precast unit modules 3' at predetermined positions. The levels of the shim plates 36 are checked and pre-adjusted accordingly to achieve a predetermined level. The upper precast unit modules 3 are then hoisted and placed on the corresponding shim plates 36. Lateral gaps between the upper precast unit modules 3 and the lower precast unit modules 3' are then filled with non-shrink grout. The non-shrink grout later hardens to form module connecting units 9.

Additional vertical connection devices 78 are later provided in upper corrugated ducts 72 of the upper precast modules 3 to connect the upper precast unit modules 3 to the lower precast

unit modules 3' within the housing units 1 and 1". In detail, an upper continuity bar 80 is afterward placed inside a corresponding upper corrugated duct 72 of the upper precast unit module 3. The upper continuity bar 80 extends from an upper end of the upper corrugated duct 72 to a lower end of the upper corrugated duct 72, and to a part of the corresponding lower corrugated duct 72' such that a part of the upper continuity bar 80 overlaps a part of the lower continuity bar 80' with the lapping length. The upper corrugated duct 72 is later in-filled with non-shrink grout, which later also flows into the lower corrugated duct 72' and fills the lower corrugated duct 72' completely. The grout is filled until the grout reaches the predetermined height of the upper corrugated duct 72, which corresponds to the lapping length of the upper continuity bar 80.

Additional upper lateral connection devices 70 are also then provided in other vertical channels 69 to connect the upper precast unit modules 3 of the first housing unit 1 to the upper precast unit modules 3 of the second housing unit 1", in a step 180.

After this, the work deck of lower level and hoist module are removed.

Different implementations of the shear connection unit 92 are possible. The shear connection unit 92 can have different number of J-bolts 95 according to different design requirements. The J-bolts 95 can also be replaced by bars, rods, or any metal object comprising elongated members, which are suitably inserted into the vertical passageways of the reinforcement links 82.

In one implementation, as seen in Figs. 18, 19, and 20, the shear connection unit 92 includes a steel plate 93 with four through holes 94 and two U-shaped steel bars 96, which are connected to the steel plate 93 by welding. Each U-shaped steel bar 96 lies on a vertical plane and it has two ends. The ends of the U-shaped bars are respectively connected to the corresponding holes 94 such that vertical planes of the U-shaped bars 96 are substantially parallel to each other for allowing the U-shaped bars 96 to be inserted into the vertical passageways of the reinforcement links 82. The steel plate 93 can have a length of approximately 200mm and a width of approximately 180 mm. Each hole 94 is located at a position that is approximately 55mm from adjacent edges of the steel plate 93.

In another embodiment, a precast unit module 3 has multiple grooves 63", which are provided on one or more walls of the precast unit module 3. Each groove 63" extends from an upper end of the wall to a lower end of the wall. The groove 63" has a shape, which is similar to that of the body portion 77.

As seen in Figs. 21 and 22, the groove 63" can include a ring connector set 74, a first mechanical connector set 75, and a second mechanical connector set 76, wherein the first connector set 75 and the second connector set 76 are similar to that of the groove 63. The connector sets 75 and 76 are not shown in the figures for the purpose of simplicity. The ring connector set 74 is placed above the first connector set 75, which is placed above the second connector set 76.

The ring connector set 74 includes a plurality of steel ring 98, each of which has a diameter of, for example, 12mm. Each ring 98 has a portion that is embedded within the wall and a remaining

portion that protrudes from a flat surface 210 of the groove 63. The adjacent rings 98 are separated by a predetermined vertical distance such that protruding portions of the rings 98 are aligned to provide a vertical passageway for receiving a
5 cottering bar 90 that passes through all the rings 98.

The ring connector set 74 is intended for connecting a first wall of a first precast unit module 3 to a second wall of a second precast unit module 3, wherein the first wall is
10 positioned adjacent to the second wall. Each ring 98 of a first ring connector set of the first wall and a corresponding ring 98 of a second ring connector set of the second wall overlap each other to provide a vertical ring passageway that passes through all the rings 98. A cottering bar 90 is inserted vertically
15 through the vertical ring passageway. The cottering bar 90 is also further inserted vertically through a first vertical passage of the first connector sets 75 of the first and second precast unit modules 3 and through a second vertical passage of the second connector sets 76 of the first and second precast
20 unit modules 3. The grooves 63 are then filled with non-shrink grout such that the grout binds the cottering bar 90 to the ring connector sets 74, to the connector sets 75 and 76, to the first wall, and to the second wall.

25 In a further embodiment, a building 10 includes two or more housing units, which are placed adjacent to each other. Each housing unit includes three or more precast unit modules 3, which are placed in a stack.

30 The improved building 10 provides several benefits.

The improved building 10 can be constructed efficiently to save construction time and construction cost. In particular, precast unit modules 3 can be quickly placed at the predetermined positions at a construction site according to reference lines, level lines, and offset lines, which are marked on the precast unit modules 3 as well as at the construction site.

Furthermore, the vertical connection devices 78 and the lateral connection devices 70 provide secure mechanical connections that bind the walls of the adjacent precast unit modules, thereby preventing any precast unit module 3 from shifting with respect to its adjacent precast unit modules 3.

Although the above description contains much specificity, these should not be construed as limiting the scope of the embodiments but merely providing illustration of the foreseeable embodiments. Especially the above stated benefits of the embodiments should not be construed as limiting the scope of the embodiments but merely to explain possible achievements if the described embodiments are put into practice. Thus, the scope of the embodiments should be determined by the claims and their equivalents, rather than by the examples given.

REFERENCE NUMBERS

	1	housing unit
	1"	housing unit
5	3	upper precast unit module
	3'	lower precast unit module
	9	module connecting unit
	10	building
	12	upper concrete floor slab
10	12'	lower concrete floor slab
	15	upper right wall
	15'	lower right wall
	18	upper left wall
	18'	lower left wall
15	21	window opening
	21'	window opening
	23	upper rear wall
	23'	lower rear wall
	26	upper front wall
20	26'	lower front wall
	29	door opening
	29'	door opening
	33	wall structure
	34	left wall
25	35	right wall
	36	shim plates
	38	bituminous strip
	39	grout bedding
	45	steel formwork
30	50	steel inner core structure
	53	steel side panel
	56	celling slab portion

	59	wall portion
	62	top frame
	63	groove
	65	steel plate
5	66	adjustable supporting system
	67	pocket portion
	68	adjustable prop
	69	channel
	70	upper lateral connection device
10	70'	lower lateral connection device
	72	upper corrugated duct
	72'	lower corrugated duct
	73	gap
	75	first connector set
15	76	second connector set
	77	body portion
	78	vertical connection device
	79	wire loop box
	80	continuity bar
20	80'	continuity bar
	81	housing
	82	reinforcement link
	83	wire loop
	85	third connector set
25	86	fourth connector set
	87	sleeve
	89	wire loop box
	90	bar
	92	shear connection unit
30	93	metal plate
	94	hole
	95	J-bolt

	96	U-shaped bar
	97	wall connection unit
	98	ring
	99	ring connector unit
5	100	flow chart
	101	full welded portion
	102	fillet welded portion
	105	step
	110	step
10	115	step
	120	step
	125	step
	130	step
	135	step
15	140	step
	145	step
	150	step
	155	step
	160	step
20	165	step
	170	step
	175	step
	180	step
	200	major surface
25	203	side surface
	206	side surface
	210	flat surface
	213	inclined surface
	216	inclined surface
30		

CLAIMS

1. A precast construction module for constructing a building comprising

- 5 - a concrete slab, and
- a group of walls consisting of
 - a first concrete wall,
 - a second concrete wall,
 - a third concrete wall, and
 - 10 - a fourth concrete wall,

wherein the slab comprises a first edge portion that is integrally connected to a lower end of the first wall, a second edge portion that is integrally connected to a lower end of the second wall, a third edge portion that is integrally connected to a lower end of the third wall, and a fourth edge portion that is integrally connected to a lower end of the fourth wall, a first vertical edge of the first wall is integrally connected to a first vertical edge of the second wall, a second vertical edge of the second wall is integrally connected to a first vertical edge of the third wall, a second vertical edge of the third wall is integrally connected to a first vertical edge of the fourth wall, and a second vertical edge of the fourth wall is integrally connected to a second vertical edge of the first wall,

25 wherein the precast construction module further comprises a plurality of corrugated ducts that are provided vertically in at least one wall that is selected from the group of walls, each corrugated duct being adapted to receive a plurality of connecting bars and to receive grout.

30

2. The precast construction module according to claim 1, wherein

each corrugated duct extends from an upper end of the at least one wall to a lower end of the least one wall and to a bottom side of the slab.

5 3. The precast construction module according to claim 1 or 2, wherein

the at least one wall is provided with at least one groove.

10 4. The precast construction module according to one of the above-mentioned claims, wherein

the at least one groove comprises a top portion and a body portion, the body portion is attached to a lower end of the top portion, the top portion comprises a horizontal cross-sectional area that is larger than a horizontal cross-sectional area of
15 the body portion.

5. The precast construction module according to claim 3 or 4, wherein

20 the at least one groove comprises a plurality of connection elements for connecting the precast construction module to an adjacent precast construction module.

6. The precast construction module according to claim 5, wherein

25 each connection element comprises a portion that is embedded within the at least one wall and a remaining portion that protrudes from a major surface of the groove.

30 7. The precast construction module according to claim 5 or 6, wherein

the connection elements comprise at least one reinforcement link.

8. The precast construction module according to one of claims 5 to 7, wherein the connection elements comprise at least one loop part.

5

9. The precast construction module according to claim 8, wherein the at least one loop part comprises a metal wire loop.

10 10. The precast construction module according to claim 8, wherein the at least one loop part comprises a metal ring.

11. A building structure comprising at least two precast
15 construction modules according to one of claims 1 to 10.

12. The building structure according to claim 11, wherein the at least two precast construction modules comprise a first lower precast construction module and a second lower precast
20 construction module that is arranged adjacent to the first lower precast construction module,
the building structure further comprises a first lower connection device for connecting the first lower precast construction module to the second lower precast construction
25 module,

wherein the first lower connection device comprises

- at least one first connection element of the first lower precast construction module,

- at least one second connection element of the second
30 lower precast construction module,

- a horizontal plate,

- at least one first connecting rod being vertically attached to a bottom of the horizontal plate,

- at least one second connecting rod being vertically attached to the bottom of the horizontal plate, and

5 - a first grouting,

wherein the at least one first connecting rod is vertically disposed in the at least one first connection element, and the at least one second connecting rod is vertically disposed in the at least one second connection element, and

10 the first grouting is disposed between the first lower precast construction module and the second lower precast construction module to bind the at least one first connection element to the at least one first connecting rod, to the at least one second connection element, to the at least one second connecting rod,
15 and to the horizontal plate.

13. The building structure according to claim 12, wherein the at least one first connection element comprises a reinforcement link.

20

14. The building structure according to claim 12 or 13, wherein the at least one second connection element comprises a reinforcement link.

25 15. The building structure according to one of claims 12 to 14, wherein the at least one first connecting rod comprises a steel J-bolt.

16. The building structure according to one of claims 12 to 14,
30 wherein the at least one first connecting rod comprises a steel U-shaped bar.

17. The building structure according to one of claims 12 to 16,
wherein
the at least one second connecting rod comprises a steel J-bolt.

5

18. The building structure according to one of claims 12 to 16,
wherein
the at least one second connecting rod comprises a steel U-
shaped bar.

10

19. The building structure according to one of claims 12 to 16,
wherein
the first lower connection device is provided at an upper
portion of the first lower precast construction module.

15

20. The building structure according to one of claims 12 to 19
further comprising a second lower connection device, the second
lower connection device comprising

- at least one first loop part of the first lower precast
construction module,
- at least one second loop part of the second lower precast
construction module,

- a linking bar that is disposed within the at least one
first loop part and within the at least one second loop part,
and

- a second grouting that is disposed between the first
lower precast construction module and the second lower precast
construction module to bind the at least one first loop part to
the at least one second loop part, to the linking bar, and to
the first grouting.

30

21. The building structure according to one of claims 12 to 20, wherein the second lower connection device is provided below the first lower connection device.

5 22. The building structure according to one of claims 12 to 21, wherein

the at least two precast construction modules further comprise a first upper precast construction module that is stacked above the first lower precast construction module,

10 the first upper precast construction module comprises

- a first upper corrugated duct and
- a first upper connecting bar, which is provided in the first upper corrugated duct,

the first lower precast construction module comprises

15 - a first lower corrugated duct, a part of the first upper connecting bar extending into the first lower corrugated duct, and

- a first lower connecting bar, which is provided in the first lower corrugated duct such that a part of the first lower connecting bar overlaps a part of the first upper connecting bar, and

20

the building structure further comprises a third grouting, which is disposed in the first lower corrugated duct and in the first upper corrugated duct to bind the first lower connecting bar to the first upper connecting bar.

25

23. The building structure according to claim 22 further comprising

- a plurality of shim plates that are provided between the first upper precast construction module and the first lower precast construction module, and

30

- a fourth grouting that is disposed between the first upper precast construction module and the first lower precast construction module to bind the shim plates to the first upper precast construction module, and to the first lower precast construction module.

24. A method for constructing a building structure at a site comprising

- positioning a first lower precast construction module according to one of claims 1 to 10 and a second lower precast construction module according to one of claims 1 to 10 in a side-by-side arrangement such that they are separated by a gap,
- positioning a horizontal plate with at least one first connecting rod and with at least one second connecting rod such that the at least one first connecting rod is disposed in at least one first connection element of the first lower precast construction module, and the at least one second connecting rod is disposed in at least one second connection element of the second lower precast construction module, and
- providing a first grout between the gap to bind the horizontal plate to the at least one first connecting rod, to the at least one first connection element, to the at least one second connecting rod, and to the at least one second connection element.

25. The method according to claim 24 further comprising

- inserting a linking bar into at least one first loop part of the first lower precast construction module and into at least one second loop part of the second lower precast construction module, and

- providing a second grout in the gap to bind the linking bar to the at least one first loop part, to the at least one second loop part, and to the first grout.

5 26. The method according to claim 24 or 25 further comprising

- positioning a first upper precast construction module according to one of claims 1 to 10 above the first lower precast construction module,

10 - inserting a first lower connecting bar into a first lower corrugated duct of the first lower precast construction module,

- inserting a first upper connecting bar into a first upper corrugated duct of the first upper precast construction module, wherein a part of the first upper corrugated duct overlaps a part of the first lower connecting bar, and

15 - providing a third grout into the first upper corrugated duct and into the first lower corrugated duct to bind the first lower connecting bar to the first upper connecting bar.

27. A connection assembly for connecting a first wall to a
20 second wall that is arranged adjacent to the first wall, the connection assembly comprising

- at least one first connection element of the first wall,
- at least one second connection element of the second wall,

25 - a horizontal plate,

- at least one first connecting rod being vertically attached to a bottom of the horizontal plate,

- at least one second connecting rod being vertically attached to the bottom of the horizontal plate, and

30 - a first grouting,

wherein the at least one first connecting rod is vertically disposed in the at least one first connection element, and the

at least one second connecting rod is vertically disposed in the
at least one second connection element, and
the first grouting is disposed between the first wall and the
second wall to bind the at least one first connection element to
5 the at least one first connecting rod, to the at least one
second connection element, to the at least one second connecting
rod, and to the horizontal plate.

28. The connection assembly according to claim 27, wherein
10 the at least one first connection element comprises a
reinforcement link.

29. The connection assembly according to claim 27 or 28,
wherein
15 the at least one second connection element comprises a
reinforcement link.

30. The connection assembly according to one of claims 27 to
29, wherein
20 the at least one first connecting rod comprises a steel J-bolt.

31. The connection assembly according to one of claims 27 to
29, wherein
the at least one first connecting rod comprises a steel U-shaped
25 bar.

32. The connection assembly according to one of claims 27 to
31, wherein
the at least one second connecting rod comprises a steel J-bolt.

30
33. The connection assembly according to one of claims 27 to
31, wherein

the at least one second connecting rod comprises a steel U-shaped bar.

34. The connection assembly according to one of claims 27 to 33
5 further comprising

- at least one first loop part of the first wall,
 - at least one second loop part of the second wall,
 - a linking bar that is disposed within the at least one first loop part and within the at least one second loop part,
- 10 and

- a second grouting that is disposed between the first wall and the second wall to bind the at least one first loop part to the at least one second loop part, to the linking bar, and to the first grouting.

15

35. The connection assembly according to one of claims 27 to 34, wherein
the at least one first loop part comprises a metal wire loop.

20 36. The connection assembly according to one of claims 27 to 35, wherein
the at least second first loop part comprises a metal wire loop.

37. The connection assembly according to one of claims 27 to
25 36, wherein
the first wall and the second wall are provided by separate prefabricated construction modules.

38. The connection assembly according to claim 37, wherein
30 The prefabricated construction modules comprise precast construction modules according to one of claims 1 to 10.