A METHOD OF AND DEVICES FOR POSITIONING ROOM MODULES TO CONSTRUCT A MODULAR BUILDING

Field of Invention

The present invention relates to the field of building construction. In particular, the present invention relates to methods and devices for construction of modular buildings.

Background of the invention

To overcome shortage of skilled labour and to increase speed of construction, pre-fabricated modular building units that may be assembled into a building have been proposed. An example of this building method is known as the MIC (Modular Integrated Construction) method which, in the general scheme, places every upper room module onto a lower room module to erect the building.

These room modules are often pre-fabricated in a remote factory, and supplied to building construction sites complete with walls, windows, doors, finishes, fixtures and fittings. Typically, these room modules are transported from the factory on the back of trucks. At the construction sites, the room modules are stacked up vertically. Each room module above is secured mechanically to the room module below, and gaps there between are filled in by concrete and steel bars.

A building constructed by the MIC method cannot be too tall, the maximum building height that is safe from collapse being limited by the structural strength of each lower room module that bears the weight of all room modules stacked on top. An overly tall MIC building might requires excessive structural redundancy at great cost to prevent the lower modules from collapsing onto itself, which could bring the whole building down. Any room module that is damaged structurally, such as by fire or cooking gas explosion, can also cause all room modules on top to collapse into the damaged room module. This kind of failure is known as the "domino" effect or a "disproportionate collapse".

An improved type of modular building has been proposed and described in Hong Kong Short Term Patent no. HK30079306 entitled A METHOD OF CONSTRUCTING A MODULAR BUILDING, which proposes erecting pairs of high-rise, load-bearing walls defining a vertical bay there between. A vertical column of room modules are inserted into the vertical bay. Each room module is secured to the load bearing walls at a different height, according to the floor heights to be provided in the competed building. The modules are not connected directly one to another and no module depend on another module for support, strength, position or securement. With the cause of failure in the lower room modules removed, HK30079306 provides a possibility of building very tall buildings using room modules.

HK30079306 describes using a hoisting crane to lift a room module by cable, and moving the room module in a horizontal direction towards the vertical bay. This is illustrated in Figure 1. The vertical bay is defined by two adjacent walls that are continually constructed higher with new wall sections using the slipform method. The

room module is transferred from the hoist cable over to movement rails installed in the vertical bay, allowing the room module to be moved into the desired position inside the vertical bay, as shown in Figure 2. Vertical lowering of the room module is not possible with slipform construction. The top of the load bearing walls are crowned with the formwork, which is a movable frame of scaffolding and platform, called here a 'cross-linking frame'. The scaffolding also provides walkways and bridges for the workers. It has been found that the transfer of room modules to the movement railings, and the removal of these movement railings from one floor to be reinstalled on another floor are time-consuming activities.

A modularly constructed building offers the possibility of quickly-assembled but sturdy buildings that are cost-effective and relies less on skilled labour. Therefore it is desired that method of HK30079306 be further improved to make it more likely to advance these advantageous.

Summary Of The Invention

In a first aspect, the invention proposes a cross-linking frame for adjacent walls for receiving room modules of a modular building, comprising: a section of scaffolding on each of two mutually-facing walls; a link-scaffolding coupled to the section of scaffolding on each of the two mutually-facing walls; the link-scaffolding being on one side of a mid-width plane extending through the mid-width of one of the adjacent walls and the mid-width of the other one of the adjacent walls; wherein a down-hanging cable can be moved into the mid-width plane.

This provides the possibility of moving a crane cable into the plane in the middle of the formwork.

In a further aspect, the invention proposes a brace for bracing the cross linking frame, the brace comprising two arms extending apart from an apex; the apex coupled for coupling the link-scaffolding; and each of the arms for coupling the sections of scaffolding each on a respective one of the two mutually-facing walls.

In yet a further aspect, the invention proposes a room module for a modular building, wherein the modular building comprises at least one a vertical bay defined between two load-bearing walls; the room module configured to be placed into the vertical bay and on supporting-brackets on the two load-bearing walls; the room module comprising a floor slab; support brackets placed a pre-determined distance above the floor slab as the position to install the support brackets onto the two load bearing walls for supporting the floor slab of another room module.

Advantageously, this provides a possibility of using a crane cable to bring all the parts of the modular buildings into the vertical bay, in a time efficient way. That is, when a present room module is brought into the vertical bay in by one move of the hoisting crane, a fixture that actually belongs to the next room module is brought along with the present room module.

Preferably, the room module further comprises a removable physical structure on the floor slab; the support brackets placed on the removable physical structure; the removable physical structure providing the pre-determined distance between the

support brackets and the floor slab; wherein removing the removable physical structure severs direct connection between the support brackets and the floor slab. In practice, the connection need not be severed.

Optionally, the physical structure can be reversibly folded onto the surface of the floor slab.

Preferably, the floor slab having two corners between which is a side of the floor slab configured to face the vertical bay when the room module is being moved to be placed into the vertical bay; at least one roller provided on each corner to roll on the proximate one of the two load bearing walls that the roller comes into contact with during insertion.

Also preferably, a plurality of rig cable engagement devices installed onto the floor slab. This feature provides the possible advantage of hoisting a room module by the base of the room module instead of the top, Relieves wall of the module from supporting the weight of the structural slab during all modes of transportation before the slab is fused to a load-bearing wall.

In a further aspect, the invention proposes a room module for a modular building, wherein the room module is configured for being secured to a loading bearing structure; and the room module comprises a part of a room module of another floor.

Preferably, the part of a room module of another floor.is arranged on the room module to be provided with the position of the part on the loading bearing structure when the room module is secured to the loading bearing structure.

Preferably, the another floor is a lower floor.

Preferably, the part of a room module of another floor is a wall.

Preferably, the wall is foldable onto and un-foldable from the floor slab.

Preferably, the wall is foldable onto and un-foldable from the floor slab by swivelling about a pivot installed on the floor slab.

Preferably, the another floor is a higher floor; and the part of a room module of another floor.is a steel bracket for securing to the load bearing structure and supporting a room module for the higher floor.

Brief Description Of The Figures

It will be convenient to further describe the present invention with respect to the accompanying drawings that illustrate possible arrangements of the invention, in which like integers refer to like parts. Other arrangements of the invention are possible, and consequently the particularity of the accompanying drawings is not to be understood as superseding the generality of the preceding description of the invention.

Figure 1 shows an example of the prior art;

Figure 2 shows a further detail in the prior art of Figure 1;

Figure 3 is a schematic illustration of an embodiment of the invention in an exploded view;

Figure 4 shows the embodiment of Figure 3 in a consolidated view

Figure 5 is a schematic illustration of an embodiment that is modified from the embodiment of Figure 3;

Figure 6 shows a plurality of open-braces that could be used in the embodiment of Figure 5;

Figure 7 is a schematic illustration of another embodiment of the invention in exploded view;

Figure 8a shows the embodiment of Figure 7 in a consolidated view;

Figure 8b shows how the embodiment of Figure 7 can improve the speed of modular building construction;

Figure 9 is a schematic illustration of yet another embodiment of the invention in exploded view;

Figure 10 is a perspective drawing of an example corresponding to the schematic illustration in Figure 9;

Figure 11 is another perspective drawing of the example in Figure 10;

Figure 12 the plan view of the example show as Figure 10;

Figure 13 is a side view of the example show as Figure 10;

Figure 14 is another perspective drawing of the example in Figure 10;

Figure 15 is a series of schematic drawings showing the use of the embodiment of illustrated in Figure 9;

Figure 16 is a perspective drawing of yet another embodiment of the invention;

Figure 17 is a perspective drawing of yet another embodiment of the invention;

Figure 18 shows an embodiment, which is a room module that is another aspect of the invention;

Figure 19 shows a part of the embodiment of Figure 18;

Figure 20 shows another part of the embodiment of Figure 18;

Figure 21 shows a variation of the part shown in Figure 20;

Figure 22 is a front view of the embodiment in Figure 18 being in use;

Figure 23a a plan view showing the embodiment of Figure 18 being in use;

Figure 23b a plan view showing a variation of the embodiment of Figure 23a;

Figure 24 shows a part of the embodiment if Figure 18;

Figure 25 is an enlarged view of a part of the embodiment of Figure 18;

Figure 26 is a series of illustrations showing the embodiment of Figure 18 being in use;

Figure 27 are technical drawings of a part of the embodiment of Figure 18;

Figure 28 is a series of technical drawings showing the embodiment of Figure 18 being in use;

Figure 29 is a series of drawings showing the embodiment of Figure 18 being in use;

Figure 30 shows a variation of the embodiment of Figure 18;

Figure 31 relates to a further embodiment ;

Figure 32 relates to the embodiment of Figure 31 further embodiment ;

Figure 33 relates to a further embodiment ; and

Figure 34 relates to a further embodiment .

Detailed Description Of Specific Embodiments

Figure 3 is an exploded, schematic view of the parts of a modular building 300 stabilized with the cross-linking frame 313. Figure 4 is the consolidated version of the view in Figure 3. The drawings show a series of parallel load-bearing walls 307 arranged in a straight row. The walls having the same width and thickness, and are uniformly spaced apart by a specific distance, which provide a straight row of vertical bays 305. The vertical bays become a block of apartments when filled up by room modules 303.

A single apartment unit may be made up of a single room module 303 or be assembled of several room modules 303. The room modules 303 are manufactured in a factory and transported to the building site for assembly.

Therefore, each vertical bay 305 is defined by mutually-facing surfaces of two adjacent load-bearing walls 307, whereas every two neighbouring vertical bays shares the load-bearing wall 307 and are each partly defined by the respective wall-surface on either side of the load-bearing wall 307. The edges of each load-bearing wall 307 are relatively narrow compared to the face of the wall, and extend vertically and in parallel to meet the horizontal edge which is the top of the wall in right angles.

During assembly of the modular building 200, the lower part of each vertical bay 305 is filled with an increasing column of room modules 303. Concurrently, a new section of wall is added onto the top every load-bearing walls, extending the vertical capacity

of the vertical bay 305. The preferred method of new wall construction is the slipform method, although this is not the only possible method to use.

The slipform method uses a formwork to lay new wall sections uniformly on all the load bearing walls. The formwork comprises wall casting moulds 311 on the top of each load-bearing wall and a cross-linking platform or frame right below the moulds. The lower part of a mould clads to the top of a load-bearing wall 307 so that the sides of the mould extend upwardly past the top of the wall, making the wall top the base of the mould 311. To cast a new section of wall, reinforcement steel bars are first installed into the space inside the mould 311 and concrete slurry poured into the mould 311 over the steel bars. The concrete dries sufficiently after four days and become a solid piece of wall, on which the mould and the cross-linking frame may be moved up. As new sections of wall are cast on all the load-bearing walls at about the same time, the formwork is raised up evenly onto all the new sections.

Although the new sections of wall are strong enough hold the weight of the mould 311 and the cross-linking frame 313, the concrete in these new sections requires another four days to cure thoroughly and exhibit the full strength of a load-bearing wall 307. For a particular section of wall to be ready to hold up a room module 303, it takes about eight days from the time in which the concrete slurry for that particular section was poured. The cross-linking frame has a function of cross-linking and thereby stabilizing all such new sections on the load-bearing walls. The cross-linking frame comprises scaffolding installed all around the entire perimeter of each new section of wall, just below the mould 311. This scaffolding also provides a working platform to give access all around the mould, and is known as a slip-form rig bay.

The slip-form rig bay provides a ledge that extends horizontally from all sides the new section of wall. The part of the slip-form rig bay on mutually-facing load-bearing walls 307 are cross-linked by more scaffolding. In this way, the ledge provides a platform for worker access all around each mould 311 and the cross-link scaffolding provides link-bridges 315 between adjacent walls. Preferably, the platforms are raised high on the scaffolding for workers to pour concrete slurry down into the moulds 311. In the lower parts of the vertical bays, the long, cured load-bearing walls are cross-linked by the installed room modules permanently.

For convenience, the side of the modular buildings 300 illustrated in the drawings of this specification that is towards the right of the page shall be called the "front", and the side of illustrated modular buildings 300 towards the left of the page shall be called the "back". The words "front" and "back" here are used relatively.

From the side-view of the modular building 300, the width of the load-bearing walls 307 determines the depth of the vertical bays 305 and, depending on the design of the room modules 303, the number of room modules 303 required to fill this depth horizontally. As shown in Figure 3, an imaginary plane extends through the centre of the load-bearing walls, and is called the mid-width plane 317 here.

In the embodiment of Figure 3 and Figure 4, a link-bridge 315 can be seen connecting the perimeter scaffolding of two adjacent walls. The side of each link-bridge 315 near the back of the modular building 300 is flushed to the back of the cross-linking frame 313, i.e. to the back edge of the ledges. The path-width of the link-bridges 315 is provided to be sufficient for worker movements. Therefore, the

front of each the link-bridge 315 is a distance away from the front of the cross-linking frame 303, and does not even reach the mid-width plane 317 . The front of the link-bridge and the perimeter scaffoldings on either ends of the link-bridge defines a cable-opening 301 in the front of the cross-linking frame 313. The cable-opening is right above the vertical-vertical bay 305 defined by the load-bearing walls to which the perimeter scaffoldings are mounted. The cable of a crane can be moved deep into the vertical bay 305, bringing with it a hoisted room module 303 that passes between the edges of the adjacent load-bearing walls 307 , as the cable-opening 301 in the formwork provides unobstructed access. The crane-cable 309 can deposit the room module 303 in a pre-determined location in the depth of the vertical bay 305 which the crane-cable 309 can reach. In this embodiment, the crane-cable 309 comes in from the front and is able to move past the mid-width plane 317. Inside the vertical bay, the room module 303 is secured onto the two adjacent load-bearing walls 307, and the crane-cable 309 releases the room module 303 and is lifted away.

Each room module 303 has two long sides, the length of which almost fills up the vertical bay-width between the mutual faces of the adjacent load-bearing walls 307. One of these long sides faces the depth of the vertical bay 305 during insertion and is called the bay-side of the room module for convenience. Orthogonal to these long sides are two short sides, each facing the respective one of the two adjacent load-bearing walls 307 during insertion.

Every room module 303 is secured in the vertical bay 305 by affixing the short sides to the facing load-bearing wall 307, and the room module 303 does not rest on another room module 303 beneath. The thoroughly cured load-bearing walls 307 are

concrete structures that are able to bear the weight of all the room modules 303 affixed thereto. This spares lower room modules 303 from bearing the weight of room modules 303 above.

If the modular building 300 is small, such that the vertical bays 305 are not very wide and deep, the cross-linking frame 313 is able to provide sufficient stability to the newly cast wall sections despite the cable-openings 301 made into the cross-linking frame 303. However, for a building of a size so large that the stability of the new sections on the load-bearing walls 307 could benefit from a stronger cross-linking frame 303 to make up for lack of cross-linking across the mouth of the cable-openings, an open-brace 501 is applied to the sections of scaffolding providing the sides of the cable opening 301, as shown in Figure 5.

The exact size of the buildings requiring the support of an open-brace 501 depends on many factors, including local weather, the building dimensions, the type of concrete and other materials used and so on. Therefore, there is no need to elaboration on these factors here, and these factors have to be considered as project-specific factors on case-by-case basis.

An open-brace 501 reinforces the lateral stability of the building being constructed around each cable-opening 301 without closing mouth of the cable-opening 301, Typically, an open-brace 501 is made of steel and comprises two open arms 601 extending and mutually spreading apart from a joint 603, and fits to the scaffoldings defining the cable-opening 301. The joint 603 is secured to the same side of the link-

bridge 315 while the arms 601 are secured to the slip-form rig bays on the adjacent load-bearing walls 307 by scaffolding couplers.

The open brace shown in Figure 5 has a curved steel bar for the joint 603, from the ends of which the arms 601 extend in such a manner that gives the open-brace 501 a U-shape. However, many other shapes and configurations of open-brace 501 are possible, as long as the cable-opening 301 is not obstructed. The open-brace 501 shape and size can also be varied for providing different degrees of strength and size fit to the cable-opening 301. Optionally, the arms 601 of the open-brace 501 may have a resilient bias urging the arms 601 to spread apart if the arms 601 are squeezed towards each other in order to fit into a cable opening 301. The biasing force exerted against the slip-form rig bays both sides of the link-bridge 315 could help to stabilize the cable opening 301 further.

Figure 6 shows non-exhaustive examples of open-braces 501 of different shapes in the plane view, all of which have two spreading arms 601 extending from a joint 603, i.e. a U-shape open-brace 501; a V-shape open-brace 501, the joint 603 of which has an acute angle defined by arms 601 extending and spreading in divergent directions; and a two-corner open-brace 501 comprising a straight and elongate member as the joint 603 and an arm 601 extending at right angle from each of the two ends of the room module 303 in the same plane, wherein the length of the joint 603 between the two corners has to correspond to the length of the link-bridge 315 in order for the arms 601 to be close enough to the slip-form rig bays on either side to be coupled thereto.

Figure 7 is an exploded, view of the schematic parts of a modular building 300 installed with another configuration of the cross-linking frame 313. In this case, the centre of the link-bridge 315 is aligned to the mid-width plane 317, i.e. straddling across the mid-width plane 317 evenly. This provides cable-openings 301 on both sides of each link-bridge 315. A cable-opening 301 on one side of the cross-linking frame is defined by the same side of the relevant link-bridge 315 and the part of the slip-form rig bays extending from this side of the link-bridge 315 to the edge of the cross-linking frame 313 on the same side. This provides a front cable-opening 301 and a back cable-opening 301 to the relevant vertical bay beneath, and allows a crane-cable 309 to enter into the depth of the vertical bay 305 from the front cable-opening 301 and from the back cable-opening 301. Advantageously, two cranes may be used, one on each side of the vertical bay 305, which could double the speed of assembly. Figure 7 shows an open-brace 501 applied to front cable-openings 301 and back cable-openings 301. The joint 603 of the open-brace 501 is coupled to the respective side of the link-bridge 315 and the arms 601 coupled to the scaffoldings on the adjacent load-bearing walls 305 on the same side of the link-bridge 315.

Figure 8a is a consolidated view of the exploded parts shown in in Figure 7, and shows a first crane-cable 309 entered into a front cable-opening 301, and has brought a room module 303 into the corresponding vertical bay 305 from the front. A second crane-cable 309 is shown partially entered into a back cable-opening 301, and has brought another room module 303 into the corresponding vertical bay 305 from the back. This embodiment allows room modules 303 to be inserted from both the front and back of each vertical bay, and the schedule of room module 303 insertions may possibly be completed in half the time required for a single-side vertical bay entry

Figure 8b illustrates how three cranes can be used to access both sides of two vertical bays arranged into a T-shape footprint, providing for speedy assembly of the modular building 300 cost-effectively and time-efficiently

However, the cross-linking frame 313 of Figure 7 and the related drawings does not allow a crane-cable 309 to come into the mid-width plane 317.

Some building designs require a room module 303, a corridor module or any other modular objects is to be placed on mid-width plane 317 along the depth of the modular building 300, i.e. the centre of the module is aligned to the mid-width plane 317 and the sides about the object centre are equidistant from the mid-width plane 317. As unless the centre of gravity is very much off-centre in the modular object, the crane-cable 309 in many cases would be aligned to the centre of the object. In these cases, the crane-cable 309 will have to be able to come into the mid-width plane 317 to deposit the modular object aligned by the object centre. However, the cross-linking frame 313 of Figure 7 and related drawings has a link-bridge 315 laid over the mid-width plane 317, preventing crane-cables 309 from coming into the mid-width plane 317.

An improved embodiment shown in Figure 9 to Figure 15 addresses the problem of inaccessible mid-width plane 317 in the embodiment of Figure 7. Figure 9 is an exploded view of the schematic parts of a modular building 300 stabilized with the cross-linking frame 313 of this embodiment. The cross-linking frame 313 in Figure 9 is similar to the cross-linking frame 313 in Figure 7, except that the link-bridges 315

are placed entirely on the one side of the mid-width plane 317. In the example as illustrated, that the link-bridges 315 are placed towards the back of the modular building 300. To be more precise, however, it is the front side of the link-bridges 315 that are now a short distance or gap away from being placed on the mid-width plane 317. In other words, the link-bridges are offset from the mid-width plane 317 of the load bearing walls.

The offset can be provided in several ways. For example, the whole of a link-bridge 315 such as that shown in Figure 7 can be moved towards the back of the cross-linking frame 313 until the link-bridge 315 is fully on the back side of the mid-width plane 317. Alternatively, the link-bridge 315 can be made narrower or replaced with narrower link-bridge 315, i.e. reducing the width of the footpath on the link-bridge 315 so that the back side of the narrower link-bridge 315 remains in the same position as the back side of the link-bridge 315 in Figure 7. The advantage of this is that the depth of the back cable-opening 301 remains as deep as before, even though the front cable-opening 301 is made deeper (Figure 7 is used as a reference for different physical configuration of the present embodiment in Figure 9, and does not mean that the embodiment of Figure 9 must be made from modifying an embodiment according to Figure 7). Preferably, both the front and back sides of the link bridges are as near to the mid-width plane 317 as possible, so as to provide cable-openings 301 on both sides of the cross-linking frame 313 that have practical and useful depths. If a cable opening 301 is not very deep, then the usefulness of the shallow cable opening 301 is severely limited. In other words, the present embodiment is to be distinguished from the cross-linking frame 313 in Figure 5 which provides only cable-openings 301 only on one side of the cross-linking frame 313.

The cross-linking frame 313 shown in Figure 9 allows modules of the building that are intended to be placed centrally on or across the mid-width plane 317 to be lifted by a crane-cable 309 that can access the mid-width plane to deposit the modules. Generally, modular buildings 300 that have modules to be placed mid-width tend to have a symmetrical design in the side view of the building. However, this is not necessarily the case, as an asymmetrical design can always include modules to be position mid-width of the load-bearing walls 307.

Figure 10 and Figure 11 are drawings of a modular building 300 being assembled and having a cross-linking frame 313 offset from the mid-width plane 317, corresponding to the schematic version in Figure 9. Figure 10 shows two room modules 303 being lifted towards the vertical bays 305, one at the front and the other at back of the modular building 300. Figure 11 shows the room module 303 in the front moved into a vertical bay 305, and the room module 303 in the back moved partially into another vertical bay but from the back. As in Figure 9, the link-bridges 315 are located the back of the mid-width plane 317, but nevertheless near the mid-width plane 317. The front cable-openings 301 therefore extend from the front of the cross-linking frame 313 deeper into the vertical bays 301 than the back cable-openings 301 from the back of the vertical bays 301. Figure 10 and Figure 11 show a longer V-shape open-brace 501 used to reinforce the front cable-openings 301 and a shorter V-shape open-brace 501 used to the back cable-openings 301.

Figure 12 a technical drawing of the plan view of the formwork over one vertical bay 301 corresponding to the line drawings in Figure 10 and Figure 11, and Figure 13 is

a side-view of the modular building 300. The slip-form rig bay all about the perimeter of each load-bearing wall 307 can be seen quite clearly in Figure 12, as well as the link-bridge 315 connecting the slip-form rig bays of both the load-bearing walls 307. Figure 13 shows a worker standing on the link-bridge 315. It can be seen that the offset of the front of the link-bridge 305 from the mid-width plane 317 is just about a gap that gives room to the thickness of a cable in this example.

As in Figure 9 to Figure 11, Figure 12 also illustrates the back of the link-bridge 315 is nearer to the back of the cross-liking frame than the front of the link-bridge 315 is near to the front of the cross-linking frame 313, and open-braces 501 for the deeper front cable-openings 301 have longer arms 601 than open-braces 501 for the shallower back cable-openings 301. However, it is not always necessary for the length of the open-brace 501 to correspond to the depth of the cable-opening 301. A slightly short open brace may provide sufficient reinforcement to the scaffoldings defining the cable-opening 301, and this depends on the depth and width of the cable opening, the type, construction and material of the scaffoldings, among other factors. On the other hand, a slightly overly-long open-brace 501 may merely protrude a very tiny bit from the relevant side of the cross-linking frame, which the crane operator can easily navigate the crane to stay clear of.

Figure 13 also shows a modular building 300 having a symmetrical design in the side view, in which a central, concrete corridor slab 1301 is placed aligned to the mid-width plane 317. That is, the edges to the short side of the corridor slab extend away in opposite directions from the mid-width plane 317 in equal distance. Along the two long sides of the corridor are opposite-facing apartment units that share access to

the corridor slab from different directions. The apartment units on the ground floor and the floor above the ground floor are illustrated as already installed. Each apartment unit is shown assembled of two room modules 303; an inner room module 303 called the entrance box 1303 placed deeper into the vertical bay and next to the corridor, and an outer room module 303 called the facade box 1305 is placed next to the entrance box 1303. The outer side of the facade box 1305 faces the outdoor environment and has a window for the apartment unit. For the next higher floor, four room modules 303 and a corridor slab are illustrated as being lifted in mid-air each by a crane-cable 309. The co-appearance of these is an illustration in a time-independent manner, to show the relative positions of the crane-cable 309 when depositing each of these.

As mentioned, the corridor module is provided in the form of a corridor slab that can be slot at both ends into doorways provided on the adjacent load-bearing walls 307, and placed on the bottom edge of the doorways. Figure 14 provides a view to these doorways by removing part of a load-bearing wall 307 and a part of the corresponding formwork from the drawings of in Figure 10 and Figure 11. The doorways of different floors are shown placed vertically along and centrally aligned to the mid-width plane 317. The doorways are made into the wall during slipform wall casting using a suitable modification of the mould 311.

Therefore, the link-bridges 315 offset from the mid-width plane 317 provides a way for the crane-cable 309 coming into the mid-width plane 317, thereby allowing the corridor slab 1301 to be brought into and deposited onto the correct position by use of the crane. If the crane-cable 309 has to deposit the corridor slab 1301 a little off-

distance, the weight of the concrete corridor slab 1301 or, for that matter, any other modular object would be too heavy for the workers to remedy the mis-placement manually.

Figure 15 correspond to Figure 14 and Figure 13, being a series of drawings that shows the stages of placing a corridor slab onto the bottom edges of the doorway on adjacent load-bearing walls. Figure 15 does not show the cross-linking frame 313 to avoid cluttering the drawings and it suffices to state that a cross-linking frame 313 with a link-bridge 315 offset towards the back of the building 300 and away from the mid-width plane 317 as shown in Figure 9 to Figure 14 is on the top of the two adjacent load-bearing walls 307 illustrated in the drawings in Figure 15.

Figure 15a shows a room module 303 for the ground floor hoisted on a crane-cable 309 and being inserted in a horizontal movement into a vertical bay 305 defined by two adjacent load-bearing walls 307, from the back of the vertical bay 305. Figure 15a also shows a corridor slab for second floor hoisted on a crane-cable 309 (which may be the cable of the same crane or a different crane) being inserted into the same vertical bay 305 but from the front. This is because the link-bridge 315 which is not shown is offset towards the back of the vertical bay 305 and away from the front. The top surface of the corridor slab is a walkway of the second floor and the bottom surface is ceiling to the corridor of the ground floor. The corridor slab for can be hoisted to a position at the mid-width of the load-bearing wall 307 because the front of the link-bridge 315 does not cross over the mid-width plane 317, thereby giving the crane-cable 309 access into the mid-width plane 317.

Figure 15b shows the two room modules 303 for the back apartment unit on the ground floor fully installed. The corridor for the second floor is also installed and supported by the lower edges of two doorways. An inner room module 303 for the front apartment on the ground floor is being inserted horizontally from the front of the vertical bay.

Figure 15c shows the first floor with an apartment unit on each side of the corridor completed. Figure 15d shows the second floor apartment units installed, along with the corridor slab for the third floor.

In other embodiments, the corridor may also be provided in form of box just like room modules 303, complete with a frame that defines a ceiling and sides walls (not illustrated), instead of a corridor slab. However, the embodiment of a corridor slab is preferred to reduce double structures e.g. a wall of the corridor box next to a wall of the apartment unit, and to return more useable space to the dwellers.

Alternatively, the corridor slab can be divided into two halves along the plane of symmetry and each half is provided as a part the inner room modules 303 of both apartment units. Therefore, when the inner room modules 303 are inserted, the two halves of the corridor are assembled into the whole of the corridor.

Figure 16 shows another embodiment of a cross-linking frame 313 similar to the embodiment shown in Figure 10 and Figure 11, having link-bridges 315 offset from the mid-width plane 317, and having cable-opening 301 on both side of the link-bridges 315. However, instead of an open-brace 501 attached every cable-opening

301, there is an open-brace 501 on only either the front cable-opening 301 or back cable-opening 301 for every vertical bay 305, and alternates between the front and back cable-openings 301 from vertical bay 305 to vertical bay 305. Depending on the size of the modular building 300, in some cases, every load-bearing wall 307 need only be stabilized by a wall-surface on one side, and it is not necessary in these cases to apply an open brace to both sides of the same load-bearing wall 307.

Figure 17a shows a further variation of the embodiment of Figure 16, in which an open-brace 501 is applied to the cable-openings 301 on both sides of the link-bridge 315 but skipping every next front and back cable-openings 301 on both sides of the link-bridge 315.

Therefore, the embodiments comprises A cross-linking frame for adjacent walls for receiving room modules of a modular building; comprising: a section of scaffolding on each of two mutually-facing walls; a link-scaffolding linking the sections of scaffolding of the two mutually-facing walls; the link-scaffolding placed to be on one side of the mid-width of at least one of the walls; wherein a down-hanging cable can be moved into alignment with the mid-width of the at least one of the walls.

Figure 18 shows the basic structure of a bare room module 303 of the preferred embodiment, comprising features that could assist in achieving swift and steady crane-operated insertion of room modules 303 into the vertical bays 305. (For completeness, it is mentioned that a room module 303 which is not bare is pre-installed with fixtures such as wall partitions, doors, windows, sinks, toilet bowls, faucets, shower screens, kitchen fixtures including cabinets and stoves.)

The room module 303 comprises a floor slab 1801 which is rectangular in the plan view. The floor slab determines the area, width and breadth of the room module, and fits to the floor slab of any adjacent room module on the same level in the vertical bay well to make a seamless combined floor. An apartment unit may be assembled of two or more of such room modules.

Steel bars are arranged on the floor slab 1801 into a skeletal frame that has the structure of a box, e.g. all the sides are either vertical or horizontal, and all the corners are in right-angle. Typically, the box structure comprises four vertical bars 1803 extending vertically from the four corners of the rectangular floor slab 1801 by a specific length. The top ends of every two of the four vertical bars 1803 on any side of the floor slab 1801 are connected by a horizontal top bar 1805. This provides four top bars 1805 forming a rectangular and horizontal ceiling frame. The top bar 1805 and the two supporting vertical bars 1803 on each side of the floor slab 1801 provide a vertical planar frame into which a wall panel may be mounted.

The short sides of the room module 303 face the proximate one of the two load-bearing walls 307 when the room module 303 is inserted into a vertical bay 305. The long side of the room module 303 faces the vertical bay 305 as the room module 303 moves in is called the bay-side.

On the top bar 1805 on each of short side of the room module is a steel support-bracket 1807 of steel. The support-bracket 1807 has an L-shape cross-section, and is pre-supplied with bolts and bolts holes for bolting the support-bracket 1807 to a load-bearing wall 307.

Preferably but not necessarily, before a room module 303 is installed into a vertical bay and becomes a part of the modular building 300, the ceiling frame is covered with a removable ceiling cover 1809 to protect the inside of the room module from dust and rain. The ceiling cover is typically any light weight material such a metal deck. Figure 19 shows an non-limiting example of the material composition of a preferred metal deck, having a layer of polyurethane placed between a layer of metal deck and a layer of plastic film cover.

Four hook sockets 1813 are evenly distributed across the surface of the floor slab 1801 and near to the corners of the floor slab 1801. Each socket can be hooked to a rig cable 2005 extending from a spreader frame which is hanging from the cable of a crane, so that the room module 303 may be lifted by the floor slab 1801. An example of the hook 2001 and socket 2003 is provided in Figure 20, in which the socket is shown installed into a raised edge 2009 provided around the floor slab 1801. Use of the raised edge to for installation of hook sockets provides a advantage of not breaking any floor tile 2007 that is pre-installed onto the floor slab 1801. Figure 21 shows a socket installed into the floor slab 1801. The example in Figure 21 would require the socket to be extracted from the floor slab 1801 when they removed and the depression in the floor to be covered with tile identical to the tiles already laid on the floor slab 1801 to repair the look of the floor after an identical or matching room

module 303 has been installed, while the example in Figure 20 requires the repair of any broken room skirting.

The optional ceiling cover has four through-holes 1811, each for a rig cable extending from the hook of a crane to be threaded through and the end of the rig cable be hooked to the socket in the corresponding position in the floor slab 1801. The diameter and positions of the through-holes are pre-determined to gives sufficient clearance to movements of a taut rig cable that could happen when the room module 303 is being lifted by the floor slab 1801. Lifting the room module 303 by the floor slab 1801 instead of the ceiling frame relieves the walls of any strict structural stiffness requirement for being able to bear the suspension of a heavy roof slab beneath and for being able to resist the roof slab's torsional load.

Figure 22 is a front view of a vertical bay showing a crane-cable 309 lifting a spreader frame 2201 from which four rig cables extend through the ceiling cover and are hooked to the sockets in the floor slab 1801. In this matter, the room module 303 is hoisted evenly into the vertical bay to be placed onto the brackets provided by a room module 303 installed earlier into the vertical bay. The optional ceiling cover of the room module 303 below is removed, rendering the room module 303 topless.

The rig cables can be released from the sockets manually by a worker once the room module is securely placed into a vertical bay 305 defined by two load-bearing walls 307, and be the rig cables are pulled out of the ceiling holes and lifted away by the crane. The ceiling cover is also removed to expose the room module 303 with an open top to allow over top access any adjacent room module 303 in the vertical bay.

The floor slab 1801 may comprise any combination of materials and structure that provides the strength required of a floor slab 1801 in a residential apartment. Preferably, the floor slab 1801 has good sound and heat insulation. At least kitchen and washing areas should have good water proofing. Importantly, the floor slab 1801 must last both physically and functionally for as long as the intended leasehold period of the modular building 300. The most straightforward choice of material and structure for the floor slab 1801 is reinforced concrete slab or, for a lighter weight and better soundproofed option, the slab can be made of a reinforced hollow concrete slab.

The bottom face of the floor slab 1801 of a room module 303 above provides the ceiling to the open top room module 303 below. This avoids a double structure between the upper and lower room modules 303, and eliminates the need to care for dirt and moisture accumulation in the gap within the double structure.

Figure 23a is a plan view of an apartment that is being assembled. The encircled insert in Figure 23a is an enlarged view of the corner of the floor slab 1801 which is similarly encircled.

The side of the drawing towards the top of the page is a corridor slab, which is laid on the bottom edge that is part of a doorway made into a load-bearing wall 307. The load-bearing walls 307 are not visible in this plane. Adjacent the corridor on the side which is lower in the page is an entrance box that has been installed. The room module 303 being inserted into a vertical bay 305, as shown by the white arrow, is

the facade box. On the other side of the two load-bearing walls 307 defining the vertical bay 305 are apartment units that have already been installed.

Preferably, the width of the bay-side of a room module 303 and the distance between adjacent load-bearing walls 307 is such that a grout gap 2301 is provided between the floor slab 1801 and each of the load-bearing walls 307. The preferred grout gap is 25 mm for most embodiments (but may be 15 mm or under 50 mm, depending on the design of the building). Grout can be filled into the grout gap for closing the space between the load between load-bearing wall 307 and floor slab 1801.

The corners of the floor slab 1801 on the bay-side are supplied with rollers 2303. If the lifting crane misaligns the room module 303 to vertical bay slightly, and a corner of the floor slab 1801 bumps onto the edge of the load-bearing wall 307, the rollers 2303 rotate on surface of this wall edge in response to the pull of the crane-cable 309, causing the room module 303 to slide across the wall edge and enter into the vertical bay. Preferably, the corners of the edge of the load-bearing wall 307 are chamfered so that the room module 303 has a gentler entry into the vertical bay if the bay-side is caught on the edge of the load-bearing wall 307 and the room module 303 is pulled to slide over the chamfer and into the vertical bay.

Figure 23b shows a variation of the embodiment, in which the rollers 2303 protrude, at 2305, over the edges of the bay-side and the corresponding short side of the floor slab 1801. The embedded rollers will be fully embedded in non-shrink grout when the slab is grouted in place.

Typically, as the room module 303 is about to enter into the vertical bay, manual pulling on the crane-cable 309 by a worker is enough to direct the room module 303 to move. The worker may stand on the platform of the cross-linking frame 313 and hook on the crane with a rod to pull the cable the move the room module 303.

Optionally, a further one or more rollers 2307 are provided on each of the short sides the floor slab 1801, typically although not necessarily, at the mid-point along the short side or even further away from the bay-side of the room module to have better insertion guidance.

Figure 24 shows the rollers 2303 provided as a sliding device 2401 that comprises two rollers 2303 set in a device housing 2403. Such a sliding device 2401 is installed into the lower corner of the opposite ends of the bay-side of the floor slab 1801, by embedding the device housing into the floor slab 1801. Preferably, the rollers 2303 protrude over the edge of the corresponding short side of the corner. While the sliding device 2401 shown in Figure 24 has two rollers 2303, it is possible in some embodiments to have only one roller 2303 in the housing. In other embodiments, the rollers 2303 can be replaced by caster wheels allowing vertical guidance as well, which reduces friction when the room module 303 is lowered onto support-brackets 1807 in the vertical bay.

Each of the short sides of the ceiling frame comprises a steel support-bracket 1807, as shown in Figure 26. The support-bracket 1807 has an L-shape in the cross section, arranged on the ceiling frame such that the corner of the L shape is within,

or at least flushed to, the outer edge of the short side to avoid being caught on the load-bearing wall 307 during insertion into a vertical bay 305. Along the side of the stem of the L-shape are provided fixture holes inserted with bolts for bolting the support-bracket 1807 into a load-bearing wall 307. The support-brackets 1807 are provided with mechanical slider, which will slide onto the wall as the bolt is being bolted into the wall. Figure 26a shows the position of the support-bracket 1807 on the ceiling frame when the room module 303 has been moved into the position inside the vertical bay 305. Figure 26b shows how the support-bracket 1807 is able to slide horizontally on the slider, so that the side of the support-bracket 1807 corresponding to the stem of the letter "L" comes into contact with the load-bearing wall 307. Figure 26c shows how the pre-supplied bolts are bolted through the load-bearing wall 307 into a cross-wall bolting.

Preferably, as shown in the plan view of a load-bearing wall 307 provided in Figure 27, the support-brackets 1807 of neighbouring room modules 303 on both sides of a load-bearing wall 307 are bolted in by the same bolts through the load-bearing wall 307.

Figure 18 shows that along the part of the support-bracket 1807 that corresponds to the stem of the letter "L' is provided three pre-installed bolts 1815 through the support-bracket 1807. Along the part of the same support-bracket 1807 that corresponds to the leg of the letter "L' is provided shear studs 1817 in the same positions long the support bracket as the bolts. The floor slab 1801 is provided with three grout pockets 1819 that are aligned to fit over the bolts affixing the support-

bracket 1807 of the room module 303 beneath, as well as the shear studs 1817. When the room modules 303 are placed in the correct support-brackets 1807 in the vertical bays, the grout pockets 1819 in the floor slab 1801 fits over shear studs 1817 to structure tie the slab onto the bearing wall, to enable the walls to function as the lateral support. Also, each grout pocket 1819 can be filled with grout to prevent gaps. Figure 27 schematically shows the grout pockets 1819 and the gaps between the load-bearing walls 307 and room modules 303 filled with grout. Although only very short shear studs are shown in the drawings, the shear studs may be much longer, depending on the requirements of the building's design.

The support-brackets 1807 are provided with at least one steel wedge that has 1817 an apex defined by two sloping sides, each sloping slide lifting away from the horizontal surface corresponding to the leg of the letter "L". Figure 25 shows the wedge 2501 in enlarged view, alongside a schematic illustration of how the floor slab 1801 of a top room module 303 fits onto the brackets of a bottom room module 303. The base of the floor slab 1801 of the room module 303 above has a corresponding cavity 2503 of the same shape and in matching positions on the short sides. If the room module 303 is positioned correctly into the support-brackets 1807 beneath, the cavity on both sides will fit as female counterpart to the corresponding wedge as male counterpart. If the slope is not positioned correctly, the room module 303 is unable to fit onto the wedges, so that the workers will know that there is a misalignment. However, as long as the cavity catches the apex, the edges of the cavity can slide down the sloping sides of the wedge into aligning the top room module 303 onto the bottom room module 303 precisely. The wedge can be placed anywhere along the surface of the leg of the L-shape of the support-bracket 1807.

The wedge may also be in the same of a cone, i.e. having a more rounded top then the sharper one as shown, the cross-section being a semi-circle placed on the support-brackets 1807. Other options include double wedges where two wedges are used, with one of the wedges being turned so that the lengths across the apices are at 90 degree one to the other.

If the apartment unit is a duplex or a maisonette that are assembled from a lower room module 303 and a upper room module 303 separately, the wedge position on the support-brackets 1807 provided on the ceiling frame of the lower room module 303 may have a different wedge position(s) and/or a different number of wedges. This provides an alert the workers that a wrong room module 303 is being on the lower room module 303. Therefore, different wedge position(s) and/or a different number of wedges can also be used to identify and control the installation of different types of room modules 303.

Hence, the wedge-an-cavity configuration is one way of ensuring quality control and avoiding confusion, as the described modular buildings 300 can be assembled very quickly and in large numbers, and mistakes can be propagated quickly. Furthermore, wedge identification of room modules 303 provides the possibility of letting identical room modules 303 to be made according to pre-specified standards and supplied at the same time from different factories, as any confusion is likely to be pre-emptively avoided.

Similarly, but less preferably, one or more wedges can also be provided on the vertical steel bars of a room module 303 to fit into corresponding cavity or cavities on the vertical steel bars of the adjacent room module 303 on the same level in the same vertical bay 305, to ensure the correct room modules 303 are installed.

Figure 28 illustrate an assembly workflow similar to that shown in Figure 15, but using topless room modules 303. Typically, when the room module 303 is inside a vertical bay 305, insertion s assisted by workers who can pull on the hosted object by a cable hanging down from the object. In Figure 28a, therefore, a first worker beneath a hoisted corridor slab is illustrated pulling on a cable hanging from the corridor slab, while a second worker is illustrated standing on a ladder device in a corridor box and being able to reach over the ceiling frame of the topless corridor box to manually help draw a lifted corridor slab over to fit over supports for the corridor slab. Figure 28b shows the second worker standing on the corridor slab that has just been installed to assist in the placement of a corridor box of the next floor and on the other side of the corridor slab. Figure 28c shows the worker inside the newly installed corridor box waiting to assist with an approaching facade box.

In a further embodiment, the room module 303 is that everything on the floor slab 1801 is removable. After a current room module 303 is placed onto support-bracket 1807 of a room module 303 beneath, and the support-brackets 1807 on the ceiling frame of current room module 303 are bolted to the load-bearing walls 307 for a room module 303 to be placed on. The steel frame between the support-brackets 1807 and the floor slab 1801 can be removed for space recovery, along with any wall

partitions and other provided fixtures. Therefore, only the floor slab 1801 placed on support-brackets 1807 become permanent a part of the completed modular building 300. Figure 29 shows how this room module 303 is used to construct a modular building 300.

Accordingly, Figure 29a shows crane-cable 309 hoisting and inserting a room module 303 horizontally into a vertical bay. Figure 29b shows the room module 303 placed on support brackets bolted into the adjacent load-bearing walls 307. The crane-cable 309 is then disconnected and lifted away. The steel support-brackets 1807 on the ceiling frame can be pushed into contact with the corresponding load-bearing wall 307, and bolted. Figure 29c illustrates that all parts of the room module 303 between the bolted support- bracket and the floor slab 1801 removed and discarded, leaving behind only the floor slab 1801, and the support brackets which are to become a part of the floor slab 1801 to be placed above.

Figure 29d shows a further room module 303 slid onto the brackets that were provided on the ceiling frame of the room module 303 that was just inserted. Figure 29e shows the upper room module 303 in the desired position, at which point in time the support-brackets 1807 of this upper room module 303 are bolted to the load-bearing walls 307. Figure 29f shows the newly inserted room module 303 removed of all fixtures so that there are only the slabs cross-linking the load-bearing walls 307.

Typically, however, it is expected that some or all of the walls and other useful fixtures pre-installed into the room module 303 by manufacturer would be kept by the

apartment unit owner. In particular, the owner of the apartment would be told that removal of the outer wall on the facade box providing the façade of the modular building 300 is not permitted.

The feature that all the fixtures placed on the floor slab 1801 can be removed provides that the apartment units assembled of the room modules 303 can be re-partitioned according to any design preferred by the home owner. This offers a degree of personalization unmatched by the prior art modular buildings 300, which is partly due to double structure from placing apartment box units complete with four walls all round a four sided ceiling and floor.

Accordingly, one of the functions of the frame on the floor slab 1801 is to indicate the vertical location on the load-bearing walls 307 for bolting the support-brackets 1807 on which the room module 303 above will be placed. As it is mainly the floor slab 1801 in a room module 303 that contributes to the building structure, and the frame on the floor slab 1801 mainly locates the support-brackets 1807, many configurations of the floor slab 1801 and the frame are possible while keeping to this useful feature.

Figure 30 shows an embodiment of a room module 303 in which separate wall frames are provided on the short sides of the floor slab 1801, without any long bar connecting the top of the wall frames and therefore there is no ceiling frame. The walls frames pivoted to turn about an axis that is parallel to the upper edge of the floor slab 1801. Therefore, the wall frames can be folded onto the floor slab 1801 to produce flat object convenient for packing and transportation. The skilled reader

would know that the wall frames might have to be adjusted in positions to give allowance to each in order for the floor slab 1801 to be even and capable of stacking stably on another identical floor slab 1801. The floor slab 1801 can be lifted by the rig cables hooked to the corresponding sockets in the floor slab 1801. When the floor slab 1801 is inserted into the vertical bay 305 and placed on the support-brackets 1807 provided with the floor slab 1801 beneath, the wall frames on the current floor slab 1801 are swivelled to be vertically erected and the support-bracket 1807 on each wall frame may be bolted into the corresponding load-bearing wall 307.

Optionally, in other embodiments, the support-brackets 1807 bolted on both sides of the same load-bearing wall 307 do not share the bolts. In this case, the bolts pre-provided in the steel bracket on one side of the room module 303 is offset in position from the bolts provided in the steel bracket on the other side of the room module 303.

While there has been described in the foregoing description preferred embodiments of the present invention, it will be understood by those skilled in the technology concerned that many variations or modifications in details of design, construction or operation may be made without departing from the scope of the present invention as claimed.

The embodiments include a floor slab providing a support-bracket that becomes a part of the apartment of the floor or storey above. In other embodiments, a floor slab

from the factory can be provided with a down flipping wall which will also become a part of another apartment but, in this case, become the walls of an apartment below.

Although four vertical bars 1803 have been described as supporting a ceiling frame and the steel brackets, the four vertical bars can be any support including a pre-installed wall that provide location for the steel brackets. In some embodiments, the walls can also be downward unfolding to provide fixture for the room module on the floor below.

A shown in Figure 31, the vertical bars can be walls 3101 that swivel up from the floor slab... This allows floor slabs to be stacked in condensed arrangement during transportation. Figure 32 is the front facing view of the up-unfolding walls. Figure 33 shows how the upper portion of the wall of an apartment a floor below is supplied with and unfold-able from the floor slab of the floor above. Figure 34 is a floor plan showing the views of Figure 31 to Figure 33.

Claims

1. A cross-linking frame for adjacent walls for receiving room modules of a modular building, comprising:

a scaffolding configured to be installed around an entire perimeter of each of two adjacent walls;

said scaffolding including ledges extending horizontally from all sides of each of the two adjacent walls;

a link-bridge configured to connect the ledges;

said link-bridge and said scaffolding together defining at least one cable opening and said at least one cable opening is configured to provide an unobstructed access to a crane-cable in use;

the link-bridge is placed offset from a mid-width plane of the two adjacent walls away from the cable opening.

2. The cross-linking frame according to claim 1, wherein a side of the link-bridge is flush with back edges of the ledges.

3. The cross-linking frame according to any one of claims 1-2, further comprising:

a brace applied to sections of the scaffolding, and said sections of the scaffolding providing sides of the at least one cable opening.

4. The cross-linking frame for adjacent walls for receiving room modules of a modular building, as claimed in claim 3, wherein

the brace is a V-shape brace comprising two arms extending apart from an apex;

the apex coupled to the link-bridge;

each of the arms coupled to each of the sections of the scaffolding.