

CONSTRUCTION SYSTEM

This application is a divisional application of Singapore patent application no. 9801075-4, the contents of which are herein incorporated by cross-reference.

The invention relates generally to a construction system for reinforced
5 concrete multi-storey buildings and has been designed especially for high-rise office or residential developments and is herein described in that context. However, it is to be appreciated that the invention has broader application and may be advantageously used in any type of multi-storey buildings including low-rise and industrial sites. Accordingly, the invention is not limited to that
10 particular application.

The use of reinforced concrete in multi-storey buildings provided a major breakthrough in construction. Previously high-rise buildings were typically made from a steel frame which included a perimeter wall formed from brick or other block construction. The advent of construction techniques using reinforced
15 concrete enabled high rise buildings to be constructed at lower costs than previously possible. As a consequence, reinforced concrete is now extensively used in high-rise constructions.

In the construction of high-rise buildings using reinforced concrete, a core, which is typically the lift or stair well provides the required stiffness to prevent
20 sheering at the footings through twisting of the building. The core is usually cast using jump form or conventional casting techniques and as it is constructed, the individual floor structures are also cast in situ and extend out from the core. On completion of the various storeys of the building, the perimeter wall is installed between adjacent storeys and finished from the exterior of the building with the
25 aid of external scaffolding. The peripheral wall is usually made from a block or glass construction and is supported by the individual floor structures of the building.

It is well recognised that being able to minimise the construction time can provide substantial cost savings. Accordingly, it is a continuing aim to refine
30 construction techniques to provide more efficient systems which minimise the construction cycle times.

An aim of the invention disclosed in co-pending Singapore application no. 9801075-4, to which this application relates, is to provide a new construction

technique for reinforced concrete multi-storey buildings. A particular aim of that invention is to improve the construction cycle time without impacting on the quality of the building, thereby providing more efficient and cost-effective techniques.

The invention disclosed in this related application provides a method of constructing a multi-storey building including the steps of; casting in situ a reinforced concrete perimeter wall, providing precast internal load bearing members including precast reinforced concrete columns and beams, locating the concrete columns within the perimeter wall, and supporting the beams on the concrete columns and establishing a concrete slab over the beams to form an individual floor structure of the building.

This construction method has substantial practical benefits. In particular, this method can reduce the construction cycle time as it minimises the amount of on-site construction required. In addition, because the internal load bearing members are precast, it enables the simultaneous construction of multiple storeys of the building.

In a particularly preferred form, the perimeter wall is formed using a slip-form or jump-form casting technique. This has the advantage that it enables the perimeter wall to be constructed without the need for external scaffolding. Moreover, because of the smooth finish provided by a jump-form formwork system, the amount of finishing required to the wall is substantially minimised. In particular, the external wall can merely be skim-coated and painted since the system formwork can achieve a smooth surface. This eliminates the erection of external scaffolding for finishing work since plastering of the external wall is not necessary. In that arrangement, the finishing work can be carried out by using gondolas suspended from the roof following completion of the structure of the building.

The concrete slab which completes the floor structure of the individual storeys of the building may be cast on-site or formed from precast elements. In a particularly preferred form of the invention described above, the concrete slab is formed from a combination of precast elements with a cast in situ topping. With this arrangement, preferably the beams, the precast elements and the cast in situ topping form a monolithic structure. Preferably, the floor structure includes both top and bottom steel reinforcement with the top reinforcement being formed in the

concrete topping and the bottom reinforcement being formed in the precast beams and slabs.

As mentioned above, an advantage of the invention disclosed in the above application is that it enables the simultaneous construction of multiple storeys of the building. In this arrangement, the peripheral wall is cast in advance of the construction of the internal floor structures of the building. The precast reinforced concrete columns, which are configured to extend over a plurality of storeys of the building, are then located within the perimeter wall and the beams are positioned at predetermined positions along the installed columns. The floor structures of the building are then completed for the plurality of storeys by starting at the lowermost storey and working upwardly.

Preferably each of the precast reinforced concrete columns include spaced apart reinforced concrete elements which are interconnected by steel reinforcement. In use, the concrete columns are positioned and the floor structure of the building is constructed to extend between these respective concrete elements.

An aim of the present invention is to provide a precast reinforced concrete column and related method which is ideally suited to, but not limited to, use in the above described construction method.

Accordingly, the present invention relates to a precast reinforced concrete column unit for use in a multi-storey building, the column unit including a plurality of aligned reinforced concrete elements, the elements being precast with steel reinforcement that is continuous through the unit and interconnects the elements in a spaced apart relationship, wherein the respective elements form the column for a respective storey of the building and wherein the spacing between adjacent elements provides a gap to enable a floor structure to be constructed between the adjacent elements.

Preferably the precast column is adapted to receive the edge region of at least one precast beam, the beam being adapted to form part of the floor structure. In a particularly preferred form, the concrete column is adapted to receive and support a plurality of beams within the gap between the adjacent elements.

An advantage of the precast column of this aspect of the invention is that it enables the construction of a structural joint of a beam between adjacent columns without requiring any coupling devices such as splice sleeves or the like to

continue the reinforcement into the adjacent column. In this aspect of the present invention, at least some of the reinforcement interconnecting adjacent concrete elements is continuous through the structural joint formed between the column and the floor structure.

5 In yet a further aspect, the present invention relates to a method of forming a structural joint between a precast reinforced concrete column and a precast reinforced concrete beam, the method including the steps of:

- 10 (i) Providing a precast reinforced concrete column unit, the column unit including first and second elements which are vertically aligned with the first element being disposed above the second element, the elements being precast with steel reinforcement that is continuous through the unit and interconnects the elements in a spaced apart manner to provide a gap between the adjacent elements;
- (ii) providing at least one precast reinforced concrete beam;
- 15 (iii) locating a region of the or each beam in the gap; and
- (iv) making a structural joint by casting concrete into the gap so as to form a unitary structure between the column elements and the or each beam.

Preferably each beam is supported at an edge region of an upper surface of the second element. Preferably, the edge region is recessed to provide a seat or
20 pocket for receiving the beam.

In one form the steel reinforcement interconnecting the first and second elements extends entirely through a central region of the elements which is adjacent to the recessed edge region of the second element. In another form, at least some of the reinforcement extends through the edge region.

25 In one form, at least one of the beams includes exposed reinforcement which extend into the recess on locating that beam in position. In the case where the steel reinforcement interconnecting the elements of the columns extends through the edge region, the reinforcement extending from the beam, is positioned so that there is no obstruction with the column reinforcement when the beam is
30 located in position. In a particularly preferred form, the steel reinforcement interconnecting the elements of the column extends through a central part of the recess and wherein the reinforcement from the beam is offset

from the centre of the beam so as to ensure that there is no obstruction on positioning of the beam.

Preferably the beam forms part of a floor structure and wherein a floor slab is cast in situ over the or each beam and into the recess.

5 It will be convenient to hereinafter describe embodiments of the invention with reference to the accompanying drawings. It is to be understood that the particularity of these drawings does not supersede the preceding broad description of the invention.

In the drawings:

10 Figure 1 is a typical storey framing plan of a building made in accordance with the invention;

Figure 2 is an elevation view of a column floor arrangement for the building of Figure 1 and illustrating precast concrete column units according to an aspect of the present invention;

15 Figure 3 is a detailed section of a floor structure of the building of Figure 1;

Figure 4 is a detailed plan view of a first precast beam-column joint of the building of Figure 1;

Figure 5 is an elevation view of the joint of Figure 4;

20 Figure 6 is a detailed plan view of a second precast beam-column joint of the building of Figure 1;

Figure 7 is an elevation view of the joint of Figure 6;

Figure 8 is a detail plan view of a third beam-column joint of the building of Figure 1;

Figure 9 is an elevation view of the joint of Figure 8;

25 Figure 10 is detailed plan view of a precast beam-wall joint of the building of Figure 1;

Figure 11 is an elevation view of the joint of Figure 10;

Figure 12 is a schematic plan view of an alternative joint detail of the beam and column and perimeter wall of the building of Figure 1; and

30 Figure 13 is a detailed elevation view of the beam-column joint of Figure 12.

Figure 1 illustrates a typical storey framing plan for a high rise reinforced concrete building 10 which in the illustrated embodiment is for residential apartments.

5 The building 10 includes a perimeter wall 11 (illustrated in solid line), a liftcore 12 and staircase well 13, all of which are formed from reinforced concrete and are cast in situ using a jump form formwork system.

10 The building 10 further includes an internal load bearing structure which includes precast reinforced concrete columns 14 (which in the illustrated embodiment are differentiated by the reference C1 to C16). The columns are adapted to support the floor structure to make up the individual storeys of the building as will be discussed in more detail below.

Figure 2 illustrates a sectional view of the building over four storeys detailing the column floor arrangement used. In Figure 2, the section is taken through a mid height of the building. A similar column structure is used
15 throughout the entire building except that the configuration of the steel reinforcement changes to accommodate the changes in loading induced in columns at different heights. In addition, the configuration of the load bearing surfaces on the columns will vary depending on the beam configuration of the floor structure as will be discussed in more detail below.

20 The columns are aligned throughout the building and are formed from precast reinforced concrete column units 16. In the illustrated form, each column unit spans three storeys of the building and comprises three separate elements, each designated 17. The elements 17 are spaced apart from one another so as to form recesses which are designed to accommodate a part of the floor
25 structure 15 so as to enable the floor structure to extend between the adjacent elements. With this construction, the respective elements 17 of the column unit 16 each span between adjacent floor structures 15 of the building.

Each column unit is precast with steel reinforcement 19 which interconnects the adjacent elements 17. It is to be appreciated that whilst the
30 illustrated units span three storeys, other sizes could be employed.

Each column unit is adapted to be connected to its adjacent column unit by interconnecting the steel reinforcement in the respective units. In the illustrated form, the lower end 26 of the column unit 16 includes suitable couplings, such as

splice sleeves (not shown) which are arranged to receive steel reinforcement 18 which protrudes from the upper end 25 of the immediately adjacent column unit 16.

5 A detailed sectional view of the floor structure 15 is illustrated in Figure 3 and includes a precast beam, precast pretensioned half planks 21 and a cast in situ topping 22. The topping 22 is cast in situ and binds the various parts together so that the floor structure becomes unitary. The floor structure 15 includes both top steel reinforcement 23 and bottom steel reinforcement 24. In the arrangement of Figure 3, the bottom reinforcement 24 forms part of the precast beam 20 whereas the top reinforcement 23 forms part of the cast
10 topping 22.

Figures 4 to 9, illustrate various configuration of the column unit 16 and the joint between the column and the precast beams 20 which forms the load bearing surface for the slab 27 of the floor structure 15.

15 Turning firstly to the arrangements illustrated in Figures 4 and 5, two beams 20^i and 20^{ii} are aligned with a column unit 16 and adapted to extend outwardly from opposite sides 28, 29 thereof.

The beams 20 are arranged to be supported on an upper end 31 of the element 17 of the column unit 16. The upper end 31 has a stepped configuration
20 to provide recesses 42, 43 at edge regions 33 of the element 17 which are adapted to receive respective ones of the beams 20^i , 20^{ii} . The steel reinforcement 19 which extends across the adjacent elements 17 to interconnect the elements is positioned to extend through a central region 32 of the elements thereby leaving the edge regions 33 free to receive the respective beams.

25 The recesses 42, 43 are both of a height which is approximately equal to the height of beams 20^i , 20^{ii} . Each beam locates on an upper bearing surface 34 of the respective recesses 42, 43 and is placed on a thin mortar bed to assist in transfer of stresses. Furthermore the bottom reinforcement 24 of the beams project out from their respective ends 30 and in the illustrated arrangement, a
30 plate 35 is welded on to the exposed end of the steel reinforcement 24 to anchor the reinforcement to the end of the beam.

Once the beams 20 are located in position, the half planks 21 are installed on temporary props (not shown) and the upper reinforcement is positioned in

place. The concrete topping 22 is then cast to complete the joint between the column and the floor structure. In casting the concrete topping, concrete is cast into the recesses 42, 43 between the upper end 31 of the lower column element 17 and its lower end 36 of the adjacent column element 17. In this way, a unitary structure is formed between the two column elements 17 and the intermediate floor structure 15.

Figures 6 and 7 illustrate a variation in the beam column joint of Figures 4 and 5. In this arrangement, an additional beam 20ⁱⁱⁱ extends from the column element 17 and is positioned in the recess 42 adjacent to the beam 20ⁱ at right angle to this beam. To accommodate this arrangement, the recess 42 is increased. To maintain the strength of the column in the enlarged area taken up by the recess 42, steel reinforcement 37 extends through the recess 42. As can be seen the steel reinforcement 32 is positioned so as not to interfere with the placement of the beams 20ⁱ, 20ⁱⁱⁱ.

The joint of Figure 6 and 7 is constructed in the same way as the joint of Figures 4 and 5 with the topping being cast into the recesses 42, 43 and between the elements 17 to form the slab 25 of the floor structure 15 and to make the floor structure 15, incorporating the beams 20ⁱ, 20ⁱⁱ and 20ⁱⁱⁱ, unitary with the adjacent elements 17 of the concrete unit 16.

A further variation is illustrated in Figures 8 and 9 where the third beam 20ⁱⁱⁱ is again incorporated. However in this arrangement the beams are configured with the columns to form a T-shape with the beam 20ⁱⁱ being aligned with the column element 17 whereas beams 20ⁱ and 20ⁱⁱⁱ extend transverse to the column element. Again, the recess 42 is enlarged to accommodate the beams 20ⁱ and 20ⁱⁱⁱ and reinforcement 37 is included to extend through the recess 42. Completion of the floor structure and the construction of the joint between the beams of the column unit 16 is completed in a similar fashion as to the earlier embodiments.

The floor structure 15 is coupled to and supported by the perimeter wall 11. Figures 10 and 11 illustrate a detailed view of the connection between the perimeter wall 11 and the floor structure 15. The wall 11 includes a recess 38 which is arranged to receive the edge of the beam 20 so as to enable the beam 20 to be supported on a bearing surface 39 formed at the base of the

recess 38. In a similar manner to the beam column connections discussed above, the bottom reinforcement 24 in the beam protrudes from the end of the beam 20 and includes a welded plate 35 which locates within the recess 38. Dry packing 40 is included on the bearing surface 39 to ensure stress transfer. The
5 perimeter wall 11 includes reinforcement 41 which projects into the recess 38 and which forms part of the top reinforcement for the floor structure 15. To complete the joint, the concrete topping is cast in situ so as to form the slab 27 of the floor structure 15. As part of this casting, concrete is cast into the recess 38 thereby forming a unitary structure between the floor structure 15 and the perimeter
10 wall 11.

Figures 12 and 13 illustrate a variation on the joint detail between the beams 20 and the precast columns 16 and cast in situ wall 11. In this arrangement, the bottom reinforcement 24 of the beams project outwardly and upwardly beyond the ends 30 of the beam 20. Similar to the earlier embodiment,
15 the precast columns include recesses 42, 43 which are formed at the upper end 31 of the respective column elements 17. However, in this arrangement, the body of the precast beams are not supported on the bearing surfaces 33 of the recesses. Rather they extend laterally adjacent to the column recess 42, 43 with only the extension of the bottom reinforcement extending into the recess 42. This
20 arrangement allows adequate clearance to simplify the placement of the beams by enabling the beams to be swung into position through a horizontal plane as illustrated in Figure 12.

As can be seen in Figures 12 and 13, the bottom reinforcement 24 is offset from a centre of the beam 20. This is done to ensure that as the beam is swung
25 into position it does not obstruct with the reinforcement 37 which extends through a central region of the respective recesses 42, 43.

Once swung into position, the beams are supported temporarily by props and scaffolding (not shown) and the steel reinforcement 23 for the concrete topping is then erected. The beam 20 is then coupled to the top reinforcement by
30 stirrups 44. Concrete is then cast in situ to complete the floor structure and to form the structural joint between the column and the floor in a similar manner as described in the earlier embodiments. This makes the beams monolithic with the

topping and the column joint thereby enabling the beams to be supported by the columns.

5 In construction of the building, the perimeter walls 11 as well as the internal lift core 12 and staircase well 13 are cast with a system jump form ahead of the construction of the internal floor structure. After the wall is cast up to the third storey, the precast columns 16 are installed. The precast beams 20 are then installed seating on the columns. The floor structure is then completed by locating the half planks 21 which are supported by the precast beams 20 and the reinforced concrete perimeter wall 11. The cast in situ constructional topping 22
10 is then cast on top of the planks to complete the floor structure. Casting of the wall and construction of the internal structures proceeds until the whole building is completed. The external walls are then finished with skim coating and painting using gondolas suspended from the roof. The windows are fixed from within the building. No external scaffolding is required.

15 An advantage of the construction system according to the invention is that it enables faster cycle times by the use of precast internal load bearing members. Furthermore, the use of precast column units which span a plurality of storeys of the building further increase the cycle times as it enables the simultaneous construction of multiple storeys of the building.

20 A further advantage of a preferred form of the invention is that the column elements do not include a corbel to support the beam and that their width is the same as the precast beams. This simplifies the precasting process as it enables both the beam and the column to share a linear precasting steel mould. Further advantages are obtained by simplifying the column-beam joint detail which again
25 speeds up the construction time. Finally by constructing the walls in situ, using a system jump formwork system eliminates labour intensive and costly plastering and external scaffolding.

30 It will be understood that various alterations, modification and/or addition may be introduced into the construction an arrangement of the parts previously described without departing from the spirit or ambit of the invention.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A precast reinforced concrete column unit for use in a multi-storey building, the column unit including a plurality of aligned reinforced concrete elements, the elements being precast with steel reinforcement that is continuous through the unit and interconnects the elements in a spaced apart relationship, wherein the
5 respective elements form the column of a respective storey of the building and wherein the spacing between the adjacent elements provides a gap to enable a floor structure to be constructed between the adjacent elements.
2. A precast column according to claim 1 wherein the element located
10 immediately below said gap includes an upper end which incorporates at least one recess adapted to receive a precast reinforced concrete beam, said beam being arranged to form part of said floor structure.
3. A precast column according to claim 2 wherein at least a majority of the steel reinforcement extends through a central region of the respective concrete
15 elements and wherein the or each recess is located adjacent to said central region.
4. A precast column according to either claim 2 or 3, wherein at least some of the steel reinforcement extends through at least one of the recesses.
5. A concrete column according to any one of claims 1 to 4, wherein the
20 column includes opposite distal ends, at least one of the distal ends incorporating exposed reinforcement to enable the column to be connected to a like column.
6. A method of forming a structural joint between a precast reinforced concrete column and a precast reinforced concrete beam, the method including the steps of:
25 (i) providing a precast reinforced concrete column unit, the column unit including first and second elements which are vertically aligned with the first element being disposed above the second element, the elements being precast with steel reinforcement that is continuous through the unit and interconnects the elements in a spaced apart manner to provide a gap
30 between the adjacent elements;
 (ii) providing at least one precast reinforced concrete beam;
 (iii) locating a region of the or each beam in the gap; and
 (iv) making a structural joint by casting concrete into the gap so as to form a unitary structure between the column elements and the or each beam.

7. A method according to claim 6 wherein each beam is supported on an upper surface of the second element.
8. A method according to claim 7 wherein the upper surface of the second element is recessed to provide a seat for receiving and supporting at least one
5 said beam.
9. A method according to any one of claims 6 to 8 wherein the or each beam forms part of a floor structure and wherein the concrete cast into the gap forms part of a floor slab which is cast over the or each beam.
10. A method according to any one of claims 6 to 9, wherein at least one beam
10 includes steel reinforcement extending from at least one end thereof and which extends into the gap on positioning of that beam.
11. A method according to claim 10, when dependent on claim 8, wherein steel reinforcement interconnecting the first and second elements extends through said seat, and wherein the steel reinforcement extending from the beam is offset from
15 a centre of the beam so as to be spaced from the reinforcement extending through the seat on positioning of that beam.
12. A method according to any one of claims 6 to 11, wherein the beam is located in the gap by being swung through a generally horizontal plane.