

A METHOD OF CONSTRUCTING A MODULAR BUILDING, A TRAY-LIKE MODULAR BUILDING COMPONENT, AND RELATED METHOD, AND A MODULAR BUILDING COLUMN ASSEMBLY

Field

[0001] The present invention relates to method of constructing a modular building, a tray-like modular building component, and related method, and a related modular building column assembly.

Background

[0002] Any discussion of the prior art throughout the specification should in no way be considered as an admission that such prior art is widely known or forms part of the common general knowledge in the field.

[0003] Multi-story building structures are typically made from concrete and/or steel, with timber being used as formwork. Generally, when constructing these buildings, framework is formed to provide the basis for columns and floors structures, with concrete and steel being formed within or adjacent to the framework so as to define the building. The construction process is generally limited to floor-by-floor so as to provide a rigid structure upon which to build additional floors.

[0004] For medium to high rise building structures, often a concrete core for the lift shafts needs to be constructed prior to floors being built to provide stability and trueness of shape to the building structure. The equipment to build the core lift shafts is expensive and this process also delays when finishing trades can commence.

[0005] Further, finishing trades, such as plumbing, rendering, electrical and sanitary must wait until the building structure is complete and the concrete is strong enough to commence their work. Finishing trade work can represent a significant proportion of the total time it takes on a building construction project.

[0006] As a result, some designers and builders have begun fabricating as much as possible off site in factory conditions and then bringing large elements to site for assembly. This often includes pre-assembled rooms that can be cumbersome to transport and/or deliver and “box-like” in appearance which doesn’t lend them to architectural flexibility.

[0007] Additionally, buildings must be fire resistant for occupational safety and code compliance. Traditionally this means that buildings are constructed from non combustible materials, such as concrete, or are treated on site with a fire retardant system.

[0008] There is a need to reduce construction times for multi-story buildings and provide architectural flexibility.

Object

[0009] It is an object of the present invention to address the above need and/or at least substantially overcome or at least ameliorate one or more of the above disadvantages.

Summary

[0010] Accordingly, in a first aspect, the present invention provides a method of constructing a modular building, the method including the following sequential steps:

constructing a multi-floor building frame by connecting a plurality of like open topped-trays and column assemblies, with the trays forming floors and the column assemblies separating the floors;

assembling walls or walls formwork to the frame; and

pouring wet concrete into the trays to form the building.

[0011] The column assemblies are preferably hollow and the wet concrete is also poured therethrough. The walls formwork are preferably hollow and the wet concrete is also poured therethrough.

[0012] A roof structure is preferably assembled to the frame. The roof structure is preferably assembled to the frame prior to the pouring of the wet concrete.

[0013] In one form, wherein wet concrete is poured into all of the trays and then allowed to cure. In another form, wet concrete is poured into some of the trays, which some trays are allowed to cure, and then wet concrete is poured into the remainder of the trays, and which remainder are allowed to cure. In a further form, wet concrete is poured into the trays progressively, which trays are progressively allowed to cure.

[0014] The trays are preferably tensioned before being constructed into the frame so as to deform the trays, whereafter the filling of the trays with concrete flattens the trays and induces post tensioning strengthening therein.

[0015] Bracing is preferably attached the exterior of the modular building.

[0016] There is also provided a tray-like modular building component adapted for filling with concrete after assembly with like components into a building frame, the component including:

a substantially rectangular frame with a pair of opposed sides and a pair of opposed ends defining an interior therebetween;

a sheet mounted to the frame and extending over the interior;

a pair of beams, each mounted to the frame along each one of the pair of sides respectively; and

a pair of end plates, each mounted to the frame along each one of the pair of ends respectively, wherein the sheet, the beams and the end plates together form an open-topped tray for receiving the concrete therein.

[0017] The tray-like modular building component preferably further includes a pair of tensioners, each mounted to and along each one of the pair of beams respectively, wherein the tensioners are adapted for tensioning the beams so as to deform the beams and the sheet.

[0018] The tray-like modular building component preferably further includes a plurality of deflector plates placed along each side beam, each deflector plate configured to allow the tensioner to pass therethrough, whereby tensioning of the tensioners engages the deflector plates and deforms the beams.

[0019] The tensioner is preferably pre-tensioned utilising a barrel and wedge assembly.

[0020] The tray-like modular building component preferably further includes a reinforcing mesh part mounted to the frame above the interior.

[0021] There is also provided a method of constructing a tray-like modular building component adapted for filling with concrete after assembly with like components into a building frame, the method including the following steps:

- assembling a substantially rectangular frame with a pair of opposed sides and a pair of opposed ends defining an interior therebetween;

- mounting a sheet to the frame which extends over the interior;

- mounting a pair of beams to the frame, each along each one of the pair of sides respectively;

- mounting a pair of end plates to the frame, each along each one of the pair of ends respectively; and

- forming an open-topped tray for receiving the concrete therein from the sheet, the beams and the end plates.

[0022] The method preferably further includes:

- mounting a pair of tensioners to the beams, each to and along each one of the pair of beams respectively; and

- tensioning the beams by adjusting the tensioners and thereby deforming the beams and the sheet.

[0023] The method preferably further includes placing a plurality of deflector plates along each side beam, each deflector plate configured to allow the tensioner to pass therethrough, whereby tensioning of the tensioners engages the deflector plates and deforms the beams.

[0024] The tensioner is preferably pre-tensioned utilising a barrel and wedge assembly.

[0025] The method further includes mounting a reinforcing mesh part to the frame above the interior.

[0026] There is also provided a modular building column assembly adapted for filling with concrete after assembly with like components into a building frame, the column assembly including:

- a column part with an open top end, an open bottom end and a hollow interior

therebetween;

at least one joiner part, with a hollow interior, extending at least partially into the column interior in an overlapping relationship with the top end or the bottom end; and

at least one fastener extending through the column part and the joiner part where they overlap so as to fix the column part to the joiner part;

wherein the interior of the column part and the interior of the joiner part are in fluid communication with each other so as to allow wet concrete to flow from one to the other.

[0027] The modular building column assembly preferably further includes a pair of parallel and spaced apart column parts with a reinforcing mesh part therebetween.

Brief Description of Drawings

[0028] Preferred embodiments of the invention will be described hereinafter, by way of examples only, with reference to the accompanying drawings, wherein:

[0029] Figure 1 is a perspective view of a single tray for use in a first embodiment of a building frame;

[0030] Figure 2 is a perspective view of a tensioning system of the tray shown in Figure 1;

[0031] Figure 3 is a further perspective view of the tensioning system of the tray shown in Figure 1;

[0032] Figure 4 shows the tray of Figure 1 installed adjacent a plurality of building frame columns for a first embodiment of a building frame;

[0033] Figure 5 shows a cross section of the tray in Figure 4;

[0034] Figure 6 is a perspective view of a plurality of the building frame columns, used to form ground and first floor walls of the first embodiment of the building frame;

[0035] Figure 7 is a close up view of the tray shown in Figure 1 used to form the first floor of the first embodiment of the building frame with the columns shown in Figure 6;

[0036] Figure 8 shows multiples of the trays shown in Figure 1 used to form the first floor of the first embodiment of the building frame with the columns shown in Figure 6;

[0037] Figure 9 shows multiples of the trays shown in Figure 1 used to form the first floor of the first embodiment of the building frame with the columns shown in Figure 6;

[0038] Figure 10 shows multiples of the trays shown in Figure 1 used to form the first and second floors of the first embodiment of the building frame with the columns shown in Figure 6;

[0039] Figure 11 shows multiples of the trays shown in Figure 1 used to form the completed six floor first embodiment of the building frame with the columns shown in Figure 6, with the wall formwork not shown;

[0040] Figure 12 shows multiples of the trays shown in Figure 1 used to form the completed six floor first embodiment of the building frame with the columns shown in Figure 6, with the wall formwork;

[0041] Figure 13 shows the tray in Figure 5, after filling with concrete;

[0042] Figure 14 shows ground floor posts and wall sections of a second embodiment of a building frame;

[0043] Figure 15 shows initial trays added to the floor posts and wall sections of Figure 14;

[0044] Figure 16 shows completed trays added to the floor posts and wall sections of Figure 15;

[0045] Figure 17 shows first floor posts and wall sections added to the ground floor of Figure 16;

[0046] Figure 18 shows second to tenth floors added to first floor of Figure 17;

[0047] Figure 19 shows external bracing added to the floors of Figure 18;

[0048] Figure 20 shows eleventh to thirtieth floors added to the floors of Figure 18, with additional external bracing; and

[0049] Figure 21 shows the completed thirty floor second embodiment of building frame, with external bracing removed.

Description of Embodiments

[0050] A tray-like modular building component 10 (hereafter tray 10) according to a first embodiment is depicted in Figures 1 to 3. The tray 10 is part of an assembly to construct a first embodiment of a building frame 300 (See Figure 11) adapted for filling with concrete to build a modular building (See Figure 12). The tray 10 comprises a substantially rectangular frame 20 having a pair of opposed sides 22 and a pair of opposed sides 24 defining an interior 30 therebetween.

[0051] The tray 10 is envisaged to be rectangular shaped, although various other forms of the tray 10 are envisaged, such as stepped ends, so as to define a balcony, or having significant portions removed, so as to define lift shafts of a building frame. The tray 10 can also have shaped ends for architectural intent to be expressed.

[0052] The frame 20 is envisaged to be manufactured to a length of between 12 to 14 metres and a width of 2½ to 3½ metres. The frame 20 may be assembled using tie straps 28 with or without turn buckles. The tie straps 28 provide a mechanism for tensioning and strengthening the frame 20. The tie straps 28 can be tightened to get a width-wise camber into the frame 20 that is intended to flatten when countering the weight of the wet concrete that will be added to the frame 20 during construction.

[0053] The tray 10 also includes a sheet 40 mounted to the frame 20 that extends over the interior 30. The sheet 40 is standard form sheeting made from steel or other suitable materials. The sheet 40 is mounted to the frame 20 using a suitable mounting method, such a fastening or gluing. The sheet 40 will be designed to support the weight of concrete when constructing the modular building.

[0054] The tray 10 also comprises a pair of beams 50, envisaged to be standard I-beams. Each beam 50 is to be mounted to the frame along each one of the pair of sides 22 respectively. The frame 20 and sheet 40 attach to and sit within a lower flange of each of the beams 50 and are secured thereto using suitable fastening means, such as screws or shot fired rivets. The

beams 50 are to be manufactured using steel, however, any suitable material capable of the deformation and strength requirements for constructing a building would also be suitable.

[0055] The tray 10 further comprises a pair of end plates 60, where each end plate 60 is mounted to the frame 20 along each one of the pair of ends 24 respectively. The end plate 60 is secured to the frame 20. It is envisaged that a plurality of standard attachment brackets may be used to secure the end plates 60 to the frame 20.

[0056] The tray 10 further includes a pair of tensioners 70. The tensioners may be cables 71 comprises of a plurality of steel strands. The cable 71 is to be fed through deflector plates 72 attached to the beams 50. The deflector plates 72 are mounted to and along each one of the respective beams 50 respectively and together with the cable. The deflector plates 72 include an aperture 73 configured to allow the cable 71 to pass therethrough. The location of the aperture 73 in the deflector plate 72 is variable in order to provide the deformation characteristics required for the tray 10. That is, as best illustrated in Figures 2 and 3, the cable 71 passes through the apertures 73. The profile the cable 71 follows is a configured so that when tensioning the cable 73, a force is applied into the deflector plates 72 that causes the deflector plates 72 to engage with the beams 50 and the sheet 40 so as to deform the beams 50 and the sheets 40 into a desired deformation profile. The amount and degree to which the deformation occurs depends on the size of the tray 10 and the expected weight of the concrete to be added on site in order to construct the building.

[0057] At the manufacturing stage, the sheet 40, the beams 50 and the end plates 60 together form an open-top tray 80 for receiving the concrete therein. The open-top tray 80 will be manufactured in a factory offsite. The tray 80 is designed to fit on the back of standard trucks for transportation to the building site. At this stage in the manufacturing process, the assembled open-top tray 80 is produced that forms the basis for the tray 10. However, as mentioned, the cables 71 are adapted for tensioning so that the beams 50 and sheet 40 are deformed. This deformation is designed to counteract the weight of the wet concrete and post-tension the tray 10 upon adding and setting of the concrete.

[0058] Figure 4 shows an exemplary deformation profile, relative to a dashed horizontal reference line, in which the (cantilever) end of the tray 10 is deflected upwards by 'd' and the middle of the tray 10 (between adjacent columns 100) is deflected upward by 'D'.

[0059] The cable 71 is pre-tensioned utilising a barrel and wedge assembly (not shown) by gripping an end of the cable 71 adjacent the barrel and wedge assembly and pulling the cable through the barrel and wedge assembly, which bears against the end plate 60.

[0060] The force is applied to the beams 50 in the factory and is load balanced therein. The force creates the deformation in the beam 50, like pre and post-tensioned concrete. In the field of stressing there are traditionally two sorts: pre-stressing; and post-tensioning. Pre-stressing applies load to the cable prior to concrete being placed and then on release of the tension the load is transferred to the concrete. Post-tensioning leaves a duct within the concrete and the force is applied, after the concrete is set, by external jacks. The duct is then grouted or filled with grease. In the embodiment depicted in the accompanying drawings, there is no duct, but rather the concrete surrounds the cable during pouring, flattening the tray to create a flat surface for the floor. This will be described below with reference to Figure 13. Live loads alone are resisted by the tray 10, but not the dead load, as in traditional approach. Further, once the concrete is poured, the cable 71 is protected from fire, and can be designed as a fire rated steel member, with no further treatment.

[0061] Either in the factory or on-site, additional floor penetrations and/or service conduits may be installed to the tray 10. It is envisaged that the additional conduits, such as plumbing, electrical, sanitary, etc., that are required can be installed easily and quickly onto the tray 10 before assembling the building frame. The conduits can then easily assembly together to form the full conduit necessary prior to concrete being added, aiding in installation time for the remaining services to commence.

[0062] Fire boards, which protect steel prone to heat, are also fitted in the factory, prior to delivery to site. As a result, costly site work is avoided. This, combined with the act of pouring concrete designed to encase steel beams, provides a fire resistant steel structure.

[0063] As seen in Figure 2, above the tray 10, the tray 10 further includes a reinforcing mesh part 90 mounted to the frame 20 that is positioned above the interior 30. It is envisaged that standard reinforcing mesh used in standard concreting applications is used. Depending on the number of trays 10 required to form a floor of a building, the mesh 90 can span only one tray 10, or a number of trays 10 as part of the assembly.

[0064] The tray 10 has outwardly extending flanges 65 configured to attach to columns 100 so as to form a building frame 300. The columns 100 are discussed in detail below.

[0065] The modular building column assembly 100 according to a second embodiment is best depicted in Figure 6. The modular building column assembly 100 is adapted for filling with concrete after assembly with like components into a building frame 300. The individual column assembly 100 includes a column part 110 with an open top end 115, an open bottom end 116 and a hollow interior therebetween. Figure 4 shows six of these column parts 110 arranged about a tray 10. Upwardly extending from the open top end 115 of the column part 110 is at least one joiner part 120. The joiner part 120 has a hollow interior and is configured to extend at least partially into the interior of the column part 110 in an overlapping relationship. The joiner part 120 extends from the top end of one column part 110 and, when assembling the building frame, joins the bottom end of another column part 110. Figure 11 illustrates the overlapping intersection of the column parts 110 to form a plurality of column parts 110 joined together by joiner part 120. The column part 110 and joiner part 120 are envisaged to be made from steel.

[0066] The column assembly 100 further includes at least one fastener 130 extending through the column part 110 and the joiner part 120 where they overlap so as to fix the column part 110 to the joiner part 120. The fastener 130 is envisaged to be a standard nut and bolt arrangement, however, due to the hidden nature of the interior of the joiner part, blind fasteners may be required. The interior of the column part 110 and the interior of the joiner part 120 are in fluid communication with each other so as to allow the concrete to flow from one to the other during construction of the building. The column parts 110 and joiner parts 120 are designed to be manufactured in a factory from traditionally available materials, but assembled in the manner disclosed herein. Internal walls can be placed immediately after concreting, using conventional or proprietary systems.

[0067] It is envisaged that plurality of column parts 110 would form the building frame for a first floor, as illustrated in Figure 8. The tray 10 would then be attached to the column part 110 by the flanges 65. The arrangement suitable for the first floor would then be re-constructed for additional floors. Figures 9 to 11 shows a plurality of different trays 10 attached to a plurality of column assemblies 100 where some of the trays 10 have open sections to allow for lift shaft and the balcony extending from the frame.

[0068] There are single columns 100 and double columns 100, depending on the structural requirements of the building. The single and double columns 100 may contain reinforcement to assist in fire resistance. The double columns act to brace the building as it is installed.

[0069] A multi-floor building frame, as depicted in Figures 9 to 12, is constructed using the following sequential steps. The frame connects a plurality of like open topped trays or components 10 and like hollow column assemblies 100, with the components 10 forming floors and column assembly's 100 separating the floors. Preferably, the column assemblies 100 would be inserted to a base 150 and the components 10 would then be attached to the column assemblies 100. This process is repeated for as many floors that are required for the overall modular building so as to produce a finished building frame 300. A roof structure 160 would then be assembled and walls 170 providing the form work would then be added to the frame. This is best illustrated in Figures 11 and 12. The form work for the walls 170 is generally standard timber with a hollow center for receiving concrete. Accordingly, pouring wet concrete into the trays and through the columns to form the building and into the wall form work can be conducted in one action and produces uniform sections that join columns and floors. As an alternative, the concrete can be poured into the trays, columns and wall formwork as separate actions. As a further alternative, the walls 170 can be made (pre cast) in a factory. In this case, wet concrete is only required to be poured into the trays and columns.

[0070] The trays 10 have been pretensioned using the tensioners 70 and tie straps 28 to form the deformed shape shown in Figure 5. Filling of the trays 10 with concrete then flattens the trays 10, as shown in Figure 13, and provides post tensioning strengthening therein.

[0071] The method of manufacturing multi-story buildings in a factory in such a way as described herein allows construction times can be halved. This generally means a typical 20 unit apartment building may be built in 6 months in first world countries. Project funding requirements are therefore significantly less and income streams from sales are received much earlier. This significantly benefits the economics of projects.

[0072] The building frame 300 is stable in its own right and does not need a core to maintain trueness during installation. The core for the lift shaft may be installed after the building has reached its maximum height. There are similar material costs to conventional

methods, but by halving construction time it reduces the preliminaries and overheads also by half.

[0073] Figures 14 to 21 show a second embodiment of a building frame 400. Like reference numerals to those used to indicate feature of the first frame 300 will be used to denote like features in the second frame 400.

[0074] Figure 14 shows ground floor posts (ie. column assemblies) 100 and wall sections 170 of the second embodiment of the building frame 400. The wall sections 170 are produced in a factory with integral diagonal bracing 172. As an alternative, bracing can be added between the posts 100, but this can block ease of access and passage between the posts 100 during construction and is thus not preferred.

[0075] Figure 15 shows two initial trays 10 added to the floor posts 100 and wall sections 170 of Figure 14. Figure 16 shows the completed first floor after all remaining trays 100 added. The gap 402 between trays 100 is for later addition of stairs and/or elevators.

[0076] Figure 17 shows first floor posts 100 and wall sections 170 added to the ground floor of Figure 16 in a similar arrangement of the ground floor. Figure 18 shows the similar addition of the second to tenth floors.

[0077] Figure 19 shows external bracing 404 added to the first ten floors. The bracing is in the form of post-tensioned strands which serve to resist building torsion and reduce movement during construction. Figure 20 shows the eleventh to thirtieth floors added to the floors of Figure 18, with additional similar external bracing.

[0078] Figure 21 shows the completed thirty floor second embodiment of building frame 400, with the external bracing removed 404. The removal of the bracing 404 allows ease of access to the exterior of the frame 400 for fitting external cladding and the like.

[0079] Although the invention has been described with reference to specific examples, it would be appreciated by those skilled in the art that the invention may be embodied in many other forms.

CLAIMS

1. A method of constructing a modular building, the method including the following sequential steps:
 - constructing a multi-floor building frame by connecting a plurality of like open topped-trays and column assemblies, with the trays forming floors and the column assemblies separating the floors;
 - assembling walls or walls formwork to the frame; and
 - pouring wet concrete into the trays to form the building.
2. The method of constructing a modular building of claim 1, wherein the column assemblies are hollow and the wet concrete is also poured therethrough.
3. The method of constructing a modular building of claim 1 or 2, wherein the walls formwork are hollow and the wet concrete is also poured therethrough.
4. The method of constructing a modular building of claim 1, 2, or 3, wherein a roof structure is assembled to the frame.
5. The method of constructing a modular building of claim 4, wherein the roof structure is assembled to the frame prior to the pouring of the wet concrete.
6. The method of constructing a modular building of any one of claims 1 to 5, wherein wet concrete is poured into all of the trays and then allowed to cure.
7. The method of constructing a modular building of any one of claims 1 to 5, wherein wet concrete is poured into some of the trays, which some trays are allowed to cure, and then wet concrete is poured into the remainder of the trays, and which remainder are allowed to cure.
8. The method of constructing a modular building of any one of claims 1 to 5, wherein wet concrete is poured into the trays progressively, which trays are progressively allowed to cure.
9. The method of constructing a modular building of any one of claims 1 to 8, wherein the trays are tensioned before being constructed into the frame so as to deform the trays, whereafter

the filling of the trays with concrete flattens the trays and induces post tensioning strengthening therein.

10. The method of constructing a modular building of any one of claims 1 to 9, wherein bracing is attached the exterior of the modular building.