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A METHOD FOR CONSTRUCTING A BUILDING

Field of the Invention

- 5 The present invention relates to a method for constructing a building. The present invention also relates to a building.

Background of the Invention

- 10 High-rise buildings are typically built-up level by level and this can be time-consuming especially if it is a high rise building. In addition, the fit-out and finishes of the building services, for example electrical and hydraulic systems, can only be performed after construction of the building. This may further delay the time whereby the tenants can begin occupying the premises.

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- Prefabricated Volumetric Construction (PPVC) is a new method of construction whereby the building, or a part of the building, is fabricated off-site and later brought on-site after it has been assembled to be fitted at its final location. A problem with PPVC is having a method of connecting sections of the building together in a secure manner that is also cost effective. Previously, this has been achieved in a manner that requires fasteners to extend through neighbouring walls to effectively pin them together. The result may not be aesthetically pleasing.

- 25 Another problem with PPVC is with the alignment and assembly of the various sections of the building. In assembling the various sections, it is critical that they are aligned so as to ensure structural stability and proper alignment of finishes. It is also important to ensure adequate coupling between the various sections and provide structural continuity in both vertical and horizontal directions. Other issues with existing PPVC technology includes handling, logistics, lifting and water tightness.

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It is generally desirable to overcome or ameliorate one or more of the above described difficulties, or to at least provide a useful alternative.

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Summary of the Invention

In accordance with the present invention, there is provided a method for constructing a building including a first module and a second module, including the steps of:

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- (a) locating a mating surface of the first module adjacent a mating surface of the second module;
- (b) Positioning a first channel of the mating surface of the first module to overlie a second channel of the mating surface of the second module;
- 10 and
- (c) at least partially filling a fastening channel formed between said first channel and said second channel with a fastener.

In accordance with the present invention, there is also provided a building including a first module and a second module, wherein:

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- (a) a mating surface of the first module is adjacent to a mating surface of the second module;
- (b) a first channel of the mating surface of the first module that overlies a second channel of the mating surface of the second module; and
- 20 (c) a fastening channel formed between said first channel and said second channel with a fastener, wherein the fastening channel is at least partially with a fastener.

Brief Description of the Drawings

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Preferred embodiments of the invention are hereafter described, by way of non-limiting example only, with reference to the accompanying drawings, in which:

- Figure 1 is perspective view of a partial building constructed from four PPVC modules;
- 30 Figure 2 is a perspective view of two PPVC modules coupled together;
- Figure 3 is a perspective view of two walls of two PPVC modules coupled together;
- Figure 4 is a perspective view of a PPVC module showing an alignment system;
- Figure 5 is a section view showing Section A of Figure 2;
- Figure 6a is a enlarged section view of Section 6a of Figure 5;
- 35 Figure 6b is an enlarged section view of Section 6b of Figure 5;

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Figure 7 is an enlarged section view of Section 7 of Figure 6b;
 Figure 8 is a section view showing Section A of Figure 2;
 Figure 9a is an enlarged section view of Section 9a of Figure 8;
 Figure 9b is an enlarged section view of Section 9b of Figure 8;
 5 Figure 10 is an enlarged section view of Section 10 of Figure 9b;
 Figure 11 is a section view showing Section A of Figure 2;
 Figure 12a is a enlarged section view of Section 12a of Figure 11;
 Figure 12b is an enlarged section view of Section 12b of Figure 11; and
 Figure 13 is an enlarged section view of Section 13 of Figure 12b.

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Detailed Description of Embodiments of the Invention

The building 10 shown in Figure 1 includes a plurality of PPVC modules 12 coupled together in a side by side configuration. The different precast components of the
 15 modules 12 are coupled together to form integral structural units. In the example shown, there are four modules 12a, 12b, 12c, 12d. However, it is anticipated that the building could include any suitable number and configuration of modules.

The modules 12 are particularly suited for building projects as they provide robustness
 20 on the overall building structure and enhanced durability. As shown, each module 12a, 12b, 12c, 12d generally includes 6 sides 14a, 14b, 14c, 14d, 14e, 14f respectively arranged to form:

- (a) a floor 14a;
- 25 (b) left 14b and right 14c side walls extending up from respective opposed sides for the floor 14a;
- (c) a ceiling 14d bridging the left and right side walls 14b, 14c; and
- (d) front and back walls 14e, 14f.

30 The 6 sides 14a, 14b, 14c, 14d, 14e, 14f enclose the internal space of each module 12 therefore allowing the unit to be fitted out off-site. For example, mechanical and electrical services may be installed off-site. Further, blockwall installation and waterproofing applications may also be performed off-site. Advantageously, a 6 sided module has its advantages in the short and long term life span of a building. For
 35 example, it provides robustness to the building at the fitting out stage, transportation,

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lifting and permanent stage. Advantageously, it protects finishes installed off-site especially fix glass panels and shower screens. It may also provide water tightness in all sides to protect high end finishes already installed off-site.

- 5 Advantageously, each PPVC module 12 may have a different configuration, for example a 2 bedroom unit or 3/4 bedroom unit with or without a balcony.

As shown, the modules 12 are also fitted off-site with windows 16, door frames 18 and balcony railings 19. Additionally, drywall partition frames and boards as well as tiles
10 and floor finishing may be installed off-site. After the PPVC module 12 is completed off-site, it is transported on-site and lifted, for example with a tower crane. Preferably, a special lifting frame is used to effectively lift and install heavy modules at the same time ensuring safety.

15 **Method of Constructing the Building 10**

As shown in Figure 2, the building 10 is constructed by performing the steps of:

- 20 (a) locating a mating surface 20 of a first module 12b adjacent a mating surface 22 of a second module 12c;
- (b) positioning a first channel 24 of the mating surface 20 of the first module 12b to overlie a second channel 26 of the mating surface 22 of the second module 12c; and
- 25 (c) at least partially filling a fastening channel 28 formed between said first channel 24 and the second channel 26 with a fastener 30.

Advantageously, each mating surface 20, 22 forms an outer peripheral surface of a side wall 14b, 14c of each module 12. For example, mating surface 20 forms an outer peripheral surface of a side wall 14c of module 12b and mating surface 22 forms an
30 outer peripheral surface of a side wall 14b of module 12c.

As particularly shown in Figure 3, each side wall 14b, 14c includes an array 32 of reinforced bars 34. Each array 32 provides structural strength to each side wall 14b and 14c in terms of flexure and shear.

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As shown, each side wall 14b, 14c includes one or more couplers 36 extending from the array 32 of reinforced bars 34 into the fastening channel 28.

The method also includes the step of inserting key bars 38 into the fastening channel 28 proximal to said couplers 36. Advantageously, key bars 38 are placed proximal to couplers 36, for example key bars 38 are placed adjacent or abutting the couplers 36. This allows the coupling mechanism of the system to activate under pull-out forces, preferably instantaneously.

Advantageously, the modules 12 are installed using alignment control apparatus 40 comprising alignment pins 42 and leveling plate 44 configured in the manner shown in Figure 4. For example, the diameter of the alignment pin 42 is 25 mm. Of course, other suitable diameters can also be used. Preferably, alignment pins 42 are used at the four corners of the top of the modules 12 to control the horizontal lateral movement. Preferably, the leveling plate 44 has dimensions of 200 X 100 X 16mm and is placed on top of alignment pin 42. A similar plate with dimensions of 200 x 100 x 1mm can be added on top of plate 44 to adjust and control the vertical alignment.

As particularly shown in Figure 3 to 7, the couplers 36 are cable loops 46 that are used to couple side walls 14c and side wall 14b of modules 12b, 12c. In this embodiment, fastener 30 is a grout 48 which is poured into the fastening channel 28 between the mating surface 20 of module 12b and the mating surface 22 of module 12c.

Preferably, the cable loop 46 is made of high-strength steel wire ropes according to European standard EN 12385-4:2002+A1, wire tensile strength Grade 1770 N/mm². Preferably, the cable loop 46 has mechanical properties of being flexible and also have a high tensile strength as compared to a normal reinforcing bar. By being flexible, the cable loop 46 provides for easy installation as it can be flexed but also has the ability to retain its original shape. With a high tensile strength, the cable loop 46 can have a reduced diameter size.

For example, cable loop 46 is affixed to the concrete by means of tying with wires unto a restrainer bar 35 as particularly shown on Figure 7. Of course, other means of affixing the cable loop 46 to the concrete is possible.

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For example, the grout 48 is high strength non-shrink grout G70 cube strength which conforms to EN445, EN446 and EN447. This allows the fluid to be able to fill cavities and to bond with the side walls 14b and 14c together to allow the system to act as a composite wall.

As particularly shown in Figures 6a, 6b and 7, the key bars 38 are substantially within the circular cable loops 46. This is to keep the walls from pulling out from each other.

The cross section of the fastening channel 28 is shaped as particularly shown in Figure 7 for providing ease in de-moulding formwork during the casting stage of side walls 14. Of course, the shape of the fastening channel 28 could be any shape.

The cable loops 46 are within the castellation joints which provide the necessary space for the cable loops 46 and the installation of key bars 38. The preferable spacing of castellation along the width of the wall is determined based on the structural requirements (pin connection) of each wall necessary to provide vertical continuity through the key bars 38.

The walls 14b, 14c are preferably 75 to 90mm thick so as to support the top slab 14d and bottom slab 14a during lifting and transportation. Preferably, the 20mm gap will be site in-fill from top with grouting to make up the overall 200mm thick composite structural wall.

Advantageously, the cable loops 46 have mechanical tensile properties appropriate for withstanding tensile forces during normal use.

Mechanical Testing Results

A total of two cable loops 46 were tested. Load was applied axially to the installed cable loops 46 by a centre-pull hydraulic jack system to the ultimate load. The maximum load applied was then recorded and the mode of failure recorded. The result are shown in the table below:

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Tensile Pull Out test on Wire Loop (circular type)

Sample Ref.	Test Member	Fixing Type	Applied Tensile Load (kN)	Observation After Test
T1	PBU panel	Wire Loop (Circular Type)	37.7	Failure within the wire loop material
T2			39.5	

Further test was performed on the vertical connections between precast wall-wall, column-wall connections with a circular connection loop. The test sample was placed on the universal testing machine in a vertical position and tension load was applied gradually until failure. The maximum load was then recorded. A total of five samples were tested.

Result:**Table : Tension Load Test**

Sample Reference	J Circular Connection Loop (JCCL) Ø6 X R60mm long Wire Rope				
	S1	S2	S3	S4	S5
Maximum Load (kN)	48.5	48.9	49.7	47.7	48.7
Position of Fracture	Drawn Out (See Photograph 2 attached)	Failure of wire (See Photograph 2 attached)		Drawn Out (See Photograph 2 attached)	Failure of wire (See Photograph 2 attached)

Further, cable loops pull out tension test results are as follows:

Cable Loop Anchorage pull out test				
Description 14 Day concrete strength	Jacking Force - kN		Design Force - kN	FOS- average value
	Sample 1	Sample 2		
Loop type (L-shape)	23.0	23.9	20	1.17
Circular type	37.7	39.5	20	1.93

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Advantageously, the grout 48 has mechanical properties that binds (sandwich) each side wall 14b and 14c together as one composite wall to allow the embodiments to be able to withstand structural loads during use. Axial compression test show sample

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- loaded to ultimate load equal to 2 times working load. Additionally, sample did not fail at ultimate test load and there was no delamination observed at the concrete/grout interface. Therefore axial compression test showed that the, sample behaved in a composite manner under axial compression and it has performed satisfactorily beyond the design capacity as an integrated unit and the strength of the grout-interface performed as well as the strength of the concrete.

Compression Test – 3mx1.2m sample size			
Description	Jacking Force kN	Design Force kN	Remarks
1mm chequered plate finish - Compression	7200	4800	No failure, no delamination
1mm chequered plate finish - Compression with ecc	7200	4800	Fail at 7200kN

- Further, bending test was performed on the sandwiched panels to verify flexural capacity of the panels and determine whether there is slipping issue between the precast panel and infill grout. The sample was loaded to failure and was found to fail by bending with flexural crack lines forming on surface. However, there was no delamination observed at the concrete/grout interface. Therefore bending test found that the sample behaved in a composite manner under bending.

Bending Test – 3mx1.2m sample size			
Description	Jacking Force kN	Design Force kN	Remarks
1mm chequered plate finish	260	173	Fail at 50% above design load

- Further, direct and indirect shear test was performed on the sandwiched panels to verify shear bond capacity between the panels and the grout using different surfaces of concrete to find the best possible rough surface finish that will achieve a high shear bond capacity.

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Direct Shear Test – 500mmx500mm sample size – 1mm chequered plate finish			
Sample No.	Shear Stress-MPa	Design Shear Stress - MPa	Factor of Safety -FOS
S1 (02.06.16)	1.45	0.44	3.29
S2 (02.06.16)	0.39	0.44	0.88
S3 (02.06.16)	0.48	0.44	1.09
S4 (02.06.16)	0.51	0.44	1.16
S1 (21.07.16)	1.44	0.44	3.27
S2 (21.07.16)	0.71	0.44	1.61
S3 (21.07.16)	0.60	0.44	1.36
S4 (21.07.16)	1.43	0.44	3.25
S5 (21.07.16)	1.22	0.44	2.77

Indirect Shear Test – 1100mmx270mm sample size				
Description	Sample 1 Shear Stress- MPa	Sample 2 Shear Stress- MPa	Design Shear Stress - MPa	FOS–lowest value
1mm chequered plate	3.59	1.71	0.44	3.88
1mm chequered plate w/ T10 bar groove	2.9	1.84	0.44	4.18
Broom brush finish	1.93	2.17	0.44	4.38
Exposed aggregates	2.40	2.21	0.44	5.02
3mm chequered plate w/ holes	1.38	1.08	0.44	2.45
5mm chequered plate	1.58	1.35	0.44	3.06
Wash aggregate	2.43	2.69	0.44	5.52
1mm chequered plate w/ 10mm groove @ 100mm	2.43	2.43	0.44	5.52

- Further, pull out tension test was performed to verify the tension capacity between the panels and the grout using different surfaces of concrete to find the best possible rough surface finished that will achieve a high tension capacity.

Pull out Tension Test Stage 1 – 500mmx800mm sample size					
Description	Jacking Force - kN			Design Force - kN	FOS– average value
	Sample 1	Sample 2	Sample 3		
1mm chequered plate	21.8	24.8	19.90	50	0.44
1mm chequered plate w/ T10 bar groove @ 150mm	70.50	64.50	47.70	50	1.22
1mm chequered plate w/ T10 bar groove @ 150mm + Studs @ 200mm	63.80	36.70	-	50	1.0
Wash aggregate + Stud @ 200mm	100.30	81.40	-	50	1.82

Pull out Tension Test Stage 2 ALL WASH AGGREGATE – 500mmx800mm sample size					
Description	Jacking Force - kN			Design Force - kN	FOS– average value
	Sample 1	Sample 2	Sample 3		
Normal recess w/o loops	128.90	94.20	179.60	50	2.68
Inverted key recess w/o loops	146.90	136.00	130.00	50	2.75
Normal recess + double loops	130.00	112.20	133.00	50	2.50
Inverted key recess + double loops	111.20	118.10	106.20	50	2.24
Normal recess + single loop + enhanced U-bar	272.80	207.30	206.30	50	4.58
Normal recess + H10 U-bar	159.70	173.60	-	50	3.33
Normal recess + double H10 U-bar	163.80	187.60	-	50	3.51

- The tests conducted led to the conclusion that the sandwich wall system performs as a composite wall after grouting. The material used as grout 48 allows the overall system of binding or coupling of the two side walls 14b, 14c together to meet the structural capacity of concrete in terms of bending, axial compression and shear. The various shear and tension tests established the a suitable surface and mechanical connection for the system. The structural design requires for a rough surface according to SS EN 1992-1-1:2008. The test showed that a rough surface achieved by washed aggregate gives a higher shear resistance value compared to the other types of rough surface tested and as such, is preferable for multi-level buildings.

Alternatively, a higher roughness i.e. indented according to SS EN 19920101:2008 may also be used. For low rise buildings i.e. with a small number of levels a smaller rough surface value may be used, for example by adopting a broom finish.

5 **Alternate Method of Constructing a Building**

In the embodiment shown in Figures 8 to 10, the couplers 36 of the modules 12b, 12c are U-bars 50 that are used to couple side walls 14c and side wall 14b. In this embodiment, fastener 30 comprises grout 48 which is used to fill the fastening
10 channel 28 between the mating surface 20 of module 14c and the mating surface 22 of module 14b.

The U-bar 50 is made of high tensile steel bar with yield strength of about 500 N/mm², for example. The U-bar 50 is preferable over cable loops 104 because it is
15 rigid and allows tensile force to be transferred rapidly. In contrast, cable loops 104 may elongate first before acting in tension. Additionally, U-bars 50 are more cost effective compared to cable loops 104.

The U-bars 50 are affixed to the precast wall 49 with proper anchorage length by
20 extending out from the array 32 of reinforced bars 34 into the fastening channel 28 as particularly shown in Figure 10. Preferably, the U-bar 50 of side wall 14c overlaps the U-bar 50 of side wall 14b as particularly shown in Figure 8.

As particularly shown in Figures 9a, 9b and 10, the key bars 38 are substantially
25 proximal to the U-bars 50.

Mechanical Testing Results

Mechanical testing for the U-bars 50 under tensile load was conducted to assess the
30 tensile strength of a H10 U-bar 50 connection joining two precast walls 49 and a grout core 48.

The table below itemises the concrete compression test results for each concrete batch by testing three concrete cubes with dimensions 10 cm x 10 cm x 10 cm.

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Concrete reference	Cube number	Compressive strength [MPa]
C1	1	82.7
C1	2	76.4
C1	3	85.2

C2	1	74.6
C2	2	78.4
C2	3	86.4

C3	1	92.3
C3	2	94.9
C3	3	91.9

The table below itemises the grout tension by flexion and compression for each grout batch by testing three grout prisms of dimensions 4 cm x 4 cm x 16 cm.

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Concrete reference	Prism number	Flexural Tensile strength [MPa]	Compressive strength, 1 [MPa]	Compressive strength, 2 [MPa]
G1	1	7.10	62.8	59.3
G1	2	7.34	59.4	56.3
G1	3	8.59	60.0	58.8
G1	4	8.80	59.6	61.7
G1	5	7.06	68.7	61.7
G1	6	7.80	64.2	63.0

G2	1	6.95	72.2	68.2
G2	2	6.91	70.3	74.9
G2	3	6.73	71.8	73.5
G2	4	5.53	72.2	69.5
G2	5	6.18	70.3	66.2
G2	6	6.85	71.8	69.2
G2	7	6.02	68.1	64.9
G2	8	7.40	66.3	69.3
G2	9	5.75	68.1	64.8
G2	10	5.74	79.1	77.0
G2	11	6.73	79.0	73.5
G2	12	6.02	75.3	75.7

G3	1	7.71	70.0	72.8
G3	2	8.47	74.3	75.2
G3	3	7.07	69.6	71.0
G3	4	9.15	58.8	59.4
G3	5	7.69	58.1	53.2
G3	6	8.65	59.2	55.1

G4	1	8.1	62.1	61.0
G4	2	8.61	63.8	63.1
G4	3	8.39	62.8	60.1
G4	4	7.63	65.4	62.0
G4	5	6.04	68.3	65.1
G4	6	8.15	67.0	64.8

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The table below itemises the tensile test results of the specimens with paraffin wax showing the maximum loads:

Specimen number	Date of test	Maximum load [kN]	Displacement corresponding to maximum load [mm]	Failure behaviour	Failure mechanism
P1	06/04/2017	40.2	3.48	Brittle	Anchorage of protruding reinforcement
P2	07/04/2017	36.1	4.37	Brittle	Anchorage of protruding reinforcement
P3	07/04/2017	43.6	3.54	Brittle	Anchorage of protruding reinforcement
P4	12/04/2017	40.0	4.38	Brittle	Anchorage of protruding reinforcement
P5	12/04/2017	40.3	4.11	Brittle	Anchorage of protruding reinforcement
P6	12/04/2017	37.7	3.45	Brittle	Anchorage of protruding reinforcement

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The table below itemises the tensile test results of the specimens without paraffin wax showing the maximum loads:

Specimen number	Date of test	Maximum load [kN]	Displacement corresponding to maximum load [mm]	Failure behaviour	Failure mechanism
B1	06/04/2017	50.0	0.10	Brittle	Shear failure of concrete panel
B2	07/04/2017	56.4	0.03	Brittle	Shear failure of concrete panel
B3	07/04/2017	33.5	3.85	Brittle	Anchorage of protruding reinforcement
B4	12/04/2017	38.3	0.07	Brittle	Shear failure of concrete panel
B5	12/04/2017	47.4	0.06	Brittle	Shear failure of concrete panel
B6	12/04/2017	50.9	0.00	Brittle	Shear failure of concrete panel

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Another Alternate Method of Constructing a Building

In the embodiment shown in Figures 11 to 13, the couplers 36 of the modules 12b, 12c are U-bars 50 that are used to couple side walls 14c and side wall 14b. In this embodiment, fastener 30 comprises chipping concrete 52 which is used to fill the fastening channel 32 between the mating surface 20 of module 14c and the mating surface 22 of module 14b. Advantageously, the distance between the mating surface

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20 of module 14c and the mating surface 22 of module 14b is at least 50mm for allowing the chipping concrete 52 to flow. Of course the distance can be any other distance.

- 5 As particularly shown in Figures 12a, 12b and 13, the key bars 38 are substantially proximal to the U-bars 50.

- 10 Chipping concrete 302 is high strength non-shrink concrete grout G70 cube strength, for example. Advantageously, aggregates are smaller in size and the mix is designed to allow the chipping concrete 302 to flow to fill every cavity. This will allow the chipping concrete 302 to bond to the mating surfaces of each side wall 14b and 14c together to act as a composite wall. Chipping concrete 302 can be used instead of grout 48 to reduce costs.

- 15 Throughout this specification, unless the context requires otherwise, the word "comprise", and variations such as "comprises" and "comprising", will be understood to imply the inclusion of a stated integer or step or group of integers or steps but not the exclusion of any other integer or step or group of integers or steps.

- 20 The reference to any prior art in this specification is not, and should not be taken as, an acknowledgment or any form of suggestion that the prior art forms part of the common general knowledge.

List of Parts

- Building 10
- Modules 12
- 5 Modules 12a, 12b, 12c, 12d
- Floor 14a
- Left wall 14b
- Right wall 14c
- Ceiling 14d
- 10 Front wall 14e
- Back wall 14f
- Windows 16
- Door frames 18
- Balcony railings 19
- 15 Mating surface 20 of a first module 12b
- Mating surface 22 of a second module 12c
- First channel 24 of the mating surface 20
- Second channel 26 of the mating surface 22
- Fastening channel 28
- 20 Fastener 30
- Array 32
- Reinforced bars 34
- Couplers 36
- Restrainer bar 35
- 25 Key bars 38
- Alignment control apparatus 40
- Grout stopper 41
- Alignment pins 42
- Backer rod 43
- 30 Levelling plate 44
- Cable loop 46
- Wire rope 47
- Grout 48
- Precast wall 49
- 35 U-bars 50

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Chipping concrete 52

Claims Defining the Invention

1. A method for constructing a building including a first module and a second module, including the steps of:
 - 5 (a) locating a mating surface of the first module adjacent a mating surface of the second module;
 - (b) positioning a first channel of the mating surface of the first module to overlies a second channel of the mating surface of the second module; and
 - 10 (c) at least partially filling a fastening channel formed between said first channel and said second channel with a fastener.
2. The method of claim 1, wherein each mating surface forms an outer peripheral surface of a side wall of each module.
- 15 3. The method of claim 2, wherein each side wall includes an array of reinforced steel bars.
4. The method of claim 3, wherein each side wall includes one or more couplers extending from the array of bars into the fastening channel.
- 20 5. The method claimed in claim 4, including the step of inserting a key into the channel proximal to said couplers.
- 25 6. The method claimed in any one of claims 4 or 5, wherein the couplers comprise one or more of the following:
 - (a) looping cables; and
 - (b) U-bars.
- 30 7. The method claimed in any one of claims 1 to 6, wherein the fastener comprises one or more of the following:
 - (a) grouting; and
 - (b) chipping concrete.

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8. A building including a first module and a second module, wherein:
- (a) a mating surface of the first module is adjacent to a mating surface of the second module;
 - (b) a first channel of the mating surface of the first module that overlies a second channel of the mating surface of the second module; and
 - (c) a fastening channel formed between said first channel and said second channel with a fastener, wherein the fastening channel is at least partially with a fastener.
9. The building of claim 8, wherein each mating surface forms an outer peripheral surface of a side wall of each module.
10. The building of claim 9, wherein each side wall includes an array of reinforced steel bars.
11. The building of claim 10, wherein each side wall includes one or more couplers extending from the array of bars into the fastening channel.
12. The building claimed in claim 11, including the step of inserting a key into the channel proximal to said couplers.
13. The building claimed in any one of claims 11 or 12, wherein the couplers comprise one or more of the following:
- (a) looping cables; and
 - (b) U-bars.
14. The building claimed in any one of claims 8 to 13, wherein the fastener comprises one or more of the following:
- (a) grouting; and
 - (b) chipping concrete.