

PPVC CONNECTOR

[0001] The present application relates to one or more PPVC (Prefabricated Prefinished Volumetric Construction) connectors for coupling PPVC modules together. The application also relates one or more methods for making, assembling, disassembling, installing, configuring, maintaining, repairing and using the one or more PPVC connectors in order to couple the PPVC modules.

[0002] The present application claims a priority date of a Singapore patent application Nr. 10201804186R, which was filed with IPOS (Intellectual Property Office of Singapore) on 17 May 2018, and has the title of Connector for PPVC Modules. Relevant content and/or subject of the earlier priority patent application is hereby incorporated by present reference wherever appropriate.

[0003] To raise construction productivity and fundamentally improve design and construction processes, Building and Construction Authority of Singapore (BCA) encourages construction industry to embrace a concept of Design for Manufacturing and Assembly (DfMA), whereby construction is designed such that as much work may be done off-site in a controlled manufacturing environment as possible.

[0004] PPVC is one of the game changing technologies that support the DfMA concept to significantly speed up building construction. PPVC can potentially achieve a productivity improvement of up to 50% in terms of manpower and time savings, depending on complexity of relevant projects. Furthermore, dust and noise pollution can be minimised as more activities are done off-site (i.e. away from building construction site). With the bulk of installation activities and manpower moved off-site to a factory controlled environment, building construction site safety is also improved.

[0005] Though important, connection between PPVC modules is inherently weak because walls, floors or side panels of different PPVC modules are prefabricated separately in factories, instead of constructed or cured together onsite continuously. Hence, the present application aims to provide one or more new and useful PPVC connectors for coupling multiple PPVC modules, which are known as building elements as well. The present application further aims to provide one or more new and useful methods for making, assembling, disassembling, installing, configuring, maintaining,

repairing and using the PPVC connector for coupling building elements or PPVC modules. Essential features of relevant inventions are provided by one or more independent claims, whilst advantageous features of these inventions are presented by their corresponding dependent claims respectively.

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[0006] According to an aspect, the present application provides a PPVC (Prefabricated Prefinished Volumetric Construction) connector that is typically fabricated before installation in order to couple, join, bind or fix a first PPVC module and a second PPVC module together permanently or temporarily. The PPVC connector comprises a first anchor for being attached to or embedded into/onto a wall (e.g. ceiling, floor, sidewall) of the first PPVC module. The PPVC connector also comprises a second anchor for being attached to or embedded into/onto the second PPVC module with non-shrink grout. The PPVC connector further comprises a frame (e.g. metal rod, rebar or plate) operable for coupling the first anchor and the second anchor together. The frame is usually a rigid, hard, tough, strong structural component or structure, although the frame is optionally resilient or springy. In contrast, a string, a rope or a floppy wire that is not capable of maintain or keep a predetermined formation in the absence of external force. The frame is configured to restrict, restrain, limit, confine, or prevent detachment, misalignment or relative movement between the first PPVC module and the second PPVC module, whether in a plane or in more than two Cartesian directions (e.g. lateral directions of the PPVC modules). The frame is alternatively known as a restrictor, a restrainer, a coupler, a firm connector or a linkage that stops departure of the two anchors or PPVC modules from each other. One or more parts of the PPVC connector are able to be integrally formed, or assembled by several components. For example, the first anchor and the frame are optionally in unitary form or snapped on, being convenient to deploy.

[0007] The PPVC connector is usually designed for manufacturing in bulk, having all of its components packaged separately. Since the first anchor and the second anchor can be ingrained or planted into walls or other parts of PPVC modules respectively at predetermined locations according to specific orientations, the frame can be speedily, easily and securely installed at a building site where the two PPVC modules are aligned and next to each other. In fact, the anchors can even be used as guides or signposts for locating PPVC modules. Since the frame or the PPVC connector is able to tie or fasten PPVC modules together, a building with the PPVC modules become robust and sturdy, being able to withstand earthquake or other natural disasters over many years.

[0008] One or more parts or pieces of the first anchor, the second anchor and the frame can have a dimension (e.g. height or length) of more than 50 millimetres, 100 millimetres, 150 millimetres, 200 millimetres, 250 millimetres or extending throughout a height of the two PPVC modules substantially. For example, one or more pieces of the first anchor, the second anchor, the frame or other components of the PPVC connector comprises one or more plates, which has a dimension (e.g. height or length) of more than 50 millimetres, 100 millimetres, 150 millimetres, 200 millimetres, 250 millimetres or extending throughout a height of the two PPVC modules substantially. If the dimension or one dimension of the plate is substantially larger than other dimensions of the plate, the plate is also perceived as an elongated plate effectively. If one or two edges of the plate are folded, a cavity defined by two neighbouring faces of the plate can define a cavity between the two neighbouring faces. For instance, if two opposite edges of the elongated plate are folded symmetrically towards each other, the elongated plate forms a trough whose cavity is able to receive grout or other types of fillers. For the convenience of usage or installation, a longitudinal direction of the elongated plate is substantially parallel to a vertical or height direction of a PPVC module before or after its coupling.

[0009] The first anchor comprises an elongated plate that may be folded (with a single fold or multiple folds at an edge or middle) (e.g. having a U-shaped profile) (in a length and/or width directions, but not in a height direction of the PPVC modules or a longitudinal direction of the first anchor) (for providing a cavity by the first anchor or together with a wall of the PPVC modules). A cross section of the first anchor optionally has a square, a round or any other geometry shape or profiles, as projection of on a two dimensional surface (e.g. a plane), such as resembling profiles of pattern blocks. As an illustration, a hollow conduit formed by the first anchor or anchor is able to receive a cylinder with diameter of about 10 millimetres (mm), 15 millimetres, 23 millimetres, 38 millimetres, 50 millimetres or 60 millimetres substantially. Similar to the first anchor or simple anchor, the second anchor optionally comprises another elongated plate that is folded with a single fold or multiple folds for providing a cavity by the second anchor.

[0010] One or more pieces of the first anchor, the second anchor and the frame are optionally corrugated, roughened or checked (e.g. having a continuous or repeated pattern of squares or other regular shapes) for capturing grout or other types of adhesives. If a component, piece or part of the PPVC connector (e.g. anchor or frame) is made of a

plate, the plate is possibly punctured, roughened or surface treated (e.g. coated, sandblasted) that is able to keep the grout or adhesives better than a smooth or polished surface.

5 [0011] One example of corrugation includes regular patterns or repeated formations on the one or more pieces of the first anchor, the second anchor and the frame. A distance between two neighbouring or close perforations is about 10 millimetres, 18 millimetres, 27 millimetres, 36 millimetres, 50 millimetres, 68 millimetres or 72 millimetres substantially. The component, piece or part is optionally further attached (e.g. welded)
10 with other thin structure for improving surface adhesion, including woven & welded wire mesh.

[0012] One or more components, pieces or parts of the first anchor, the second anchor and the frame are sometimes perforated for passing grout through perforations on the
15 first anchor, the second anchor or the frame. Since one or more adhesives (including grout) are slurry before curing or solidification, the one or more adhesives are capable flow through the perforations in order to fill cavity of the first anchor, the second anchor, both anchors or the PPVC connector, whether alone or together with one or more PPVC modules. If the perforations are substantially similar, each similar perforation sometimes
20 has an outer diameter of 8 millimetres, 16 millimetres, 20 millimetres, 28 millimetres or 36 millimetres substantially.

[0013] Preferably, one or more of the first anchor, the second anchor and the frame have a thickness or diameter of three (03), four (04), six (06), eight (08) millimetres
25 substantially. Rods or plates of these parts that are made of steel or steel alloy are able to be manufactured in large quantity at low cost and high quality.

[0014] In some cases, the frame comprises a first coupler having two wings, extensions or prongs that are spaced apart and possibly face each other in forming a cavity, resembling a "C" or "U" shape for receiving one or more edges (e.g. two edges) of the
30 first anchor and the second anchor respectively. The two projected parts (e.g. known as prongs) are able to kept protruded parts of the anchors inside the cavity, which locks the two anchors and their respective PPVC modules together.

[0015] In some instances, the frame further comprises a second coupler having two wings, extensions or prongs that are spaced apart for receiving edges or extensions of the first anchor and the second anchor. The two couplers of the frame are able to hold the two anchors from opposite or multiple sides or directions, improving strength of the joint between the two PPVC modules. Embodiments of the application provides that the frame further comprises a rib (e.g. a plate or rod) that joins the first coupler and the second coupler together.

[0016] The first anchor can comprise a first bar (also known as, rod, rebar or reinforcing bar) and a second bar that are spaced apart from each other. Similarly, the second anchor comprises a bar and another bar that are also spaced apart from each other. The first bar or second bar is operable to extend along a longitudinal direction of any of the anchors, and/or parallel to a height or vertical direction of any of the PPVC modules. A PPVC module is a building unit, including a living unit, a bathroom unit, a storeroom unit or a sitting room unit, which are capable of being joined, assembled or stacked to complete a building or a, integral part of the building.

[0017] The present application further provides an assembly or building assembly of PPVC modules (e.g. a multistorey building) that comprises a first PPVC module, a second PPVC module and possibly other PPVC modules. The first anchor of the PPVC connector is attached or embedded to the first PPVC module, whilst the second anchor of the same PPVC connector is attached or embedded to the second PPVC module. The first PPVC module and the second PPVC module are sometimes laterally assembled together, being neighbouring to each other. The assembly or building assembly is a unitary body because the PPVC connector securely fastened the two PPVC modules together, whether temporarily or permanently. One or more of the assemblies are further capable of being stacked, preferably by aligning stacked PPVC modules along their respective walls. In fact, the PPVC connector is further possible protrude above a PPVC module for aligning a top PPVC module. For example, the PPVC connector has a cavity to receive a bar or dowel bar that passes through two longitudinally aligned PPVC connectors in their cavities.

[0018] The assembly of PPVC modules can further comprise a filler, an adhesive, sealant and/or a binder that fills cavities formed by the first anchor, the second anchor, the frame or a combination of any of these parts or components, whether fully, partially,

progressively or instantaneously. The filler, adhesive and/or binder not only expel air from the cavities, but also unite the parts (e.g. the PPVC connector and PPVC modules) integrally. It is often desirable that the PPVC connector, the filler, the adhesive, the sealant and/or the binder is water resistant, fireproof, fire retardant, shockproof, pest resistant, corrosion resistant, weatherproof, wear resistant, or having a combination of any of these characteristics.

[0019] The first anchor and the second may be aligned (e.g. face each other with openings of their cavities) for receiving the frame or an opposite piece (e.g. an anchor). Since the PPVC connector may be mass produced, a building constructor or worker is easy to identify matching pieces of anchors on different PPVC modules for matching.

[0020] One or more cavities are optionally formed by the first anchor, the second anchor and the frame extends substantially over an entire height of any of the PPVC modules. The PPVC connector are optionally configured to extend over an entire height or a portion of a PPVC module. For example, two PPVC connector extend throughout the entire height of two neighbouring PPVC modules, whilst another PPVC connector extends only a portion of the height in the middle of the two joining PPVC modules.

[0021] The PPVC connector is sometimes submerged substantially into or below a surface (e.g. buried inside) of a wall of one of the PPVC modules, whether fully or partially. Hence, one or more parts of the PPVC connector (e.g. first anchor) becomes integrally joined to a PPVC module, which provides a strong linkage for coupling two PPVC modules together. The PPVC connector possibly offers an unbreakable, shatterproof or adamant connexion, which ensures integrity of the building assembly.

[0022] Embodiments of the assembly of PPVC modules comprises a first PPVC connector and a second PPVC connector, which are substantially identical or similar to the PPVC connector. The first PPVC connector and the second PPVC connector are attached or embedded to the same wall of any of the PPVC modules. Accordingly, a single PPVC module has multiple pieces of PPVC connectors or anchors for joining another PPVC module. The multiple pieces of PPVC connector is possible to confine, reduce, eliminate or obviate misalignment or detachment of two connected PPVC modules.

[0023] The first PPVC module and the second PPVC module are preferably spaced apart from each other with an even gap in-between for infilling by grout or filler. Instead of having hard walls of two neighbouring PPVC modules being pushed against each other, the filler or grout provides a “glue” and “cushion”, which can be used to adjust distance between two neighbouring PPVC modules, whether laterally or vertically. Multiple, additional or other types of connectors are optionally installed between two laterally or vertically neighbouring PPVC modules in order to fasten the two PPVC modules together. These PPVC connectors are optionally further connected or inter-locked to each other for secure and resilient fastening, such as against earthquake.

[0024] In some cases, the assembly of PPVC module further comprises a third PPVC module that is stacked on any of the PPVC modules. Two stacked PPVC modules are optionally aligned vertically by one or more bars or dowel bars, which sometimes are inserted into a PPVC connector or anchor. A single bar or dowel bar is optionally inserted into multiple PPVC connectors or anchors, which are aligned vertically in order to provide a straight cavity. For instance, a bar, a rebar or a dowel bar is enclosed by the first anchor. The bar, rebar or dowel bar is subsequently casted into the anchor or PPVC connector by grout, cement or any other adhesive, providing excellent bonding between PPVC modules.

[0025] According to another aspect, the present application provides a method for using a PPVC connector. The method comprises a first step of attaching a first anchor to a wall of a first PPVC module; a second step of attaching a second anchor to a wall of a second PPVC module; and a third step of coupling the first anchor and the second anchor by a frame in order to prevent detachment between the first PPVC module and the second PPVC module. Some of these steps can be combined, divided or changed in sequence. For example, the second anchor is firstly attached to the wall of the second PPVC module. The present method provides a simple, reliable and low cost of securing two PPVC modules together.

[0026] The method can further comprise a step of filling a gap between the first anchor, the second anchor and the frame with a filler (e.g. adhesive, grout). The filler not only can optionally glue the two PPVC modules together, but also can be used to adjust distance between the two adjoining PPVC modules. In some circumstances, the filler is resistive to water penetration, pest, corrosion or any other impairment.

[0027] The method of may additionally comprise a step of bonding the first PPVC module and the second PPVC module together by curing the filler. When applied, the filler is sometimes a fluidic or slurry form, being easy to flow or entering gaps. Once cured, whether by air, heat or automatically over a predetermined period of time, the filler is able to seal any shape or size of gap, being flexible and reliable for infilling. The filler will create confinement effect between the first anchor and the second anchor by using frame, and increase bond and tie force between the connected PPVC modules.

[0028] According to a further aspect, the present application provides a method for making a PPVC connector. The method comprises a first step of providing a plate for attaching the plate to a wall of a first PPVC module as an anchor; a second step of corrugating the plate for improving surface adhesion of the plate to the wall; and a third step of folding the plate for creating multiple sides in order to attach to the wall more securely. Some of these steps can be combined, divided or changed in sequence. For example, the third step of folding the plate optionally precedes the previous the second step of corrugating the plate. Parts of the PPVC connectors are able to be manufactured easily at low cost.

[0029] The method can further comprise a step of offering a frame for coupling the plate with another anchor together. The frame is able to prevent or reduce movement of the two anchors or two adjoining PPVC modules from detachment, which typically move in a plane or two dimensional according to a Cartesian coordinate system. Put differently, under a cylindrical coordinate system, the frame is able to delimit, restrict, restrain or prevent respective movement between two adjoining PPVC modules in its cylindrical axis, especially confining radial movement of the cylindrical coordinate system.

[0030] The accompanying figures (Figs.) illustrate embodiments and serve to explain principles of the disclosed embodiments. It is to be understood, however, that these figures are presented for purposes of illustration only, and not for defining limits of relevant applications.

Fig. 1 illustrates a plan of two facing walls with an assembly;

Fig. 2 illustrates a plan and a perspective of the assembly for coupling the two facing walls;

Fig. 3 illustrates a perspective of a C-channel and a lipped C-channel;

Fig. 4 illustrates a perspective of an inner face of a first wall having five indentations;
Fig. 5 illustrates a perspective of two facing walls with the assembly;
Fig. 6 illustrates a side view of two walls stack on top of each other; and
Fig. 7 illustrates a perspective of two PPVC modules joined at an adjoining long face.

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[0031] Exemplary, non-limiting embodiments of relevant inventions will now be described with references to the above-mentioned figures.

[0032] Fig. 1 illustrates a plan of two facing walls with an assembly 100. The plan of two
10 similar walls arranged side by side along an adjoining long face 102 with a wall breadth
104 of about one hundred millimetres (100 mm), a wall length 106 of about one thousand
two hundred millimetres (1,200 mm) and a wall height 108 of about three thousand one
hundred and fifty millimetres (3,150 mm) (not shown in Fig. 1). A grating gap 110 of about
20 mm separates the two walls.

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[0033] The assembly comprises a PPVC (Prefabricated Prefinished Volumetric
Construction) connector for coupling a first PPVC module 208 and a second PPVC
module 210. The PPVC module 208,210 comprises walls, floors and ceilings which are
constructed and assembled at an offsite fabrication facility. This PPVC module 208,210
20 is then transported and installed in a building under building works. In the following
description, the connector for walls are described in detail; coupling two walls side by
side at one face and coupling two walls by stacking one on top of the other at another
face.

[0034] For ease of identification the two similar walls are known as a first wall 112 and a
second wall 114. The first wall 112 and the second wall 114 has six faces each. The top
outer surface of the first wall 112 and the second wall 114 is known as a first top face
116 and a second top face 117 respectively. An opposite face of the first top face 116 is
a first bottom face 118 which is not shown in Fig. 1. An opposite face of the first adjoining
30 long face 102 is a first opposite long face 120. A first primary side face 122 is a narrow
face that meets the first adjoining long face 102 with the first opposite long face 120 and
the first top face 116 with the first bottom face 118. Opposite the first primary side face
122 is a first secondary side face 124. The term "opposite" is used to describe a distal
side or a far side across a proximal side.

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[0035] There are three assemblies as seen on the first top face 116 of the first wall 112 comprising a first assembly 126, a second assembly 128 and a third assembly 129. The second assembly 128 is interposed between the first assembly 126 and the third assembly 129. Each assembly 126,128,129 comprises an at least one anchor and a restrictor 134. Further details of each assembly 126,128,129 will be described subsequently. The restrictor 134 is also known as a restrainer or a frame.

[0036] A first anchor 130 is secured to the first wall 112 whilst a second anchor 132 is secured to the second wall 114. The restrictor 134 encloses the first anchor 130 and the second anchor 132 in other words, the restrictor 134 brings the two anchors 130,132 together which holds the two walls 112,114 together.

[0037] The first assembly 126 proximal to the first primary side face 122 has a first assembly-to-side distance 136 of two hundred millimetres (200 mm). The first assembly-to-side distance 136 is measured from the first primary side face 122 to a centre of the first assembly 126 proximal to the first primary side face 122 or from the first secondary side face 124 to a centre of the third assembly 129 proximal to the first secondary side face 124. A first-to-second assembly distance 138 is four hundred millimetres (400 mm) as measured from the centre of the first assembly 126 to the centre of the second assembly 128.

[0038] The first wall 112 has three indentations 140,142,144 on the adjoining long face 102 which is clearly shown in Fig. 4. A first indentation 140 is proximal to the first primary side face 122. A second indentation 142 is at the centre of the first wall 112. A third indentation 144 is proximal to the first secondary side face 124 of the first wall 112. The first indentation 140 has an indentation depth 148 of fifty millimetres (50 mm) and an indentation breadth 146 of two hundred millimetres (200 mm). The first indentation 140 and the third indentation 144 have similar dimensions. The second indentation 142 has an indentation depth 148 of seventy-five millimetres (75 mm) and an indentation breadth 146 of two hundred millimetres (200 mm). Notably, the second indentation 142 has a deeper indentation i.e. deeper into the wall.

[0039] The first assembly 126, the second assembly 128 and the third assembly 129 as mentioned comprises the first anchor 130, the second anchor 132 and the restrictor 134. In the case of the first assembly 126, the first anchor 130 is a C-shaped anchor which is

known as C-channel 150 whilst the first anchor 130 of the second assembly 128 is a shear bar 135 embedded in the first wall 112 in an erected position exposing a top section at the first top face 116. There are two shear bars 135 embedded in each second indentation 142 of each wall 112,114. The anchor is used to describe a device being
5 secured to a fixed structure such as the wall.

[0040] The restrictor 134 of the first assembly 126 also has a C-shaped profile which is known as the lipped C-channel 152 is smaller in size compare to the anchor 130,132 or the C-channels 150. The restrictor 134 of the second assembly 128 has a square profile
10 with four rounded corners circumscribing the two first anchors 130 and the two second anchors 132. The restrictor 134 used in the second assembly 128 is also known as a roof slab connector 206. The restrictor 134 is used to describe a connector that connects or binds more than one anchor 130,132 together.

[0041] Noting in the first assembly 126 there are black markings. The black markings denote perforations along the first anchors 130 and the second anchors 132 specifically for the first assembly 126 which are not shown in Fig. 1. From the plan, the first anchors 130 and the second anchors 132 have perforations at two flanks. The restrictor 134 in the first assembly 126 has perforations at a long side and two short sides. The two short
15 sides flanking from the long side. The black markings or the perforation has an outer diameter of twenty millimetres (20 mm).

[0042] Fig. 2 illustrates a plan and a perspective of the first assembly 126 for coupling the two facing walls. The first assembly 126 comprises the C-channel 150 (anchor 130) and the lipped C-channel 152 (restrictor 134). The C-channel 150 is also known as CC1 and the lipped C-channel 152 is also known as CC2. The walls are not shown in Fig. 2.
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[0043] The C-channel 150 comprises a base portion 154, a right portion 156 and a left portion 158. The right portion 156 and the left portion 158 flanking on each end of the base portion 154. The right portion 156 and the left portion 158 further extends over the base portion 154 forming an overhanging extension 166 to form an open portion 160. Interposed between the open portions 160 of the two C-channel 150 is a corrugated pipe 178. The corrugated pipe has a pipe diameter 180 of fifty millimetres (50 mm). Inserted in the corrugated pipe 178 at the right open portion 160 is a dowel bar 182 as shown by
30 a shaded circle.
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[0044] The base portion 154 has a base breadth 162 of two hundred millimetres (200 mm). The right portion 156 and the left portion 158 has a side portion depth 164 of fifty millimetres (50 mm). The overhanging extension length 168 over the base portion 154 measures fifty millimetres (50 mm) on each side. A C-channel thickness 170 measures four millimetres (04 mm).

[0045] The restrictor 134 of Fig. 2 is formed by having the two lipped C-channel 152 joined together at a middle section by a rebar 172 as shown in Fig. 2. The lipped C-channel 152 also has a similar profile to the C-channel 150 but smaller in size as seen from the plan. Three rebar 172 are used to join the two lipped C-channel 152 specifically along a lipped C-channel length 174 of the lipped C-channel 152. The lipped C-channel length 184 measures three thousand one hundred and fifty millimetres (3,150 mm) which is similar to the wall height 108. Each rebar has a rebar length 174 of seventy-two millimetres (72 mm) with a rebar diameter 176 of six millimetres (06 mm).

[0046] In the perspective of the first assembly 127 of Fig. 2, the three rebar 172 are not seen. The three rebar 172 are positioned along the lipped C-channel length 184 specifically at one thousand and fifty millimetres (1,050 mm) interval between each rebar 172. A partial view of the perforations is seen on the overhanging extensions 166 of the C-channel 150. A partial view of the perforations is also seen on the lipped C-channel 152.

[0047] Fig. 3 illustrates a perspective of the C-channel 150 and the lipped C-channel 152. The C-channel 150 is shown on the left hand side and the lipped C-channel 152 is shown on the right hand side.

[0048] The C-channel 150 having the right portion 156 and the left portion 158 flank on the two edges of the base portion 154. Concentric holes 186 are formed on the overhanging extensions 166 on the right portion 156 and the left portion 158. The diameter of each concentric hole 186 is twenty millimetres (20 mm). There are nine concentric holes 186 which are equally distributed along a C-channel extension length 188 of the overhanging extension 166. A concentric hole gap 190 between two concentric holes 186 is three hundred and fifty millimetres (350 mm).

[0049] The lipped C-channel 152 comprises a lipped base portion 192, a lipped right portion 194, a lipped left portion 196 and a lipped overhanging portion 198. Similar to the C-channel 150, the lipped C-channel 152 has a similar profile but smaller. The lipped base portion 192 measures eighty millimetres (80 mm). The lipped right portion 194 and the lipped left portion 196 measures forty millimetres (40 mm) each. The lipped overhanging portion 198 measures fourteen millimetres (14 mm). The lipped C-channel has a lipped C-channel thickness of four millimetres (04 mm). There are nine concentric holes 186 each on the lipped right portion 194, the lipped left portion 196 and the lipped base portion 192. The concentric holes 186 are equally spaced along a length of the lipped C-channel 152.

[0050] The C-channel extension length 188, the lipped C-channel length 184 and the wall height 108 all has the same measurement of three thousand one hundred and fifty millimetres (3,150 mm). The concentric holes 186 that are on the C-channel 150 and the lipped C-channel are representations. There are more than nine concentric holes 186 in reality.

[0051] Fig. 4 illustrates a perspective of the first adjoining long face 102 of a first wall 112 having five indentations. The first indentation 140, the third indentation 144 and a fifth indentation 204 has a C-channel 150 embedded therein. The first indentation 140, the third indentation 144 and the fifth indentation 204 extends along the height of the first wall 112 which has a wall height 108 measuring three thousand one hundred and fifty millimetres (3,150 mm). A corrugated pipe 178 is joined to the C-channel 150 lengthwise specifically at the centre of the base portion 154 in the first indentation 140, the third indentation 144 and the fifth indentation 204. The length of each corrugated pipe 178 is eight hundred millimetres (800 mm).

[0052] The first indentation 140 is positioned at a first assembly-to-side distance 136 of two hundred millimetres (200 mm) from the first side face 122. This same measurement applies from the second side face 124 to the fifth indentation 204.

[0053] The first-to-second assembly distance 138 of four hundred millimetres (400 mm) applies between indentations; the first indentation 140 to the second indentation 142, from the second indentation 142 to the third indentation 144, from the third indentation 144 to the fourth indentation 202 and from the fourth indentation 202 to the fifth

indentation 204. The wall length 106 measures two thousand millimetres (2,000 mm) in total. The second indentation 142 and the fourth indentation 202 has two vertical shear bars 135 embedded therein. The second indentation 142 and the fourth indentation 202 has an indentation depth 148 of 75 mm which means 75 mm of the shear bars 135 are exposed.

[0054] Fig. 5 illustrates a perspective of two facing walls 112,114 with the assemblies 126,128. Two similar walls are positioned in which the adjoining long faces 102 are facing each other. The first indentation 140 of the first wall 112 meets the fifth indentation 204 of the second wall 114. The second indentation 142 of the first wall 112 meets the fourth indentation 202 of the second wall 114. The third indentation 144 of the first wall 112 meets the third indentation 144 of the second wall 114. The fourth indentation 202 of the first wall 112 meets the second indentation 142 of the second wall 114. The fifth indentation 204 of the first wall 112 meets the first indentation 140 of the second wall 114.

[0055] Two lipped C-channel 152 are inserted into the two adjoining C-channels 150 in the first indentation 140, the third indentation 144 and the fifth indentation 204. The lipped C-channel 152 is positioned orthogonally with respect to the C-channel 150 before inserting in the two C-channels 150. The overhanging extension 166 of the C-channel 150 and the lipped overhanging portion 198 of the lipped C-channel 152 are communicatively engaged. Over at the second indentation 142 and the fourth indentation 202 a roof slab connector 206 is communicatively engaged with the two shear bars 135 of the first wall 112 and the two shear bars 135 of the second wall 114.

[0056] The lipped C-channel 152 is protruded over the first top face 116 and the second top face 117 of the two walls 112,114. The protrusion measures two hundred and forty-five millimetres (245 mm) measured from the top face 116,117 to the apex of the lipped C-channel 152.

[0057] Fig. 6 illustrates a side view of two walls 112,114 stack on each other specifically the second wall 114 is on top of the first wall 112. The lipped C-channel 152 protruded from the top face 116 of the first wall 112 extends into the bottom of the C-channel 150 of the second wall 114. The lipped C-channels 152 of the second wall 114 protrudes out from the second top face 117 of the second wall 114. The corrugated pipes 178 are in between the C-channels 150. The dowel bars 182 are within the corrugated pipes 178

which extends from the second top face 117 of the second wall 114 to the end of the corrugated pipes 178 inside the first wall 112.

[0058] Fig. 7 illustrates a perspective of two PPVC modules 208 joined at an adjoining long face 102. The first PPVC module 208 is a terminating PPVC module which has PPVC connectors only on one side thereof. The second PPVC module 210 has PPVC connectors on the two adjoining long faces 102 thereof. The PPVC connectors comprise first, the C-channel 150 acts as the anchor and the lipped C-channel 152 which acts as the coupler; and second the shear bars 135 which act as the anchor and the roof slab connector 206 acts as the coupler.

[0059] The second PPVC module 210 has an exposed adjoining long face 102 revealing the eight long indentations that extends from the top face 116 to the bottom face 118 thereof. The exposed adjoining long face 102 corresponds to the first wall 112 as shown in Fig. 4. Each of the eight indentations have a pair of C-channels 150 embedded. The two C-channels 150 are embedded within and along the indentation and facing each other.

[0060] The roof slab connector 206 is a bar formed into a square with rounded corners. The first PPVC module 208 and the second PPVC module 210 are coupled by placing the roof slab connector 206 into the two exposed shear bars 135 of the first PPVC module 208 and into the remaining two shear bars 135 of the second PPVC module 210. The roof slab connector 206 circumscribing the four shear bars 135. There are six short indentations on the exposed adjoining long face 102. Each short indentation is interposed between two long indentations. Each short indentation has two shear bars 135 embedded exposing the top section of the shear bars 135 for receiving the roof slab connector 206. Alternatively, the roof slab connector 206 can be a sheet of solid metal with four holes bored in four positions which correspond to the positions of the shear bars 135 embedded in the walls of the PPVC modules 208,210.

[0061] The placement of the PPVC modules 208, 210 is with respect to a three-dimensional coordinate system 212 (also known as artesian coordinate system). The second PPVC module 210 is positioned on the adjoining long face 102 of the first PPVC module 208 having the PPVC connectors 126, 128, 129 specifically in the x-axis direction. The PPVC modules 208, 210 can also be placed on top of the first PPVC module 208

and the second PPVC module 210 in the z-axis direction as shown in Fig. 7. More PPVC modules can also be placed in the x-axis direction provided there are PPVC connectors available in the PPVC module in that direction. Both x-axis and y-axis represent lateral directions of the PPVC modules 208, 210, whilst the z-axis represents a vertical direction of the PPVC modules 208, 210. If using a cylindrical coordinate system, both x-axis and y-axis are radial directions, whilst z-axis is known as cylindrical or longitudinal axis, such as longitudinal axes of the PPVC connectors or assemblies 126, 128, 129.

[0062] Functionally, the PPVC connectors 126, 128, 129 provides a coupling means to couple two walls together. The PPVC connector 126, 128, 129 can comprise the first assembly 126 and the second assembly 128. Terms of PPVC connector, connector and the assembly 126, 128, 129 are coupling means which are analogous, sometimes used interchangeably.

[0063] The two walls 112, 114 which is part of the PPVC module 208 are made of concrete which is a composite material composed of fine and coarse aggregate bonded together with a fluid cement that hardens over a time period. The aggregate is a broad category of coarse to medium grained particulate material used in construction, including sand, gravel, crushed stone, slag, recycled concrete and geosynthetic aggregates.

[0064] The first assembly 126 comprises a C-channel 150 and a lipped C-channel 152. A first C-channel 150 is embedded in the first wall 112 and a second C-channel 150 is embedded in the second wall 114. The two C-channels 150 embedded in the two walls provide the anchor which extends from the top face 116 to the bottom face 118 of the wall.

[0065] The lipped C-channel comprises the restrictor 134 which provides a coupling of the two walls together by securing the two C-channels 150. The lipped C-channel is communicatively engaged with the two C-channels 150 by sliding downwards from the top face 116.

[0066] The C-channel 150 and the lipped C-channel 152 are made of structural steel. Structural steel is used and can be described as 'S275J2' or 'S355K2W'. In these examples, 'S' denotes structural rather than engineering steel; 275 or 355 denotes the yield strength in Newtons per square millimetre or the equivalent mega Pascals; J2 or K2

denotes the materials toughness by reference to Charpy impact test values; and the 'W' denotes weathering steel. Further letters can be used to designate fine grain steel ('N' or 'NL'); quenched and tempered steel ('Q' or 'QL'); and thermomechanically rolled steel ('M' or 'ML'). Alternatively, steel used for building construction in the United States use standard alloys identified and specified by ASTM (American Section of the International Association for Testing Materials) International.

[0067] In practice, a first PPVC module 208 comprising at least one wall is installed on a levelled plane. The levelled plane can be structural pillars which are supporting the first PPVC module 208 from beneath. The structural pillars have protruding rebar that provides the installation of the first PPVC module 208 thereon. Subsequent PPVC modules 208 are installed either next to the first PPVC module 208 or on top of it. Hence, the lipped C-channel is inserted from the top face of the wall through the two C-channels 150. As the rebar from the structural pillars extends into the bottom of the C-channels 150 of the first PPVC module 208, the lipped C-channel 152 inserted via the top face 116 will have exposed partial section extending from the top face 116. The exposed partial section of the lipped C-channel 152 is to provide a guide for the insertion of another C-channel 150 of another PPVC module 208 stacked on top.

[0068] The concentric holes 186 on the overhanging extensions 166 of the C-channel 150 provides a channel for the grout to flow freely in a cavity. The cavity refers to a hollow space in the C-channel 150. The grout is to filled the cavity. The concentric holes 186 on the lipped base portion 192, the lipped right portion 194 and the lipped left portion 196 provides the free flowing of the grout in the cavity as well as in the grating gap 110. The grating gap 110 is formed with the two walls are in close proximity but not contacting so as to allow the grout to bind the two walls together and also provides an expansion gap in hot weather. As the grout is of a certain viscosity, the concentric hole gap 190 between each concentric hole 186 is kept at 50 mm to ensure complete immersion of the grout without any air pocket formed.

[0069] The overhanging extensions 166 of the C-channel 150 and the lipped overhanging portion 198 of the lipped C-channel 152 provide a gap and a guide when inserting the lipped C-channel 152. The gap can be marginally proximal to each other (referring to the two C-channels 150 and the lipped C-channel 152). To ensure a fixed gap between two lipped C-channels 152 and to facilitate easy installation, the rebar 172 is used to join the

two lipped C-channels 152 specifically at the lipped base portions 192. The rebar 172 can be chosen to be longer to have the lipped C-channel 152 proximal to the C-channels 150 or shorter to be spaced further apart.

5 [0070] The corrugated pipe 178 is joined to the inner surface specifically at the centre of the base portion 154 of the C-channel 150. The corrugated pipe 178 provides a sleeve and a guide for the insertion of the dowel bar 182. The dowel bar 182 provides added structural strength. The corrugated pipe 178 extends partially along the C-channel 150 for allowing a lower section end of the dowel bar 182 to be covered by the grout. An
10 upper section of the dowel bar 182 is in the corrugated pipe 178. Grout also flows into the corrugated pipe 178 engulfing the dowel bar 182. The corrugated pipe 178 having the uneven surface provides additional bonding of the grout thereon.

[0071] The second assembly 128 provides an alternative to the coupling of the two walls. Two shear bars 135 are embedded into the wall specifically at the adjoining long face
15 102 of each wall. Only a partial top end of the shear bars 135 are exposed to provide the restrictor 134 to attach itself to the two shear bars 135. The indentation depth 148 of the second assembly extends partially below the top face 116 of the wall. The indentation depth 148 provides a fixed distance on how far the restrictor 134 can travel. The second assembly can provide some sort of locking mechanism to secure the two walls prior to
20 installing the lipped C-channels 152 into the C-channels 150 for the first assembly 126.

[0072] The PPVC connector provides a method of making which comprises firstly, embedding the first C-channel 150 to the first wall 112 of the first PPVC module 208; secondly, embedding the second C-channel 150 to the second wall 114 of the second
25 PPVC module 210; and finally coupling the first C-channel 150 and the second C-channel 150 by a lipped C-channel 152 in order to prevent detachment between the first PPVC module 208 and the second PPVC module 210. The C-channels 150 are pre-casted in a mould together with concrete.

30 [0073] A method of assembling the two PPVC modules 208,210 in particular the two walls which has the PPVC connector. The method comprises bringing the first wall 112 of the first PPVC module 208 and the second wall 114 of the second PPVC module 210 in proximity which form the grating gap 110. To secure the two walls, lipped C-channels 152 are first placed in the second indentation 142 and the fourth indentation 202.
35 Followed by placing the roof slab connectors 206 at the first indentation 140, third

indentation 144 and the fifth indentations 204. Dowel bars 182 are inserted into the corrugated pipes 178. Non-shrink grout is then poured into the cavities till fully filled.

[0074] In the application, unless specified otherwise, the terms "comprising", "comprise", and grammatical variants thereof, intended to represent "open" or "inclusive" language such that they include recited elements but also permit inclusion of additional, non-explicitly recited elements.

[0075] As used herein, the term "about", in the context of concentrations of components of the formulations, typically means $\pm 5\%$ of the stated value, more typically $\pm 4\%$ of the stated value, more typically $\pm 3\%$ of the stated value, more typically, $\pm 2\%$ of the stated value, even more typically $\pm 1\%$ of the stated value, and even more typically $\pm 0.5\%$ of the stated value.

[0076] Throughout this disclosure, certain embodiments may be disclosed in a range format. The description in range format is merely for convenience and brevity and should not be construed as an inflexible limitation on the scope of the disclosed ranges. Accordingly, the description of a range should be considered to have specifically disclosed all the possible sub-ranges as well as individual numerical values within that range. For example, description of a range such as from 1 to 6 should be considered to have specifically disclosed sub-ranges such as from 1 to 3, from 1 to 4, from 1 to 5, from 2 to 4, from 2 to 6, from 3 to 6 etc., as well as individual numbers within that range, for example, 1, 2, 3, 4, 5, and 6. This applies regardless of the breadth of the range.

[0077] It will be apparent that various other modifications and adaptations of the application will be apparent to the person skilled in the art after reading the foregoing disclosure without departing from the spirit and scope of the application and it is intended that all such modifications and adaptations come within the scope of the appended claims.

Reference Numerals

	100	plan of two facing walls with an assembly
	102	first adjoining long face
5	104	wall breadth
	106	wall length
	108	wall height
	110	grating gap
	112	first wall
10	114	second wall
	116	first top face
	117	second top face
	118	first bottom face
	120	first opposite long face
15	122	first primary side face
	124	first secondary side face
	126	first assembly
	127	a perspective of the first assembly
	128	second assembly
20	129	third assembly
	130	first anchor
	132	second anchor
	134	restrictor
	135	shear bar
25	136	first assembly-to-side distance
	138	first-to-second assembly distance
	140	first indentation
	142	second indentation
	144	third indentation
30	146	indentation breadth
	148	indentation depth
	150	C-channel, CC1

	152	lipped C-channel, CC2
	154	base portion
	156	right portion
	158	left portion
5	160	open portion
	162	base breadth
	164	side portion depth
	166	overhanging extension
	168	overhanging extension length
10	170	C-channel thickness
	172	rebar
	174	rebar length
	176	rebar diameter
	178	corrugated pipe
15	180	pipe diameter
	182	dowel bar
	184	lipped C-channel length
	186	concentric hole
	188	C-channel extension length
20	190	concentric hole gap
	192	lipped base portion
	194	lipped right portion
	196	lipped left portion
	198	lipped overhanging portion
25	200	perspective of the adjoining long face
	202	fourth indentation
	204	fifth indentation
	206	roof slab connector
	208	first PPVC module
30	210	second PPVC module
	212	three-dimensional coordinate system

Claims

1. A PPVC connector for coupling a first PPVC module and a second PPVC module, the PPVC connector comprising
- 5 ➤ a first anchor for attaching to the first PPVC module;
- a second anchor for attaching to the second PPVC module; and
- a frame for coupling the first anchor and the second anchor together;
- 10 wherein the first anchor, the second anchor, the frame or a combination of any of these are configured to provide a cavity in-between for receiving a filler in order to create confinement effect;
- at least one of the first anchor, the second anchor and the frame comprises at least one plate; and
- the at least one plate is folded laterally for having multiple sides to be attached to the first PPVC module.
- 15
2. The PPVC connector of claim 1, wherein at least one of the first anchor, the second anchor and the frame is roughened.
3. The PPVC connector of claim 1 or 2, wherein
- 20 at least one of the first anchor, the second anchor and the frame is perforated.
4. The PPVC connector of any of the preceding claims, wherein the frame comprises a first coupler having two wings that are spaced apart for providing a receptacle in order to receive portions of the first anchor and the
- 25 second anchor.
5. The PPVC connector of claim 4, wherein the frame further comprises a second coupler having two wings that are spaced apart for receiving portions of the first anchor and the second anchor.
- 30
6. The PPVC connector of claim 5, wherein the frame further comprises a rib that joins the first coupler and the second coupler together.
- 35

7. The PPVC connector of any of the preceding claims, wherein the frame comprises at least one rod for joining the first PPVC module and the second PPVC module together.
- 5 8. An assembly of PPVC modules comprising
- a first PPVC module;
 - a second PPVC module; and
 - the PPVC connector according to any of the preceding claims;
- 10 wherein the first anchor is attached to the first PPVC module, and the second anchor is attached to the second PPVC module.
9. A method for making a PPVC connector, the method comprising
- providing a plate for attaching to a first PPVC module as an anchor;
 - corrugating the plate for improving surface adhesion of the plate;
 - 15 ➤ folding the plate for creating multiple sides in order to attach to the first PPVC module by the multiple sides; and
 - providing a cavity at the plate for receiving a filler in order to create confinement effect.
- 20 10. The method of claim 9 further comprising offering a frame for coupling the plate as an anchor with another anchor together.
11. The method of claim 9 or 10, wherein the folding the plate comprises folding the plate laterally.
- 25