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(54) **Title:** LOST FORMWORK CLADDING AND CONNECTOR AND METHOD OF USING SAME

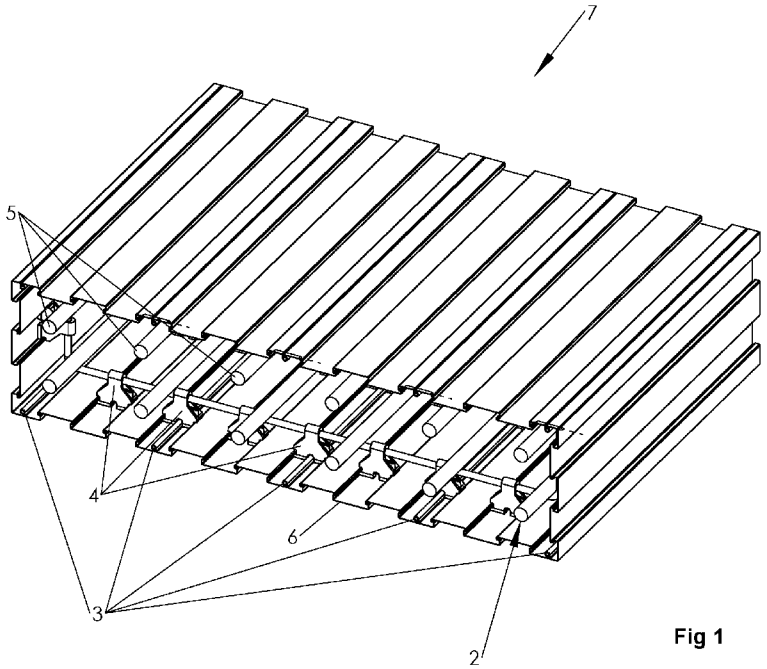

Fig 1

(57) **Abstract:** A connector (4) for securing a formwork panel (3) of a kind having first connection formations at a fixed distance from a predetermined boundary, the connector including: a compression resistant spacer and tensile tie element having a first end and a second end defining a spacer depth there between; one or more second connection formations extending from said first end for securing the connector to said first connection formations on the formwork panel; and means at the second end for securing to said predetermined boundary. In one form the connector is configured to secure such panels to a prefabricated reinforcement cage (2), and in another form to secure a first wall of interconnected panels to an opposing set of interconnected panels to form a formwork for a wall. The connectors may also be adapted to retain reinforcement rods within the wall. Preferably each panel has one or more indentations configured to engage with protuberances provided at an adjacent end of the connectors. The slots may be T/shaped to receive and retain outwardly extending protuberances on the connectors.

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[Continued on next page]

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Lost formwork cladding and connector and method of using same

Field of the invention

[0001] The present invention relates to "lost formwork" concrete filled reinforced construction systems, where the cladding defining the outside surfaces of the formwork remains part of the final structure after concrete is poured into the formwork and cured.

[0002] The invention in a first commercial application has been developed primarily for use in offsite prefabrication of structural forms such as steel reinforced concrete columns and the like, and will be described herein with reference to this preferred use. However, it will be appreciated by those skilled in the art that a similar form of that aspect of the invention may also suited for use in constructing lost formwork structures for steel reinforced structural forms that are fabricated on site.

[0003] The invention in a second commercial application has been developed primarily for use in on site construction of lost formwork walling systems and will be described with reference to that use. However, it will be clear that it is not limited to that particular application.

Background to the invention

[0004] 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 common general knowledge in the field.

[0005] Lost formwork methods of construction are widely used in the building industry for forming structural load bearing walls and columns and the like. Such systems typically include a number of panels that define the external surfaces of the form, with an arrangement of steel reinforcing elements disposed within the form. In most heavy load bearing applications, the reinforcing elements are supported or tied together into a three-dimensional cage type arrangement. This cage of reinforcing elements is ideally disposed a predetermined distance from the external panels, to ensure adequate and even concrete coverage of the steel reinforcement after the concrete has been poured into the form.

[0006] One of the biggest challenges in structures of this kind is ensuring that the formwork panels are supported to resist the hydrostatic pressures applied by the wet concrete during the

pour and prior to the concrete curing, while at the same time ensuring that the reinforcing elements remain in their designed location. This is particularly relevant in tall structures like walls and columns where the head of flowable concrete creates significant pressure against the cladding.

[0007] While external bracing may be used in some applications, this is dependent on the nature of the structure to which the form is to be secured and reliance on external bracing doesn't help facilitate offsite prefabrication.

[0008] Most commonly in wall and column structures, removable tensile tie elements in the form of long bolts (generally known as "Z-bars") are used that extend through conduit that passes through the reinforcing and opposing cladding panels and are secured by external fasteners against the external surfaces of the formwork cladding panels. Where needed, internal spacers are disposed between the reinforcing elements and the panels to position the reinforcement and panels in their designed locations, which are secured in place by the tensile forces applied by the tie elements. This method is time consuming and results in a number of holes in the finished concrete structure which need to be patched and finished.

[0009] An improvement was proposed by the applicant in WO2016/061627 which describes, in one embodiment, the use of tensile ties in the form of high strength flexible strapping, which results in a lighter structure and an outer surface that is much easier to finish, as the strapping is easily covered over with further cladding or simply cut and removed. It also readily facilitates off-site prefabrication of forms pre-loaded with correctly positioned reinforcement. However, there is still a need to provide openings in the formwork cladding panels to receive the tensile ties and once again forming the holes and securing the ties is still relatively labour intensive.

[0010] Further improvements were proposed by the applicant in WO2017/201577 which included a two part connector, including an internal part and an external part, which easily snapped together to secure to the cladding in between, but again this required openings be provided in the cladding. While another alternative embodiment was proposed that secured at one end to the reinforcement and at the other to the inner surface of the cladding, the need to screw and/or glue or otherwise secure the connector flanges to the inner surface of the cladding was time consuming.

[001 1] There are also other systems that obviate the requirement for drilling through holes and inserting tie elements, by providing rigid internal web elements of metal or cladding material that extend between opposing formwork cladding panels. However, these rigid web elements take up a lot of internal space and often section the void internally, thereby reducing the space available for the reinforcing and limiting the design to certain structures. For example, in Australia, use of systems of this kind are limited to structures classified as walls as defined by the relevant concrete design code AS3600. The rigid web elements in these systems can also inhibit the concrete flow and access to the reinforcement during the concrete pour making it difficult to ensure the structural integrity of the final form.

[0012] It is an object of the present invention to overcome or ameliorate at least one of the disadvantages of the prior art, or to provide a useful alternative.

Summary of the invention

[0013] According to the invention there is provided a connector for securing a formwork panel of a kind having first connection formations at a fixed distance from a predetermined boundary, the connector including: a compression resistant spacer and tensile tie element having a first end and a second end defining a spacer depth there between; one or more second connection formations extending from said first end for securing the connector to said first connection formations on the formwork panel; and means at the second end for securing to said predetermined boundary.

[0014] In a first commercial application, the predetermined boundary is a reinforcing rod that may form part of a prefabricated reinforcement cage, or other reinforcement configuration including secured bar or mesh.

[0015] According to a first aspect of the invention there is provided a connector for securing reinforcing rod elements to an adjacent spaced formwork panel having first connection formations, the connector including: a compression resistant spacer and tensile tie element having a first end and a second end defining a spacer depth there between; one or more second connection formations extending from said first end for securing the connector to said first connection formations on the formwork panel, and reinforcing rod retention means extending from said second end.

[0016] Preferably, the first connection formations on the formwork panels are in the form of indentations and the second connection formation or formations on the connector are in the form of protuberances configured to engage the indentations in the formwork panels. However, it will be appreciated that the opposite arrangement could also work with indentations as the second connection formations on the connector and protuberances as the first connection formations on the formwork panels.

[0017] The first and second connection formations may be adapted to interact in any manner that will provide a strong and secure connection that will withstand the tensile loads which will apply, particularly during a concrete pour when the wet mix will apply a hydrostatic pressure to the assembly until it has cured. While this may be achievable with a direct press fit arrangement, the preferred configuration is to provide a sliding interaction transverse to the spacer depth direction. In one particularly preferred arrangement the first and second connection formations are in the form of a dovetail or T slot like configurations. Preferably the receiving slots are provided in the formwork panels and the corresponding interlocking protuberances are formed on the connector, but again this could be reversed and still function within the confines of the invention.

[0018] Preferably, the connector is generally longitudinal, extending in a longitudinal direction generally transverse to the spacer depth to align with a length of reinforcing rod. In one preferred form, the compression resistant spacer is in the form of a spacer web.

[0019] In one preferred form, the connector is a single piece structure preferably made of a suitable polymeric material that has two opposing halves configured to resiliently deform about its second end where a reinforcing rod retention formation is provided, so that it can be opened up and placed over a reinforcing rod from a side remote from the formwork panel to which it is to be secured. At a location between the rod receiving second end of the connector and the second connection formations at the opposite end, catch formations are provided, one on each half, to thereby secure the connector in a closed position to the reinforcing rod. The catch formations can again be of any suitable configuration, but this time configured to retain the two connected halves of the connector together in a direction transverse to the spacer depth and the reinforcing rod retention means. In one form this is achieved by provision of interacting resiliently deformable hook or barb arrangements provided on each half, which deform as the two parts are bought together and then snap into inter- locking engagement to secure the connector.

[0020] In this same embodiment, the distal ends of the two opposing halves of the connector form flanges which extend longitudinally outwardly from the top to form protruding slide formations which are configured to slidingly engage corresponding channel formations provided on the specially configured formwork panels. The slide formations may be continuous along the longitudinal length of the connector, corresponding to the longitudinal extent of a reinforcing rod, or more preferably include a gap to accommodate a formwork panel join as described below.

[0021] In a preferred form according to the second aspect of the invention, the formwork panels are fairly narrow in width but have a constant cross section which means they can be produced as a continuous element and cut to length as required. The panels also have interconnecting longitudinal edge formations, which enable them to be joined side by side as needed to form various sizes and shapes of forms. The interconnecting edge formations can again be of any suitable type that will provide the requisite strength of join, particularly in tension in a direction between adjacent sheets. However, a preferred configuration is for each panel to have a first small roll formed lip formation on one side and a correspondingly larger second roll formed lip formation at the other which will slidingly receive and retain the smaller first roll formed lip formation from a similar adjacent panel. By providing a gap between the sliding connecting formations on the connectors, adjacent panels can be secured across each connector, with the panel join located in the gap.

[0022] In a preferred form the formwork panels are corrugated to define a series of parallel dovetail or T shaped slots that correspond with the longitudinally protruding formations provided on the connectors.

[0023] The shape of the reinforcing rod receiving means may be arcuate to conform closely to an adjacent portion of the circular periphery of the reinforcing rod, or may include flat regions to reduce the tendency of the connector rotating on the reinforcing rod. In one preferred form the formwork panels are roll formed from 0.7mm mild steel and in another are extruded to a thickness of 1.5 - 2.5mm in aluminium. Typical weights are around 9kg per square metre. Typical widths of sheet include 250/300/450mm. The connectors may be made from suitable polymeric materials which include polypropylene and nylon, but other plastics materials can also be used. Preferably the material will be suitable for injection moulding or extrusion, have a tensile yield strength of at least 30Mpa, a flexural strength of at least 30Mpa and a suitable impact toughness.

[0024] Desirably, the corrugations provided in the formwork panels are configured to enable nesting of the panels during transport. In one form this is achieved by varying the width of alternating adjacent corrugations so that by offsetting the panels by one corrugation, a second panel can nest closely within as described hereafter.

[0025] The reference to reinforcing rods used herein includes reference to any reinforcement bar element and includes tie elements commonly referred to as ligatures.

[0026] In applications where the reinforcing rod elements are prefabricated into a cage structure prior to assembly with the formwork panels, it may be desirable to produce a range of connectors based around the nominal offset required, which include connectors that are slightly longer and slightly shorter than that offset, to allow for manufacturing tolerances in the cage. In a preferred application where the cage comprises parallel spaced longitudinal reinforcing rods tied by ligatures that circumscribe some or all of the longitudinal rods, the connectors are secured to the ligatures. However, the fact that each connector can vary in plan position without preventing attachment, as you are aligning with a slot and not a single hole as in some of the prior art, means that this particular system can cope better with manufacturing tolerances than the applicant's previous systems.

[0027] According to a second aspect of the invention there is provided a method of constructing a reinforcement and formwork panel assembly comprising the steps of: securing the reinforcing rod retention means provided on the second end of one or more connectors according to the first aspect of the invention to a reinforcing rod or rods; and securing a first length of formwork panel according to the second aspect of the invention by interlocking the second connector formations on the connectors with the first connector formations on the formwork panel. Where necessary, the method may also include the step of securing one or more further lengths of formwork panel as required and as described herein.

[0028] Preferably the method is applied to constructing a prefabricated reinforcement and formwork assembly for a longitudinally extending structural element, the assembly including: a prefabricated longitudinally extending reinforcement cage; a series of interconnected formwork panels according to the second aspect of the invention, wherein the panels are secured with the reinforcement cage using a plurality of connectors according to the first aspect of the invention.

[0029] In one form, the method may include the step of selecting connectors of varying depth as needed to accommodate variations in offset due to manufacturing tolerances arising during prefabrication of the reinforcement cage.

[0030] In a second commercial application, the connector is configured for use with formwork panels to form a wall structure and the predetermined boundary is an opposing wall surface.

[0031] According to a third aspect of the invention there is provided a connector for securing a formwork panel having first connection formations at a fixed distance from an opposing wall surface, the connector including: a compression resistant spacer and tensile tie element having a first end and a second end defining a spacer depth there between; one or more second connection formations extending from said first end for securing the connector to said first connection formations on the formwork panel; and means at the second end for securing to said opposing wall surface.

[0032] Preferably, the opposing wall also comprises a formwork panel, ideally having the same first connection portions, and the second end of the connector has the same second connection formations as the first end. As with the first embodiment connector, the manner of interlocking engagement between the first connecting formations in the panels and the second connecting formation on the connectors can take numerous forms. However, in the currently preferred embodiment, the compression resistant spacer and tensile tie element is a single element of generally H shaped cross section and the connecting formations in the panel are T shaped channels of the kind previously described that engage with generally T shaped second connection formations formed on the connector. Again, in a preferred form, a gap is provided between the second connection formations to accommodate panel interconnecting joints where required. In this manner to T connector may have a generally “dog bone” shaped profile.

[0033] In a preferred form, the second embodiment connector also includes one or more apertures intermediate the ends for guiding and/or securing reinforcing rods.

[0034] According to a fourth aspect of the invention there is provided a method of constructing a wall by interconnecting opposing formwork panels having first connection formations with connectors according to the third aspect of the invention that have second connection formations at each end that engage the first connection formations in the opposed

panels, and progressively connecting further adjacent formwork panels to be similarly interconnected with additional connectors.

[0035] While the connectors of the first aspect of the invention, and methods of constructing reinforcement and formwork using them has significant advantages in enabling fast and accurate assembly of prefabricated reinforced formwork assemblies without the need for expensive tools or jigs for retaining the structure during slow adhesive curing processes, it will be appreciated that the connectors can be used in any application on or off site where reinforcing rods or cages need to be secured to formwork and there is adequate access to engage the formwork panels with the connectors. This may be particularly relevant where the interconnection between the panels and the connectors is a sliding interconnection.

[0036] Similarly, the connectors of the third aspect of the invention in combination with the described formwork panels readily facilitate erection of a permanent formwork structure for building walls on site, but if required could also be prefabricated where, for example, access on site may be limited.

[0037] According to a fifth aspect of the invention there is provided a formwork panel of any suitable configuration that is manufactured so as to be at least partially translucent or transparent whereby it is possible to view some or all of the concrete after it has been poured into the form. In preferred forms, this is achieved by using an appropriate polymeric material such as PET plastic.

Brief description of the drawings

[0038] Preferred embodiments of the invention will now be described, by way of example only, with reference to the following drawings in which:

[0039] Figure 1 is a perspective view of a complete prefabricated column form structure using a plurality of first embodiment connectors and first embodiment form panels according to a first aspect of the invention;

[0040] Figure 2 is a perspective view of one of the first embodiment connectors shown in Figure 1;

[0041] Figure 3 is an end view of the first embodiment connector in Figure 2;

[0042] Figure 4 is a side view of the first embodiment connector in Figure 2;

[0043] Figure 5 is a perspective view illustrating a first stage in the assembly of a column form as shown in Figure 1;

[0044] Figure 6 is a perspective view illustrating a subsequent step in the assembly of a column form as shown in Figure 1;

[0045] Figure 7 is a perspective view illustrating a near final stage in the assembly of a column form as shown in Figure 1;

[0046] Figure 8 is an end view of a second embodiment panel according to the invention designed to be nestable with a like panel;

[0047] Figure 9 is an end view of two of the panels of Figure 8 illustrating the nestable configuration that is particularly useful for storage and transport;

[0048] Figure 10 is a perspective view of a first embodiment connector according to the fourth aspect of the invention particularly suited for constructing formwork for walls;

[0049] Figures 11- 13 illustrate the manner by which the connector in Figure 10 is installed between opposing formwork panels of Figure 8; Figures 14 to 17 illustrates progressive use of connectors of Figure 10 to connect between opposing formwork panels and simultaneous secure across joins between adjacent panels: and

[0050] Figure 18 is a sectional part view transverse to the formwork panel in a completed structure illustrating means by which further cladding may be secured.

Description of preferred embodiments

[0051] Referring to Figures 1 to 7 there is shown a column form 1 manufactured by encasing a prefabricated reinforcement cage 2 with specially configured interlocking first embodiment form panels 3 using first embodiment connectors 4 that physically interact and lock with the panels 3.

[0052] The prefabricated reinforcement cage 2 comprising a plurality of parallel spaced longitudinally extending reinforcement rods 5, secured in a three dimensional cage configuration by means of longitudinally spaced circumferentially extending external ligatures 5. These ligatures are usually made from the same or similar material as the longitudinal reinforcing rods. The ligatures 5 are secured to the longitudinal reinforcing rods 4 by any suitable means, but most often by localised welding.

[0053] Details of a first embodiment connector as illustrated in the drawings are best shown in Figures 2 to 4. The connector 4 is preferably made from a polymeric material and includes a compression resistant spacer element and tensile tie in the form of opposing webs 7 that have panel engaging formations 8 at a first end of the connector. The webs 7are resiliently connected at the second end to form a reinforcing rod retention means in the form of an openable contoured region 9 that has inwardly directed stop formations shown at 10. It will be seen in the illustrated embodiment that there is plenty of material between the base of region 9 and the hinge. This will enable drilling out of the aperture where needed to increase the offset and accommodate manufacturing tolerances on the cage when needed. In other versions, mould inserts may be used to produce connectors of different effective offset lengths.

[0054] The panel engaging formations 8 in the illustrated embodiment extend longitudinally beyond the adjacent indents 11 to define opposing L shaped slide formations which are configured to slidingly engage corresponding channel formations provided on the specially configured formwork panels as described in more detail below. Preferably two formations 8 are provided at the end of each web 7 to provide an overall T shaped profile as shown in Figure 4 with a gap 12 in between which can accommodate panel interconnecting joints when required. Looking at the end view the formations 8 also taper outwardly in thickness towards the ends to maximise the amount of material at the connection with the panel to enhance the strength at the join.

[0055] The connector also includes catch means for securing the hinged halves of the connector about a reinforcement rod. In the illustrated embodiment these are in the form of opposing resiliently deformable hook or barb extensions 14 provided on an inner surface of each web. These barbs 14 deform in a transverse direction as the two parts are bought together and then snap into inter-locking engagement to secure the connector to the rod. In the illustrated embodiment, one barb extends outwardly and downwardly, and the other extends outwardly and upwardly.

[0056] Preferably the first embodiment connectors 4 are made from moulded plastic. Suitable polymeric materials include polypropylene and nylon, but other plastics materials can be used. Preferably the material will be suitable for injection moulding, have a tensile yield strength of at least 30Mpa, a flexural strength of at least 30Mpa and a suitable impact toughness. In a preferred form, the connectors are injection moulded from polypropylene, have a length of about 65mm at the panel engaging end and 25mm at the reinforcing rod engaging end.

[0057] Turning next to the formwork panels, the illustrated first embodiment is best viewed in detail in Figures 5 and 6. As can be seen, each panel 3 has a plurality of channels 15 that are formed with a dovetail or T slot type cross section to correspond with connection formations on the connectors defined by protrusions 8 and adjacent indents 11. The panels are preferably roll formed and also include longitudinal edge formations in the form of a first small roll formed bead 16 on one side and a second larger roll formed bead 17 on the other which will slidingly receive and retain the first roll formed lip 16 of an adjacent panel. In the currently preferred form 0.7mm thick sheet steel is used.

[0058] A method of constructing a column form utilising the connector 4 and interlocking formwork panels 3 will now be described with particular reference to Figures 6 and 7.

[0059] As a first step, a plurality of connectors 4 are secured to first surface of a reinforcement cage 2 as shown in Figure 6 such that the spacing between connectors corresponds with the spacing between the channels 15 on the panels. The connectors are secured to the ligatures 6 by forcing the webs apart at the open end and feeding the open connector from the inside of the cage 2 and then pulling the webs outwardly to engage the ligature in the space 9. The two webs 7 are then bought together such that the two barb formations 14 on the inside of each web, deform on engagement to push the barbs away from

each other, and then return resiliently to form the catch as shown in Figures 2 and 3 which then prevents the webs moving apart.

[0060] Once the connectors are secured to the cage 2, a first panel 3 can be slid on as shown, with the channels 15 sliding over the connecting formations 8 on each connector to form a secure join that is very strong in the relevant direction transverse to the direction of sliding. After a first panel is secured, a second can be slid into position in the same way, ensuring that the adjacent panel edges also engage, the resulting joint being accommodated in the gap 12 formed in each connector. This process of attaching connectors and then sliding on and interconnecting panels is continued as shown in Figure 7 for each long side of the assembly and then appropriately configured end panels are added until the assembly is complete as shown in Figure 1.

[0061] During use concrete is poured into the cavity and the connectors act in tension, with the prefabricated cage, to hold the external formwork panels in place.

[0062] The size and number of connectors required for any given application will vary according to the structure. In the assembly illustrated in Figure 1, which is for forming columns for use in high rise construction, the ligatures are typically spaced at 250mm centres, meaning the connectors are similarly spaced longitudinally. The spacing peripherally will depend on the structure shape and expected loading. The aim is to ensure sufficient connectors to withstand the loads applied during assembly and most importantly during the post assembly concrete pour. In one currently preferred embodiment the T slots in the panels have a maximum width of just over 65mm with a similar gap between each channel.

[0063] It will also be appreciated that when sheet metal is used, it may be possible to use thinner than expected sheet, by increasing the rigidity of each sheet by using embossing techniques, particularly in directions transverse to the channels. Additional corrugations can also be used in the channel direction to the same effect if needed.

[0064] While the embodiments of connectors illustrated are generally longitudinal, this is not essential and could be proportionally shorter or longer or of different peripheral shape, so long as the rod engagement means securely attaches to the reinforcing elements, the spacer element operates to space and retain the rod element from the formwork panel, and the panel engagement means form a strong connection with the associated formwork panels.

[0065] Similarly, while the preferred form of the first embodiment connector described uses an arrangement with two opposing arms or webs to secure to the reinforcement rods, this is not essential and could be varied. For example the connector could include rod retention means in the form of an open end with two resilient curved arms that can deform by push fit over the ligature to form the connection to the reinforcement, and the panel engaging formations extend at the opposite end, with a single interconnecting web formation in between.

[0066] Further, the use of the first embodiment connectors and formwork panels of the invention are not limited to making pre-fabricated column forms of the kind described herein. For example, they may also be used for making prefabricated beams or walls, or in constructing lost formwork structures on-site where the connectors connect directly to the reinforcement.

[0067] Turning next to Figures 8 and 9 there is shown a second embodiment formwork panel 3' which can be used in the applications previously described, or in relation to on site construction of a wall form. With this alternative panel, and subsequently introduced alternative embodiments of other elements such as the connector, similar or like reference numerals will be used wherever possible to denote corresponding features.

[0068] As can be seen the panel 3' is very similar to first embodiment panel 3, in that it includes one or more channels 15 that are are formed with a dovetail or T slot type cross section to form retaining apertures 21 that correspond with connection formations on the connectors 4 defined by protrusions 8 and adjacent indents 11, and longitudinal edge formations terminating in the form of a first small roll formed bead 16 on one side and a second larger roll formed bead 17. The primary difference is that the protuberances in the form of inverted T shaped channels 20, formed between the engagement channels 15, are widened relative to the T shaped channels to enable nesting of two panels 3' by offsetting by one channel or corrugation as shown in Figure 9. As will be shown in Figures 14 to 17, when the roll formed bead 16 of one panel joins with the larger roll formed bead 17 of an adjacent channel, the adjacent formations form another T slot channel 15.

[0069] In the preferred form illustrated, the panel 3' is also made from a suitably strong plastics material such as polypropylene, which may be of a recycled form. In the illustrated embodiment the width of each panel is around 240mm, the minimum width of the channels 15 is around 60mm and maximum width of the intermediate protuberance is around 55mm and the

thickness of the sheet is approximately 3mm. In one particularly preferred form the panel is made from a material that is at least partially translucent or transparent so that it is possible to view the concrete flow within the formwork during construction and readily facilitate engineering sign off post construction.

[0070] Referring next to Figure 10 there is shown a perspective view of a second embodiment connector 4' which is configured for use with the panels 3 and 3' previously described, but which is specifically configured to space and join opposing formwork panels to form a wall system. The connector 4' in the illustrated form has a generally dog bone shaped profile, with a central elongate body 7' which defines a compression resistant web that acts to space the panels and at the same time act as a tensile tie as the formwork is filled with concrete.

[0071] Extending from either end of the body 7' are opposed outwardly extending generally L shaped panel engaging formations 8'. Once again a gap 12' is provided between these formations to accommodate panel interconnecting joints where required. Preferably the body 7' has a width slightly narrower than the minimum width of the channels 15 in the panels and a thickness transverse to that width that is narrower again.

[0072] Disposed within the body 7' adjacent each pair of panel engaging formations 8' are reinforcing bar receiving apertures 9' that extend through the thickness of the connector. The apertures may be simple through holes 22. However, where the apertures are provided closely adjacent the panel engaging formations, the apertures may include a slit to enable the panel engaging formations to be resiliently compressed towards each other during installation, so they can then reopen and lock against the panels. In such instances the split apertures may also include additional reinforcing as shown in the Figures. In the preferred use, the connectors are oriented such that the channels 9 and apertures 22 locate vertically extending reinforcement rods.

[0073] The connectors 4' are extremely simple to install to create a wall formwork structure. In this regard they are inserted firstly between two opposed panels 3' in an orientation transverse to the final position, and then simply rotated such that the panel engaging formations 8' on the connector are first urged towards each other as described above and then resiliently open lock in to connection with the retaining apertures 21 in the panels. This process is clearly illustrated in Figures 11 to 13. In the preferred form, the panel engaging formations 8'

are configured such that there is some resilient deformation into the gap 12' and there is an interference fit with the apertures 21, so that the connectors effectively deform and then click into the locked in position.

[0074] Figures 14 to 17 illustrate how simple it is to continue the process to create a wall structure. In this process, the connectors are secured at predetermined spaced intervals along the length of two opposed panels and then extended in a horizontal direction as needed. This is achieved as illustrated by first slidably interconnecting adjacent vertical panels and similarly connecting these together in the same way. As can be seen, the joints 23 between the panels where edges 16' and 17' are slidably interconnected, is readily accommodated in the gaps 12' provided at each ends of the connectors 4'.

[0075] The length of the connectors is varied according to the wall thickness required, which is usually measured as the distance 24 between the innermost faces of the opposed panels 3'. Typical dimension ranges include 150mm and 250mm, but it will be appreciated that this can be varied as required and the size of the connectors varied accordingly to fit. The panel thickness may also be varied as needed to accommodate different loads during construction.

[0076] Turning finally to Figure 18 there is shown a sectional part view taken transverse to the formwork panel 3 in a completed structure illustrating means by which further cladding may be secured. In this particular embodiment a cladding panel 25 is secured to the exterior surface of the formwork by means of clips 26 that are retained within generally T shaped channels 20, formed between the connector engagement channels 15. The clips may be relatively short and spaced along the length of the formwork pane, or could be continuous strips. The clips include parallel outwardly extending sides 27 which include indentations or serrations 28 that are adapted to receive and retain engaging formations 29 provided on suitably configured furring channels 30 which can simply be pressed into position as shown and the panels then secured to the channels. It will be appreciated that other configurations would be possible to achieve the same function. However, the main advantage is that by having the furring channels secured to the inwardly directed channels 20, the cladding panel 25 sits virtually flush with the outer surface of the formwork. As such, the overall dimensions can be matched with those achieved with conventional formwork structures which would need surface mounted battens secured to the outer surface of the formwork panels.

[0077] The new formwork panel and first embodiment connector of the invention offer significant advantages over prior art systems for producing formwork for structural columns and the like. For example, the use of metal panels or plastic panels over systems using fibre cement, not only provides a much lighter weight solution, but also enables quantification of the structural benefit of a metal skin at the extremities of the formwork, particularly for columns. In addition, corners are automatically reinforced by means of the roll formed panel joins. Unlike prior art systems that utilise fibre cement or other non structural materials, the finished size of the form according to the invention also more closely approximates the structural size, which in prior art systems would solely be the reinforced concrete within the formwork, but excluding, the formwork panels. Additionally, the use of profiled metal sheet, particularly steel, has the potential to reduce the amount of internal longitudinal reinforcement rods due to the composite action between the concrete and the inherently structural steel sheet. Investigations are currently underway to quantify these benefits and prepare appropriate design guides.

[0078] Additionally, there is much less waste than with systems using fibre cement or timber sheet, where certain sizes may not fit in with stock panel sizes, leading to unusable off-cuts that must be discarded.

[0079] Similar comments apply to the walling system that utilise metal or plastic panels in combination with the double ended connectors of the third aspect of the invention. The wall forms are simply clipped together as required. When used with the preferred nestable form of formwork panel which can be flat packed, it is easy and highly cost effective to transport the system elements to the site. Additionally, the simple twist lock connector system means that no skilled labour is required for assembly, which also makes the system ideal for the DIY market.

[0080] If a different external finish to the structural column or wall form is required such as fibre cement or plasterboard, this can easily be secured to the completed form. It is also envisaged that cladding mounts may be provided that are configured to engage the external channels on the form panels. In this manner the total size of the finished structural element is no larger than that arising from conventional construction.

[0081] Labour costs are also reduced substantially due to the elimination of any need to pre-cut openings in the panels, align connectors accurately with discrete holes, apply conventional fasteners, wait for adhesive to cure, or patch up holes after installation. In addition, where the panels are to be made from metal by roll forming, these can be quickly and efficiently made by

the prefabricator without needing to hold large amounts of stock or be vulnerable to hold ups or shortages from external suppliers.

[0082] It will also be appreciated that while one particular arrangement has been disclosed by which the distal ends of the connectors lockingly engage the specially configured formwork panels, other interlocking configurations that avoid the need for separate fasteners or adhesives could also be used. For example, the ends of the connectors could include a T-shaped or dovetailed aperture adapted to receive correspondingly configured protruding formations formed on the panels. Other conventional press fit, key hole or cam type interactions could also be used.

[0083] Accordingly, while the invention has been described with reference to particular examples, it will be appreciated that it may be embodied in many other forms.

CLAIMS

1. A connector for securing a formwork panel of a kind having first connection formations at a fixed distance from a predetermined boundary, the connector including: a compression resistant spacer and tensile tie element having a first end and a second end defining a spacer depth there between; one or more second connection formations extending from said first end for securing the connector to said first connection formations on the formwork panel; and means at the second end for securing to said predetermined boundary.

2. A connector for securing reinforcing rod elements to an adjacent spaced formwork panel having first connection formations, the connector including: a compression resistant spacer element having a first end and a second end defining a spacer depth there between; one or more second connection formations extending from said first end for securing the connector to said first connection formations on the formwork panel, and reinforcing rod retention means extending from said second end.

3. A connector according to claim 1 wherein the first connection formations on the formwork panels are in the form of indentations and the second connection formation or formations on the connector are in the form of protuberances configured to engage the indentations in the formwork panels.

4. A connector according to claim 1 or claim 2 wherein the first and second connection formations together form a slidingly interconnecting dovetail or T slot like joint.

5. A connector according to claim 3 wherein receiving slots are provided in the formwork panels and the corresponding interlocking protuberances are formed on the connector.

6. A connector according to any one of the preceding claims wherein the connector is generally longitudinal, extending in a longitudinal direction generally transverse to the spacer depth to align with a length of reinforcing rod.

7. A connector according to any one of the preceding claims wherein the connector is a single piece structure made of a suitable polymeric material that has two opposing halves interconnected at its second end where a reinforcing rod retention formation is provided, so that it can be opened up and placed over a reinforcing rod from a side remote from the formwork panel to which it is to be secured.

8. A connector according to claim 7 wherein at a location between the rod receiving second end of the connector and the second connection formations at the opposite end, catch formations are provided, one on each half, to thereby secure the connector in a closed position to the reinforcing rod.

9. A connector according to claim 7 wherein the catch formations are configured to retain the two connected halves of the connector together in a direction transverse to the spacer depth and the reinforcing rod retention means.

10. A connector according to claim 8 wherein the catch is achieved by provision of a resiliently deformable hook or barb arrangements provided on either half, which deform as the two parts are bought together and then resiliently snap into inter- locking engagement to secure the connector.

11. A connector according to any one of claims 6 to 9 wherein the distal ends of the two opposing halves of the connector form dovetail or T section like formations which are configured to slidingly engage corresponding channel formations provided on the specially configured formwork panels.

12. A formwork panel for use with one or more connectors according to any one of claims 1 to 10 including first connection formations for securingly engaging with the second connection formations on the one or more connectors.

13. A formwork panel according to claim 11 including interconnecting longitudinal edge formations for securingly engaging an adjacent panel

14. A formwork panel according to claim 12 wherein each panel has a first roll formed lip formation on one side and a corresponding inverted second roll form formation at the other which will slidingly receive and retain the first roll formed lip formation from a similar adjacent panel.

15. A formwork panel according to any one of claims 12 to 14 wherein the formwork panels are corrugated to define a series of parallel dovetail or T type slots that correspond with the dovetail or T type formations provided on the connectors.

16. A method of securing a reinforcing rod to a formwork panel comprising the steps of securing one or more connectors according to any one of claims 1 to 11 to the reinforcing rod and then securing a formwork panel according to any one of claims 12 to 15 to the one or more connectors.

17. A reinforced concrete structure comprising an internal reinforcement cage bounded by steel formwork panels according to any one of claims 12 to 15 which are secured to the cage by means of connectors according to any one of claims 1 to 11 and filled with concrete, wherein the amount of reinforcement in the cage is reduced significantly from similar structures utilising formwork panels not made from steel.

18. A connector for securing a formwork panel having first connection formations at a fixed distance from an opposing wall surface, the connector including: a compression resistant spacer and tensile tie element having a first end and a second end defining a spacer depth there between; one or more second connection formations extending from said first end for securing the connector to said first connection formations on the formwork panel; and means at the second end for securing to said opposing wall surface.

19. A connector according to claim 18 wherein the opposing wall surface is a further formwork panel having first connection formations and the second end of the connector includes further second connection formations for securing to the first connection formations of the opposing further formwork panel.

20. A connector according to claim 19 wherein the formwork panel first connection formations are indentations and the connector second connection formations are protuberances, each sized whereby the second connection formations of the connectors can be inserted into the panel first connection indentation formations on the panels in an insertion orientation where the protuberances do not extend into a portion of the indentations and then rotated into a locking orientation whereby the protuberances extend into said portion of the indentations to effect an interlocking engagement of the panels to the connectors.

21. A method of constructing a wall by interconnecting opposing formwork panels having first connection formations with connectors according to any one of claims 18 to 20 that have second connection formations at each end that engage the first connection formations in the

opposed panels, and progressively connecting further adjacent formwork panels to be similarly interconnected with additional connectors.

22. A reinforced concrete structure including formwork made according to the method of claim 21 which is subsequently core filled with concrete.

23. A two part clip and furring channel arrangement for use with the formwork panel of as herein described.

24. A formwork panel according to any one of claims 12 to 15 is manufactured so as to be at least partially translucent or transparent whereby it is possible to view some or all of the concrete after it has been poured into the form.

25. A formwork panel of any suitable configuration that is manufactured so as to be at least partially translucent or transparent whereby it is possible to view some or all of the concrete after it has been poured into the form.

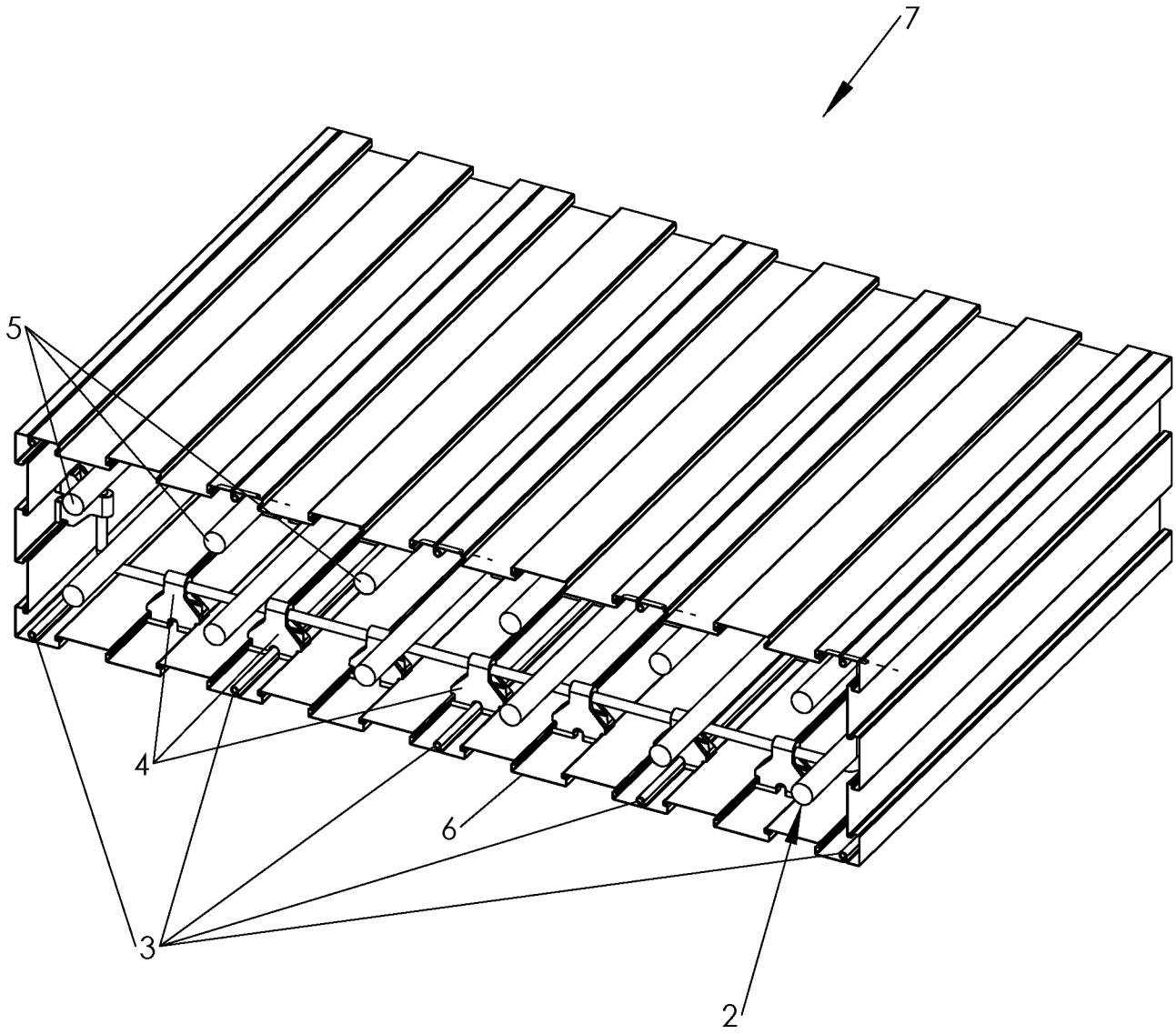

Fig 1

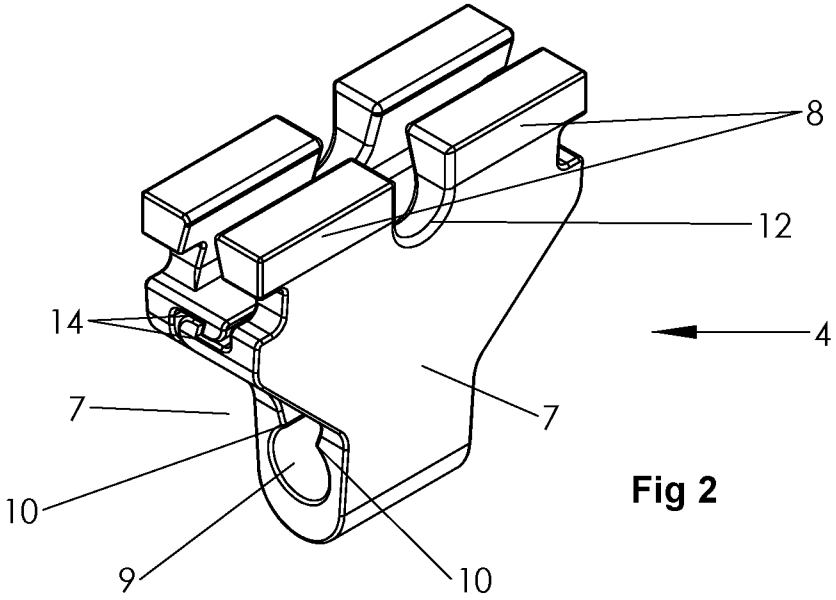

Fig 2

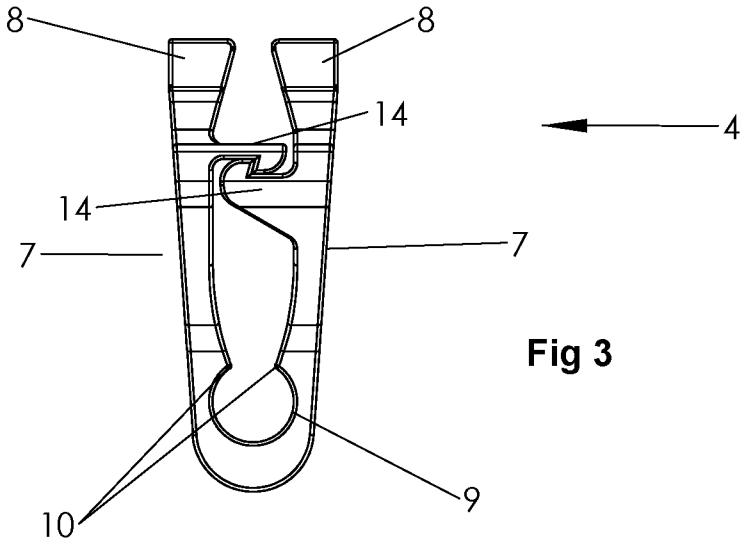

Fig 3

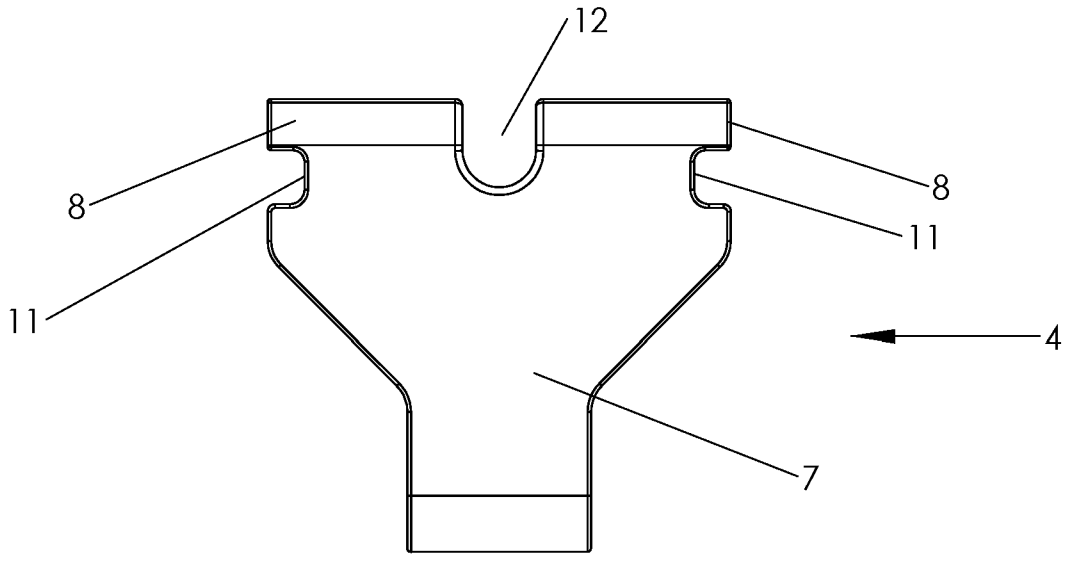

Fig 4

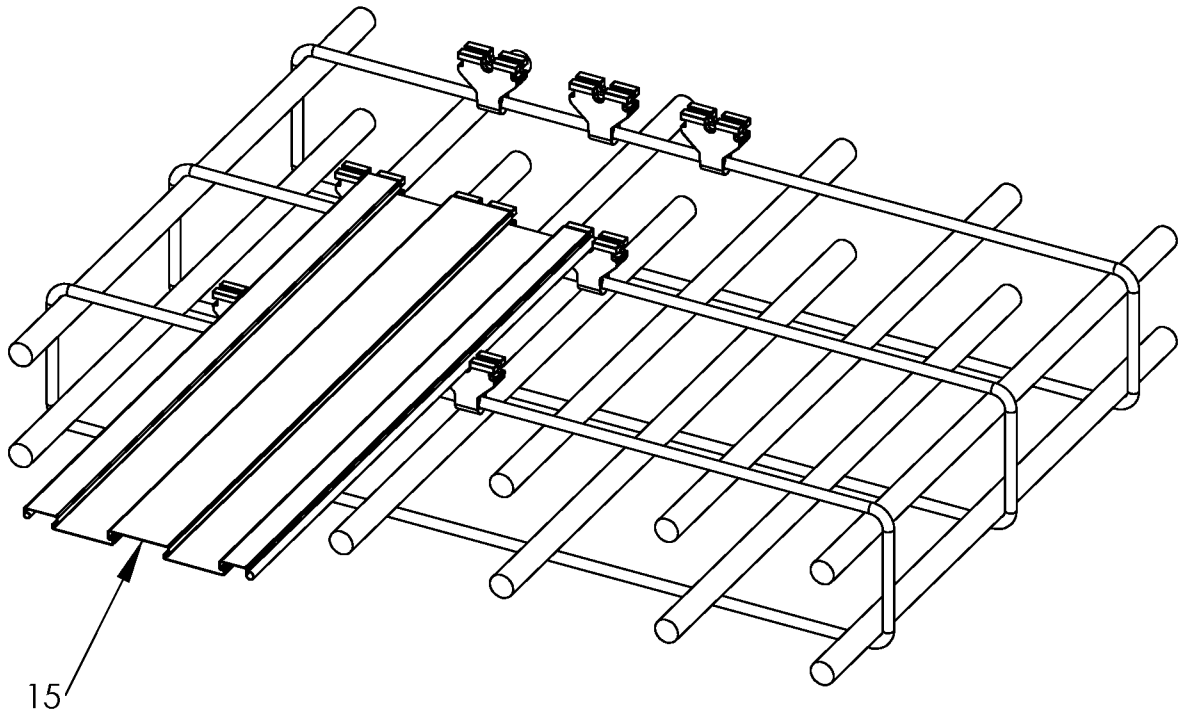

Fig 5

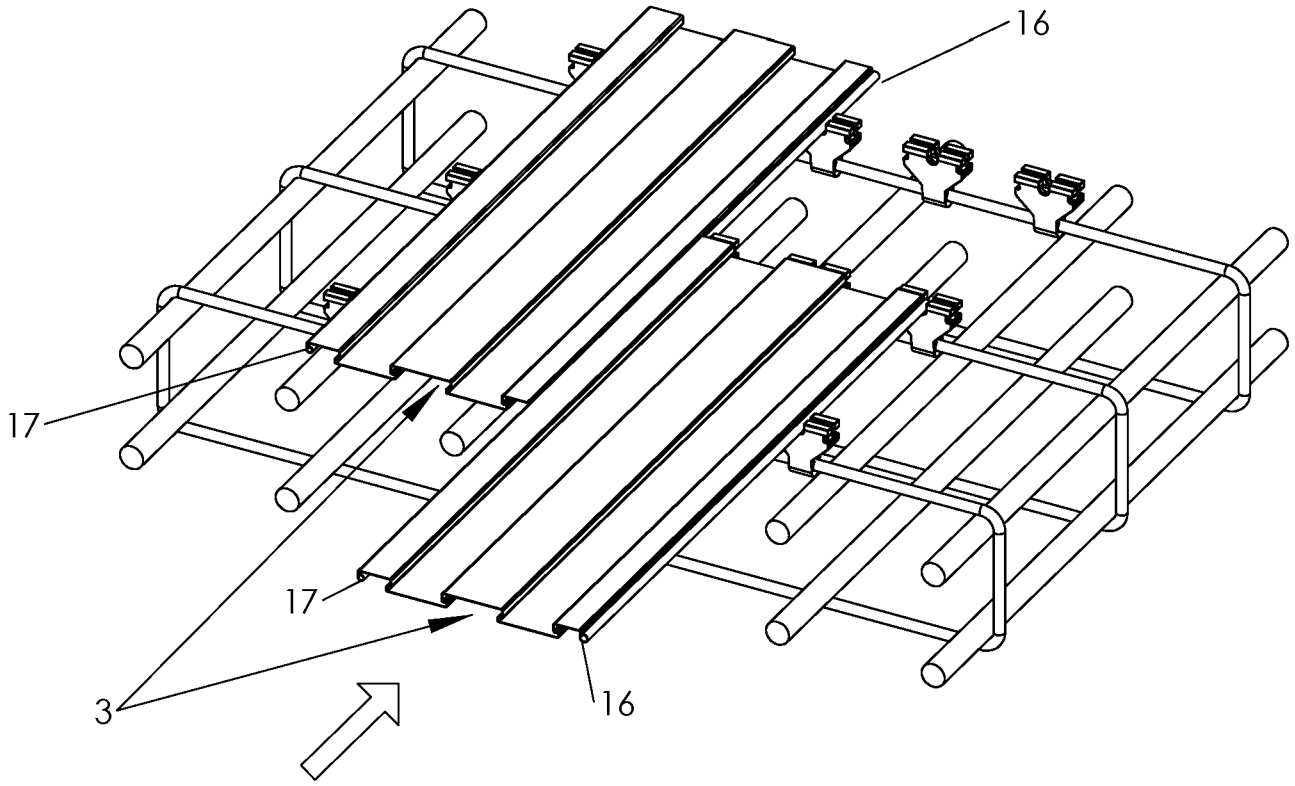

Fig 6

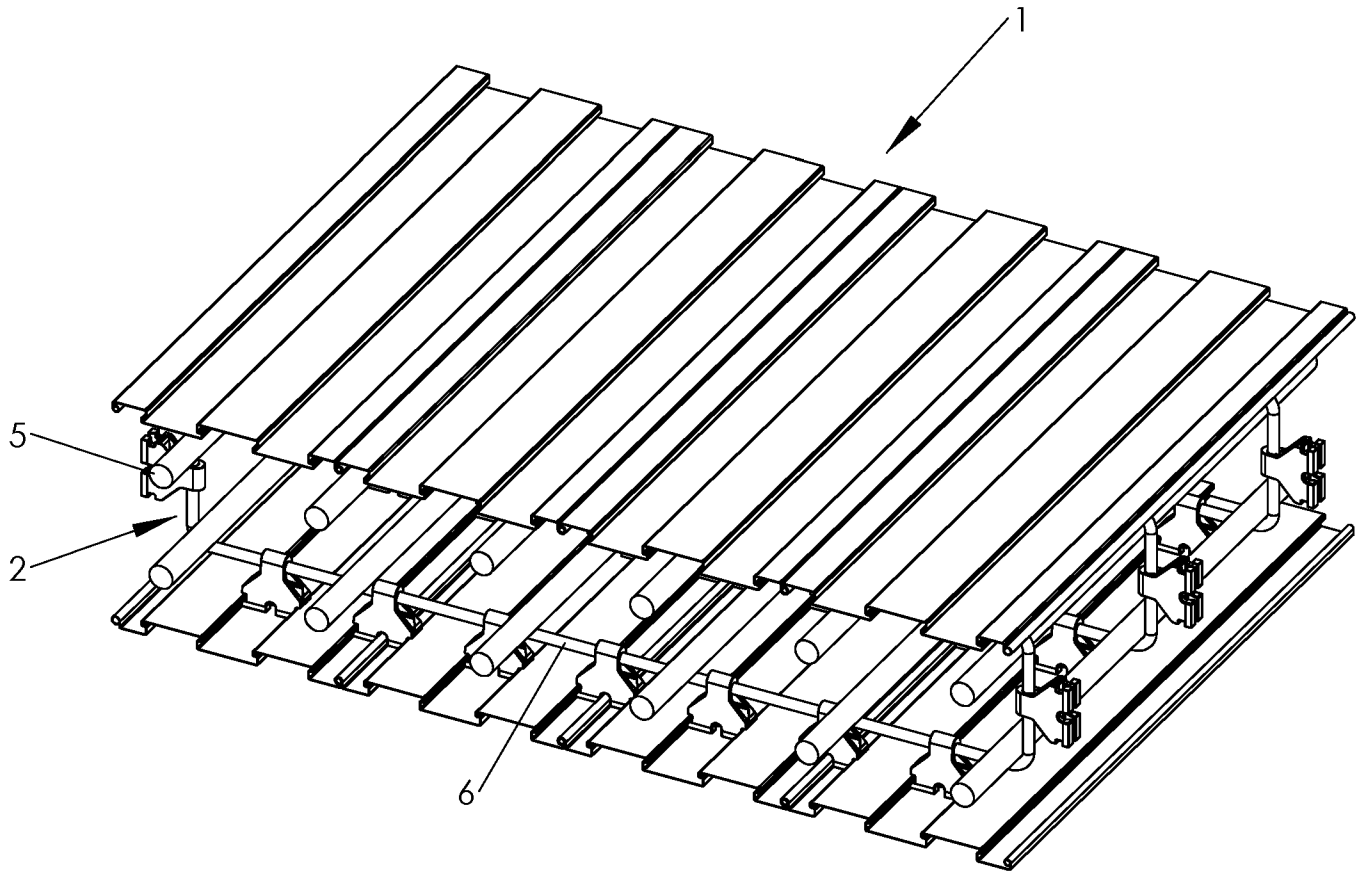

Fig 7

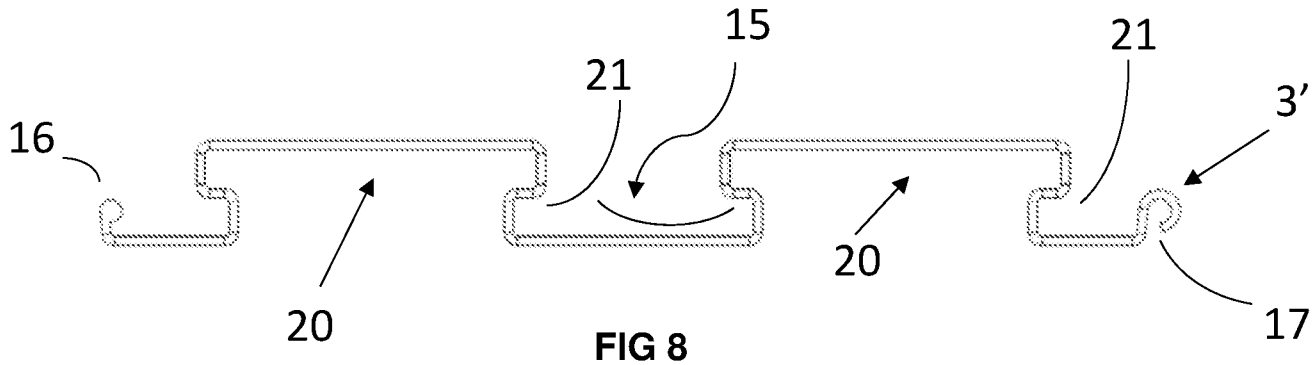

FIG 8

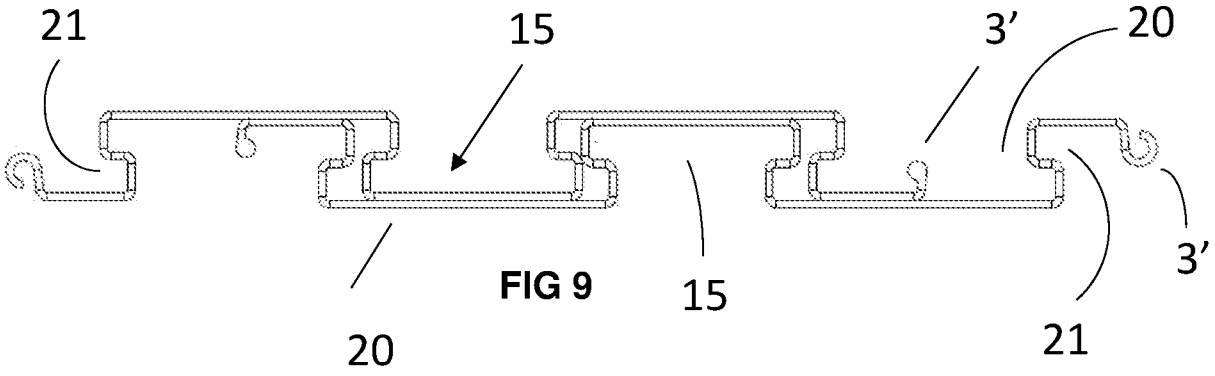

FIG 9

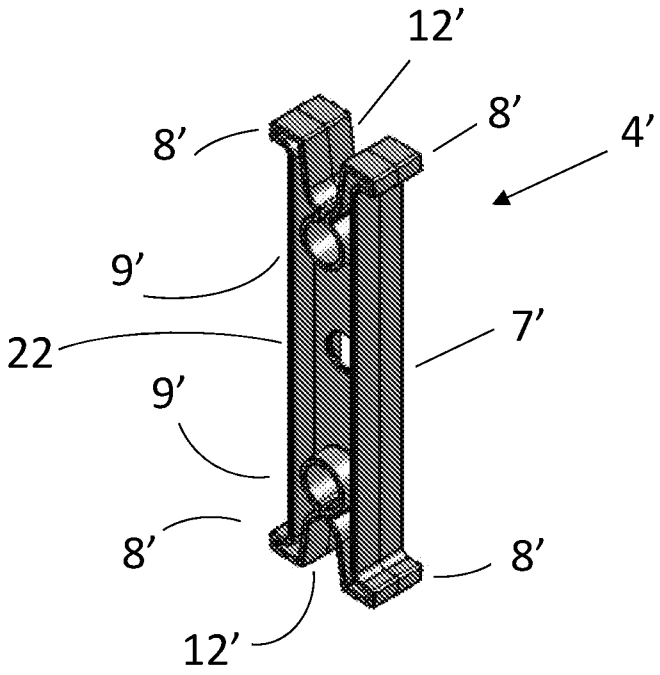

FIG 10

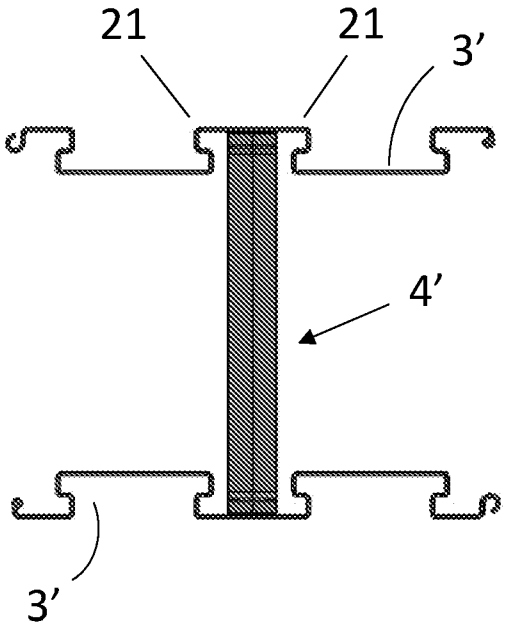

FIG 11

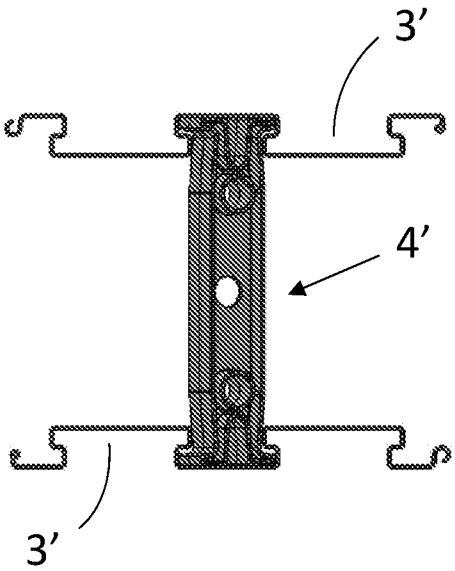

FIG 12

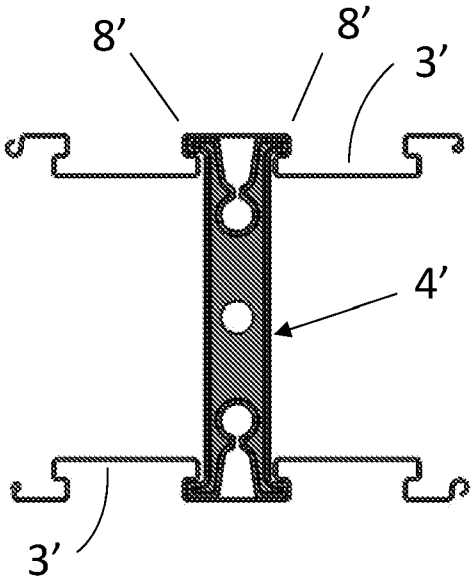

FIG 13

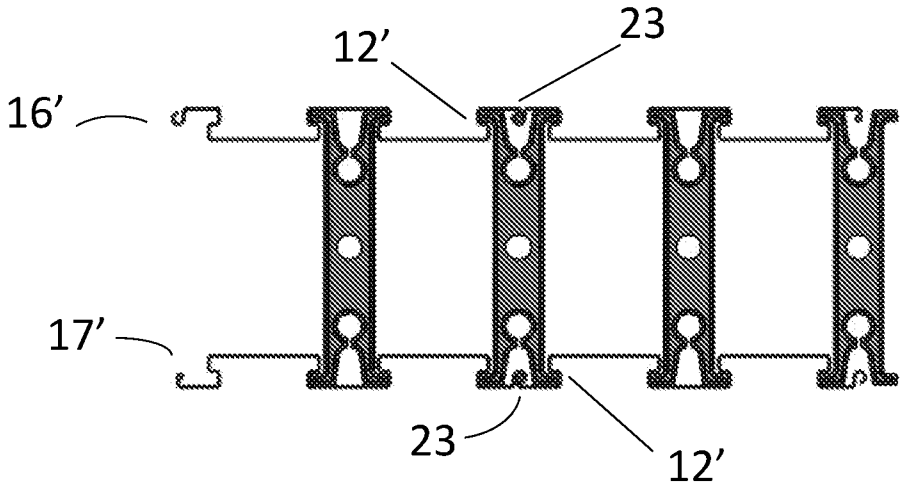

FIG 14

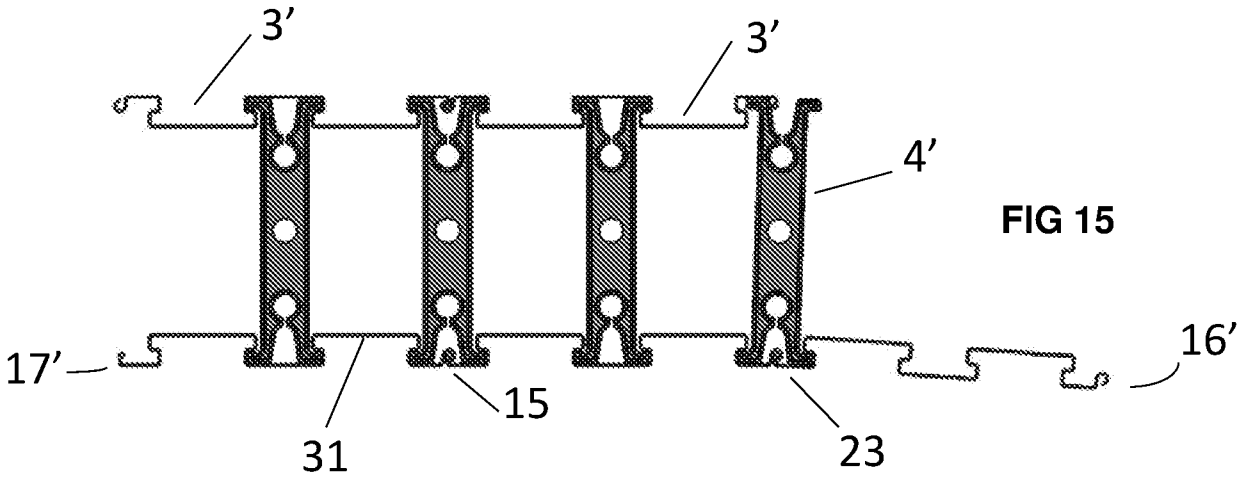

FIG 15

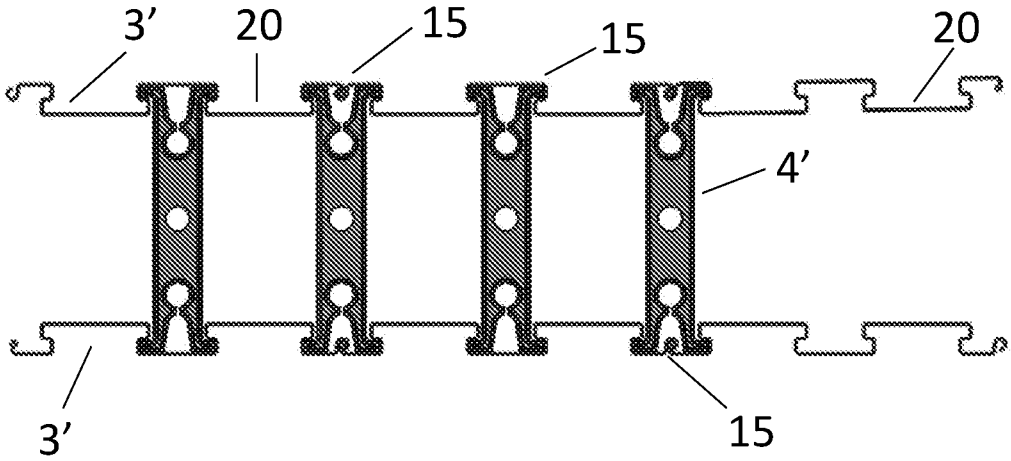

FIG 16

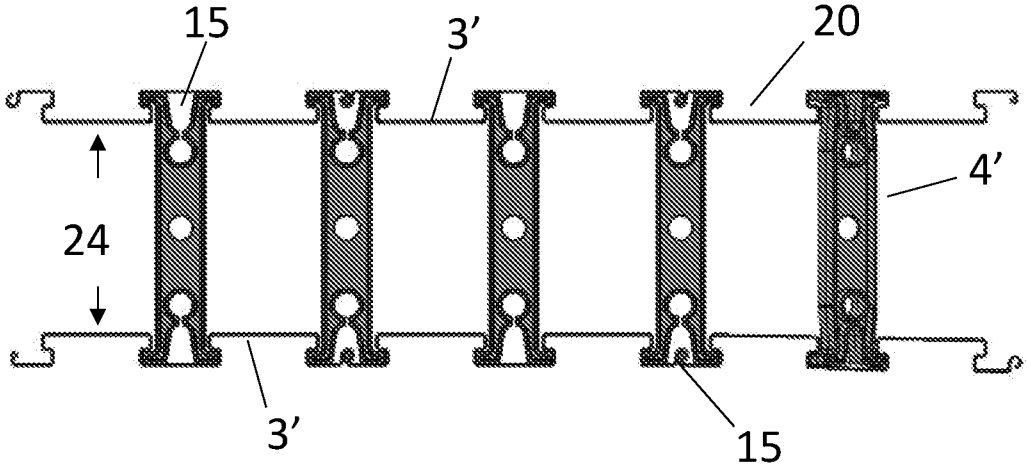

FIG 17

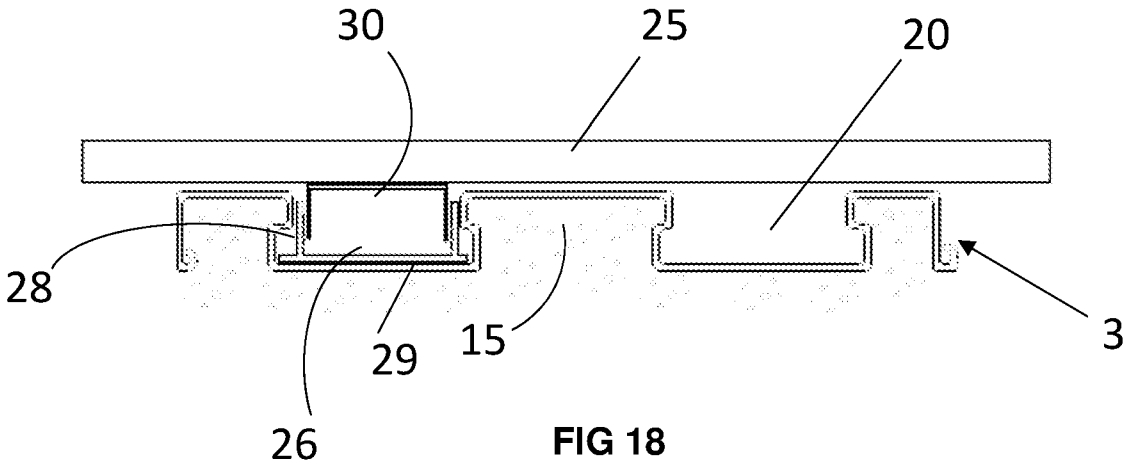

FIG 18

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2019/050074

A. CLASSIFICATION OF SUBJECT MATTER

E04B 1/41 (2006.01) E04G 17/06 (2006.01) E04C 5/16 (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Databases: EPODOC, WPIAP, PATENW, Google Patents,
IPC/CPC: E04G21/12, E04C5/[16,168,206], E04B2/8623, E04G17/[00,04,06,047,0721,0707], E04G2017/[062,0633], E04B1/41, E04G9.
Keywords: Panel, Spacer, Reinforcement, Corrugate, Fold, Dove, Polymer, Bar, Connector, Transparent or the like in various combinations.
Cited/Citing of relevant documents.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	

[X] Further documents are listed in the continuation of Box C [X] See patent family annex

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
28 February 2019	28 February 2019
Name and mailing address of the ISA/AU	**Authorised officer**
AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA Email address: pct@ipaustralia.gov.au	Tom Millist AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No. +61262832709

INTERNATIONAL SEARCH REPORT C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		International application No. **PCT/AU2019/050074**
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2017/201577 A1 (WYETT) 30 November 2017 Fig 1,9, 11, 12	1 - 3, 5, 6 - 10, 12, 15 - 17, 24
X	WO 2010/003211 A1 (SAULRO INC) 14 January 2010 Fig 10, 12, 15; Page 15	1 - 6, 11 - 13, 15 - 17, 24
X	US 2013/0312350 A1 (KREIZINGER) 28 November 2013 Fig 1, 3, 4, 10B, 17; [0091], Abstract	1, 2, 4, 6, 12, 14 - 22, 24
X	WO 2006/066379 A1 (MCNAMARA) 29 June 2006 Fig 1, 2a, 5a; Abstract	1, 2, 15 - 22, 24
X A	US 2014/0115990 A1 (BRODOWSKI) 01 May 2014 [0040] [0040]	25 24

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2019/050074

Box No. 11 Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. [ ] Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
the subject matter listed in Rule 39 on which, under Article 17(2)(a)(i), an international search is not required to be carried out, including

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. [ ] Claims Nos:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a)

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

See Supplemental Box for Details

1. [ ] As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. [X] As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. [ ] As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. [ ] No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

[ ] The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

[ ] The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

[ ] No protest accompanied the payment of additional search fees.

Supplemental Box

Continuation of: **Box III**

This International Application does not comply with the requirements of unity of invention because it does not relate to one invention or to a group of inventions so linked as to form a single general inventive concept.

This Authority has found that there are different inventions based on the following features that separate the claims into distinct groups:

- Group I: Claims 1, 3 - 5, 12, 14, 15, 24 (in part) and claims 2, 6 - 11, 13, 16, 17 (in full) are directed to a connector for securing a formwork panel. The feature of a reinforcement rod retention means extending from said second end is specific to this group of claims.

- Group II: Claims 1, 3 - 5, 12, 14, 15, 24 (in part) and claims 18 - 22 (in full) are directed to a connector for securing a formwork panel. The feature of a means at the second end for securing to said opposing wall is specific to this group of claims.

- Group III: Claim 24 (in part) and claim 25 (in full) are directed to a formwork panel. The feature of the formwork panel being at least partially transparent is specific to this group of claims.

PCT Rule 13.2, first sentence, states that unity of invention is only fulfilled when there is a technical relationship among the claimed inventions involving one or more of the same or corresponding special technical features. PCT Rule 13.2, second sentence, defines a special technical feature as a feature which makes a contribution over the prior art.

When there is no special technical feature common to all the claimed inventions there is no unity of invention.

In the above groups of claims, the identified features may have the potential to make a contribution over the prior art but are not common to all the claimed inventions and therefore cannot provide the required technical relationship. Therefore there is no special technical feature common to all the claimed inventions and the requirements for unity of invention are consequently not satisfied *a priori.*

INTERNATIONAL SEARCH REPORT Information on patent family members	International application No. **PCT/AU2019/050074**

This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document/s Cited in Search Report		Patent Family Member/s	
Publication Number	**Publication Date**	**Publication Number**	**Publication Date**
WO 2017/201577 A1	30 November 2017	WO 2017201577 A1	30 Nov 2017
		AU 2017268708 A1	03 Jan 2019
		SG 11201810118Y A	28 Dec 2018
WO 2010/003211 A1	14 January 2010	WO 201000321 1 A1	14 Jan 2010
		CA 2730526 A1	14 Jan 2010
		US 2011099932 A1	05 May 2011
US 2013/0312350 A1	28 November 2013	US 20133 12350 A1	28 Nov 2013
		US 8621817 B1	07 Jan 2014
		US 8959862 B1	24 Feb 2015
		US 9016027 B1	28 Apr 2015
		US 9359778 B1	07 Jun 2016
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		BR PI0419240 A	22 Jan 2008
		CN 101120146 A	06 Feb 2008
		EP 1836364 A1	26 Sep 2007
		MX 2007007608 A	03 Aug 2007
		US 2009272876 A1	05 Nov 2009
		US 7837174 B2	23 Nov 2010
US 2014/0115990 A1	01 May 2014	US 20141 15990 A1	01 May 2014
		US 8739496 B2	03 Jun 2014

End of Annex

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.