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(54) Structural insulated panel for a foundation wall and foundation wall incorporating same

(57) A foundation wall comprises a plurality of abutting, generally upright structural insulated panels, each of the panels comprising a slab of insulation sandwiched between first and second sheets and a top plate extending along the top of the panel and overlaying the insulation. The lower end of the panel is devoid of a bottom plate.

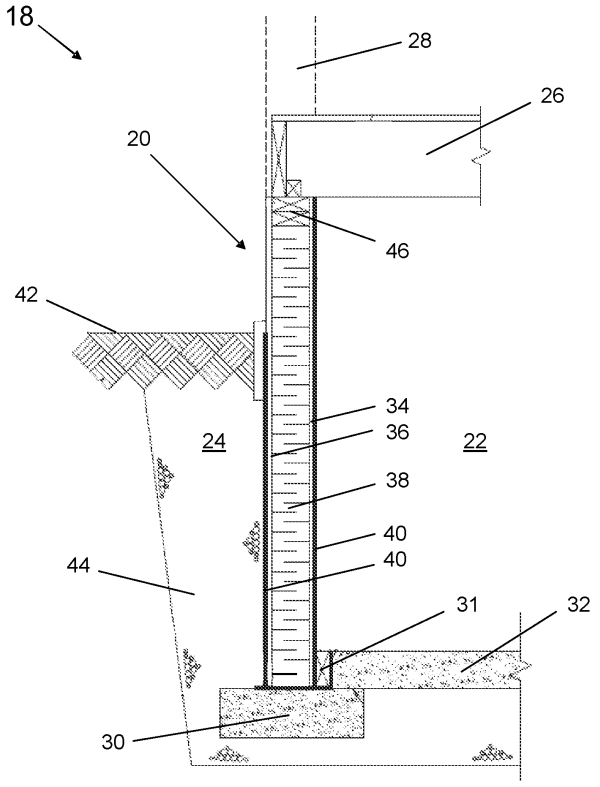

Figure1

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Description

Field of the Invention

[0001] The present invention relates generally to building structures and in particular, to a structural insulated panel for a foundation wall and to a foundation wall incorporating the same.

Background of the Invention

[0002] Structural insulated panels ("SIPs") are becoming an increasingly more common material used in the construction of residential homes and other structures. Conventional SIPs have a sandwich-type structure, and comprise two sheets typically of a wood-based material, such as plywood or oriented strand board ("OSB"), that are bonded to an inner slab of foam insulation. Expanded polystyrene ("EPS") is typically used for the insulation, with extruded polystyrene and polyurethane foam sometimes being used. The bonded sandwich structure of SIPs has been demonstrated to provide comparable strength to a conventional wall consisting of a lumber stud frame filled with slabs of fiberglass insulation. SIPs are typically fabricated as sheets of a standard size (e.g. 4 feet x 8 feet), which can then be cut to size on-site as needed prior to installation.

[0003] A key advantage of SIPs over conventional fiberglass/lumber stud frame walls is the superior thermal insulating performance offered by the closed cell structure of expanded polystyrene, which consists of a network of closed pockets of air trapped in the polystyrene. This closed cell structure results in the foam insulation being both airtight, which is beneficial for thermal insulation, and impermeable to moisture, which prevents the occurrence of water-related damage such as rotting and mould growth that could otherwise occur in "open cell" insulation materials such as fiberglass.

[0004] A number of SIP designs have been considered. For example, U.S. Patent No. 6,279,287 to Meadows discloses a prefabricated building panel that includes first and second side panel members. A thermally insulating core is disposed between the first and second panel members. A first panel end surface includes a pair of spaced projections defining a channel-way, while a second panel end surface includes a pair of spaced channels separated by a plug. Two adjacent building panels may be interconnected by engaging the pair of projections at the first end surface with the pair of channels and plug at the second end surface.

[0005] U.S. Patent No. 6,599,621 to Porter discloses a flat structural panel for building construction that includes an inner insulating core of plastic foam and a pair of opposed outer facings, or sheets, bonded to the insulating core. One of the outer facings is formed of gypsum composite, or gypsum fiberboard, while the other outer facing is formed of a special plastic-impregnated OSB. The gypsum and OSB facings form the inner and outer surfaces of the panel. The facings provide high tensile strength, with the gypsum composite or fiberboard facing also providing resistance to fire and insects.

[0006] U.S. Patent Application Publication No. 20060117689 to Onken et al. discloses an insulated structural panel formed with a rigid foam core, a plurality of vertical hat channels on either face of the rigid foam core, and horizontal top and bottom L-channels on either face of the rigid foam core. The plurality of vertical hat channels on opposing faces of the rigid foam core is connected so as to compress the rigid foam core, thus adding structural strength to the insulated structural panel.

[0007] While more commonly used for above-ground walls of residential structures, the high strength and impermeability to moisture also render SIPs suitable for use as foundation walls. In these applications, a portion of the foundation wall is below grade (i.e. below the ground surface), and the base of the foundation wall is typically placed upon a footing, which can either comprise a solid structure, such as a concrete pad, or a hard particulate bed, such as compacted gravel bed.

[0008] Although the axial and bending strengths of SIPs are known to be high, conventional SIPs typically require additional support along both their top and bottom surfaces. This support is usually provided by either one or more longitudinal strips of lumber secured to the top and bottom surfaces of the SIPs (commonly referred to as "plates"), or U-shaped, longitudinally extending bands secured to the top and bottom surfaces of the SIPs. While the plates and bands contribute to the overall strength of the SIPs, they add to the quantity of material used in their construction and thereby increase cost.

[0009] It is therefore an object of the present invention to provide a novel structural insulated panel and a foundation wall incorporating the same.

Summary of the Invention

[0010] Accordingly, in one aspect there is provided a foundation wall comprising a plurality of abutting, generally upright structural insulated panels, each of the panels comprising a slab of insulation sandwiched between first and second sheets and a top plate extending along the top of said panel and overlaying said insulation, the lower end of said panel being devoid of a bottom plate.

[0011] In one embodiment, the insulation is expanded foam such as for example expanded polystyrene. The first and second sheets are formed of material selected from the group comprising plywood, preserved plywood, oriented strand board and preserved oriented strand board. A recess is formed in the insulation of each panel to accommodate the top plate. The sheets and insulation of each panel also define a flat bottom surface. The bottom surfaces of the panels are supported by a footing such as for example, a concrete pad or a compacted gravel bed. Adjacent panels may be joined by butt joints, spline joints or lap joints.

[0012] According to another aspect, there is provided

a structural insulated panel comprising: a first sheet; a second sheet; and insulation sandwiched between and bonded to the first and second sheets, wherein the first and second sheets and insulation are configured to define a generally planar, bottom surface of said panel.

Brief Description of the Drawings

[0013] Embodiments will now be described more fully with reference to the accompanying drawings in which:

[0014] Figure 1 is a cross-sectional side view of a foundation wall comprising a plurality of abutting structural insulated panels ("SIPs");

[0015] Figures 2a and 2b are cross-sectional side views of a base of the foundation wall of Figure 1 supported by concrete pad and compacted gravel bed footings, respectively;

[0016] Figures 3a and 3b are cross-sectional top views showing a lumber spline joint and a SIP spline joint, respectively, formed between two adjacent SIPs in the foundation wall of Figure 1;

[0017] Figures 4a, 4b, and 4c are isometric, cross-sectional top, and isometric views, respectively, showing a corner configuration formed between two adjacent SIPs in the foundation wall of Figure 1;

[0018] Figure 5 is an isometric view of a SIP in the foundation wall of Figure 1 having a window opening therein;

[0019] Figures 6a and 6b are cross-sectional top views showing a lap joint formed between two adjacent SIPs in a foundation wall;

[0020] Figures 7a and 7b are cross-sectional side views of a frost wall comprising abutting SIPs supported by concrete pad and compacted gravel footings, respectively;

[0021] Figure 8 is a cross-sectional top view showing a butt joint formed between two adjacent SIPs in the frost wall of Figures 7a and 7b;

[0022] Figures 9a to 9f are cross-sectional views showing temporary lateral supports used with the butt joint of Figure 8; and

[0023] Figure 10 is a cross-sectional top view showing a corner configuration formed between two adjacent SIPs in the frost wall of Figures 7a and 7b.

Detailed Description of the Embodiments

[0024] Turning now to Figure 1, a foundation wall is shown and is generally identified by reference numeral 18. In this embodiment, foundation wall 18 comprises a plurality of abutting, generally upright structural insulated panels ("SIPs") 20 that define vertical walls in the foundation of a residential structure, such as a house, and that separate an interior 22 of a living space in a lower level or basement of the residential structure from an exterior 24 of the residential structure. At the same time, SIPs 20 provide support for loads imposed by the residential structure above SIPs 20. In the embodiment shown, SIPs 20 provide support for a floor joist system 26 and upper outer walls 28. The lower ends of SIPs 20 are supported by footing 30. In this embodiment, the footing 30 is a concrete pad, as shown in Figure 2a. SIPs 20 and footing 30 are arranged in an abutting relationship with screed boards 31 and concrete slab 32, the latter of which serves as a floor of interior 22.

[0025] Each SIP 20 has a generally sandwich-type structure that provides high strength both axially (i.e. along the vertical and horizontal axes) and in bending. In particular, each SIP 20 comprises an interior sheet 34, which faces interior 22 of the residential structure and an exterior sheet 36, which faces exterior 24. The materials used for interior sheet 34 and exterior sheet 36 are selected according to local building and construction codes for preserved wood foundations (e.g. CAN/CSA S406-M92, "Construction of Preserved Wood Foundations", a standard required by the 1995 National Building Code of Canada). In this embodiment, exterior sheet 36 is either preserved spruce/pine/fir ("SPF") plywood or preserved oriented strand board ("OSB") and interior sheet 34 is non-preserved OSB. Occupying the volume between and bonded to sheets 34 and 36 is a layer or slab of expanded foam insulation 38. In this embodiment, foam insulation 38 is expanded polystyrene ("EPS"), which is a material known to have "closed-cell" structure, meaning it comprises a structure of generally unconnected air pores within a matrix of polystyrene. As is known in the art, closed-cell materials such as EPS are impermeable to moisture and liquids, as no route exists for moisture to travel through the material. Similarly, closed-cell materials are airtight, and consequently provide superior thermal insulating properties as compared to fiberglass, which has what can be described as an "open cell" structure and which is therefore not inherently airtight.

[0026] SIPs 20 may be used with a moisture barrier covering one or both sheets 34, 36, depending on the requirements of local building and construction codes. In the embodiment shown in Figures 1 and 2a, interior sheet 34 and exterior sheet 36 are covered on their outer surfaces by a respective moisture barrier 40 that serves to block the entry of moisture into SIPs 20 from either side. Such moisture is typically in the form of either atmospheric humidity or ground water, the latter of which may be present within the exterior 24, specifically below grade 42 and within gravel backfill 44. The material and thickness of moisture barrier 40 is similarly selected in accordance with local building and construction codes and in this embodiment, moisture barriers 40 are polyethylene sheets having a thickness of 0.15 mm (6 mil). Although the inherent moisture impermeability of EPS, as described above, renders the use of one or more moisture barriers 40 somewhat redundant, moisture barriers 40 aid in blocking the flow of water around SIPs 20 such as, for example, through the joints formed between adjacent SIPs 20, or through the joints formed between SIPs 20 and footing 30.

[0027] Each SIP 20 also comprises a recess formed

in the upper surface of foam insulation 38 that is sized to accommodate a top plate 46, as shown in Figure 1. Top plate 46 comprises one or more horizontally-oriented lumber boards having a width comparable to the thickness of the foam insulation 38. In the embodiment shown, top plate 46 comprises two stacked horizontal boards of lumber, known in the art as a "double plate" configuration. Top plate 46 serves two functions. Firstly, top plate 46 provides a wood body atop SIP 20 to which abutting lumber may be fastened, such as by nails, screws, plates, or any other suitable fasteners. This may facilitate the fastening of floor joist system 26 to SIP 20, for example. Secondly, top plate 46 provides lateral support at the top of the SIP 20 to evenly distribute loads both along the length and across the thickness of the SIP 20. In the embodiment shown, top plate 46 distributes the vertical load imposed by floor joist system 26 and upper outer wall 28 evenly along the length and across the thickness of the SIP 20. The bottom surface of the insulation 38 is aligned with the bottom surfaces of the sheets 34 and 36 giving the SIP 20 a generally flat, planar bottom surface.

[0028] As shown Figures 1 and 2a, the bottom surface or base of each SIP 20 is supported directly by footing 30 in the absence of a bottom plate, owing to the inherent strength of the SIP 20. This absence of a bottom plate allows the quantity of material required to fabricate each SIP 20 to be reduced, which in turn results in a lower cost as compared to other, conventional structural insulated panels. Moreover, as compared to fiberglass/lumber stud frame walls, SIPs 20 can be fabricated using only 20% of the lumber that would be required to construct a conventional lumber stud frame wall of the same size.

[0029] Rather than supporting the SIPs 20 on a concrete footing 30, the SIPs 20 may alternatively be supported on a footing of a compacted gravel bed 72, as shown in Figure 2b. In this case, support strips 33 may be placed between the base of the SIPs 20 and the compacted gravel bed 72. In the embodiment shown, plywood support strips 33 have a width greater than the width of the SIPs 20, and serve to distribute the vertical load imposed by the SIPs 20 over a larger area of the compacted gravel bed 72 so as to reduce local stresses. The material used for support strips 33 is selected according to local building and construction codes and in this embodiment, support strips 33 are formed of preserved "SPF" plywood.

[0030] A variety of joints may be used to join abutting SIPs 20 of the foundation wall 18 and Figures 3a and 3b show two such exemplary joints. As can be seen, Figure 3a shows a lumber spline joint in which a vertically-oriented lumber spline 50 is accommodated within vertical recesses formed in facing sides of the foam insulation 38 of two adjacent SIPs 20. In the embodiment shown, spline 50 comprises a single lumber board having dimensions commensurate with the size of the recesses formed in the foam insulation 38. Strips of caulking 52 are provided along the seams formed between the abutting interior sheets 34 and the abutting exterior sheets 36 of the SIPs 20. Moisture barriers 40 cover the interior sheets 34 and exterior sheets 36 of both SIPs 20. Caulking 52 and moisture barriers 40 serve to block the passage of moisture through the spline joint formed between SIPs 20.

[0031] Figure 3b shows a SIP spline joint in which a SIP spline 54 is accommodated within vertical recesses formed in facing sides of the foam insulation 38 of two adjacent SIPs 20. SIP spline 54 has a similar cross-sectional structure to each SIP 20, and comprises a volume of expandable foam 39 sandwiched between two appropriately-sized sheets 35. As sheets 35 are exposed to interior conditions only, the material used for each of the sheets 35 is either oriented strand board ("OSB") or plywood. Strips of caulking 52 are provided along the seams formed between the abutting interior sheets 34 and the abutting exterior sheets 36 of the SIPs 20. Moisture barriers 40 cover the interior sheets 34 and exterior sheets 36 of both SIPs. Caulking 52 and moisture barriers 40 serve to block the passage of moisture through the spline joint formed between SIPs 20.

[0032] A foundation corner configuration formed by two abutting SIPs 20 is illustrated in Figures 4a to 4c. Vertical recesses are formed in adjacent sides of the foam insulation 38 of the SIPs 20. An end plate 56 which in the embodiment shown, is a lumber board, as depicted in Figure 4b, is accommodated by each vertical recess. A cover strip 58 is used to cover each end plate 56 to provide protection from exterior 24. The material used for each cover strip 58 is selected according to local building and construction codes and in this embodiment, each cover strip 58 is formed of preserved "SPF" plywood.

[0033] Also shown in Figure 4a is an electrical conduit 60, which comprise a vertical bore provided through the insulation 38. Electrical conduits 60 are typically positioned at regular intervals along the height of the SIPs 20, and provide channels within the SIPs 20 for accommodating electrical wiring. Plumbing chases can be cut onsite as needed. Figure 4c shows the top plate arrangement for the corner configuration. As can be seen the lengths of the two boards forming each top plate 46 are staggered in a manner to allow the boards of the top plates 46 to overlap at the corner and form a flush top plate.

[0034] One or more SIPs 20 forming the foundation wall 18 can be configured to accommodate an opening, such as for example a door or a window. Figure 5 shows a SIP 520 that comprises a window opening. SIP 520 is a modification of SIP 20, from which a portion has been removed to create the window opening, and this window opening is bordered by a window frame comprising a sill plate 62, two jack studs 64, and a lintel 66. As revealed by the cutaways, lintel 66 rests upon jack studs 64, which are themselves connected to sill plate 62 by angle irons.

[0035] While the vertical sides of the foam insulation 38 of the SIPs 20 are typically recessed to accommodate an end plate or spline, as shown for example in Figures 3a to 4b, the recesses can be omitted. In this case, lap

joints can be formed between adjacent SIPs 20 as depicted in Figure 6a, which shows two abutting SIPs 620. As with SIP 20 described in Figures 1 to 5, each SIP 620 comprises an interior sheet 634 and an exterior sheet 636 bonded to foam insulation 638. To facilitate the connection between adjacent SIPs 620, the vertical side surfaces of the interior sheets 634 and exterior sheets 636 of the SIPs 620 carrying mating formations, in this case tongues 668 and grooves 670 as shown in Figure 6b. Tongue 668 is accommodated within groove 670 at the seams between the sheets 634 and 636, as is known in the art. Caulking 652, together with moisture barriers 640, serve to block the passage of moisture through the lap joint formed between SIPs 620. The caulking 652 provided along the seam formed between the exterior sheets 636 of the SIPs 620 has been made semi-transparent so as not to obscure the visibility of tongue 668 and groove 670. It will be appreciated that this lap joint, in which a connecting spline is absent, further reduces the quantity of lumber used in the foundation wall by an amount on the order of 50%, as compared to the spline joint depicted in Figure 3a.

[0036] In addition to being used to separate an interior living space from the exterior, the SIPs can also be used in a foundation frost wall. Figure 7a shows a frost wall comprising a plurality of abutting, generally upright SIPs 720 that define vertical walls in the foundation of a residential structure, such as a house, and that support loads imposed by the overhead structure. In the embodiment shown, the upper ends of SIPs 720 floor joist system 726 and upper outer walls 728. The lower ends of SIPs 720 are supported by a concrete pad footing 730.

[0037] Each SIP 720 has a generally sandwich-type structure that provides high strength both axially (i.e. along both the vertical and horizontal axes) and in bending. Unlike SIPs 20, SIPs 720 are surrounded by gravel backfill 744 on both sides, as depicted in Figure 7a. Consequently, each SIP 720 comprises exterior sheets 736 on both sides of a layer of expanded foam insulation 738. The material used for the exterior sheets 736 is selected according to local building and construction codes (e.g. CAN/CSA S406-M92, "Construction of Preserved Wood Foundations"). In this embodiment, each exterior sheet 736 is formed of preserved "SPF" plywood. Similar to the previous embodiments, the exterior sheets 736 are bonded to the foam insulation 738, which in this embodiment is EPS, or other suitable material which has a "closed-cell" structure as described above. As SIPs 720 do not separate an interior living space of a residential structure from an exterior, no moisture barriers are required to be used with SIPs 720.

[0038] Each SIP 720 also comprises a recess formed in the upper surface of the foam insulation 738 that is sized to accommodate a top plate 746 as shown in Figure 7b. Similar to top plate 46, top plate 746 comprises one or more horizontally-oriented lumber boards having a width commensurate with the thickness of the foam insulation 738. In the embodiment shown, top plate 746 has a double plate configuration and comprises two such horizontal boards. Top plate 746 serves two functions, namely to provide a lumber surface to which abutting lumber may be fastened, and to also provide support at the top of SIP 720 to evenly distribute vertical loads both along the length and across the thickness of SIP 720. In the embodiment shown, top plate 746 distributes the vertical load imposed by floor joist system 726 and upper outer wall 728 evenly upon the length and thickness of SIP 720.

[0039] The inherent strength of the SIPs 720 allows them to be used in the absence of a bottom plate. The base of each SIP 720 can be placed upon a concrete pad footing 730, as shown in Figure 7a, or upon a footing comprising a compacted gravel bed 772, as shown in Figure 7b. As the vertical sides of the SIPs 720 are flush and free of recesses, butt joints are used to join adjacent SIPs 720, as depicted in Figure 8.

[0040] During construction of the frost wall using SIPs 720, it may be useful to provide some temporary support at the base of each butt joint between adjacent SIPs 720. For example, some lateral support applied at the base of each SIP 720 can aid in the alignment and the support of the assembled frost wall prior to backfilling. Figures 9a to 9f depict several methods for providing this lateral support. Figures 9a and 9b depict the use of two lumber blocks 774 placed in an abutting relationship on either side of the butt joint formed between two adjacent SIPs 720. Each lumber block 774 is secured to footing 730 using suitable fasteners 776, such as for example nails, screws, bolts etc. Figures 9c and 9d depict the use of two angle irons 778 placed in an abutting relationship on either side of the butt joint formed between two adjacent SIPs 720. Angle irons 778 are fastened both to footing 730 and to SIPs 720 using suitable fasteners 780 and 781, respectively. Figures 9e and 9f depict the use of a U-channel 782 placed around the bottom of abutting SIPs 720. U-channel 782 is typically used when the footing is a compacted gravel bed 772 as depicted in Figure 7b. As will be appreciated by one skilled in the art, lumber blocks 774, angle irons 778, and U-channel 782 provide lateral support and alignment of the base of the butt joint only and in a temporary fashion, such as until the addition of gravel backfill 744, and do not supply any significant structural support to SIPs 720 that would otherwise be provided by any bottom plate.

[0041] Figure 10 shows a top view of a frost wall corner configuration formed between two adjacent SIPs 720. Similar to the corner configuration shown in Figures 4a and 4b, vertical recesses are provided in adjacent sides of the foam insulation 738 of adjacent SIPs 720. End plates 756 and 757 are accommodated by the vertical recesses. In the embodiment shown, end plates 756 and 757 are identically sized, but are of different materials owing to the different environments to which they are exposed. As end plate 757 has direct exposure to gravel backfill 744, the material used for end plate 757 is selected in accordance with local construction and building

codes, and in this embodiment is formed of preserved "SPF" lumber. In contrast, end plate 756 does not have direct exposure to gravel backfill 744 and consequently is exposed to a different and milder environment. In this embodiment, end plate 756 is formed of standard (non-preserved) "SPF" lumber.

[0042] While a butt joint is described as being used between adjacent SIPs 720 forming the frost wall, it will be appreciated that a similar butt joint may be used to join structural insulated panels in other applications. Similarly, while a lap joint is described as being used to join adjacent SIPs 620 in the foundation wall, a similar lap joint may be used to join SIPs in other applications.

[0043] While the material used for the sheets of the above embodiments is referred to as being plywood, preserved plywood, oriented strand board, or preserved oriented strand board, those of skill in the art will appreciate that the material used for the sheets may be of any other suitable material known in the art.

[0044] While the foam insulation of the SIPs is described as being EPS, those of skill in the art will appreciate that the insulation may be any of expanded polystyrene, extruded polystyrene, and/or polyurethane foam, or any other suitable insulating foam having adequate mechanical, structural, and/or thermal properties known in the art.

[0045] Although embodiments have been described above with reference to the accompanying drawings, those of skill in the art will appreciate that variations and modifications may be made without departing from the spirit and scope thereof as defined by the appended claims.

Claims

1. A foundation wall comprising:

a plurality of abutting, generally upright structural insulated panels, each of the panels comprising a slab of insulation sandwiched between first and second sheets and a top plate extending along the top of said panel and overlaying said insulation, the lower end of said panel being devoid of a bottom plate.

2. A foundation wall according to claim 1 wherein the insulation is expanded foam.

3. A foundation wall according to claim 2 wherein the expanded foam is expanded polystyrene.

4. A foundation wall according to any one of claims 1 to 3, wherein the first and second sheets are formed of material selected from the group comprising plywood, preserved plywood, oriented strand board, and preserved oriented strand board.

5. A foundation wall according to any one of claims 1 to 4 further comprising a recess formed in the insulation of each panel to accommodate said top plate, the sheets and insulation of each panel defining a flat panel bottom surface.

6. A foundation wall according to claim 5 wherein the bottom surfaces of said panels are supported by a footing, said footing preferably being one of a concrete pad and a compacted gravel bed.

7. A foundation wall according to any one of claims 1 to 6, wherein adjacent panels are joined by one of butt joints, spline joints and lap joints.

8. A foundation wall according to any one of claims 1 to 7 further comprising a moisture barrier on at least one of the first and second sheets of the panels.

9. A foundation wall according to claim 8 comprising a moisture barrier on both the first and second sheets of the panels.

10. A structural insulated panel comprising:

a first sheet;
a second sheet; and
insulation sandwiched between and bonded to the first and second sheets, wherein the first and second sheets and insulation are configured to define a generally planar, bottom surface of said panel.

11. A structural insulated panel according to claim 10 wherein the insulation is expanded foam.

12. A structural insulated panel according to claim 11 wherein the expanded foam is expanded polystyrene.

13. A structural insulated panel according to any one of claims 10 to 12, wherein the first and second sheets are formed of material selected from the group comprising plywood, preserved plywood, oriented strand board, and preserved oriented strand board.

14. A structural insulated panel according to any one of claims 10 to 13 further comprising a recess formed in a top surface of the insulation, the recess sized to accommodate a top plate

15. Use of a structural insulated panel according to any one of claims 10 to 14 in a foundation wall.

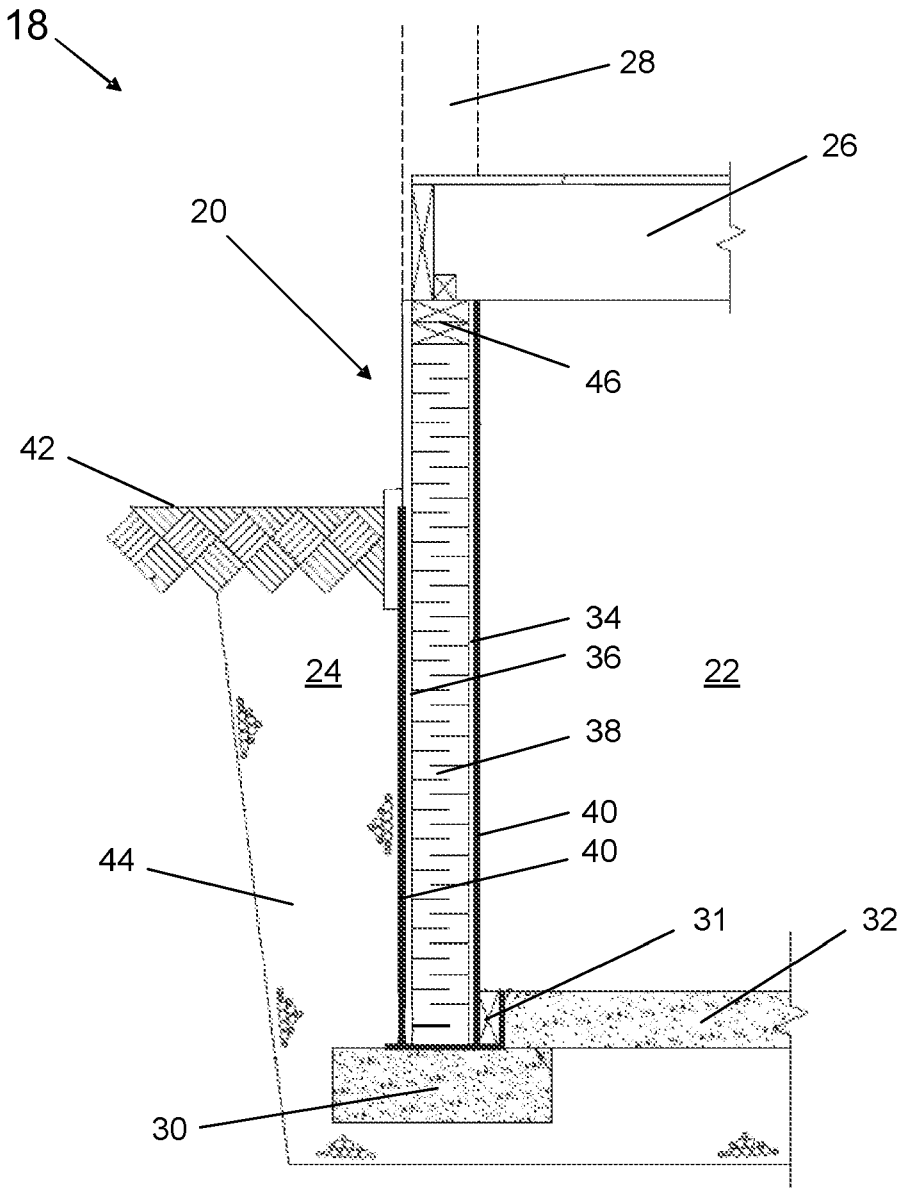

Figure1

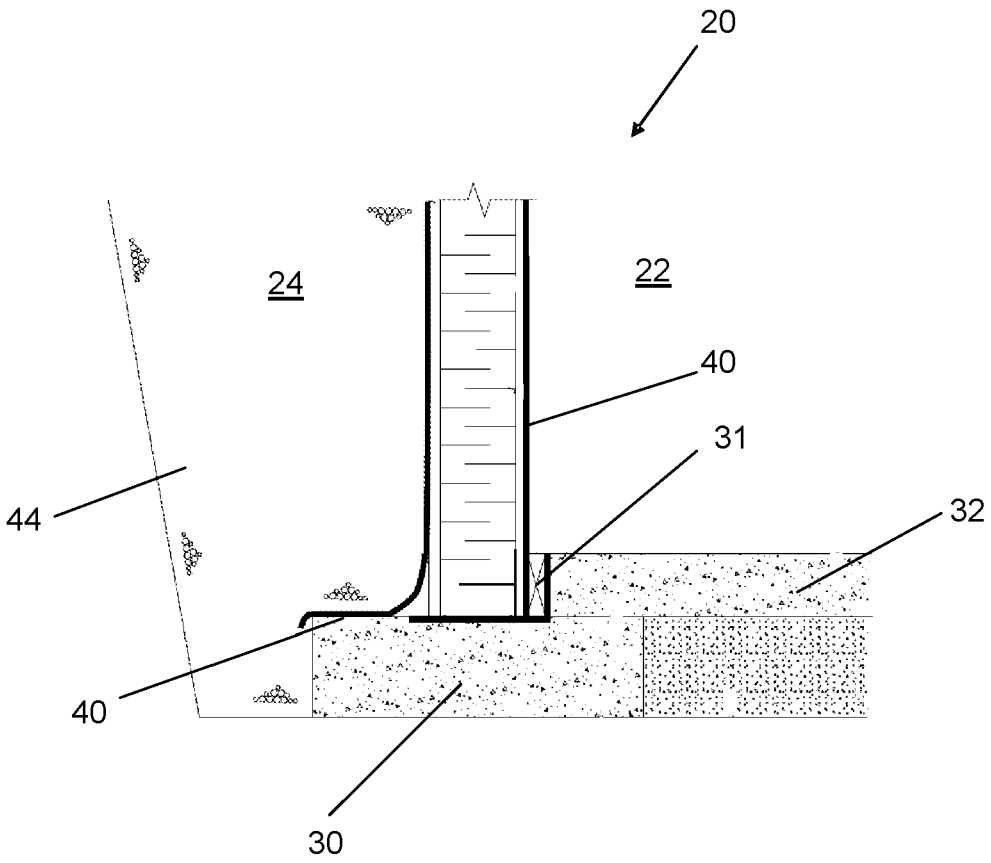

Figure2a

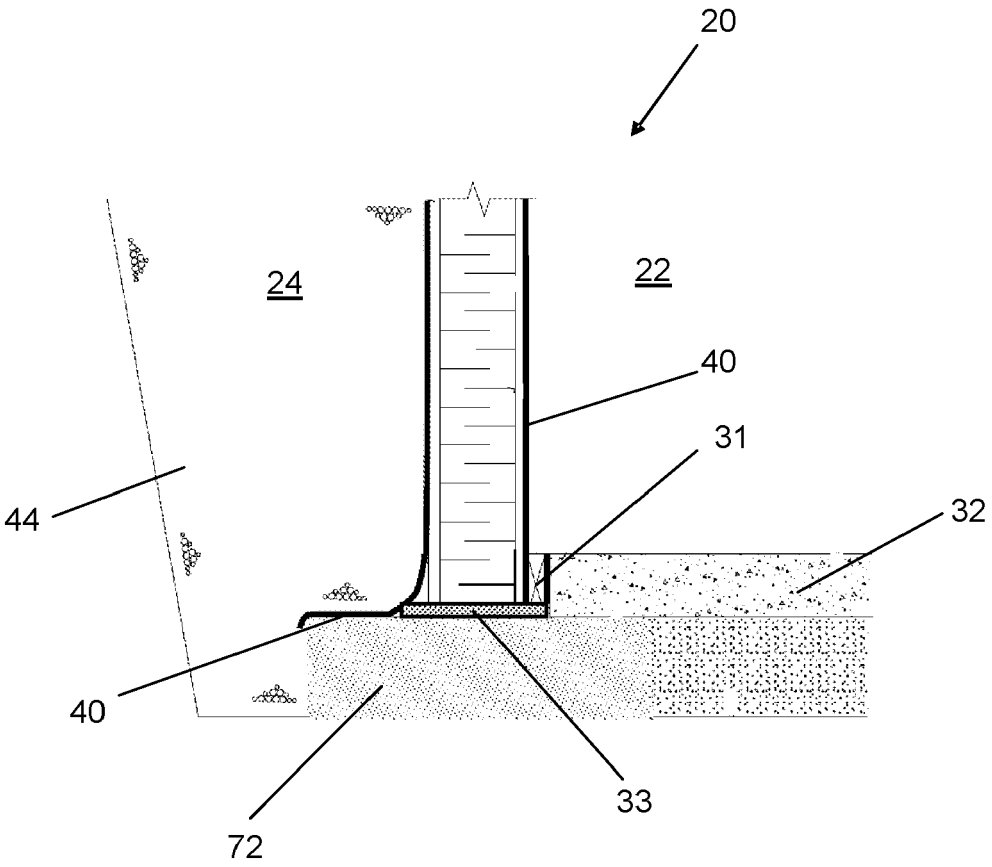

Figure2b

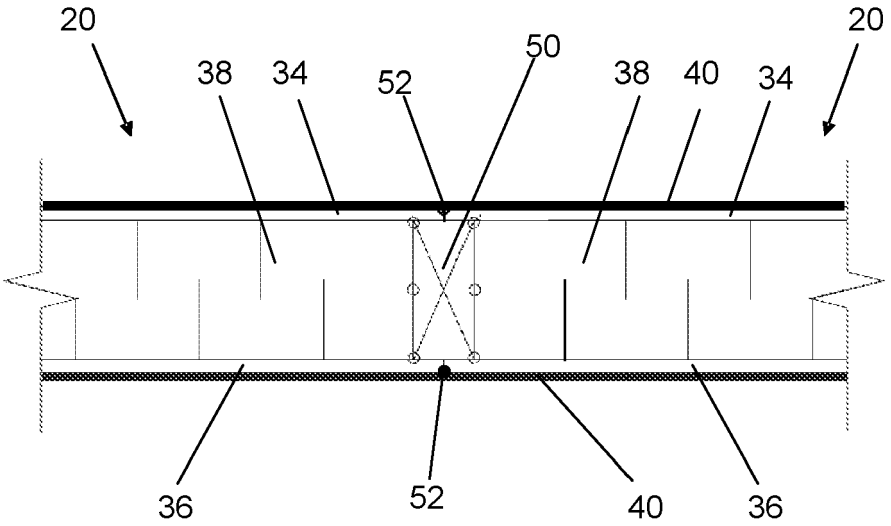

Figure3a

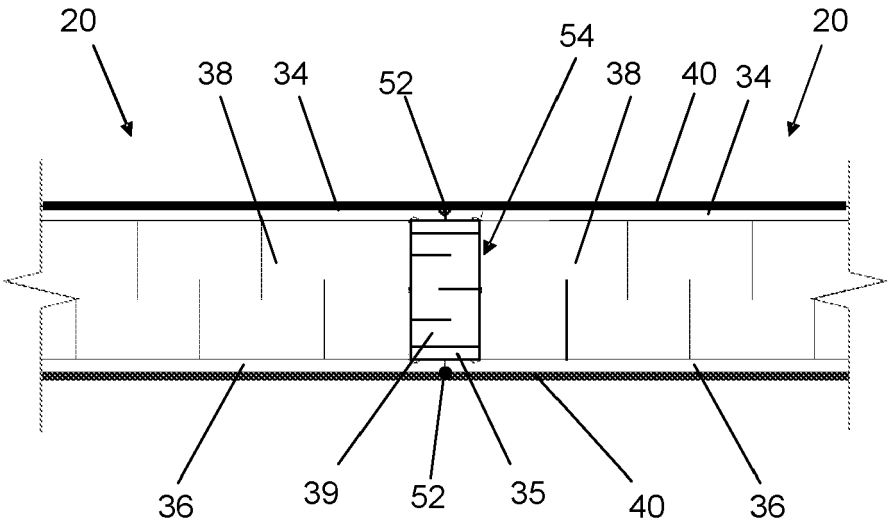

Figure3b

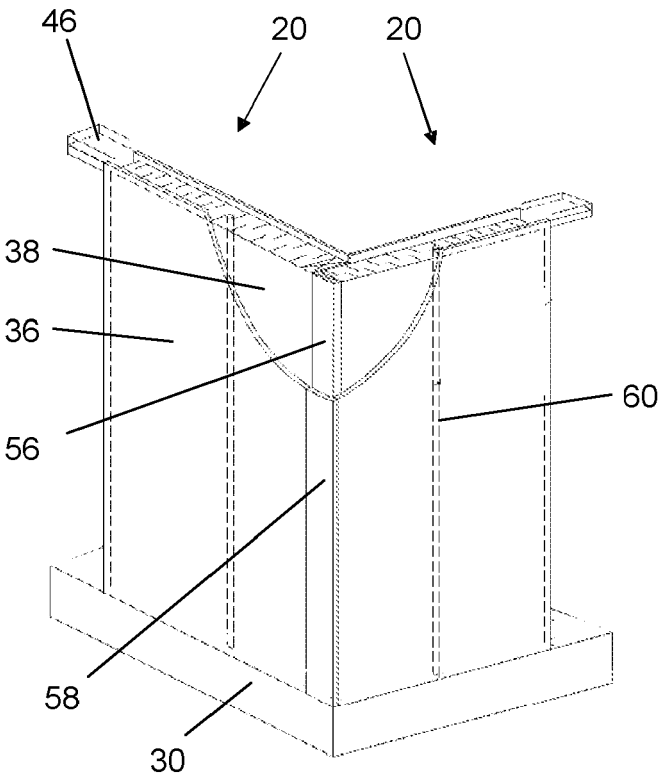

Figure4a

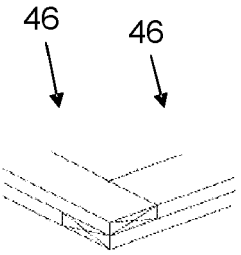

Figure4c

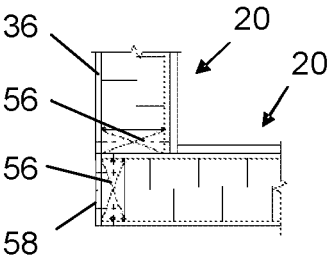

Figure4b

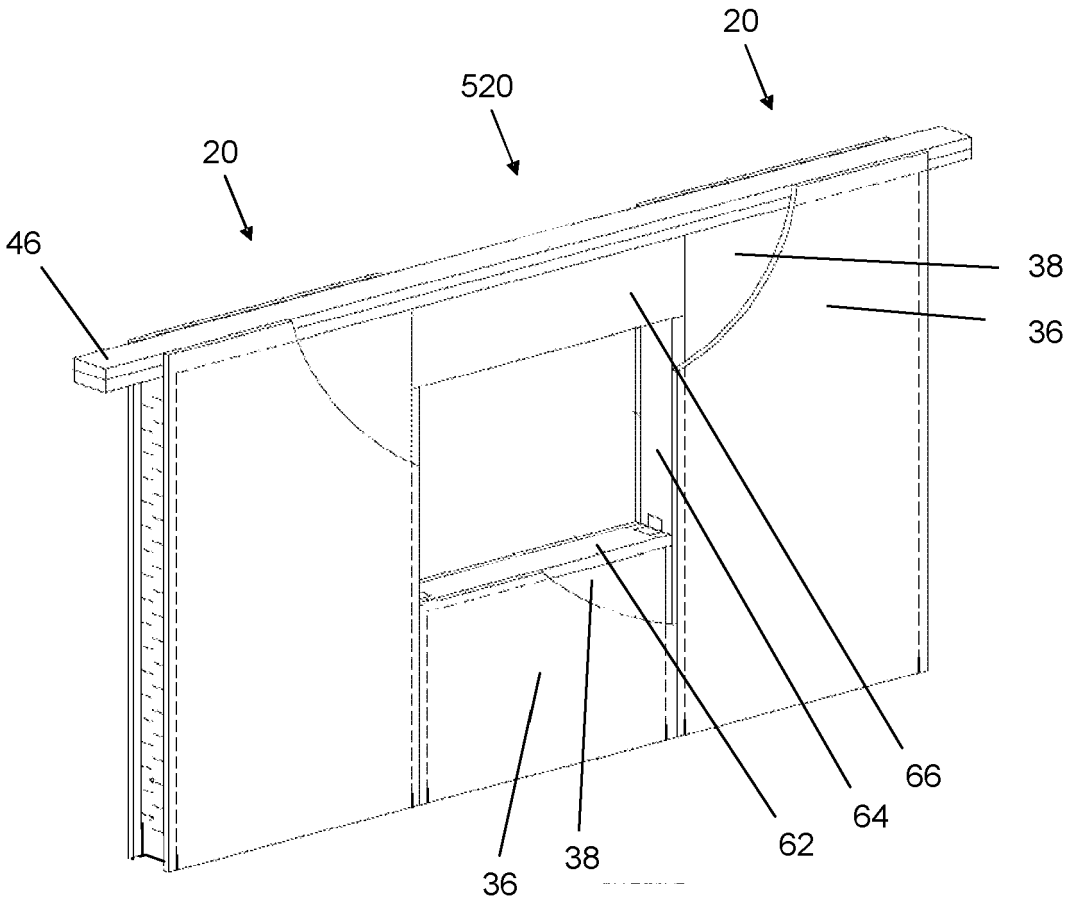

Figure5

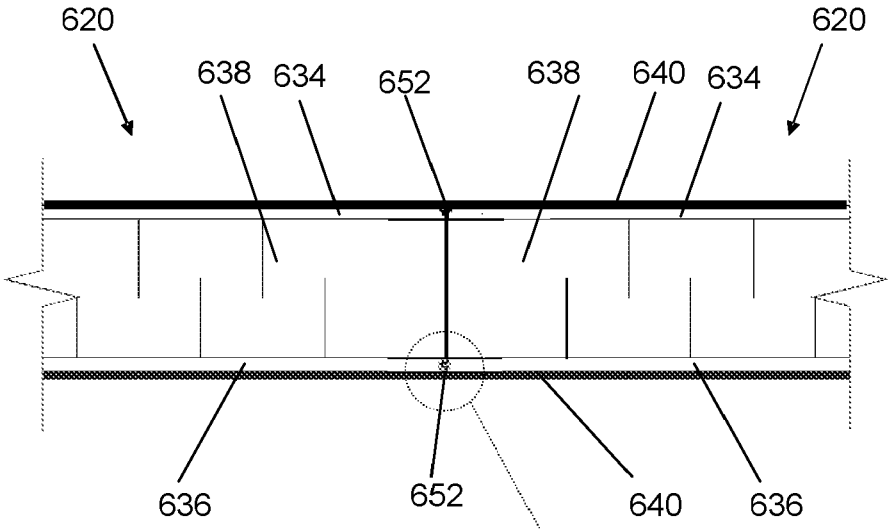

Figure6a

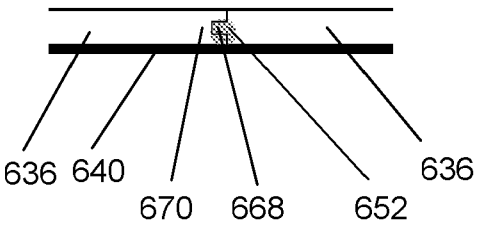

Figure6b

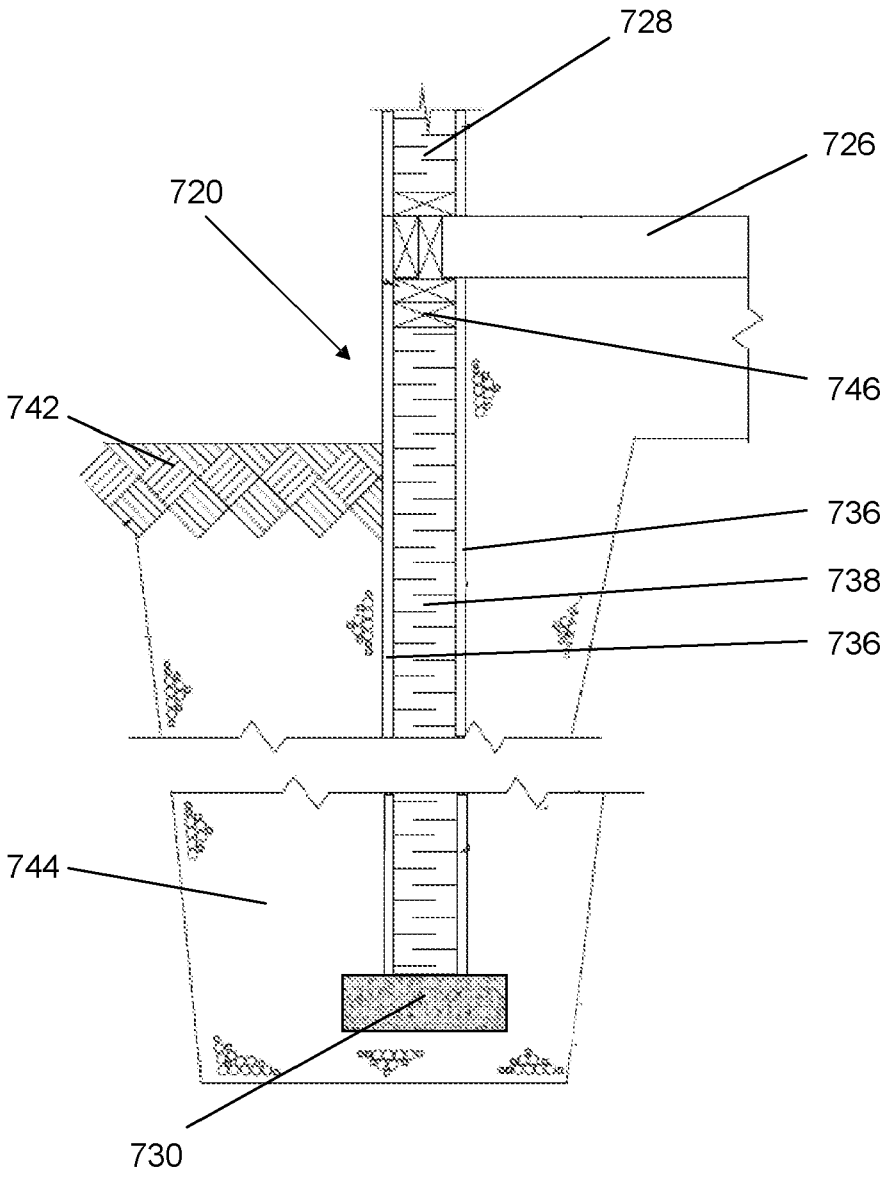

Figure7a

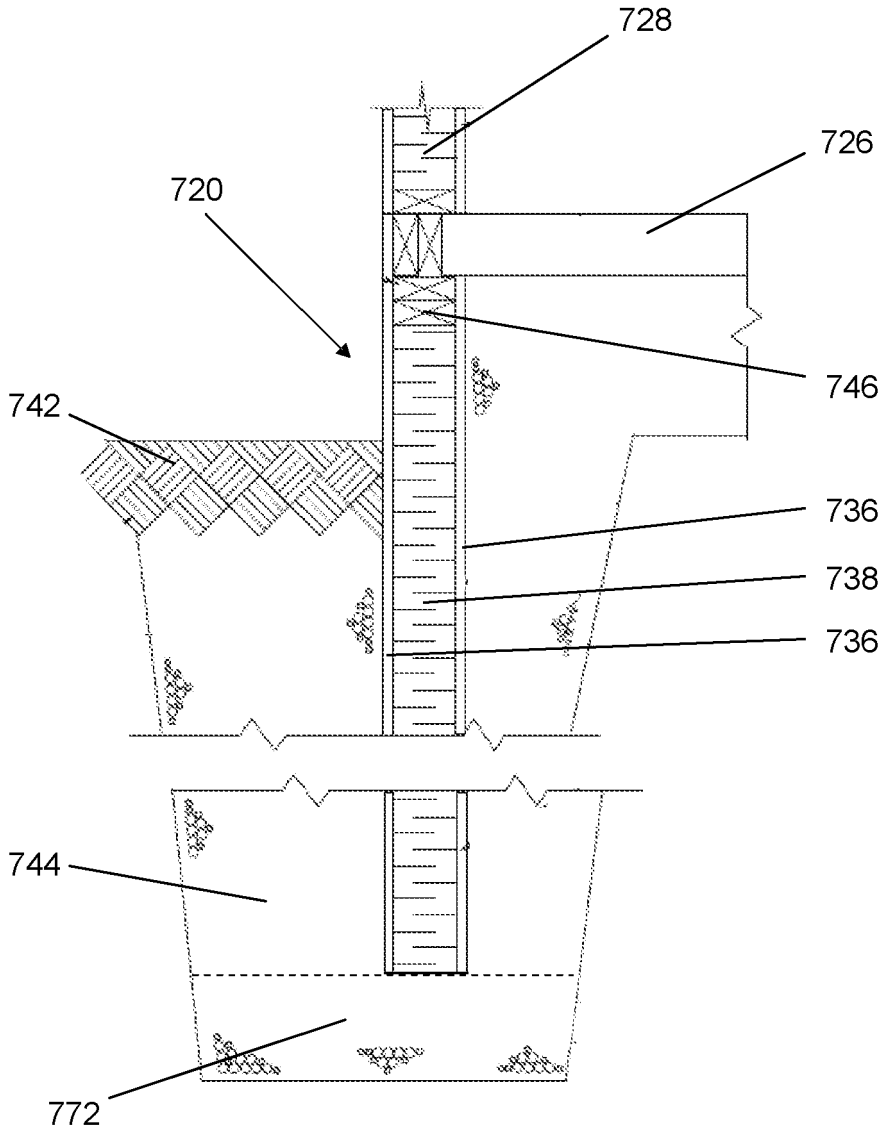

Figure7b

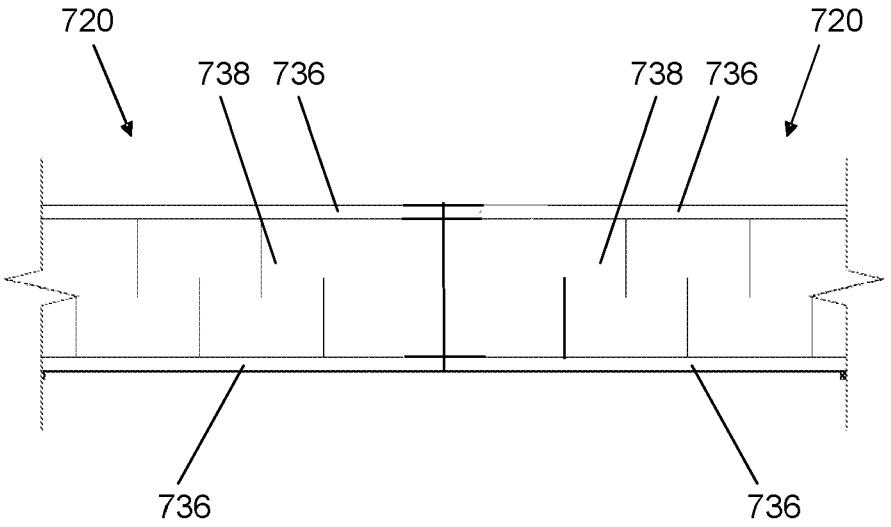

Figure8

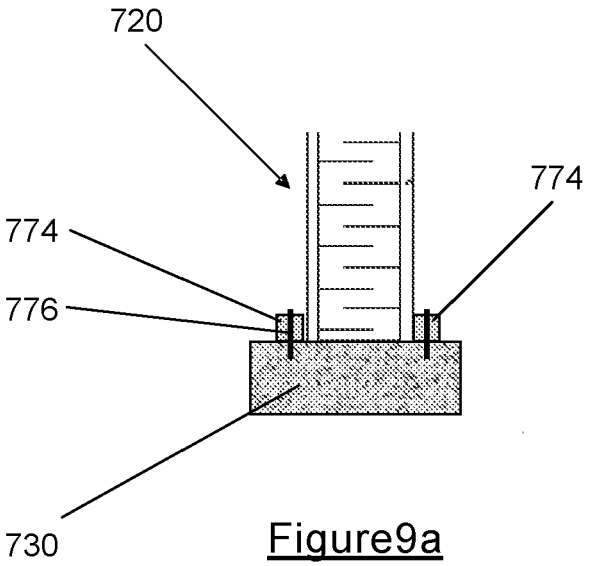

Figure9a

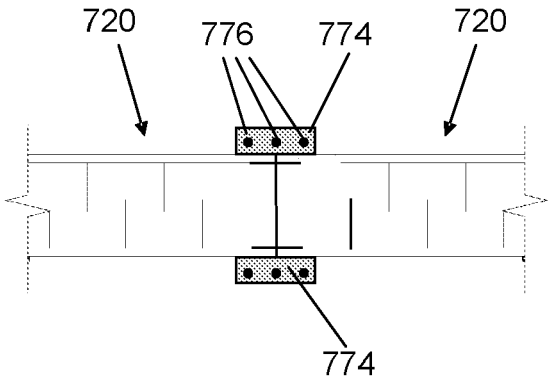

Figure9b

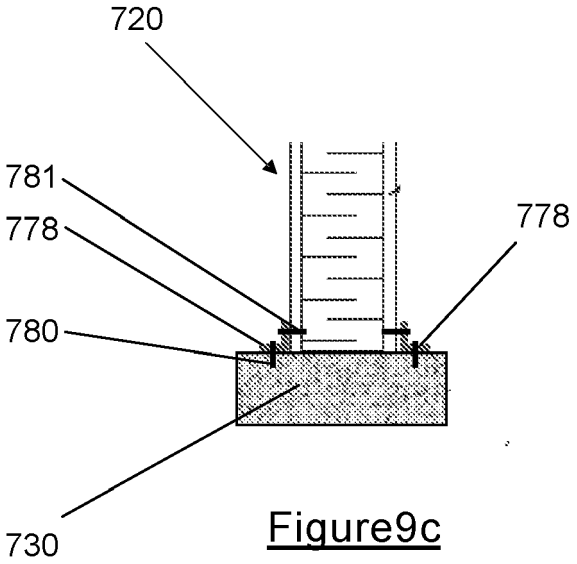

Figure9c

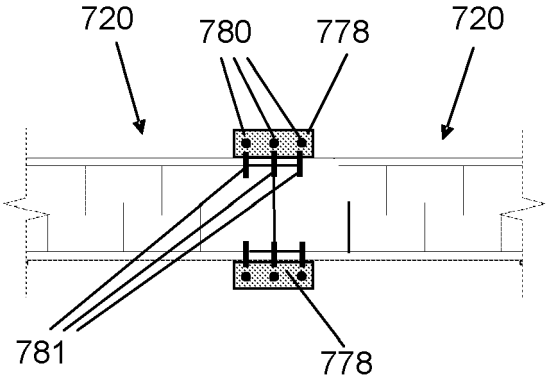

Figure9d

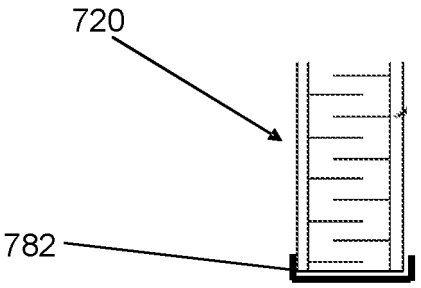

Figure9e

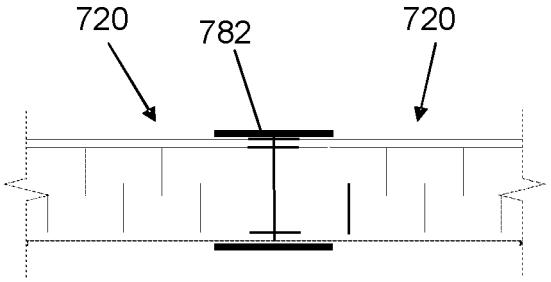

Figure9f

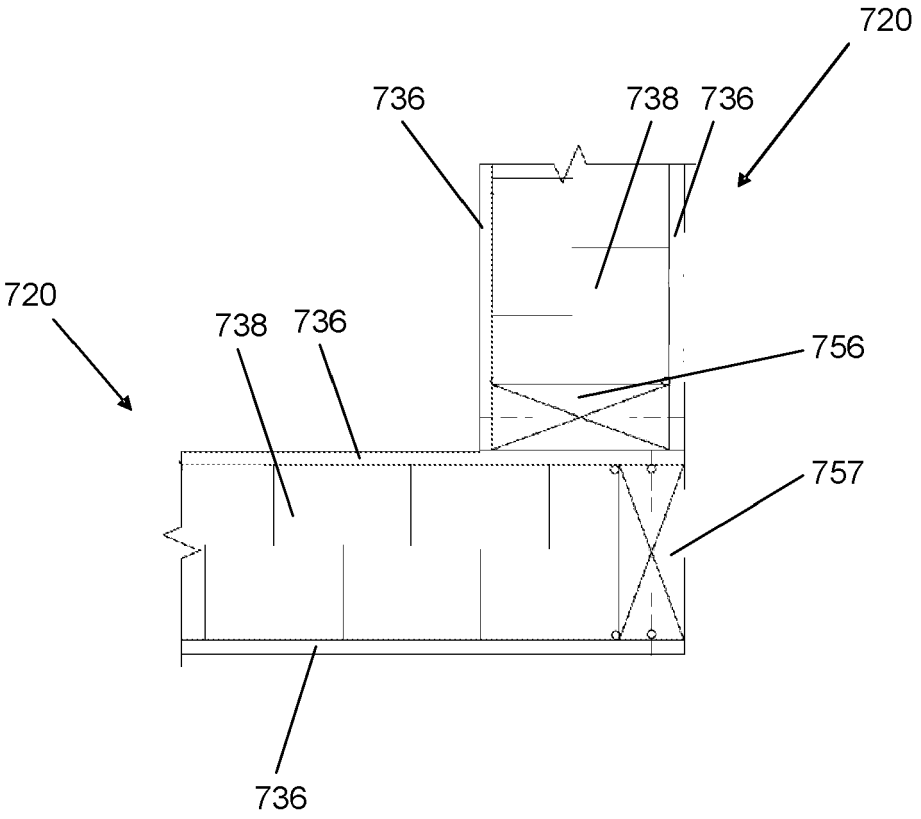

Figure10

REFERENCES CITED IN THE DESCRIPTION

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- US 6599621 B, Porter **[0005]**
- US 20060117689 A, Onken **[0006]**