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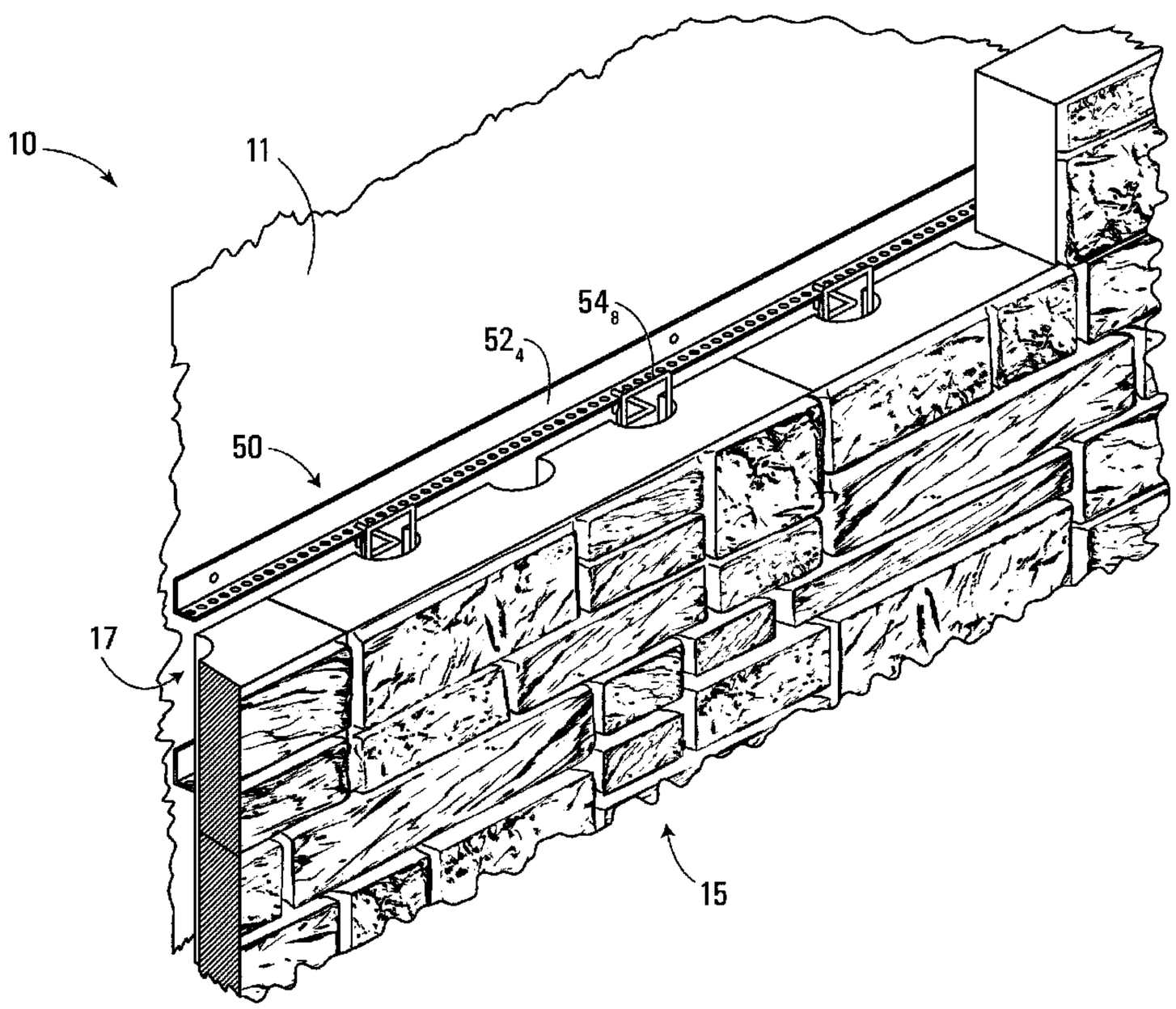
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(54) Title: EXTERIOR WALL STRUCTURE OF A BUILDING



(57) Abrégé/Abstract:
An exterior wall structure of a building. The exterior wall structure comprises an inner wall and an outer wall that are separated from each other to define a cavity therebetween. The outer wall comprises a plurality of concrete blocks. The exterior wall structure also comprises a connection system interconnecting the inner wall and the outer wall. The connection system comprises a plurality of elongated structural members, each elongated structural member being fastened to the inner wall. The connection system also comprises a plurality of connecting elements, each connecting element being connected to a given one of the elongated structural elements and to a given one of the concrete blocks. Each of the elongated structural members is connected to plural ones of the concrete blocks via plural ones of the connecting elements.

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ABSTRACT

An exterior wall structure of a building. The exterior wall structure comprises an inner wall and an outer wall that are separated from each other to define a cavity therebetween. The outer wall comprises a plurality of concrete blocks. The exterior wall structure also comprises a connection system interconnecting the inner wall and the outer wall. The connection system comprises a plurality of elongated structural members, each elongated structural member being fastened to the inner wall. The connection system also comprises a plurality of connecting elements, each connecting element being connected to a given one of the elongated structural elements and to a given one of the concrete blocks. Each of the elongated structural members is connected to plural ones of the concrete blocks via plural ones of the connecting elements.

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EXTERIOR WALL STRUCTURE OF A BUILDING

FIELD OF THE INVENTION

The present invention relates to exterior wall structures of residential, commercial or other buildings.

BACKGROUND

An exterior wall structure of a residential, commercial or other building often comprises an inner wall and an outer wall that are separated from each other so as to define a cavity therebetween. The cavity contributes to impeding moisture intrusion into the inner wall, equalizing pressure on either side of the outer wall, and insulating the exterior wall structure.

The outer wall typically comprises masonry units (e.g., bricks or concrete blocks) stacked and arranged into courses (rows) with mortar holding the masonry units together and filling their interfaces. The inner wall is usually linked to the outer wall by wall ties (e.g., corrugated wall ties) that are individually fastened to the inner wall and anchored in the mortar of the outer wall.

During construction of this type of exterior wall structure, it is not uncommon for excess mortar to bridge the outer wall and the inner wall and/or fall and clog weep holes of the wall structure that are provided for water drainage. This detrimentally affects the exterior wall structure's ability to impede moisture intrusion and allow pressure equalization.

These detrimental effects may be encountered whenever mortar is used to hold and fill interfaces of the masonry units of the outer wall. In particular, this applies when the masonry units are concrete blocks with a natural stone appearance that are used to provide a natural and aesthetic look to the exterior wall structure. For production considerations, the concrete blocks are typically cast in such a way that their height is oriented generally vertically during casting. This casting process often results in the concrete blocks having significantly different heights, thereby requiring mortar to compensate for differences in height of the concrete blocks when

they are placed in the outer wall. Furthermore, in order to have their natural stone appearance, the concrete blocks may be subjected after casting to a mechanical artificial aging/weathering process (e.g., tumbling, object impacting, etc.) to realize desired natural stone characteristics. This process can damage lateral surfaces of the concrete blocks which can end up forming gaps in the interfaces of the concrete blocks when placed in the outer wall, thereby requiring mortar to fill these gaps.

There is therefore a need for improvements in exterior wall structures with inner and outer walls separated by a cavity.

SUMMARY OF THE INVENTION

As embodied and broadly described herein, the invention provides a system for interconnecting an outer wall and an inner wall of an exterior wall structure, the outer wall and the inner wall being separated from each other to define a cavity therebetween, the outer wall comprising a plurality of concrete blocks. The system comprises a plurality of elongated structural members, each elongated structural member being adapted to be fastened to the inner wall. The system also comprises a plurality of connecting elements, each connecting element being adapted to be connected to a given one of the elongated structural elements and to a given one of the concrete blocks. Each of the elongated structural members is adapted to be connected to plural ones of the concrete blocks via plural ones of the connecting elements.

The invention also provides a system for use in constructing an exterior wall structure, the exterior wall structure comprising an inner wall. The system comprises a plurality of concrete blocks adapted to be stacked to erect an outer wall of the exterior wall structure, the outer wall and the inner wall intended to be separated from each other to define a cavity therebetween. The system also comprises a plurality of elongated structural members, each elongated structural member being adapted to be fastened to the inner wall. The system also comprises a plurality of connecting elements, each connecting element being adapted to be connected to a given one of the elongated structural elements and to a given one of the concrete blocks. Each of the elongated structural members is adapted to be connected to plural ones of the concrete blocks via plural ones of the connecting elements.

The invention also provides an exterior wall structure. The exterior wall structure comprises an inner wall and an outer wall comprising a plurality of concrete blocks. The inner wall and the outer wall are separated from each other to define a cavity therebetween. The exterior wall structure also comprises a plurality of elongated structural members, each elongated structural member being fastened to the inner wall. The exterior wall structure also comprises a plurality of connecting elements, each connecting element being connected to a given one of the elongated structural elements and to a given one of the concrete blocks. Each of the elongated structural members is connected to plural ones of the concrete blocks via plural ones of the connecting elements.

The invention also provides a method for use in constructing an exterior wall structure, the exterior wall structure comprising an inner wall. The method comprises securing at least one elongated structural member to the inner wall. The method also comprises placing a plurality of concrete blocks horizontally adjacent to each other to form a course. The method further comprises, for each of the concrete blocks, connecting each of at least one connecting element to the concrete block and to one of the at least one elongated structural member secured to the inner wall in alignment with the course.

The invention also provides a plurality of dry-cast concrete blocks for use in constructing an outer wall of an exterior wall structure, the exterior wall structure comprising an inner wall, the outer wall and the inner wall intended to be separated to define a cavity therebetween. Each of the dry-cast concrete blocks comprises: a front surface comprising at least one portion having a cast texture with a natural stone appearance; a rear surface defining with the front surface a thickness of the dry-cast concrete block; two lateral surfaces defining a height of the dry-cast concrete block; and two lateral surfaces defining a width of the dry-cast concrete block. A difference in height between different ones of the dry-cast concrete blocks is less than about 1 mm.

These and other aspects of the invention will now become apparent to those of ordinary skill in the art upon review of the following description of embodiments of the invention in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

A detailed description of embodiments of the invention is provided below, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 shows a portion of an exterior wall structure of a building, in accordance with an embodiment of the invention;

Figure 2 shows an inner wall, an outer wall, and a connection system of the exterior wall structure, with certain concrete blocks of the outer wall being removed;

Figure 3 shows a vertical cross-sectional view of the exterior wall structure;

Figure 4 shows a horizontal cross-sectional view of the exterior wall structure;

Figure 5 shows a perspective view of a given one of the concrete blocks of the outer wall of the exterior wall structure;

Figure 6 shows a cross-sectional view of the given one of the concrete blocks shown in Figure 5, taken along line 6-6;

Figure 7 shows a portion of one of a plurality of elongated structural members of the connection system of the exterior wall structure;

Figures 8A to 8D respectively show a perspective view, a front elevation view, a side elevation view, and a top view of one of a plurality of connecting elements of the connection system of the exterior wall structure;

Figure 9 is a flowchart illustrating an example of a method for advancing construction of the exterior wall structure;

Figure 10 shows an embodiment of the exterior wall structure in which mortar is optionally provided on an external side of the outer wall;

Figure 11 shows an embodiment of the exterior wall structure in which a band of sealant material is optionally applied to lateral surfaces of certain ones of the concrete blocks of the outer wall; and

Figure 12 is a flowchart illustrating an example of a process for manufacturing concrete blocks in accordance with an embodiment of the invention.

It is to be expressly understood that the description and drawings are only for the purpose of illustrating certain embodiments of the invention and are an aid for understanding. They are not intended to be a definition of the limits of the invention.

DETAILED DESCRIPTION OF EMBODIMENTS

Figures 1 and 2 show a portion of an exterior wall structure 10 of a building (e.g., a house or other residential building, a commercial building, etc.), in accordance with an embodiment of the invention. The wall structure 10 comprises an inner wall 11 and an outer wall 15 that are separated from each other so as to define a cavity 17 therebetween. The wall structure 10 also comprises a connection system 50 interconnecting the inner wall 11 and the outer wall 15. The wall structure 10 is further provided with flashing (not shown) and weep holes (not shown) for water drainage.

The cavity 17 forms an air space between the inner wall 11 and the outer wall 15 and may have any suitable width (e.g., about 25 mm, 50 mm or any other suitable width). The cavity 17 contributes to impeding moisture intrusion into the inner wall 11, equalizing pressure on either side of the outer wall 15, and insulating the wall structure 10.

With additional reference to Figures 3 and 4, the inner wall 11 may comprise a frame 19 (e.g., wood framing members such as studs, metal framing members, etc.), insulation material (e.g., fiberglass, cellulose, etc.) placed within space defined by the frame 19, a paneling layer 21 (e.g., drywall boards, etc.), a vapor barrier (retarder) layer 25 (e.g., plastic sheet such as polyethylene sheet, etc.), an outer sheathing layer 29 (e.g., plywood, oriented strand board (OSB), etc.), and an air and water barrier layer 31 (e.g., housewrap such as Tyvek™

housewrap, etc.). It will be appreciated that the inner wall 11 may be constructed using various other materials and components.

The outer wall 15 comprises a plurality of concrete blocks 12_1-12_N. The concrete blocks 12_1-12_N are stacked and arranged into a plurality of courses (rows). Each course includes given ones of the concrete blocks 12_1-12_N positioned horizontally adjacent to one another. For solidity considerations, the given ones of the concrete blocks 12_1-12_N in one course are offset relative to the given ones of the concrete blocks 12_1-12_N in an adjacent course.

As shown in Figure 10, mortar 33 can optionally be provided on an external side of the outer wall 15. The mortar 33 may be a mixture of cement, lime, or gypsum plaster with sand and water, or any other suitable plastic building material that hardens. The mortar 33 is purely optional (i.e., it can be omitted) and can be provided on the external side of the outer wall 15 primarily for aesthetic purposes. Indeed, as further described below, the concrete blocks 12_1-12_N enable the outer wall 15 to be built without requiring mortar to hold (bond) them together or fill their interface. That is, no mortar needs to be provided between lateral surfaces of adjacent ones of the concrete blocks 12_1-12_N in order to hold the concrete blocks 12_1-12_N together or fill their interface. This absence of mortar between lateral surfaces of adjacent ones of the concrete blocks 12_1-12_N results in the cavity 17 being free of mortar. By avoiding mortar bridging the outer wall 15 and the inner wall 11 or falling and clogging the weep holes, this contributes to the cavity 17 impeding moisture intrusion in the inner wall 11 and promoting pressure equalization between either side of the outer wall 15.

With additional reference to Figure 5, a given concrete block 12_j of the concrete blocks 12_1-12_N ($1 \leq j \leq N$) will be described in further detail. It will be appreciated that this description similarly applies to other ones of the concrete blocks 12_1-12_N.

The concrete block 12_j is a dry-cast concrete block, i.e., it is made of no-slump concrete. No-slump concrete (also known as zero-slump concrete) can be viewed as concrete with a slump of 6 mm or less. It will be appreciated that various types of no-slump concrete are possible and may be used. It will also be appreciated that other types of concrete (e.g., measurable-slump concrete) may be used in other embodiments.

The concrete block 12_j can be said to have a generally rectangular prism configuration with a front surface 14_1, a rear surface 14_2, and four lateral surfaces 14_3-14_6. The lateral surfaces 14_3 and 14_4 define a height of the concrete block 12_j, the lateral surfaces 14_5 and 14_6 define a width of the concrete block 12_j, and the front surface 14_1 and the rear surface 14_2 define a thickness of the concrete block 12_j.

The front surface 14_1 is intended to be exposed when the concrete block 12_j is placed in the outer wall 15. In this example, the front surface 14_1 comprises seven portions 20_1-20_7 with a cast texture having a natural stone appearance, i.e., an aged, worn, or weathered appearance that resembles natural stone. As described later on, this cast texture is realized during casting of the concrete block 12_j and may be based on a natural stone's surface which has been used to produce a mold for casting the concrete block 12_j. For ease of reference, the portions 20_1-20_7 of the front surface 14_1 and their cast texture with a natural stone appearance will hereinafter be referred to as the "natural stone-like surface portions" 20_1-20_7.

The natural stone-like surface portions 20_1-20_7 are separated from each other by depressions 30_1-30_5 of the front surface 14_1 that can serve as false joints. When the concrete block 12_j is placed in the outer wall 15, the natural stone-like surface portions 20_1-20_7 results in an area of the outer wall 15 being perceivable as including several (in this case, seven) natural stones of different sizes and configurations.

Although the front surface 14_1 comprises a plurality of natural stone-like surface portions (in this case, seven), it is to be understood that, in other embodiments, any number of natural stone-like surface portions may be provided. For example, in Figure 1, some of the concrete blocks 12_1-12_N are provided with five or six natural stone-like surface portions. As another example, in a particular case, the front surface 14_1 may comprise only one natural stone-like surface portion, which may be an entirety of the front surface 14_1 (i.e., all of that surface) or a limited portion of the front surface 14_1 (i.e., not all of that surface). It is also to be understood that, in some embodiments, the front surface 14_1 may not comprise any natural stone-like surface portion.

With additional reference to Figure 6, a given natural stone-like surface portion 20_k of the natural stone-like surface portions 20_1-20_7 ($1 \leq k \leq 7$) will be described in further detail. It will

be appreciated that this description similarly applies to other ones of the natural stone-like surface portions 20_1-20_7.

The natural stone-like surface portion 20_k has a visually discernible boundary 22. In cases where the natural stone-like surface portion 20_k would be contiguous to a chamfered, rounded, or otherwise non-natural stone looking edge portion of the concrete block 12_j (e.g., an edge portion serving as a joint), the boundary 22 of that natural stone-like surface portion would be considered to be configured such that the chamfered, rounded or otherwise non-natural stone looking edge portion is not part of that natural stone-like surface portion.

The natural stone-like surface portion 20_k includes a pattern of cast relief elements 23_1-23_M formed during casting of the concrete block 12_j. This pattern of cast relief elements 23_1-23_M includes a plurality of peaks and a plurality of valleys, which are sized so as to be visually distinguishable when the concrete block 12_j is placed in the wall structure 10. It is to be understood that various other patterns of cast relief elements are possible.

The cast texture of the natural stone-like surface portion 20_k defines a "surface level difference" ΔL, which refers to the normal distance between a maximum level L_{max} of that surface portion and a minimum level L_{min} of that surface portion. As shown in Figure 6, the concrete block 12_j can be viewed as defining orthogonal X, Y and Z axes, where the X-Y plane is parallel to a plane that would be formed by the natural stone-like surface portion 20_k if that surface portion was flat, i.e., the plane in which lies the boundary 22 of the natural stone-like surface portion 20_k. A level L at a given point of the natural stone-like surface portion 20_k can be viewed as a plane parallel to the X-Y plane, and the surface level difference ΔL can be viewed as being measured along the Z axis.

In this example, the minimum level L_{min} of the natural stone-like surface portion 20_k is located at its boundary 22. Generally, the minimum level L_{min} of a natural stone-like surface portion may be located anywhere on that surface portion, including not at its boundary. The maximum level L_{max} of a natural stone-like surface portion may also be located anywhere on that surface portion, including at its boundary 22.

The surface level difference ΔL may be greater than 10 mm, for example, between 10 mm and 30 mm. For instance, in one embodiment, the surface level difference ΔL may be about 20 mm. This enables the natural stone-like surface portion 20_k to exhibit desired natural stone appearance characteristics for a wall structure. It is generally contemplated that a surface level difference ΔL of greater than 4 mm achieves satisfactory results in terms of natural stone appearance of a surface portion of a concrete block since it enables presence of visually distinguishable cast texture features mimicking surface texture of natural stone.

It is to be noted that different ones of the natural stone-like surface portions 20_1-20_7 of the concrete block 12_j may define a common or distinct surface level difference ΔL and may have common or distinct maximum levels L_{max} and minimum levels L_{min}.

Each of the cast relief elements 23_1-23_M of the natural stone-like surface portion 20_k reaches a respective level L that is the maximum level L_{max}, the minimum level L_{min}, or a level therebetween. In this embodiment, a plurality of the cast relief elements $23_1 \ldots 23_M$ are seen in Figure 6 as extending to the maximum level L_{max} of the natural stone-like surface portion 20_k and separated from each other by other ones of the cast relief elements $23_1 \ldots 23_M$ that only extend to lower levels

Also, in this embodiment, each of the cast relief elements $23_1 \ldots 23_M$ of the natural stone-like surface portion 20_k that is a valley (e.g., the cast relief element 23_2) can be viewed as having a respective depth D, which refers to the normal distance between the maximum level L_{max} of that surface portion and that valley's deepest point. Depending on the surface level difference ΔL, in some embodiments, the respective depth D of each of one or more valleys of the natural stone-like surface portion 20_k may be greater than 4 mm, for example, between 4 mm and 10 mm. This may further enhance natural stone appearance characteristics exhibited by the natural stone-like surface portion 20_k.

The natural stone-like surface portion 20_k is capable of interacting with ambient light to create shadows that further contribute to its natural stone appearance. More particularly, as shown in Figure 6, each point of the cast texture of the natural stone-like surface portion 20_k defines a respective "texture angle" θ, which refers to the angle between a plane parallel to the X-Y plane and a plane tangent to the natural stone-like surface portion 20_k at that point. In one

embodiment, the respective texture angle θ of each of a plurality of points of the natural stone-like surface portion 20_k may be between about 75° and about 90°. This may contribute to creation of shadows on the natural stone-like surface portion 20_k that further enhance its natural stone appearance. Configuring a dry-cast concrete block with a surface level difference ΔL in the above-mentioned ranges has been found to facilitate formation of such texture angles θ during casting. It is noted, however, that the above-mentioned values of texture angle θ are presented for example purposes only and are not to be considered limiting in any respect.

In this embodiment, the depression 30_3 of the front surface 14_1 that separates the natural stone-like surface portions 20_1 and 20_2 can be viewed as having a respective depth, which refers to the normal distance between the maximum level L_{max} of either of these surface portions and that depression's deepest point. Similar comments apply in respect of each of the depressions 30_1, 30_2, 30_4 and 30_5 of the front surface 14_1. Depending on the surface level difference ΔL, in some embodiments, the respective depth of each of the depressions 30_1-30_5 may be at least 10 mm, for example, between 10 mm and 30 mm. For example, in a particular case, the respective depth of each of the depressions 30_1-30_5 may be about 20 mm. This may further enhance natural stone appearance characteristics exhibited by the natural stone-like surface portions 20_1-20_5 of the concrete block 12_j.

Continuing with Figures 5 and 6, the rear surface 14_2 of the concrete block 12_j is adapted to allow the concrete block 12_j to be connected to the inner wall 11 by the connection system 50. More particularly, in this embodiment, the rear surface 14_2 has a plurality of grooves 37_1-37_3. Each of the grooves 37_1-37_3 extends between the lateral surfaces 14_3 and 14_4 and has a curved configuration tapering or closing towards its opening. In other embodiments, the rear surface 14_2 may be provided with one or more grooves having any suitable configuration. As described later on, each of the grooves 37_1-37_3 is adapted to receive a component of the connection system 50 that anchors the concrete block 12_j and contributes to interconnecting the inner wall 11 and the outer wall 15.

Each of the lateral surfaces 14_3-14_6 of the concrete block 12_j will normally face a lateral surface of another one of the concrete blocks 12_1-12_N (except for certain ones of the concrete blocks 12_1-12_N that are located at extremities of the outer wall 15). Since the natural stone-like surface portions 20_1-20_7 are realized during casting of the concrete block 12_j without requiring

any subsequent mechanical artificial aging/weathering process (e.g., tumbling, object impacting, etc.) that could otherwise damage the lateral surfaces 14_3-14_6, each of these lateral surfaces is relatively flat and smooth. These flatness characteristics of the concrete blocks 12_1-12_N are such that any gap which may exist between lateral surfaces of adjacent ones of the concrete blocks 12_1-12_N can be viewed as being negligible. As a result, lateral surfaces of adjacent ones of the concrete blocks 12_1-12_N form interfaces that can prevent water from easily passing between these concrete blocks and reaching the cavity 17.

In addition, and as further discussed below, the concrete block 12_j is cast with its thickness oriented generally vertically, i.e., with its height and width oriented generally horizontally. This casting process helps to render negligible any difference in height between different ones of the concrete blocks 12_1-12_N and to render negligible any difference in width between different ones of the concrete blocks 12_1-12_N. For example, the difference in height between different ones of the concrete blocks 12_1-12_N may be less than about 1 mm, and in some cases less than about 0.5 mm. Similar comments apply with respect to the difference in width between different ones of the concrete blocks 12_1-12_N. The negligible difference in height between adjacent ones of the concrete blocks 12_1-12_N is such that no mortar is required to compensate for it when these concrete blocks are placed in the outer wall 15. The negligible difference in width between different ones of the concrete blocks 12_1-12_N enables accurate alignment of one or more of the grooves 37_1-37_3 of each of these concrete blocks with one or more of the grooves 37_1-37_3 of other ones of these concrete blocks when they are stacked on one another to form the outer wall 15.

Flatness characteristics and height tolerances of the concrete blocks 12_1-12_N thus enable the outer wall 15 to be built without requiring mortar to hold these concrete blocks together or fill their interface. As mentioned above, not having to use mortar to hold the concrete blocks 12_1-12_N together or fill their interface allows the cavity 17 to be free of mortar, which contributes to impeding moisture intrusion in the inner wall 11and promoting pressure equalization between either side of the outer wall 15.

With reference now to Figures 2 to 4, the connection system 50 interconnects the inner wall 11 and the outer wall 15. More particularly, the connection system 50 comprises a plurality of elongated structural members 52_1-52_P secured to the inner wall 11 and a plurality of

connecting elements 54_1-54_T connected to different ones of the elongated structural members 52_1-52_P and to different ones of the concrete blocks $12_1 \ldots 12_N$.

The elongated structural members 52_1-52_P are disposed substantially horizontally on the inner wall 11 so as to be aligned with the courses of concrete blocks $12_1 \ldots 12_N$. More particularly, each of the elongated structural members 52_1-52_P is disposed on the inner wall 11 so as to be aligned with given ones of the concrete blocks 12_1-12_N forming a course and is connected to these concrete blocks via certain ones of the connecting elements 54_1-54_T. Thus, each of the elongated structural members 52_1-52_P is connected to plural ones of the concrete blocks 12_1-12_N that are part of a course via plural ones of the connecting elements 54_1-54_T. In addition, a particular one of the elongated structural members 52_1-52_P may be disposed on the inner wall 11 so as to be proximate to the lateral surface 14_3 of each of the concrete blocks 12_1-12_N forming a first course and to the lateral surface 14_4 of each of the concrete blocks 12_1-12_N forming a second course immediately above the first course. This allows each of the connecting elements 54_1-54_T that is connected to the particular one of the elongated structural members 52_1-52_p to be connected to one of the concrete blocks 12_1-12_N forming the first course and one of the concrete blocks 12_1-12_N forming the second course. Also, in some cases, two or more of the elongated structural members 52_1-52_P may be disposed on the inner wall 11 so as to be aligned with given ones of the concrete blocks 12_1-12_N forming a course and may be connected to these concrete blocks via certain ones of the connecting elements 54_1-54_T. It will thus be appreciated that the elongated structural members 52_1-52_P and the connecting elements 54_1-54_T cooperate to interconnect the inner wall 11 and the outer wall 15 at various points that are distributed in the wall structure 10. They also cooperate to interconnect individual ones of the concrete blocks 12_1-12_N, thereby enhancing strength and solidity of the outer wall 15.

Referring additionally to Figure 7, a given elongated structural member 52_g of the elongated structural members 52_1-52_P ($1 \leq g \leq P$) will be described in further detail. It will be appreciated that this description similarly applies to other ones of the elongated structural members 52_1-52_P.

In this embodiment, the elongated structural member 52_g comprises a first portion 57 and a second portion 59 angled relative to the first portion 57. In this case, the angle is

approximately a right angle such that the elongated structural member 52_g has an L-shaped configuration. The elongated structural member 52_g may be made of metallic material (e.g., galvanized steel) and has a length that facilitates its transportation, handling and installation on the inner wall 11. For example, it may have a length of at least 1 m (e.g., about 10 ft or 3.048 m).

The first portion 57 is adapted to be fastened to the inner wall 11. In this embodiment, this is achieved by providing the first portion 57 with a plurality of apertures 60 adapted to receive fasteners that are used to fasten the elongated structural member 52_g to the inner wall 11 (e.g., to the frame 19 of the inner wall 11). The fasteners may be screws, nails, or any other suitable fasteners. The apertures 60 are sized to accommodate the fasteners they are intended to receive (e.g., they may have a diameter of about 7/32 in or 5.56 mm). The apertures 60 are longitudinally distributed on the first portion 57 and spaced from each other so as to facilitate securing of the elongated structural member 52_g to the inner wall 11. For example, adjacent ones of the apertures 60 may be spaced by a distance of at least 0.2 m (e.g., about 16 in or 0.406 m). When the elongated structural member 52_g is fastened to the inner wall 11, the fasteners in the apertures 60 and the first portion 57 lying against the inner wall 11 cooperate to plug holes in the inner wall 11 that receive the fasteners, thereby preventing air and water infiltration into the inner wall 11 via these holes and promoting pressure equalization between either side of the outer wall 15.

The second portion 59 is adapted to be connected to individual ones of the connecting elements 54_1-54_T. In this embodiment, this is achieved by providing the second portion 59 with a series of apertures 62 each adapted to receive a portion of one of the connecting elements 54_1-54_T. Each of the apertures 62 is sized to accommodate the portion of the one of the connecting elements 54_1-54_T it is intended to receive (e.g., it may have a diameter of about 7/32 in or 5.56 mm). The apertures 62 are longitudinally distributed on the second portion 59 and spaced from each other so as to enable individual ones of the connecting elements 54_1-54_T to be connected to the elongated structural member 52_g at different locations. This allows an individual one of the connecting elements 54_1-54_T to be connected to the elongated structural member 52_g at a location where it registers with one of the grooves 37_1-37_3 of a given one of the concrete blocks 12_1-12_N in order to interconnect that concrete block and that elongated structural member. For instance, adjacent ones of the apertures 62 may be spaced by a distance

of at least 7mm (e.g., about 3/8 in or 9.525 mm). The second portion 59 has a width that is such that it does not reach the outer wall 15 when the elongated structural member 52_g is secured to the inner wall 11 (e.g., about 0.625 in or 15.875 mm), thereby not bridging the cavity 17.

While in this embodiment each of the elongated structural members 52_1-52_P has a certain configuration, it is to be understood that each of the elongated structural members 52_1-52_P may have various other configurations in other embodiments. For example, each of the elongated structural members 52_1-52_P may have a C-shaped configuration including two portions, each similar to the second portion 59 of the elongated structural member 52_g with its series of apertures 62, such that a portion of one of the connecting elements 54_1-54_T can be received in apertures of these two portions.

With additional reference to Figures 8A to 8D, a given connecting element 54_b of the connecting elements 54_1-54_T ($1 \leq b \leq T$) will be described in further detail. It will be appreciated that this description similarly applies to other ones of the connecting elements 54_1-54_T.

In this embodiment, the connecting element 54_b comprises a first portion 61 for connection to one of the elongated structural members 52_1-52_P and a second portion 63 for connection to one of the concrete blocks 12_1-12_N. In this example, the connecting element 54_b comprises a rod bent to form the first portion 61 and the second portion 63. The rod may have a circular cross-section (e.g., with a diameter of about 4.75 mm) and may be made of metallic material (e.g., galvanized steel). This bent configuration allows economic production of the connecting elements 54_1-54_T and facilitates their installation. The connecting element 54_b may have any suitable dimensions (e.g., in this case, it may have an overall height of about 3 in or 76.2 mm, an overall width of about 2.25 in or 57.15 mm, and an overall depth of about 1.27 in or 32.26 mm).

The first portion 61 is adapted to be connected to a given one of the elongated structural members 52_1-52_P. In this case, the first portion 61 is configured so as to be insertable into one of the apertures 62 of the given one of the elongated structural members 52_1-52_P. When the first portion 61 is inserted into one of the apertures 62 of the given one of the elongated

structural members 52_1-52_P, the connecting element 54_b is connected to that elongated structural member.

The second portion 63 is adapted to be connected to a given one of the concrete blocks 12_1-12_N. In this case, the second portion 63 is configured so as to fit and be retained in one of the grooves 37_1-37_3 of the given one of the concrete blocks 12_1-12_N. To that end, the second portion 63 comprises a first part 65 and a second part 67 that can be pressed and displaced towards each other to allow the second portion 63 to be positioned in one of the grooves 37_1-37_3 of the given one of the concrete blocks 12_1-12_N. When the second portion 63 is positioned in one of the grooves 37_1-37_3 of the given one of the concrete blocks 12_1-12_N, the second portion 63 engages that groove and is retained therein, thereby anchoring the connecting element 54_b to that concrete block. The connecting element 54_b is thus connected to the given one of the concrete blocks 12_1-12_N.

While in this embodiment each of the connecting elements 54_1-54_T has a certain configuration, it is to be understood that each of the connecting elements 54_1-54_T may have various other configurations in other embodiments. In particular, the connecting elements 54_1-54_T may be connected to the elongated structural members 52_1-52_P and to given ones of the concrete blocks 12_1-12_N in various other ways in other embodiments.

By virtue of their cooperation, the elongated structural members 52_1-52_P and the connecting elements 54_1-54_T therefore interconnect the inner wall 11 and the outer wall 15 at various points.

It will thus be appreciated that the wall structure 10, and particularly the outer wall 15 and the connection system 50, present several desirable features.

For example, in this embodiment, natural stone-like surface portions of the concrete blocks $12_1 \ldots 12_N$ (such as the natural stone-like surface portions 20_1-20_7 of the concrete block 12_j) contribute to providing a natural and aesthetic look to the outer wall 15.

In addition, the natural stone appearance of each of the concrete blocks $12_1 \ldots 12_N$ is realized during casting of these concrete blocks, without requiring any subsequent mechanical artificial

aging/weathering process (e.g., tumbling, object impacting, etc.). Also, since they are made of no-slump concrete, production time for the concrete blocks $12_1 \ldots 12_N$ may be significantly less than that required for wet-cast concrete blocks. Concrete blocks such as the concrete blocks $12_1 \ldots 12_N$ may therefore be mass-produced with high efficiency. An example of implementation of a process for manufacturing concrete blocks such as the concrete blocks $12_1 \ldots 12_N$ will be presented later on.

Furthermore, owing to this casting process, any difference in height and width between different ones of the concrete blocks 12_1-12_N is negligible and lateral surfaces of adjacent ones of the concrete blocks 12_1-12_N form interfaces that can prevent water from easily passing between these concrete blocks and reaching the cavity 17. This enables the outer wall 15 to be built without requiring mortar to hold the concrete blocks 12_1-12_N together or fill their interfaces, resulting in the cavity 17 being free of mortar. As mentioned above, this mortarless nature of the cavity 17 avoids mortar bridging the outer wall 15 and the inner wall 11 or falling and clogging the weep holes, thereby enabling the cavity 17 to impede moisture intrusion in the inner wall 11 and promote pressure equalization between either side of the outer wall 15.

Moreover, the connection system 50, through cooperation between the elongated structural members 52_1-52_P and the connecting elements 54_1-54_T, strengthens the wall structure 10 by interconnecting the inner wall 11 and the outer wall 15 at various points that are distributed in the wall structure 10. The elongated structural members 52_1-52_P and the connecting elements 54_1-54_T also cooperate to interconnect individual ones of the concrete blocks 12_1-12_N, thereby enhancing strength and solidity of the outer wall 15. By being exposed to air in the cavity 17 and not being in contact with mortar, the elongated structural members 52_1-52_P and the connecting elements 54_1-54_T remain dry and are thus less prone to rusting then conventional wall ties.

Construction of the wall structure 10 can also be effected conveniently and efficiently. For instance, assuming that the inner wall 11 has been constructed using conventional methods, an example of a method for advancing construction of the wall structure 10 will now be described with reference to Figure 9.

At step 400, one or more of the elongated structural members 52_1-52_P are secured to the inner wall 11. Each of the one or more of the elongated structural members 52_1-52_P is secured to the inner wall 11 so as to be aligned with given ones of the concrete blocks 12_1-12_N that will be placed to form a course of the outer wall 15. This is effected using knowledge of the height of the concrete blocks 12_1-12_N. In this example, each of the one or more of the elongated structural members 52_1-52_P is fastened to the inner wall 11 by using fasteners in its apertures 60.

At step 410, given ones of the concrete blocks 12_1-12_N are placed horizontally adjacent to one each other so as to form a course.

At step 420, for each of the given ones of the concrete blocks 12_1-12_N that have been placed to form the course, each of one or more of the connecting elements 54_1-54_T is connected to that concrete block and to one of the one or more of the elongated structural members 52_1-52_P that have been secured to the inner wall 11 in alignment with the course. In this example, a given one of the connecting elements 54_1-54_T is connected to a given one of concrete blocks 12_1-12_N that has been placed to form the course and to a given one of the one or more of the elongated structural members 52_1-52_P that have been secured to the inner wall 11 in alignment with the course by inserting its first portion 61 into one of the apertures 62 of that given elongated structural member and by positioning its second portion 63 in one of the grooves 37_1-37_3 of that given concrete block so as that it fits and is retained therein.

In this example, steps 400 to 420 are repeated to form each new course of concrete blocks in order to progressively erect the outer wall 15.

It will be appreciated that this method is presented for example purposes only as various modifications and enhancements are possible. For example, flashing, weep holes and other elements can be provided using conventional means during construction of the wall structure 10. As another example, as shown in Figure 10 and as mentioned previously, mortar 33 may optionally be provided on the external side of the outer wall 15 for aesthetic purposes. As yet another example, as shown in Figure 11, a band of sealant material 70 may be applied to lateral surfaces of certain ones of the concrete block 12_1-12_N in order to further contribute to impermeability of the outer wall 15. Any suitable sealant material may be used. The band of

sealant material 70 has a width that is significantly less (e.g., a quarter) of the width of the lateral surfaces of the certain ones of the concrete block 12_1-12_N on which it is applied. That is, the band of sealant material 70 is such that, when it is compressed by lateral surfaces of adjacent ones of the concrete blocks 12_1-12_N, no excess sealant material can reach and go into the cavity 17. While it may be used in some cases, it is to be understood that the band of sealant material 70 is entirely optional and may be omitted.

The concrete blocks 12_1-12_N and the connection system 50 thus enable the outer wall 15 to be efficiently and conveniently constructed and connected to the inner wall 11. In particular, since no mortar is required to hold the concrete blocks 12_1-12_N together or fill their interfaces, construction of the outer wall 15 is practically insensitive to weather conditions and does not require time to allow mortar to dry. Structural solidity of the outer wall 15 is immediate owing to the connection system 50. Installation of the connection system 50 is rapid and easy and requires no special skill.

Turning now to Figure 12, there is shown a flowchart illustrating an example of a process for manufacturing concrete blocks such as the concrete blocks $12_1 \ldots 12_N$.

At step 200, no-slump concrete is placed into a mold. To facilitate mass-production, in one embodiment, the mold has a plurality of cavities. In other embodiments, a plurality of molds each with a single cavity or each with a respective plurality of cavities may be used. To further facilitate mass-production, the mold may be located such that concrete blocks are placed on a production board when removed therefrom.

Each cavity of the mold is configured to form a respective concrete block comprising a surface with one or more natural stone-like surface portions (e.g., the front surface 14_1 of the concrete block 12_j with its seven natural stone-like surface portions 20_1-20_7). To that end, each cavity is defined in part by a surface of the mold that includes at least one portion with a surface texture corresponding to the desired natural stone appearance (hereinafter referred to as "the at least one natural stone-like surface portion of the mold"). In embodiments directed to producing concrete blocks with a plurality of natural stone-like surface portions (such as those shown in Figure 1), each cavity of the mold that is intended to form such concrete blocks defines a corresponding plurality of natural stone-like surface portions. Each of the at least one

natural stone-like surface portion of the mold thus defines a surface level difference $\Delta L'$ that corresponds to the desired surface level difference ΔL (Figure 6) of the corresponding natural stone-like surface portion of the concrete block to be formed. Each point of this surface portion also defines a respective texture angle θ' corresponding to the desired texture angle θ (Figure 6) of each point of the corresponding natural stone-like surface portion of the concrete block to be formed.

In order to closely simulate natural stone, in one embodiment, each given natural stone-like surface portion of the mold, and thus the corresponding natural stone-like surface portion of concrete blocks to be formed by the mold, is based on a natural stone's surface. In one example of implementation, data representative of at least a portion of the natural stone's surface is obtained, for instance, via three-dimensional scanning of the natural stone's surface. The obtained data may then be computer processed using software in order to generate data representative of the given natural stone-like surface portion of the mold. In some cases, this processing may include modifying the obtained data representative of at least a portion of the natural stone's surface to set the desired surface level difference $\Delta L'$ and texture angles θ' of the given natural stone-like surface portion. This processing may also ensure that the data representative of the at least one natural stone-like surface portion of the mold will result in the at least one corresponding natural stone-like surface portion of concrete blocks to be formed by the mold providing at least three points that are located relative to each other such that at least one other concrete block may be supported thereon in a stable manner.

As another possible consideration, in embodiments where individual ones of the cavities of the mold are intended to form concrete blocks of similar overall dimensions but with natural stone-like surface portions that have different configurations (e.g., different patterns of cast relief elements), these individual cavities may be designed to each have a common volume in order to facilitate production. In other words, a first cavity intended to form concrete blocks with natural stone-like surface portions having a first configuration may have a first volume, and a second cavity intended to form concrete blocks with natural stone-like surface portions having a second configuration different from the first configuration may have a second volume substantially corresponding to the first volume. This facilitates provision of substantially the same quantity of concrete into each cavity of the mold, which in turn facilitates efficient

casting of concrete blocks in the mold and subsequent removal of the concrete blocks therefrom.

In embodiments where individual ones of the cavities of the mold are intended to form concrete blocks of significantly different overall dimensions and with natural stone-like surface portions that have different configurations (e.g., different patterns of cast relief elements), similar production benefits may be achieved by designing these individual cavities to each have a common volume per unit area.

Each cavity of the mold is configured such that a concrete block that is cast therein has its thickness oriented generally vertically, i.e., has its height and width oriented generally horizontally. This helps to render negligible any difference in height and width between different concrete blocks that are cast.

The mold may be manufactured via computer-aided manufacturing based on the data representative of each given natural stone-like surface portion of the mold. With no-slump concrete being used, the mold may be made of metal or other rigid material. There is no requirement for one or more portions of the mold to be made of elastomeric material (e.g., rubber), which is typically used in molds for casting wet-cast concrete blocks with a natural stone appearance.

Thus, during step 200, each cavity of the mold is filled with no-slump concrete in order to form a concrete block comprising a surface with one or more natural stone-like surface portions.

At step 202, the no-slump concrete in the mold is consolidated. Consolidation may include inducing vibration of the no-slump concrete in the mold so as to cause it to compact itself and closely conform to each cavity of the mold. A pre-vibration phase may be effected during step 200 to facilitate filling of the no-slump concrete in the mold and its eventual consolidation. Consolidation may also include application of pressure on the concrete in combination with its vibration. It will be appreciated that consolidation may be effected using various other techniques.

Upon completion of step 202, the no-slump concrete in each cavity of the mold has formed into a concrete block comprising a surface with one or more natural stone-like surface portions.

At step 204, the concrete block in each cavity of the mold is removed therefrom and continues on the production board. The concrete blocks may be directly stored for curing purposes. Since provision of a natural stone appearance is effected during casting, the concrete blocks do not require a subsequent mechanical artificial aging/weathering process (e.g., tumbling, object impacting, etc.) to impart them with such an appearance. Also, this absence of a mechanical artificial aging/weathering process that could otherwise damage lateral surfaces of the concrete blocks results in these lateral surfaces being relatively flat and smooth. In addition, with each concrete block having been cast with its height and width oriented generally horizontally, any difference in height and width between different concrete blocks is negligible.

The concrete blocks may directly be stacked or palletized in a stable manner since the at least one natural stone-like surface portion of each concrete block may have been configured to provide at least three points that are located relative to each other to ensure such stable supporting. With the concrete blocks being made of no-slump concrete, curing times are relatively short such that they are available for use within a short period of time (e.g., one day).

At step 206, each cavity of the mold is cleaned such that casting of new concrete blocks may be effected. In one embodiment, a cleaning unit uses a fluid to clean each cavity of the mold. The fluid may be a gas (e.g., compressed air) or a liquid whose flow relative to each cavity of the mold, and particularly each natural stone-like area of the mold, removes therefrom substantially any remaining no-slump concrete. Such a fluid-based cleaning action advantageously enables rapid cleaning of each cavity of the mold, thereby increasing production efficiency. In some cases, the cleaning unit may also use, in addition to the fluid, one or more brushes to clean each cavity of the mold, whereby the fluid-based cleaning action is combined with a brushing cleaning action. It will be appreciated that other embodiments may employ various other types of cleaning action.

In this example, the process returns to step 200 where a new production cycle begins. In some embodiments, utilization of no-slump concrete in combination with rapid cleaning of the mold

and other elements of the process may enable a production cycle to take a relatively short period of time (e.g., 15 to 20 seconds per square meter of finished products in some cases).

Although various embodiments and examples have been presented, this was for the purpose of describing, but not limiting, the invention. Various modifications and enhancements will become apparent to those of ordinary skill in the art and are within the scope of the present invention, which is defined by the attached claims.

CLAIMS

1. A system for interconnecting an outer wall and an inner wall of an exterior wall structure, the outer wall and the inner wall being separated from each other to define a cavity therebetween, the outer wall comprising a plurality of concrete blocks, said system comprising:
   - a plurality of elongated structural members, each elongated structural member being adapted to be fastened to the inner wall; and
   - a plurality of connecting elements, each connecting element being adapted to be connected to a given one of said elongated structural elements and to a given one of the concrete blocks;

   wherein each of said elongated structural members is adapted to be connected to plural ones of the concrete blocks via plural ones of said connecting elements.

2. A system as claimed in claim 1, wherein each of said elongated structural members comprises a first portion adapted to be fastened to the inner wall and a second portion adapted to be connected to given ones of said connecting elements.

3. A system as claimed in claim 2, wherein said first portion and said second portion form an L-shaped configuration.

4. A system as claimed in claim 2, wherein said first portion comprises a first plurality of apertures adapted to receive fasteners for fastening said elongated structural member to the inner wall and said second portion comprises a second plurality of apertures each adapted to receive a portion of a given one of said connecting elements.

5. A system as claimed in claim 1, wherein each of said elongated structural members has a length of at least 1 m.

6. A system as claimed in claim 1, wherein each of said connecting elements comprises a first portion for connection to a particular one of said elongated structural members and a second portion for connection to a particular one of the concrete blocks.

7. A system as claimed in claim 6, wherein each of said elongated structural members comprises a plurality of apertures, said first portion being insertable into one of the apertures of said particular one of said elongated structural members to connect said connecting element to said particular one of said elongated structural members.

8. A system as claimed in claim 6, wherein each of the concrete blocks comprises a rear surface having at least one groove, said second portion being configured to fit and be retained in one of the at least one groove of the particular one of the concrete blocks to connect said connecting element to the particular one of the concrete blocks.

9. A system as claimed in claim 1, wherein each of said connecting elements comprises a rod bent to form a first portion for connection to a particular one of said elongated structural members and a second portion for connection to a particular one of the concrete blocks.

10. A system for use in constructing an exterior wall structure, the exterior wall structure comprising an inner wall, said system comprising:

- a plurality of concrete blocks adapted to be stacked to erect an outer wall of the exterior wall structure, the outer wall and the inner wall intended to be separated from each other to define a cavity therebetween;
- a plurality of elongated structural members, each elongated structural member being adapted to be fastened to the inner wall; and
- a plurality of connecting elements, each connecting element being adapted to be connected to a given one of said elongated structural elements and to a given one of said concrete blocks;

wherein each of said elongated structural members is adapted to be connected to plural ones of said concrete blocks via plural ones of said connecting elements.

11. A system as claimed in claim 10, wherein each of said elongated structural members comprises a first portion adapted to be fastened to the inner wall and a second portion adapted to be connected to given ones of said connecting elements.

12. A system as claimed in claim 11, wherein said first portion and said second portion form an L-shaped configuration.

13. A system as claimed in claim 11, wherein said first portion comprises a first plurality of apertures adapted to receive fasteners for fastening said elongated structural member to the inner wall and said second portion comprises a second plurality of apertures each adapted to receive a portion of a given one of said connecting elements.

14. A system as claimed in claim 10, wherein each of said elongated structural members has a length of at least 1 m.

15. A system as claimed in claim 10, wherein each of said connecting elements comprises a first portion for connection to a particular one of said elongated structural members and a second portion for connection to a particular one of said concrete blocks.

16. A system as claimed in claim 15, wherein each of said elongated structural members comprises a plurality of apertures, said first portion being insertable into one of the apertures of said particular one of said elongated structural members to connect said connecting element to said particular one of said elongated structural members.

17. A system as claimed in claim 15, wherein each of said concrete blocks comprises a rear surface having at least one groove, said second portion being configured to fit and be retained in one of the at least one groove of said particular one of said concrete blocks to connect said connecting element to said particular one of said concrete blocks.

18. A system as claimed in claim 17, wherein the at least one groove comprises a plurality of grooves.

19. A system as claimed in claim 10, wherein each of said connecting elements comprises a rod bent to form a first portion for connection to a particular one of said elongated structural members and a second portion for connection to a particular one of said concrete blocks.

20. A system as claimed in claim 10, wherein each of said concrete blocks is a dry-cast concrete block and has a front surface comprising at least one portion having a cast texture with a natural stone appearance.

21. A system as claimed in claim 20, wherein said at least one portion comprises a plurality of portions each having a cast texture with a natural stone appearance.

22. A system as claimed in claim 21, wherein said plurality of portions are separated from each other by at least one depression of said front surface.

23. A system as claimed in claim 22, wherein each of said at least one depression serves as a false joint.

24. A system as claimed in claim 20, wherein said at least one portion is an entirety of said front surface.

25. A system as claimed in claim 20, wherein each of said concrete blocks has two lateral surfaces defining a height of said concrete block, and wherein a difference in height between different ones of said concrete blocks is less than 1 mm.

26. A system as claimed in claim 25, wherein each of said concrete blocks has two lateral surfaces defining a width of said concrete block, and wherein a difference in width between different ones of said concrete blocks is less than 1 mm.

27. An exterior wall structure comprising:

- an inner wall;
- an outer wall comprising a plurality of concrete blocks, said inner wall and said outer wall being separated from each other to define a cavity therebetween;
- a plurality of elongated structural members, each elongated structural member being fastened to said inner wall; and
- a plurality of connecting elements, each connecting element being connected to a given one of said elongated structural elements and to a given one of said concrete blocks;

wherein each of said elongated structural members is connected to plural ones of said concrete blocks via plural ones of said connecting elements.

28. A method for use in constructing an exterior wall structure, the exterior wall structure comprising an inner wall, said method comprising:

- securing at least one elongated structural member to the inner wall;
- placing a plurality of concrete blocks horizontally adjacent to each other to form a course; and
- for each of the concrete blocks, connecting each of at least one connecting element to said concrete block and to one of the at least one elongated structural member secured to the inner wall in alignment with the course.

29. A plurality of dry-cast concrete blocks for use in constructing an outer wall of an exterior wall structure, the exterior wall structure comprising an inner wall, the outer wall and the inner wall intended to be separated to define a cavity therebetween, each of said dry-cast concrete blocks comprising:

- a front surface comprising at least one portion having a cast texture with a natural stone appearance;
- a rear surface defining with said front surface a thickness of said dry-cast concrete block;
- two lateral surfaces defining a height of said dry-cast concrete block; and
- two lateral surfaces defining a width of said dry-cast concrete block;

wherein a difference in height between different ones of said dry-cast concrete blocks is less than 1 mm.

30. A plurality of dry-cast concrete blocks as claimed in claim 29, wherein said difference in height is less than about 0.5 mm.

31. A plurality of dry-cast concrete blocks as claimed in claim 29, wherein a difference in width between different ones of said dry-cast concrete blocks is less than 1 mm.

32. A plurality of dry-cast concrete blocks as claimed in claim 29, wherein said rear surface has at least one groove enabling said dry-cast concrete block to be connected to the inner wall via a connection system.

33. A plurality of dry-cast concrete blocks as claimed in claim 32, wherein said at least one groove comprises a plurality of grooves.

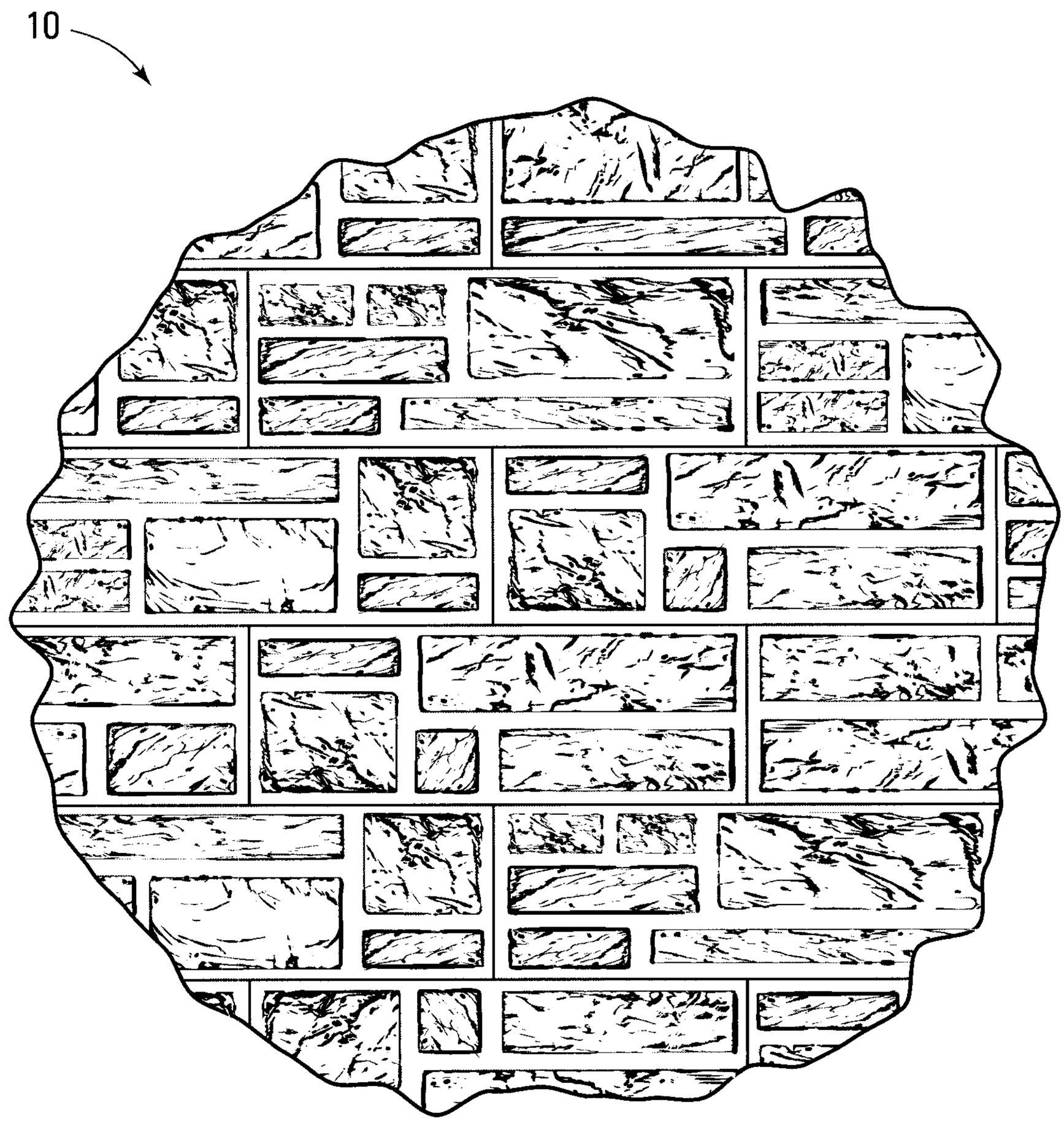


FIG. 1

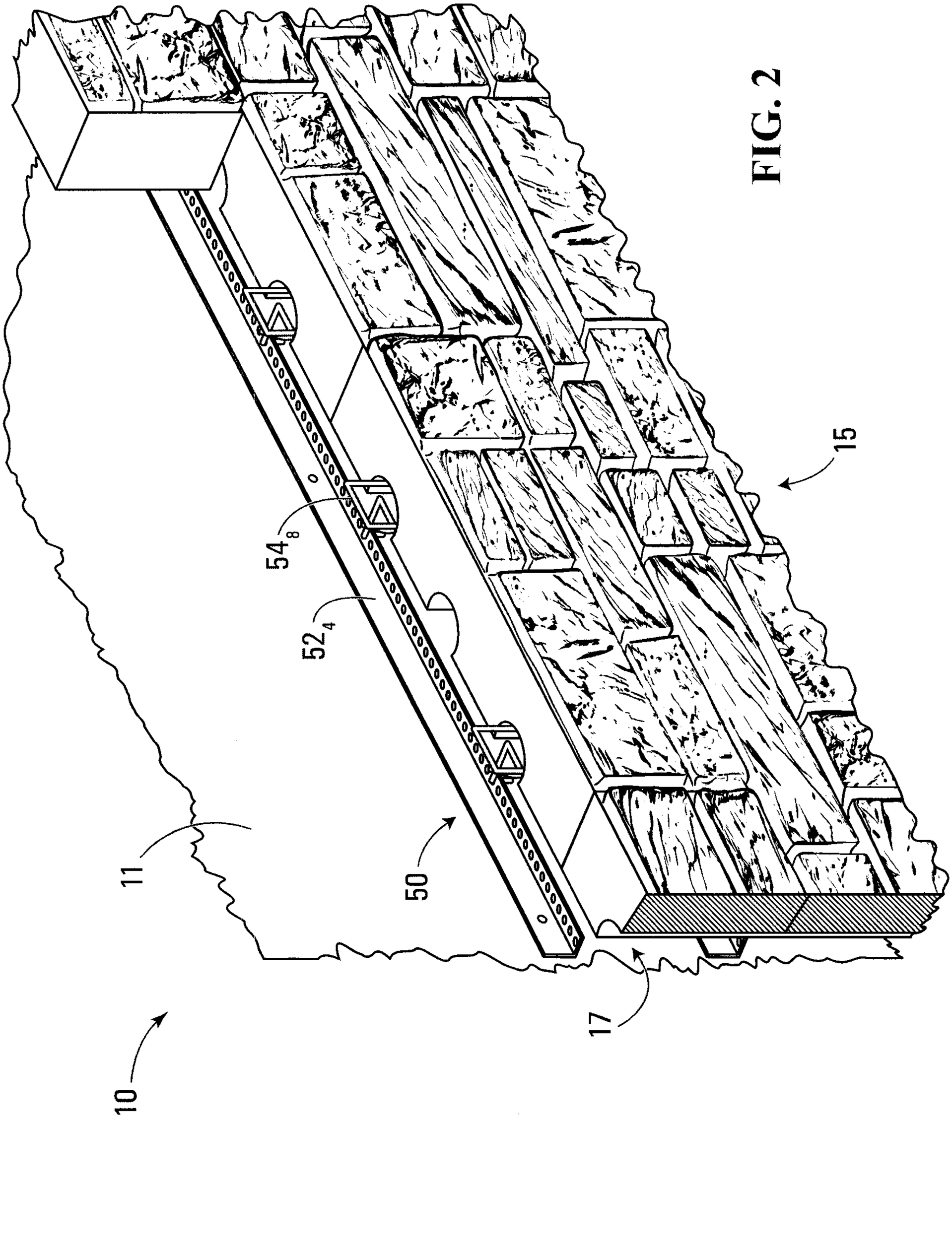


FIG. 2

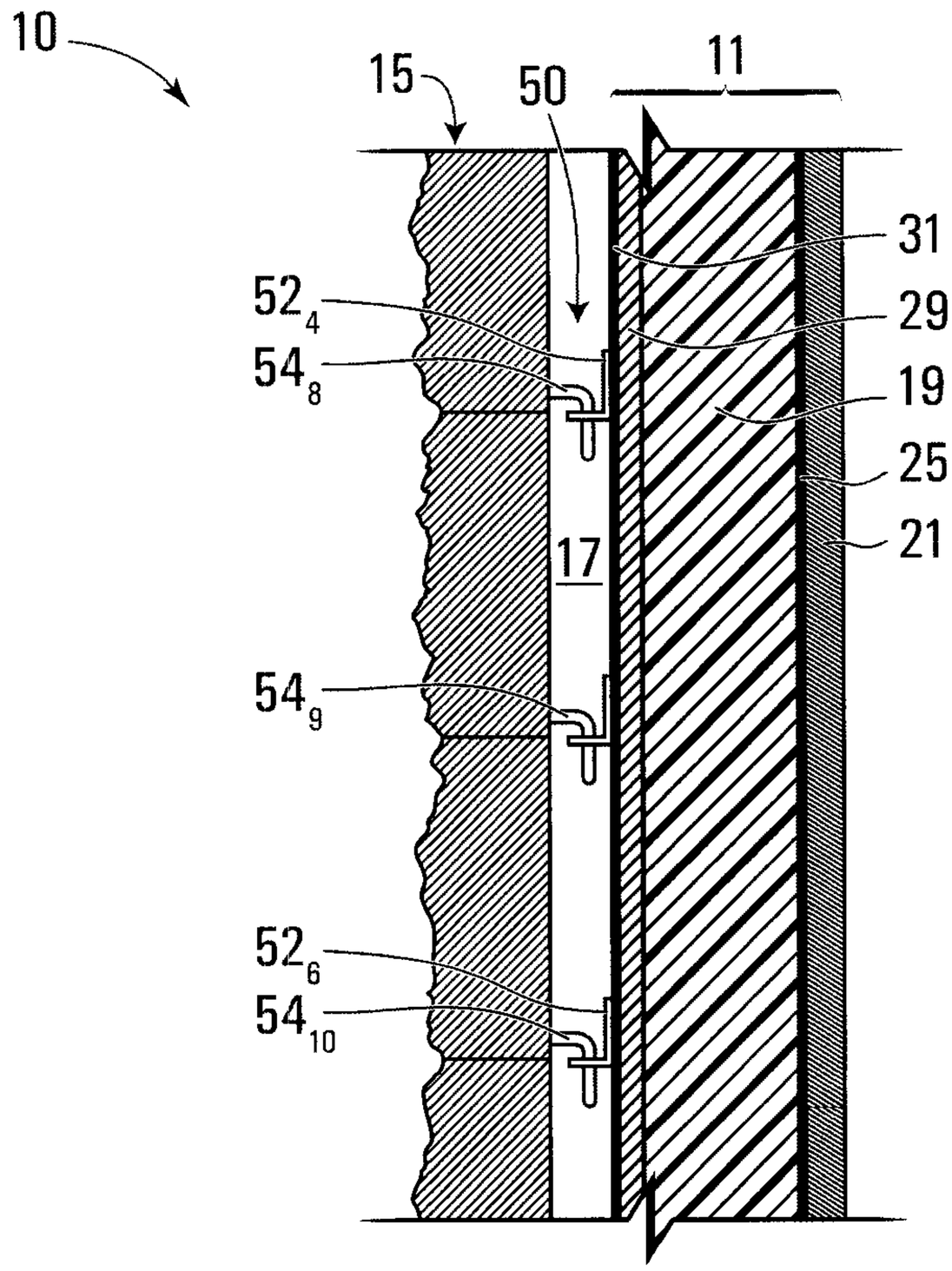

10
15
50
11
31
52_4
29
54_8
19
25
17
21
54_9
52_6
54_{10}

FIG. 3

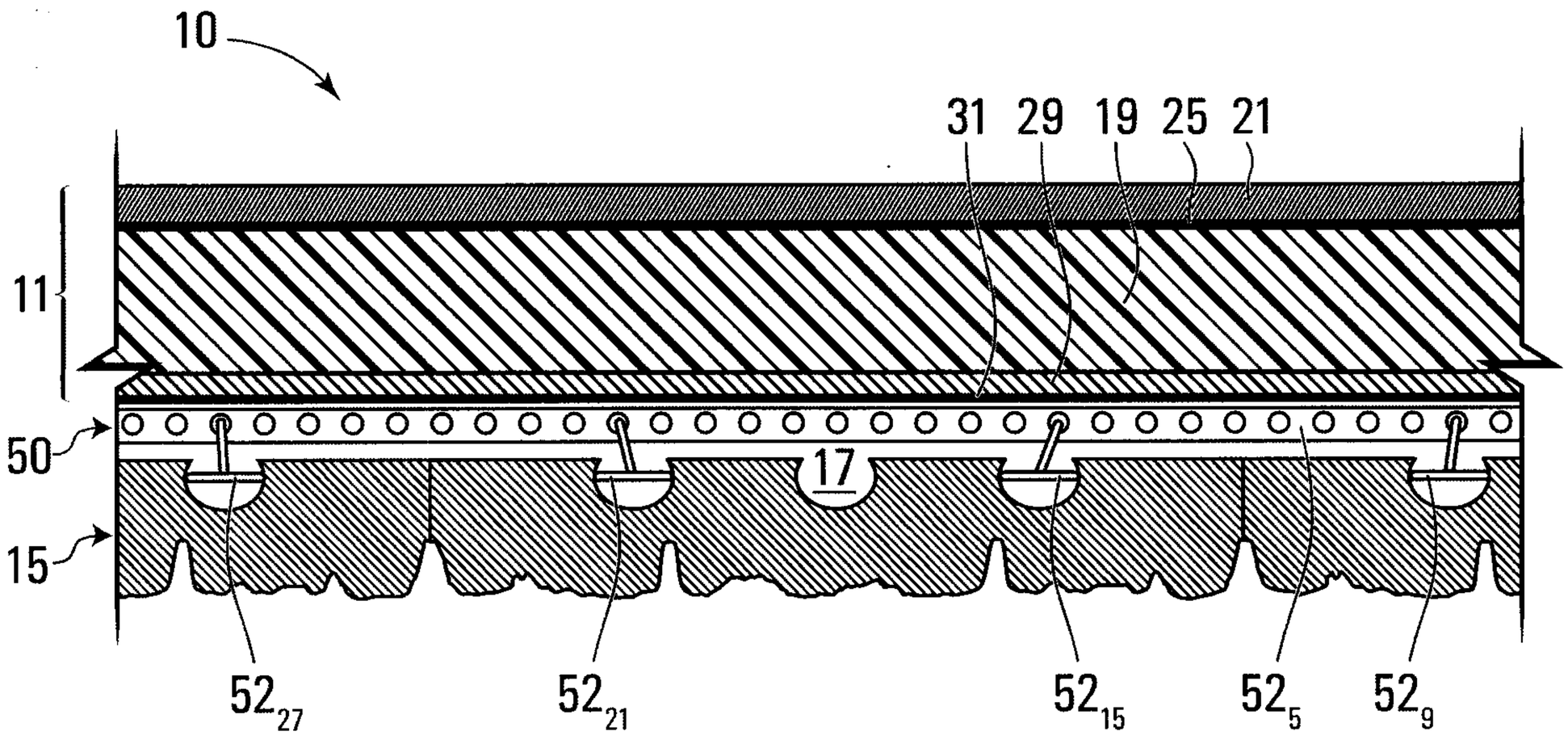

10
31
29
19
25
21
11
50
17
15
52_{27}
52_{21}
52_{15}
52_5
52_9

FIG. 4

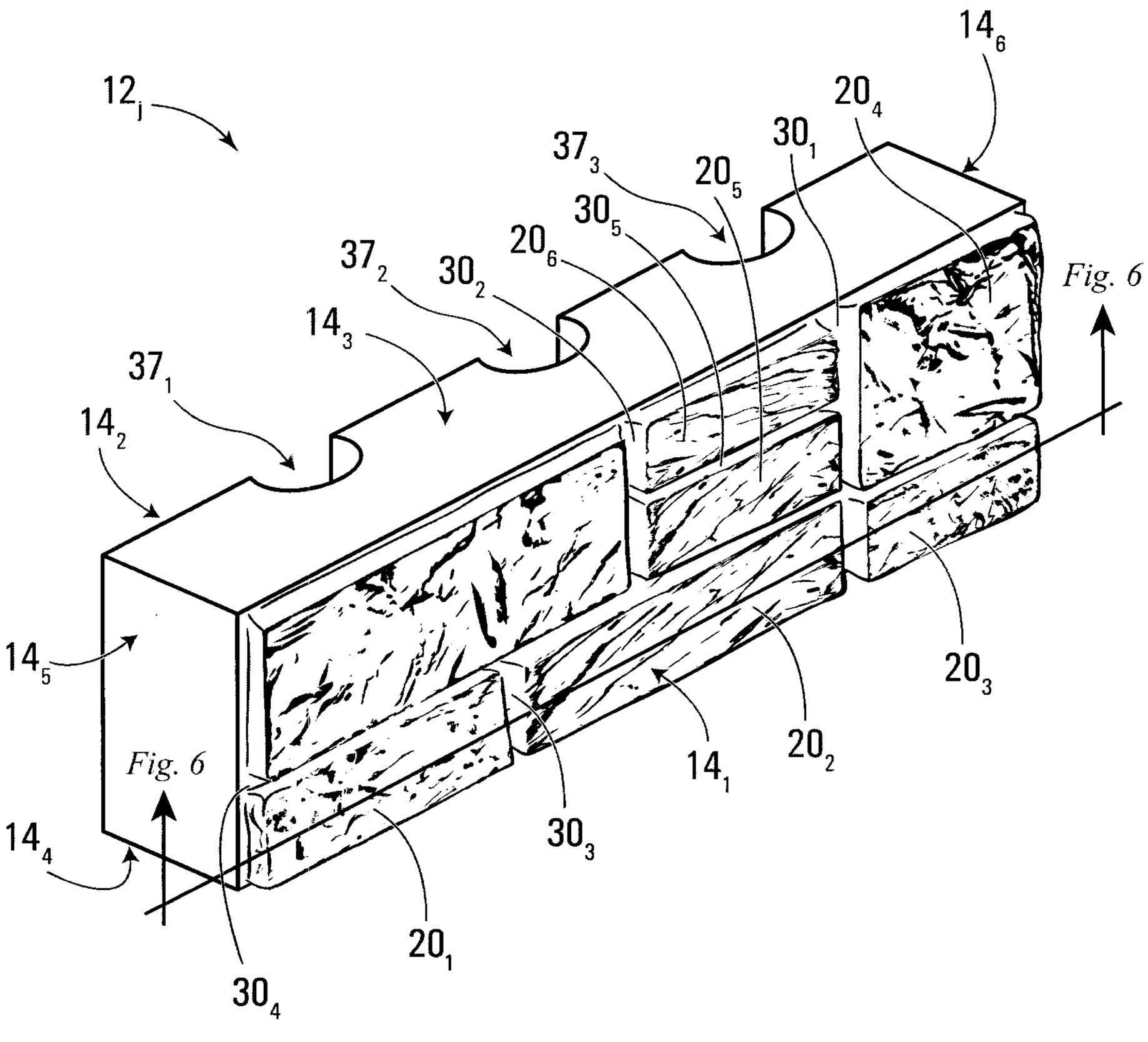


Fig. 6

Fig. 6

FIG. 5

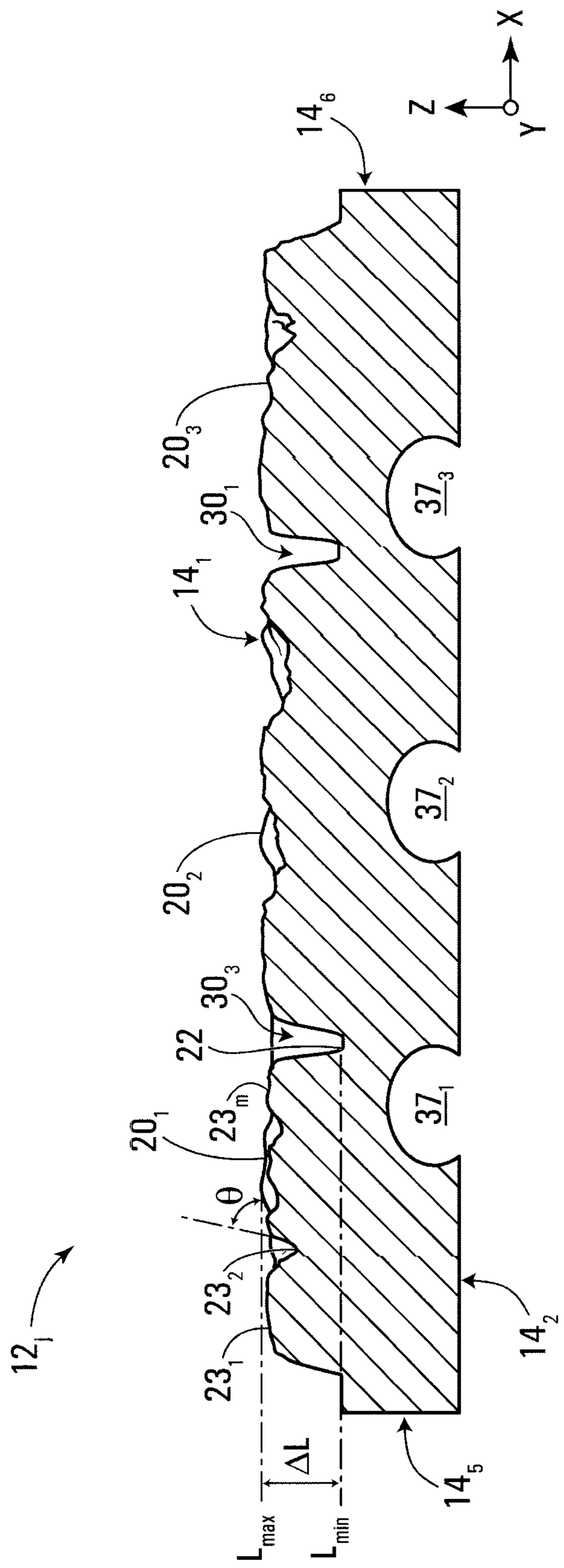

X
Z
Y
14_6
20_3
30_1
14_1
37_3
37_2
20_2
30_3
22
20_1
23_m
37_1
θ
23_2
23_1
12_j
14_2
14_5
L_{max}
ΔL
L_{min}

FIG. 6

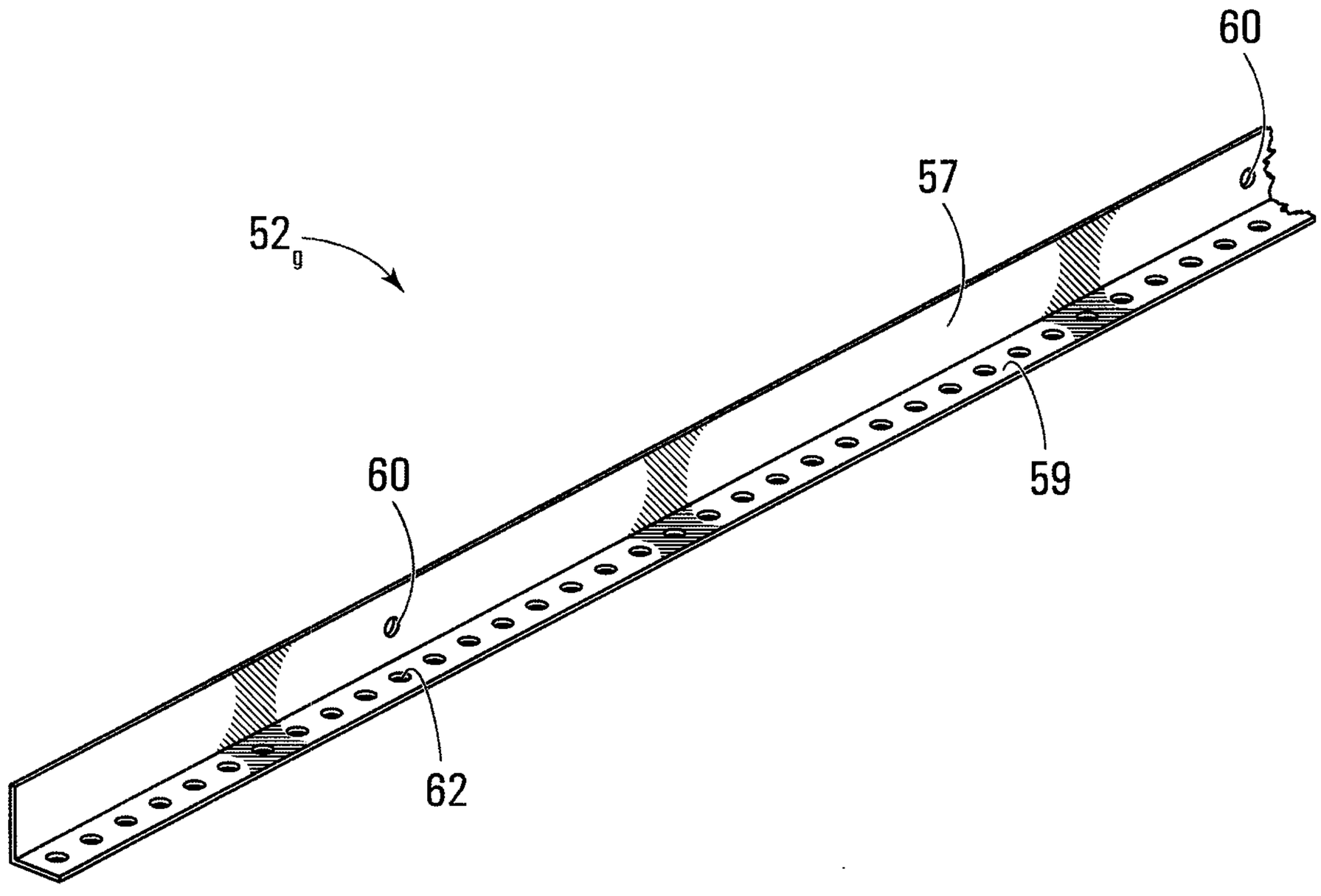


FIG. 7

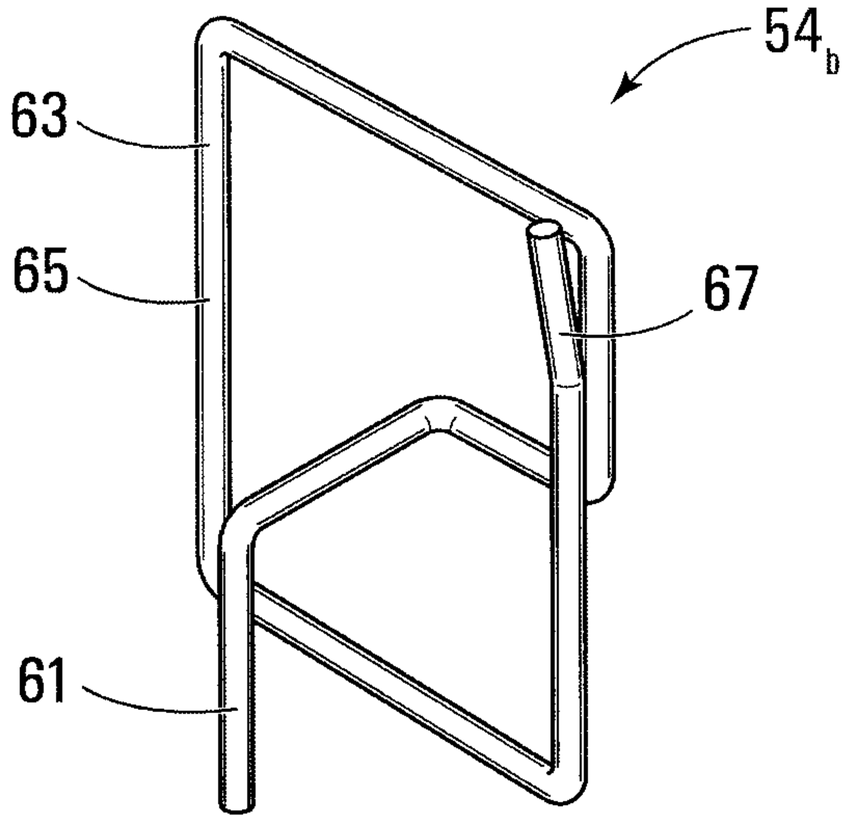


FIG. 8A

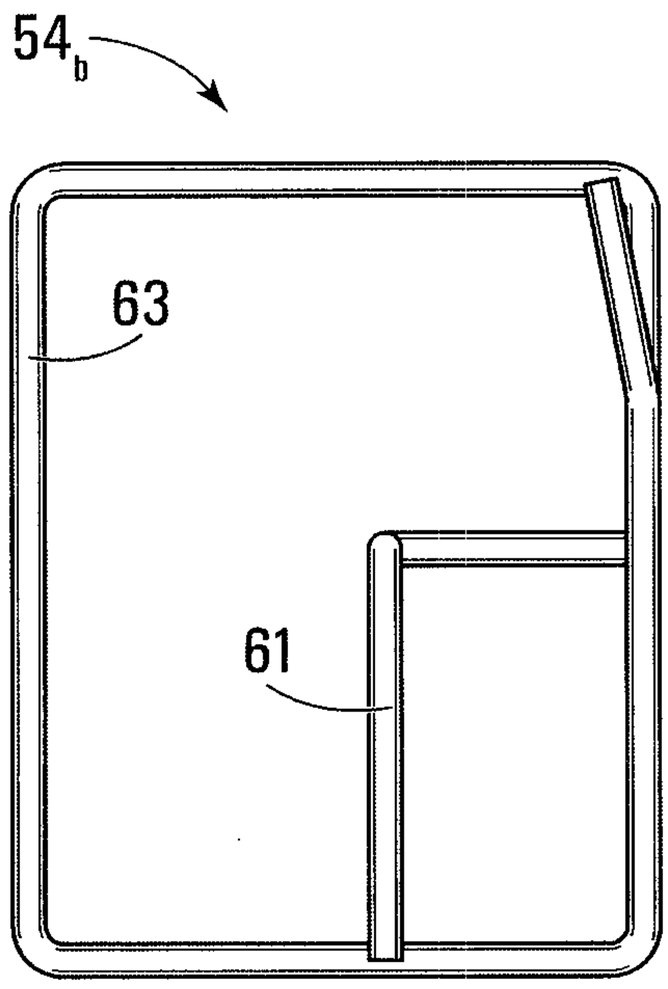


FIG. 8B

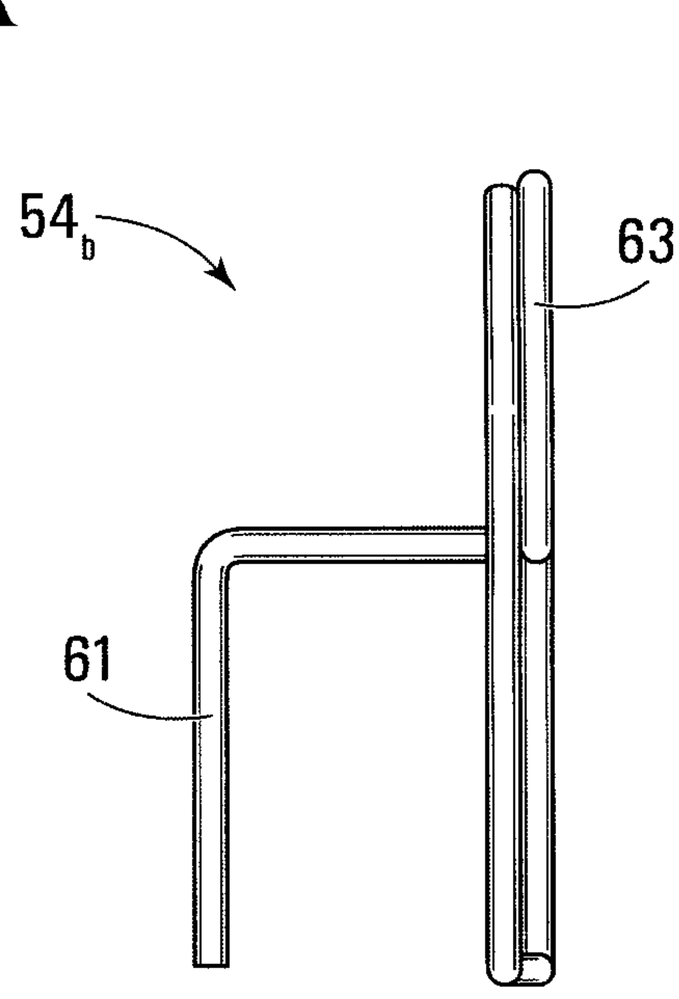


FIG. 8C

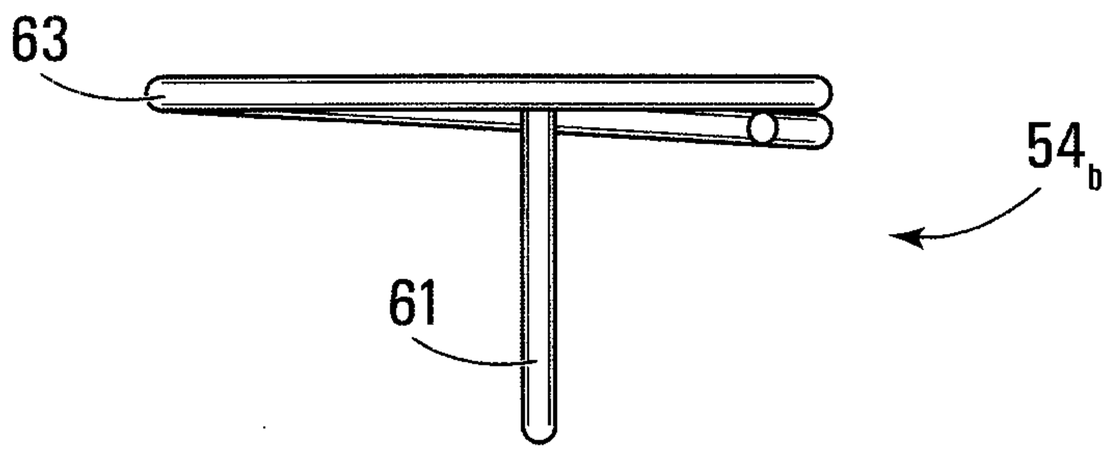


FIG. 8D

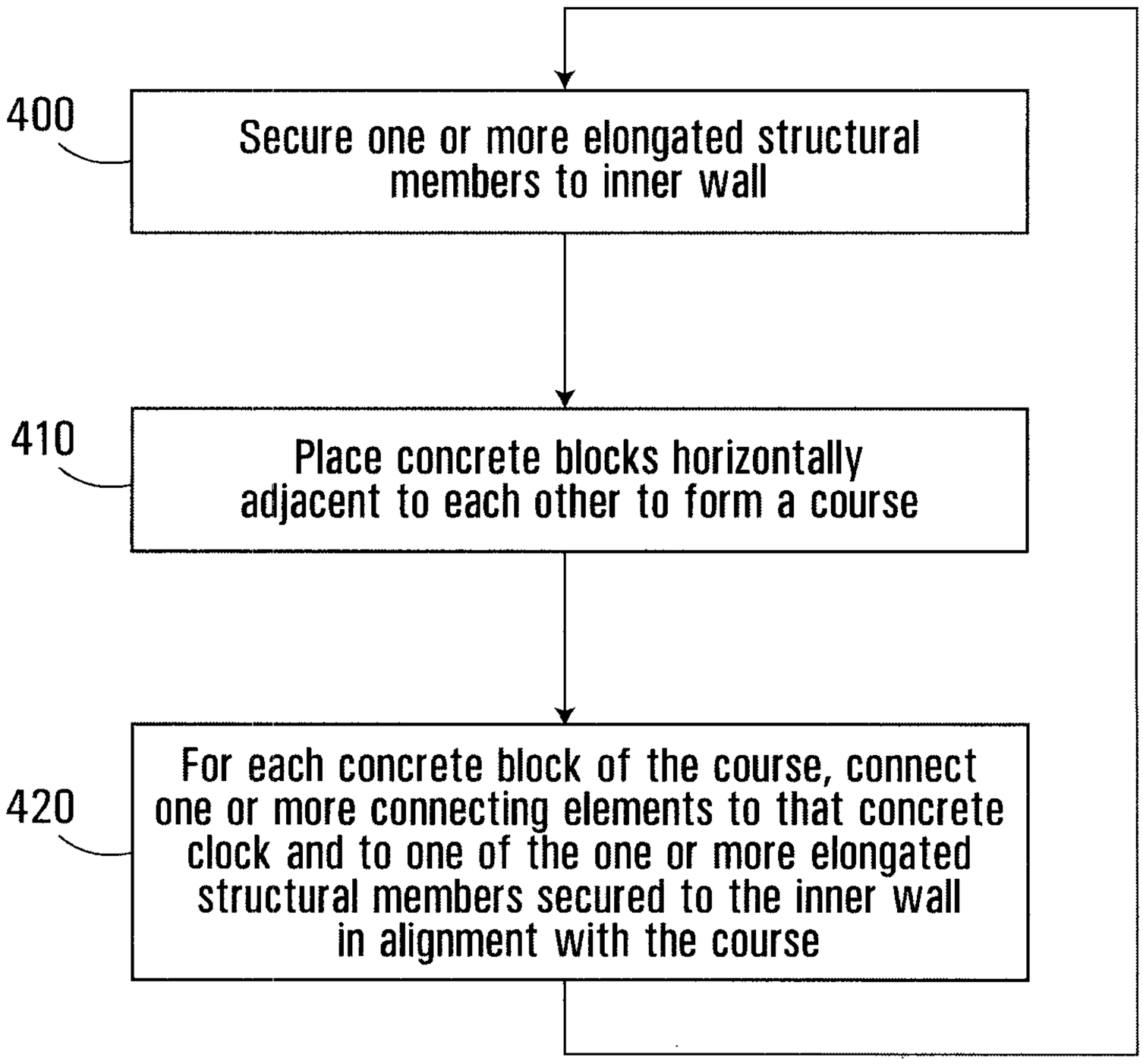

400
Secure one or more elongated structural members to inner wall
410
Place concrete blocks horizontally adjacent to each other to form a course
420
For each concrete block of the course, connect one or more connecting elements to that concrete clock and to one of the one or more elongated structural members secured to the inner wall in alignment with the course

FIG. 9

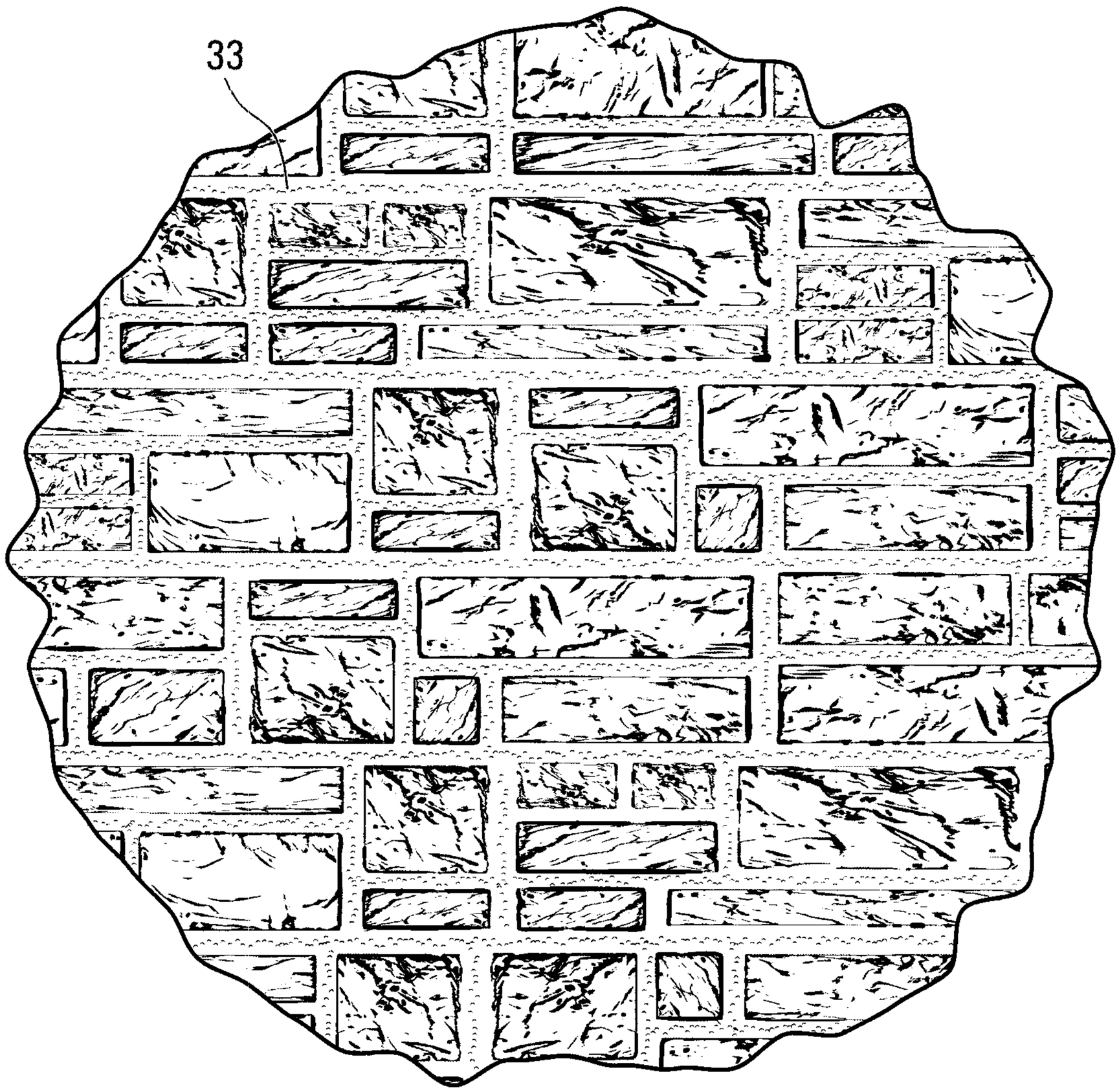


FIG. 10

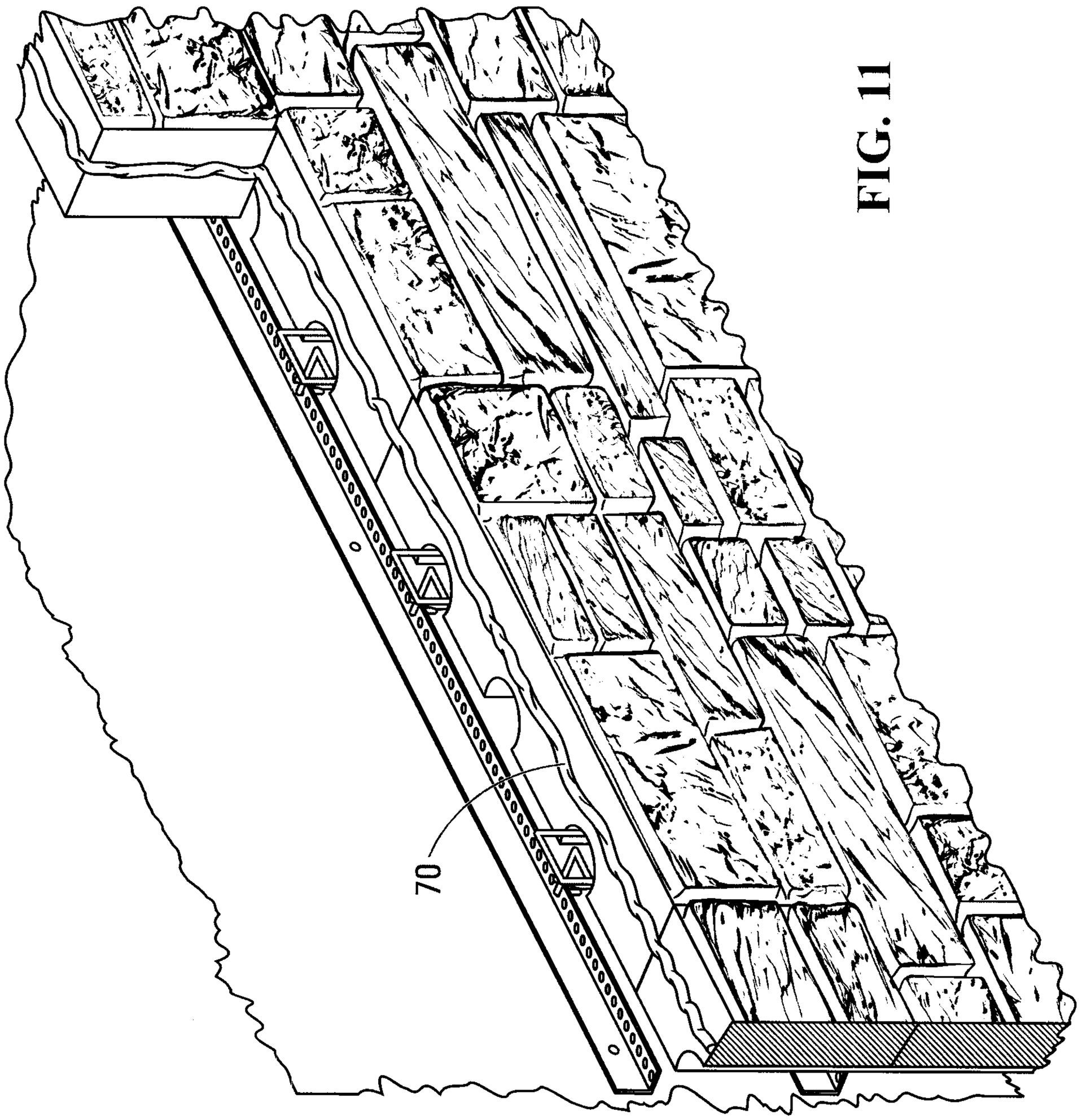


FIG. 11

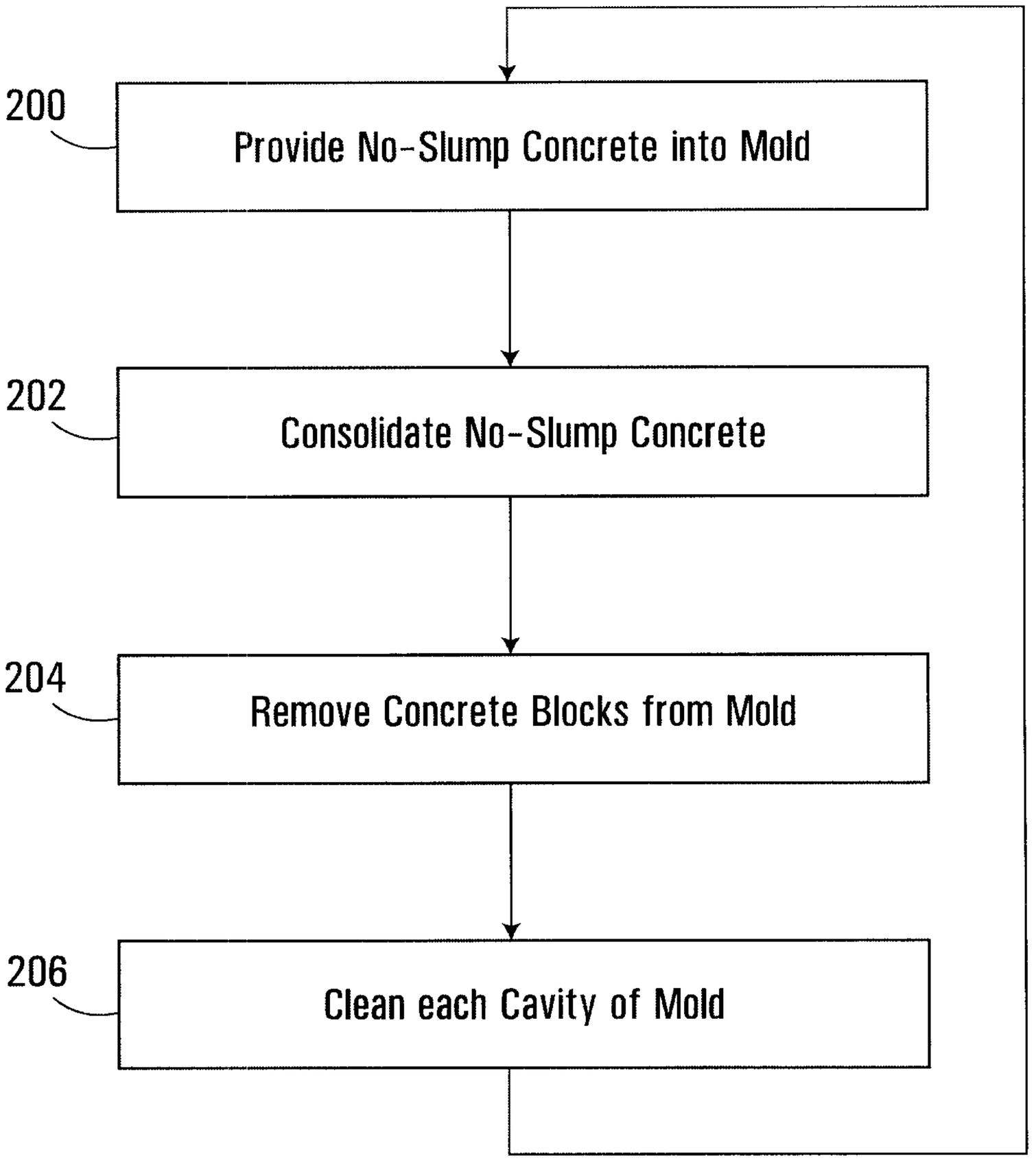
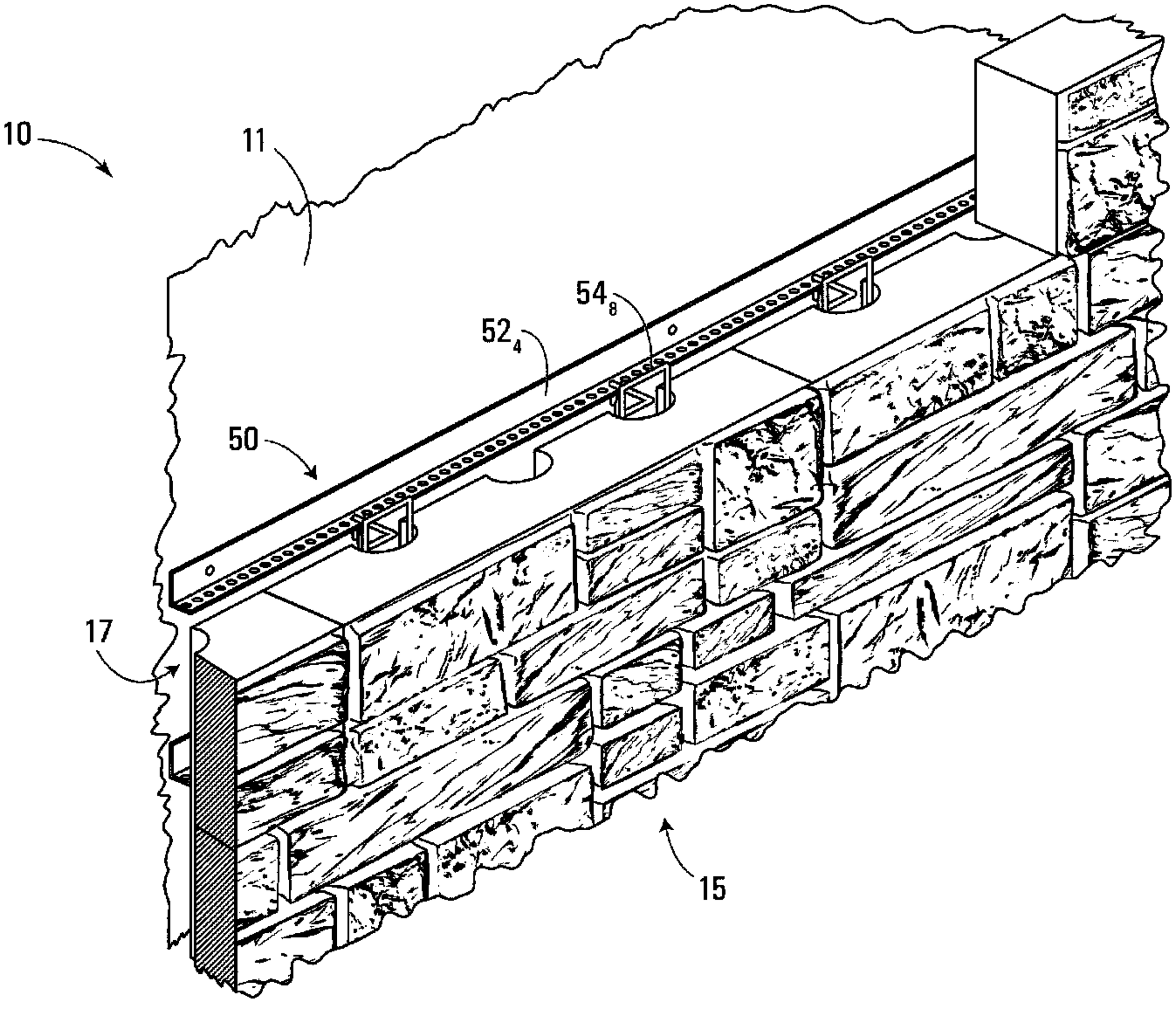

200
Provide No-Slump Concrete into Mold
202
Consolidate No-Slump Concrete
204
Remove Concrete Blocks from Mold
206
Clean each Cavity of Mold

FIG. 12


10
11
54_8
52_4
50
17
15