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(54) **Title**: METHOD AND APPARATUS FOR MANUFACTURING A BRICK WALL AND A BRICK WALL STRUCTURE

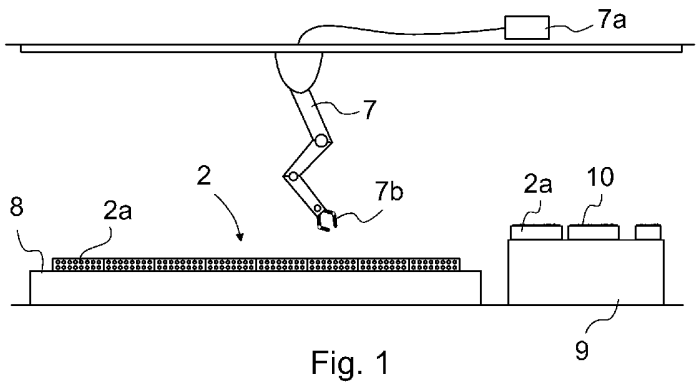

Fig. 1

(57) **Abstract**: The object of the invention is a method and an apparatus for building a brick wall, and a brick wall structure manufactured according to the method. A brick wall is built from brick wall elements (1) manufactured at the factory, which brick wall elements comprise at least a façade part (2) composed of bricks (2a), thermal insulation (5) and an inner wall part (6) composed of bricks (6a). The brick wall with its wall elements (1) is designed by means of the CAD system and the wall elements (2) forming the wall are manufactured in a CAM-controlled manner at the factory to be at least ready for finishing by means of an actuator (7).

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METHOD AND APPARATUS FOR MANUFACTURING A BRICK WALL AND A BRICK WALL STRUCTURE

The object of the invention is a method as defined in the preamble of claim 1 and an apparatus as defined in the preamble of claim 5 for manufacturing a brick wall, and also a brick wall structure as defined in the preamble of claim 8.

In prior art solutions brick walls are generally built up at the construction site directly in their final position. A problem in this case is the large amount of material and large amount of work, and also the need of hoisting appliances for the many scaffoldings and supports. In addition, a dedicated space must be reserved for bricks and for the transportation of bricks. Brickwork at the construction site is often exposed to the weather and is heavy, dirty and slow work to perform by hand. As a result of all this, brick wall structures are expensive and slow to build and for this reason they are not competitive with respect to other wall structures. Also the accuracy and quality of the work vary a lot because quality control is awkward. A further problem in conventional brickwork is that it produces large amounts of waste and rubbish that must be cleaned up during the work and after the work. Another problem is that the construction costs of conventional brickwork are difficult to price accurately.

Prior art also includes a solution in which large wall elements are built up semi-automatically such that a brick wall element to be manufactured is prefabricated in factory premises, where a conveyor belt brings the bricks to be laid directly to the mason or masons who then lay(s) the bricks onto the wall element by hand, building the wall element in a

conventional manner on a vertical plane one layer after the other upwards. After drying, the finished wall element is transported to the construction site and installed into its position. A problem in this solution is the proportion of manual work, which is considerable and which manual work is slow and also expensive. Wall elements built in this way are not sufficiently competitive either with respect to other wall structures.

Known in the art is also a solution in which the bricks of the frame structure are laid onto a flat base according to the model of the wall, leaving essentially large gaps spaced at even intervals between the bricks. When the bricks are in their position, fresh concrete is poured on top of the bricks and into the gaps between the bricks, which concrete is finally leveled and left to dry. In this way a finished single-layer concrete-brick wall element is produced with its window and door openings and also with its electrical wiring. The brick is a part of a concrete element and also partly acts as thermal insulation and lightens the weight of the element. In addition, the need for reinforcement is also less than in a pure concrete element. With this solution, however, a finished, or a nearly finished, wall is not achieved either, but instead a frame structure manufactured at the factory must be completed at the worksite by adding at least a thermal insulation layer and a façade layer onto it. If a layer of bricks is laid on the façade at the worksite the problems are the same as already described above.

Known in the art are also different automatic machines, which build up brick walls or stone walls of the thickness of one layer, but do not, however, assemble complete wall elements that would comprise, *inter alia*, an inner wall layer, a

thermal insulation layer and a façade layer. Also in these solutions a considerable proportion of manual work remains at the construction worksite, which accumulates the drawbacks characteristic of manual work that are already mentioned before.

The aim of this invention is to eliminate the aforementioned drawbacks and to achieve a simple, effective, reliable and advantageous method and apparatus for manufacturing a brick wall structure, and particularly suitably for manufacturing a brick wall element. The aim of this invention is also to achieve a method and an apparatus for manufacturing a brick wall utilizing a CAD-CAM system. Another aim of the invention is to achieve a simple and advantageous brick wall structure. The method according to the invention is characterized by what is disclosed in the characterization part of claim 1. Likewise, the apparatus according to the invention is characterized by what is disclosed in the characterization part of claim 5, and the brick wall structure according to the invention is characterized by what is disclosed in the characterization part of claim 8. Other embodiments of the invention are characterized by what is disclosed in the other claims.

An advantage of the solution according to the invention is that when using a CAD-CAM system as an aid in the design and manufacture of a brick wall, by the aid of automation a competitive wall structure that is also easy to manufacture is achieved. Another advantage of a manufacturing method that is implemented in indoor facilities, protected from the weather and automatically, is also that wall elements to be manufactured according to the invention are made to precise measurements, can easily be tailored and a comprehensive

quality assurance, which conversely does not succeed at the construction worksite and with a conventional construction method, can be set for the manufacturing process. Owing to fast manufacturing, the construction time of the building shortens. In addition, the CAD-CAM system enables the start of the manufacturing immediately after the design of the building is completed. One advantage is also an environmentally-friendly manufacturing method because single-use moulds are not needed as in concrete element manufacturing. Likewise, the amount of various waste and rubbish to be thrown away decreases. Another advantage is that the manufacture occurs in a workshop technology manner and does not contain manual work phases that are prone to errors.

A further advantage is that elements can be marked in connection with the manufacturing of the elements, in which case the installation phase is easier and installation errors are avoided. An advantage is also that the manufacturing process of wall elements includes very little water, or no water at all, so problems caused by water are avoided in the installation of walls. Yet another advantage is the reduction of the overhead costs of the worksite and the reduced handling of heavy materials at the worksite. An additional advantage is that there is no need to reserve space for numerous scaffoldings, brick piles, mortar containers, brick transportation, *et cetera*.

The good quality achieved also ensures precise delivery times and it is easy even for a house builder to manage deliveries of goods and costs, which can be accurately estimated by means of the quantity calculation produced by CAD design. A further advantage is the free architectural planning of

element construction, since a wall element to be built up is formed from small-sized modules, with which it is easy to make all types of free shapes. Additionally, in connection with architectural planning, the constructor can follow the cost development by means of a cost calculation produced by the product information model.

The wall element itself is also structurally advantageous, of uniform quality and it has a good thermal insulation capacity because not all structures need brick ties that are taken through insulation and that act as heat bridges. Owing to its structure a wall element is also rigid and durable. A wall structure manufactured according to the invention is well suited to both residential housing and to public building. An additional advantage is that the same robot line can perform surface treatment on the façade e.g. with decorative spraying.

In the following the invention will be described in more detail by the aid of two examples of its embodiments with reference to the attached drawings, wherein

Fig. 1 presents a diagrammatic and simplified side view of a bricklaying apparatus of a wall element according to the invention,

Fig. 2 presents a simplified top view of the manufacture of a wall element according to the invention,

Fig. 3 presents a top view of one brick wall structure according to the invention, and

Fig. 4 presents a top view of a second brick wall structure according to the invention.

The invention is based on a method and an apparatus based on CAD-CAM for manufacturing a brick wall. According to the method a brick wall is made of wall elements, which are designed by means of a CAD system, and the wall elements of a wall, with their façade bricks 2a, thermal insulation 5, 5a, and inner wall bricks 6a, are manufactured at the factory by means of one or more robots 7 using CAM control to be either fully finished or at least ready for finishing. According to the invention the starting point of the CAD design and of the CAM manufacturing is a complete building, the design data of which is used as the basis for building up the bricks 2a and 6a. The aim of the invention is also a brick wall structure manufactured according to the method.

Figs. 1 and 2 present a simplified and diagrammatic bricklaying apparatus according to the invention. For the sake of clarity the bricklaying robot is omitted from Fig. 2. Additionally, in the phase presented by Fig. 2 the façade layer 2 of the wall element is not yet fully finished. The apparatus comprises at least a support base 8 essentially on a horizontal plane, on top of which support base a brick wall element 1 is manufactured one layer after the other essentially on a horizontal plane. In the proximity of the support base is a base 9 for the bricks 2a and 6a to be laid. Bricks 2a, 6a are brought to the base 9 either with a conveyor or with a hoist, and before bringing the bricks 2a, 6a they are provided at least on one of their long sides with a binding agent 10, such as with a mineral adhesive or with mortar. The conveyor or hoist is not shown in the figures.

The apparatus also comprises an actuator 7 provided with a control system 7a and a suitable user interface, the actuator 7 being, for example, an industrial robot or corresponding

provided with a numerical control and is equipped to function in a manner according to the control of the CAD-CAM system. There can also be more than one actuator 7 or actuators corresponding to them and they are preferably fitted to operate together and to assist one another. An actuator 7 is fitted to fetch the bricks 2a, 6a brought to the base 9, e.g. one or only a few bricks, e.g. also two or three bricks at a time, and to move the bricks 2a, 6a one or only a few bricks, e.g. also two or three bricks at a time, to a place according to the CAD design onto their sides on the support base 8 and joined to the adjacent bricks such that the binding agent on the long side adheres to one or more bricks that are already on the support base 8. The ends of the bricks 2a, 6a comprise preferably a key joint so that the bricks stay well together end-to-end. The actuator 7 operates fully automatically according to the CAD design, and when making a wall also leaves appropriate openings at the points of windows and doors. In addition, the gripper part 7b can be easily changed in the actuator 7, if necessary, so that it can handle other components of a wall element to be manufactured. If there are a number of actuators 7, different actuators may already comprise suitable gripper parts 7b ready for handling other components of a wall element.

Fig. 3 presents one brick wall element 1 manufactured with the method and apparatus according to the invention. The brick wall structure comprises at least a façade part 2 composed of bricks 2a, an air gap 3 inside said part, thermal insulation 5 further inside the air gap and an innermost inner wall part 6 composed of bricks 6a. The bricks 6a of the inner wall part comprise large vertical apertures in the centre, through which e.g. electrical conduits can be drawn.

The thermal insulation 5 in the wall structure 1 according to Fig. 3 is of self-supporting polyurethane, onto the outer surface of which a plurality of essentially vertical and perforated profiled battens 4 that are at a horizontal distance from each other are fixed at their inner edges, which profiled battens are further fixed at their outer edges to the inner surface of the façade part 2 composed of bricks 2a such that an air gap 3 of essentially the thickness of the profiled battens 4 remains between the thermal insulation 5 and the façade part 2. Air is able to flow in the air gap 3 through the holes in the side walls of the profiled battens 4.

Correspondingly, the inner wall part 6 composed of bricks 6a is directly fixed to the inner surface of the thermal insulation 5 by means of a seam 6b composed of mineral adhesive, masonry mortar or other corresponding binding agent. The actual load-bearing part of the wall element 1 is the inner wall part 6 composed of bricks 6a, which part can also be called a frame structure. The polyurethane 5 bears e.g. the bricks 2a of the façade part 2. The wall element 1 with all its layers is thus a module that is finished or at least nearly finished at the factory by means of CAD design and CAM manufacture, the size, thickness and shape of which module are easily variable.

The thermal insulation 5a in the wall structure 1 according to Fig. 4 is a soft and pre-shaped wool element or is of some other suitable thermal insulation material. Since a wool insulation is not a self-supporting structure, the wool insulation is made to be a load-bearing wool element 5a by means of load-bearing and power-transmitting tie elements 11 placed in the wall element 1 at suitable intervals. The wool

element 5a binds the inner wall part 6 through the insulation wool to the façade part 2 by means of tie elements 11. Also in this wall structure an air gap 3 is between the façade part 2 and the thermal insulation 5a.

With the method according to the invention a brick wall structure is manufactured e.g. as follows:

First the building with its brick walls and wall elements 1 is designed by means of the CAD system, in which case also the quantity of materials and prices are calculated in addition to shapes and strength calculations. When the CAD design is ready, the design data of the wall structure is delivered to the manufacturing unit at the factory of the wall elements 2, in which unit wall elements 1 are manufactured on the basis of the design data of the CAD design by means of a CAM system using one or more automatic actuators 7, such as industrial robots or corresponding devices, operating on the basis of the CAM control for laying and fixing bricks 2a and 6a and also for fixing other components 4, 5 and 5a.

A wall element 1 is manufactured such that first a façade part 2 composed of bricks 2a is manufactured on top of an essentially flat support base 8, which forms a horizontal plane, by laying bricks 2a that are brought with a conveyor, a hoist or a corresponding device and that are provided at one of their long edges with mineral adhesive, mortar or other binding agent 10 onto the base 9 one or only a few bricks at a time, e.g. also two or three bricks at a time, into their position on the support base 8 by means of an actuator 7 according to the CAD design, in which case a single-layer brick façade part 2 is formed on the support

base 8 according to the CAD design and with the façade side facing downwards towards the support base 8. The façade layer increases on the support base in this way essentially on the horizontal plane in two dimensions, in the width direction of the final wall and in the final height direction.

When the façade part 2 is finished and has dried sufficiently, perforated profiled battens 4 that produce an air gap 3 are fixed to the inner surface of the façade part 2. The fixing occurs again according to the CAD design and with an actuator 7 or with some other suitable actuator, and on top of the support base 8 or some other suitable support base and essentially on a horizontal plane. Polyurethane acting as thermal insulation 5 is further fixed to the inner surface of the profiled battens 4, i.e. to the upper surface of the profiled battens on the supporting platform, by means of a suitable binding agent, such as an adhesive, mortar, a mechanical method or corresponding, to the upper surface of which polyurethane a frame brick layer that comprises bricks 6a and forms the inner wall part 6 on the horizontal plane is further fixed by means of an actuator 7. The bricks 6a are fixed to the polyurethane 5 by means of a seam 6b composed of mineral adhesive, masonry mortar or other corresponding binding agent. If it is desired to fix the inner wall part 6 mechanically, in addition to adhesive or without adhesive, to the façade part 2, when the inner wall part 6 is assembled the actuator 7 installs mechanical brick ties through the polyurethane insulation 5 at intervals set in the CAD design.

If necessary, each layer fixed to the wall element 1 is allowed to dry before the next layer is added. In this way wall elements 1 are manufactured at the factory by means of one or more actuators 7, such as an industrial robot or a

corresponding device, using a CAM system to be at least ready for finishing.

If soft insulation wool is used as thermal insulation the bricks 6a and 2a of the inner wall part 6 and of the façade part 2 are bound to each other through thermal insulation 5a with power-transmitting and load-bearing tie elements 11. This procedure is also performed preferably automatically according to the CAD design. Mechanical brick ties acting as tie elements 11 can be e.g. bars, which are tightened into their position with nuts or which are pushed through the insulation and through the brick layers and finally bent into their position. Essentially similar mechanical tie elements can be used with both polyurethane insulation 5 and a wool element 5a.

It is obvious to the person skilled in the art that the invention is not limited solely to the example described above, but that it may be varied within the scope of the claims presented below. Thus, for example, the phases of the method and the structure of the apparatus and also the wall structure can be different to what is presented above. For example, the manufacture of a wall element can also comprise some manual manufacturing phases, or the work sequence can be totally different.

For example, if brick ties are used the manufacturing phases of a wall element can be e.g. as follows: First the aforementioned robot-type actuator manufactures a frame structure, which acts as an inner wall, on the supporting platform on a horizontal plane by fixing the inner wall bricks to each other according to the CAD design. After this the thermal insulation is placed into its position by means

of either one or more actuators and if polyurethane is used as thermal insulation the actuator makes holes through the thermal insulation for the tie elements and pushes the tie elements into their position. Next, profiled battens enabling an air gap are placed on top of the polyurethane insulation and finally a façade layer is manufactured as the topmost layer. In connection with the manufacture of the façade layer the actuator tightens the tie elements between the inner wall structure and the façade structure either with a nut, by bending or in any other suitable manner.

It is also obvious to the person skilled in the art that a wall element can be laid and manufactured according to the invention also in a vertical position by means of a robot and other automatic or semi-automatic actuators.

It is further obvious to the person skilled in the art that although only a brick wall structure is presented above, the outer layer and inner layer of a wall element can also be manufactured from other essentially small-sized construction components than bricks. The outer layer and inner layer of a wall element can be manufactured essentially in the same manner also from different types of brick blocks, construction blocks and building stones. In the claims the term brick thus also refers to the aforementioned different types of brick blocks, construction blocks and building stones.

It is additionally obvious to the person skilled in the art that a brick element can also be manufactured from blocks of different types and different sizes, which blocks meet the thermal insulation values, i.e. U values, set for wall structures.

Furthermore, it is also obvious to the person skilled in the art that instead of an end-to-end key joint of bricks the ends of bricks can be essentially even and mortar or some other suitable binding agent is placed also between the ends in connection with the brickwork.

CLAIMS

1. Method for building a brick wall, in which method a brick wall is built from prefabricated brick wall elements (1), which comprise at least a façade part (2) composed of bricks (2a), thermal insulation (5) and an inner wall part (6) composed of bricks (6a), and in which method the brick wall with its wall elements (1) is designed by means of a CAD system, **characterized** in that wall elements (2) forming the wall are manufactured at the factory in a CAD-controlled manner by means of one or more actuators (7) to be at least ready for finishing by laying bricks (2a, 6a), which are provided with mortar or other binding agent (10), with the actuator (7) into their position on the wall element (1), according to the CAD design, 1-3 bricks (2a or 6a) at a time, suitably two bricks (2a or 6a) at a time or one brick (2a or 6a) at a time.

2. Method according to claim 1, **characterized** in that the façade part (2) composed of bricks of a wall element (1) is manufactured on top of an essentially flat support base (8), which forms a horizontal plane, by laying bricks (2a, 6a) that are brought with a conveyor, a hoist or a corresponding device and that are provided at least at one of their edges with mortar or other binding agent (10) onto a base (9) by means of an actuator (7), such as an industrial robot or a corresponding device, according to the CAD design, into their position on the support base (8) forming a brick wall essentially on the horizontal plane in two dimensions.

3. Method according to claim 1 or 2, **characterized** in that the wall element (1) is manufactured essentially on the horizontal plane by first manufacturing the façade part (2)

composed of bricks (2a) on top of the support base (8), after which perforated profiled battens (4) producing an air gap (3) are fixed to the inner surface of the façade part (2), onto the top of which profiled battens polyurethane (5) acting as thermal insulation is fixed, onto the upper surface of which polyurethane a frame brick layer forming the inner wall part (6) is further fixed by means of an actuator (7), and in that each layer fixed to the wall element (1) is allowed to dry, if necessary, before the next layer is added.

4. Method according to claim 1 or 2, **characterized** in that the wall element (1) is manufactured essentially on the horizontal plane by first manufacturing the façade part (2) composed of bricks (2a) on top of the support base (8), after which a thermal insulation element (5a) equipped with power-transmitting and load-bearing tie elements (11) that produce an air gap (3) is fixed to the inner surface of the façade part (2), onto the inner surface of which thermal insulation element the frame brick layer forming the inner wall part (6) is further fixed by means of an actuator (7).

5. Apparatus for building a brick wall, which apparatus comprises at least a support base (8) for supporting the brick wall element (1) forming the brick wall and a base (9) for the bricks (2a, 6a) of the brick wall and also one or more actuators (7) at least for fixing the bricks (2a, 6a) to the wall element (1) to be manufactured, **characterized** in that the actuator (7) is provided with a CAM control to transfer and to fix at least bricks (2a, 6a) provided with mortar or other binding agent (10) to the brick wall element (1) to be manufactured according to the CAD design into their correct positions 1-3 bricks (2a or 6a) at a time, suitably

two bricks (2a or 6a) at a time or one brick (2a or 6a) at a time.

6. Apparatus according to claim 5, **characterized** in that the actuator (7) is an industrial robot or a corresponding CAM-controlled device equipped with a changeable gripper part (7b), which gripper parts (7b) are fitted for handling and moving bricks or corresponding pieces of different sizes and types and other components of the wall element (1).

7. Apparatus according to claim 5 or 6, **characterized** in that the apparatus comprises means for providing separate bricks (2a, 6a) with mortar (10) or other suitable binding agent before the bricks (2a, 6a) are moved to be used by the actuator (7).

8. Brick wall structure, which brick wall comprises at least a façade part (2) composed of bricks, thermal insulation (5, 5a), an inner wall part (6) composed of bricks and at least a structure bearing the weight of the façade part (2) between the façade part (2) and the inner wall part (6), **characterized** in that in the hoisting phase the thermal insulation (5), or a combination of the thermal insulation (5a) and a separate load-bearing structure, is the structure bearing the weight of the façade part (2).

9. Brick wall structure according to claim 8, **characterized** in that the thermal insulation (5) is of self-supporting polyurethane, onto the outer surface of which a plurality of essentially vertical and perforated profiled battens (4) that are at a horizontal distance from each other are fixed at their inner edges, which profiled battens are further fixed at their outer edges to the inner surface of the outer wall

part (2) composed of bricks such that an air gap (3) of essentially the thickness of the profiled battens (4) remains between the thermal insulation (5) and the outer wall part (2).

10. Brick wall structure according to claim 8, **characterized** in that the thermal insulation (5a) is a self-supporting thermal insulation element (5a) equipped with power-transmitting and load-bearing tie elements (11) that produce an air gap (3).

11. Brick wall structure according to claim 8, 9 or 10, **characterized** in that the inner wall part (6) composed of bricks is directly fixed to the inner surface of the thermal insulation (5) by means of a seam (6b) composed of masonry mortar or other corresponding binding agent.

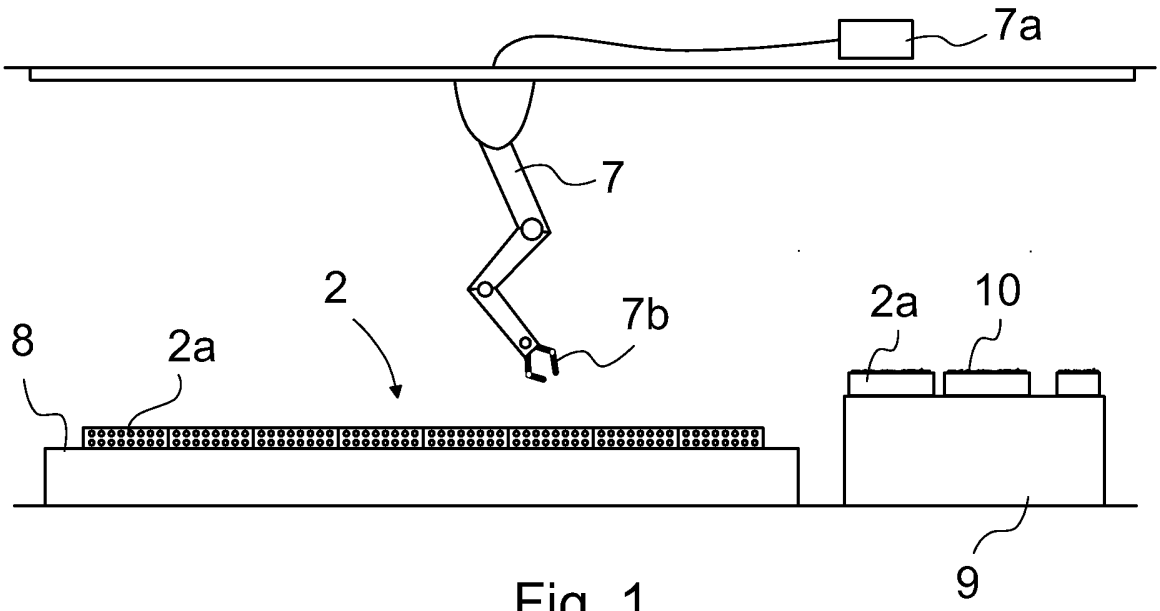

Fig. 1

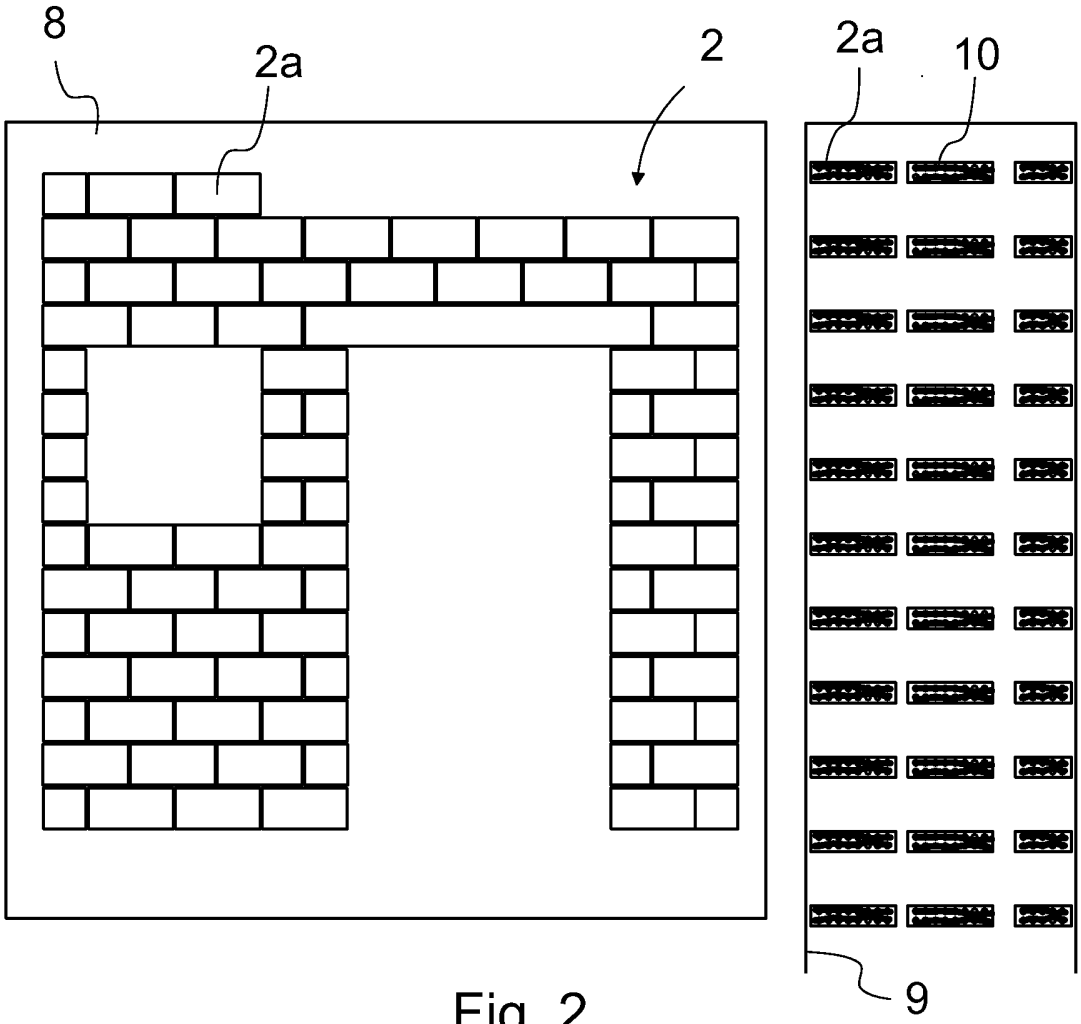

Fig. 2

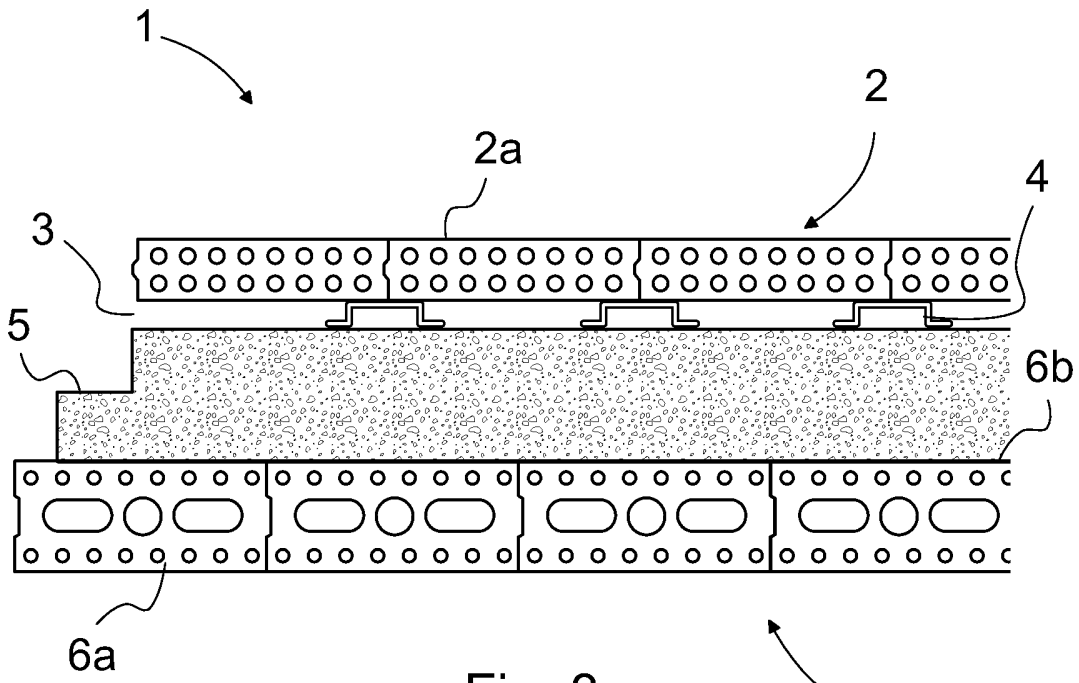

Fig. 3

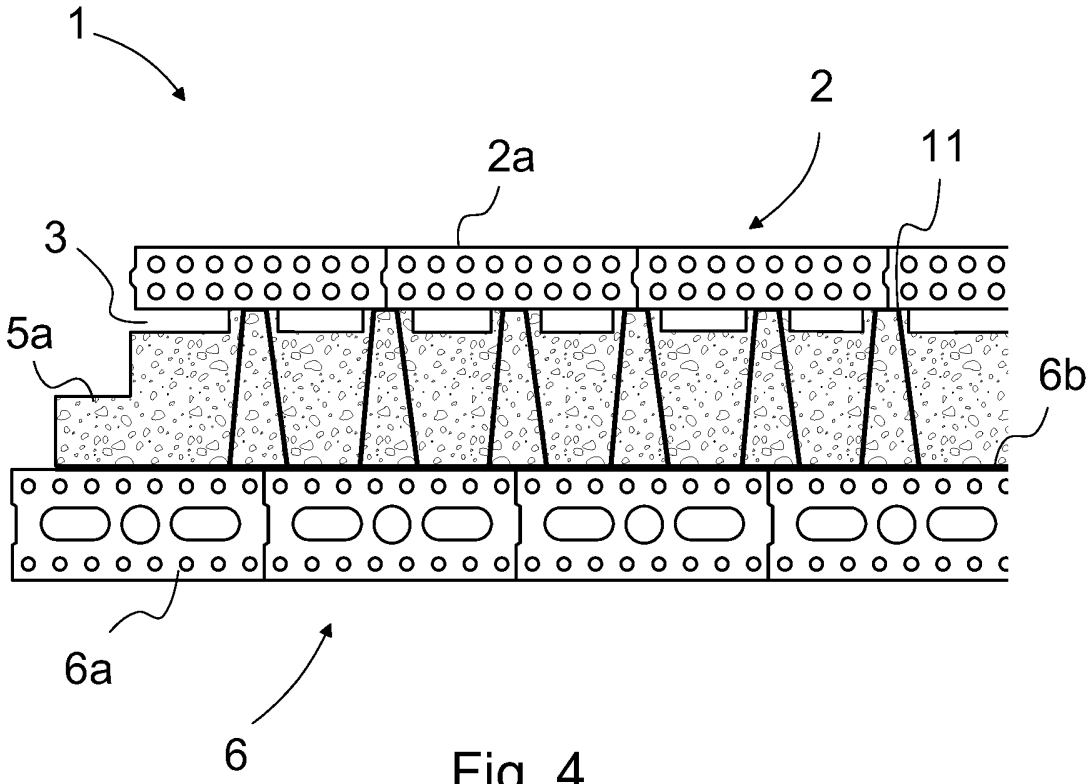

Fig. 4