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(54) **A building seismic strengthening system**

(57) The building seismic strengthening system according to the invention solves the problem of strengthening walls (1) of existing buildings with massive cross laminated timber panels (3) of monolithic or multi-piece assembly, with or without openings (7) for the existing windows and doors, and attached to the inner and/or outer side of walls (1) with a layer of glue (4) and additionally connected with anchoring bolts (5) and self-tapping wood screws (11). The system is especially useful for strengthening of existing buildings on seismically active areas.

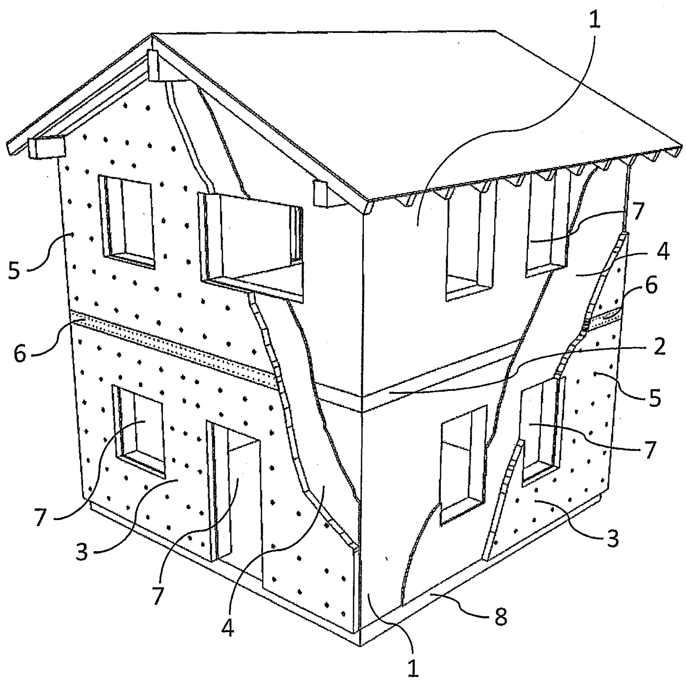

Fig. 1

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Description

The subject of the invention

[0001] The subject of the invention is a system for seismic strengthening of buildings, or to be more specific, a system for seismic strengthening of walls and connecting of floor planes of existing buildings with massive cross laminated timber panels, which also includes an insulation effect.

[0002] According to the international patent classification the invention belongs to E04G23/02 and to E04H9/02 and, additionally, to E04B1/74.

Technical problem

[0003] The technical problem solved by this invention is seismic and energy retrofit of existing buildings that were not built to withstand seismic loads. The retrofit is performed with cross laminated timber panels, which are used to strengthen the walls and floor planes of timber, stone, masonry and concrete buildings with the aim to withstand horizontal forces caused by an earthquake or strong wind and at the same time to ensure a higher thermal insulation of buildings.

Current state of the art

[0004] There are quite some known systems for seismic strengthening of existing buildings.

[0005] According to document KR 100989218 a method for seismic strengthening of partition walls of an existing masonry building is known. Steel rods are drilled into the walls from one or both sides. They are sticking out and are orientated perpendicularly to the wall plane. Just next to the wall, from one or both sides, steel rods are placed diagonally over the whole wall area in both directions. The steel rods are moulded in a layer of non-shrinkable mortar that connects the new construction with the existing one. Weakness and deficiency of this solution is above all in the fact that in order to provide the mortar layer(s), a framework needs to be constructed and later removed. The proposed solution of clamping a wall with steel rods does not significantly differ from the conventional solution of using a steel mesh.

[0006] According to document JP 9228658 a method for seismic strengthening of the walls of an existing building with laminated timber plates made of glued laminated timber (parallel lamination) is known. The plates are used as infill of existing frames and are attached to them with connecting construction and steel mechanical fasteners. Weakness and deficiency of this solution is above all in the fact that parallel glued laminated timber plates are used that are very deformation sensitive to moisture changes, which negatively influences the existing strengthening construction. In addition, the compression and tension strengths of parallel-glued laminated timber elements perpendicularly to fibers are very low. Furthermore, weakness and deficiency is in the fact that this solution is only usable for concrete frame constructions and only from the inside but not the outside of an existing building. Hence the outer walls of a building are not seismically strengthened. Such strengthening structures are only used as partition walls. As the strengthening timber structure can only be attached around its perimeter, it can only be connected at floor levels. Therefore such a system is especially problematic for buildings that do not have RC floor slabs.

[0007] According to document JP 2009174148 a method for seismic strengthening of reinforced concretes buildings with strengthening panels, additional concrete walls and light-weight infills is known. The walls of an existing building are confined with strengthening panels, bolted together with threaded rods, hence clamping the walls and transferring friction forces to themselves. Weakness and deficiency of this solution is in the fact that it is only suitable for reinforced concrete frame-type structures and that using a light material for filling in the gap between the strengthening panels and existing walls is unreliable, making the construction more demanding.

[0008] Furthermore, according to document JP 2009097165 an outer strengthening structure of an existing building where the strengthening frame is connected to the outer side of the structure at storey levels is known. A separate strengthening frame is connected to each individual storey and the frames are later connected together, as a rule, at mid-storey height. Weakness and deficiency of this solution is in the fact that it is mostly suitable for frame-type structures, that it is only attached to the existing structures at storey levels and that the strengthening frames on the outer side significantly change the buildings' appearance.

[0009] The common characteristic of described known solutions is that the walls of buildings are cladded with unsuitable strengthening panels or infills, whereby their construction and connections do not enable sufficient seismic strengthening, they are not useful for all types of walls and partition walls of a building, they do not improve the thermal insulation of seismically retrofitted buildings and due to the high carbon footprint of steel and concrete they do not meet contemporary ecology demands. As these strengthening panels and infills do not provide a thermal insulation effect, additional thermal insulation needs to be installed on building façades.

[0010] Due to the formerly mentioned weaknesses and deficiencies of known seismic retrofitting solutions of existing buildings in seismic areas, there is a need for an effective strengthening system for all types of walls that will allow a sufficient seismic mainly horizontal load transfer and also a sufficient thermal insulation of buildings, all in the scope of valid ecology standards.

The technical problem solution

[0011] According to the invention, the technical problem is resolved with a seismic strengthening system whose main feature is that it is conceived as a cladding from massive cross laminated timber panels that can be used to confine all load bearing and partition walls from the outer and/or inner sides of existing buildings regardless of the building material. The massive cross laminated timber panels serve as strengthening panels that due to their structure also serve as a thermal insulation of the building. Various implementations of massive plates are possible and are glued to the walls and additionally connected with bolts.

[0012] The invention will be more precisely described in relation to the feasibility example and figures, which show as follows:

- Fig. 1 the strengthening system according to the invention shown via a partial cross section of the outer envelope of an existing building in an isometric projection
- Fig. 2 a building's wall cladded with a massive monolithic panel in a dimetric projection
- Fig. 3 same as in Fig. 2, however, the massive panel used for cladding and strengthening a wall is assembled from smaller pieces
- Fig. 4 a longitudinal cross section through a floor construction of a strengthened wall cladded with a massive timber panel and partial cross sections of connection elements
- Fig. 5 a detail of massive panel connections in the example of assembled panels, with a partial cross-section of attachment
- Fig. 6 a cladded and strengthened building's wall with a massive panel running uninterrupted from the foundation to the roof of the building

[0013] The building seismic strengthening system is made from massive cross laminated timber panels 3 with which the walls 1 of an existing building are cladded from the outer and/or inner side. The massive cross laminated timber panels 3 are attached to the walls with a layer of glue 4 and additionally fixed with connections, namely anchor bolts 5 in the presented feasibility example, and self-tapping wood screws 11. The openings 7 for the existing windows and doors in walls 1 of an existing building are cut out of the massive cross laminated timber panels 3 and/or encircled with them so that they are left uncovered. In some other feasibility example, not shown here, some doors and windows in the walls 1 of an existing building can also be covered with massive cross laminated timber panels 3.

[0014] For existing buildings with two or more floors the massive cross laminated timber panels 3 are interconnected with flat steel ties 6, typically at around each floor structure 2 area. In the described feasibility example of the seismic strengthening system according to the invention the massive cross laminated timber plates 3 are placed onto the walls 1 of the masonry building. This is shown in Fig. 1. In some other feasibility example, not shown here, the massive cross laminated timber plates 3 can also be used to clad and strengthen walls 1 made from concrete, timber or any other material, which can be used for this purpose, or a combination of materials, with or without an insulation layer and/or a façade.

[0015] As shown in Fig. 2, the walls 1 in the appurtenant storeys of an existing building can be strengthened with a monolithic massive cross laminated timber plate 3 that completely and in one piece covers the inner and/or outer side of an individual wall 1. In such a case the openings 7 for existing doors and/or windows in wall 1 are cut out of the massive cross laminated timber panel 3, which runs from the foundation 8 and partially over the edge of the floor structure 2, in advance. As mentioned before the monolithic massive cross laminated timber panels 3 are attached to the walls 1 and floor structures 2 with a layer of glue 4 and additionally connected with anchoring bolts 5 placed over their surface at a certain spacing. A layer of glue 4 suitable for the task is used.

[0016] As shown in Fig. 3, the walls 1 of the existing building can be cladded, conversely strengthened, from one or both sides, with massive cross laminated timber panels 3 made from several smaller pieces 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7 to 3.n of various shapes and dimensions. Together they form connecting areas 9 that are additionally connected on adjacent edges with self-tapping wood screws 11. Individual pieces 3.1 to 3.n of the massive cross laminated timber panel 3 are attached to wall 1 as in the feasibility example in Fig. 2, namely with anchoring bolts 5. The advantage of the multi-piece assembly of the massive cross laminated timber panels 3 over before described monolithic one, is that cutting of openings 7 for the existing windows and doors is not necessary as the openings are formed during the cladding and attaching of pieces of massive cross laminated timber panels 3.1 to 3.n around window and door openings in walls 1 of an existing building. Above all the multi-piece assembly is easier if the massive cross laminated timber panels 3 are being attached to the inner side of walls 1. Smaller pieces 3.1 to 3.n are lighter and allow for an easier manipulation without the need for lifting equipment.

[0017] In some other feasibility example, not shown here, different walls 1 can be cladded with massive cross laminated timber panels 3, both with monolithic and multi-piece assemblies combined, as shown in Fig. 2 and Fig. 3.

[0018] Regardless of the type of the aforementioned assemblies of massive cross laminated timber panels 3, monolithic or multi-piece or combined, the connecting areas 9 in the floor structure 2 zones of an existing building are made in the same way as prescribed below. The connecting areas 9, where the massive cross laminated timber plates 3 attached to walls 1 in two adjacent stories connect, are preferentially covered along the perimeter of the floor structure 2 with a flat steel tie 6 with holes 12 that is attached to the adjacent connecting massive cross laminated timber panels 3 with self-tapping wood screws 11. Shear forces and bending moments are transferred via the flat steel ties 6 from higher to lower floors of an existing building. As described before, in all these examples, the massive cross laminated timber panels 3 are attached to the walls 1 of an existing building with a layer of glue 4 and additionally fastened with anchoring bolts 5 and washers 10. The described is presented in Fig. 4.

[0019] When assembling the massive cross laminated timber panels 3 at parallel or perpendicular connecting areas 9 the so called seam-connections are made with self-tapping wood screws 11, preferentially drilled under an angle 90° or 45° as shown in Fig. 5. It applies that 45°drilling is used for parallel plate connecting areas 9 and 90°drilling for overlapping connections.

[0020] In some feasibility examples the walls 1 of existing buildings can be cladded and strengthened with massive cross laminated timber panels 3 that run from the foundation 8 to the roof of the building, or any other height, in one piece.

[0021] The massive cross laminated timber panels 3 are tailored to the geometry of the existing building's envelope. Optimally, they are made from 3 to 7 or even more layers of cross laminated timber lamellas of arbitrary thickness where every layer runs perpendicularly to the two neighbouring ones. The necessary thickness of the massive cross laminated timber panels 3 is prescribed according to the static and seismic demands of the building. The panels need to be made[Z1] with a hydraulic system press.

[0022] The massive cross laminated timber panels 3 can be attached to the walls 1 of an existing building from the outer and/or inner side in the same formerly prescribed manner.

[0023] The layer of glue 4 is made of epoxide resin and added fillers with which we can fill larger deviations between the existing walls 1 of an existing building and massive cross laminated timber panels 3. An epoxy resin allowing for up to a few centimetre glue layer 4 is chosen.

[0024] The anchoring bolts 5, with which massive cross laminated timber panels 3 are attached to the walls 1 on an existing building, preferentially ensure a suitable bond forming between the two. During an earthquake the anchoring bolts 5 ensure that delamination does not occur between the massive cross laminated timber panels 3 and the cladded and strengthened existing walls 1, namely allowing the layer of glue 4 to perform.

[0025] As described earlier, the openings 7 in massive cross laminated timber panels 3 can be cut out before their attachment onto the walls 1 of an existing building or they can be tailored to shape by assembling smaller pieces 3.1 to 3.n around the existing windows and doors in the wall 1. If using monolithic massive cross laminated timber panels 3, there is a possibility of a prior installation of builders' joinery into the openings 7, which shortens and simplifies the work on terrain and ensures a higher quality of individual part assembly.

[0026] The massive cross laminated panels 3 are glued and bolted onto walls 1 of an existing building but not also into its foundation 8, hence leaving them undamaged and in their original shape. As the massive cross laminated timber panels 3 attached to the walls 1 of an existing building have a relatively low mass the additional load on the foundation is minimal and can hence be neglected in practice.

[0027] The building seismic strengthening system according to the invention is above all useful for strengthening the walls 1 of existing buildings built in seismically active areas but not designed to withstand seismic loads. In case of a catastrophic earthquake the system allows minor damage to buildings but it prevents their collapse due to the fairly flexible strengthening cage formed by massive cross laminated timber panels 3 attached to the walls 1.

Claims

1. The building seismic strengthening system is **characterised by the fact that** the walls (1) of an existing building are cladded with massive cross laminated timber panels (3) from the outer and/or inner side with the use of a layer of epoxide glue (4) and additionally connected with anchoring bolts (5) with washers (10); that the height of individual massive cross laminated timber panels (3) can be arbitrary, though preferentially equal to the distance between the floor structures (2) and/or equal to the distance between the foundation (8) and the roof of the building.

2. The system according to Claim 1 is **characterised by the fact that** the massive cross laminated timber panels (3) that can be made either monolithic, covering complete individual walls (1) of an existing building in one piece or in a multi-piece assembly where more pieces (3.1) to (3.n) are put together to cover the individual walls (1).

3. The system according to Claim 2 is **characterised by the fact that the** openings (7) for the existing doors and windows in walls (1) can be previously cut out of the monolithic massive cross laminated timber panels (3), if necessary.

4. The system according to Claim 2 **is characterised by the fact that** the windows and doors in walls (1) of the existing building can be encircled with separate pieces (3.1) to (3.n) of massive cross laminated timber panels (3) so that they form appropriate openings (7).

5. The system according to Claim 1 **is characterised by the fact** that the massive cross laminated timber panels (3) are connected within an individual storey at connecting areas (9) and are joined together with self-tapping wood screws (11).

6. The system according to Claim 1 **is characterised**

by the fact that the massive cross laminated timber panels (3), attached to walls (1) between adjacent storeys, are connected together at transitions from lower to upper storey with at least one flat steel tie (6) so that the latter covers the appurtenant connecting area (9) and is connected to the massive cross laminated timber panels (3) with self-tapping wood screws (11).

7. The system according to Claim 1 **is characterised the fact that** the massive cross laminated timber panels (3) are optimally made from at least three to seven or more layers of timber lamellas that run perpendicularly to each other and are glued together.

8. The system according to Claim 1 **is characterised the fact that** the massive cross laminated timber panels (3) are glued and attached to walls (1) on the inner and/or outer side of existing buildings made from arbitrary building materials, non-metallic and/or metallic.

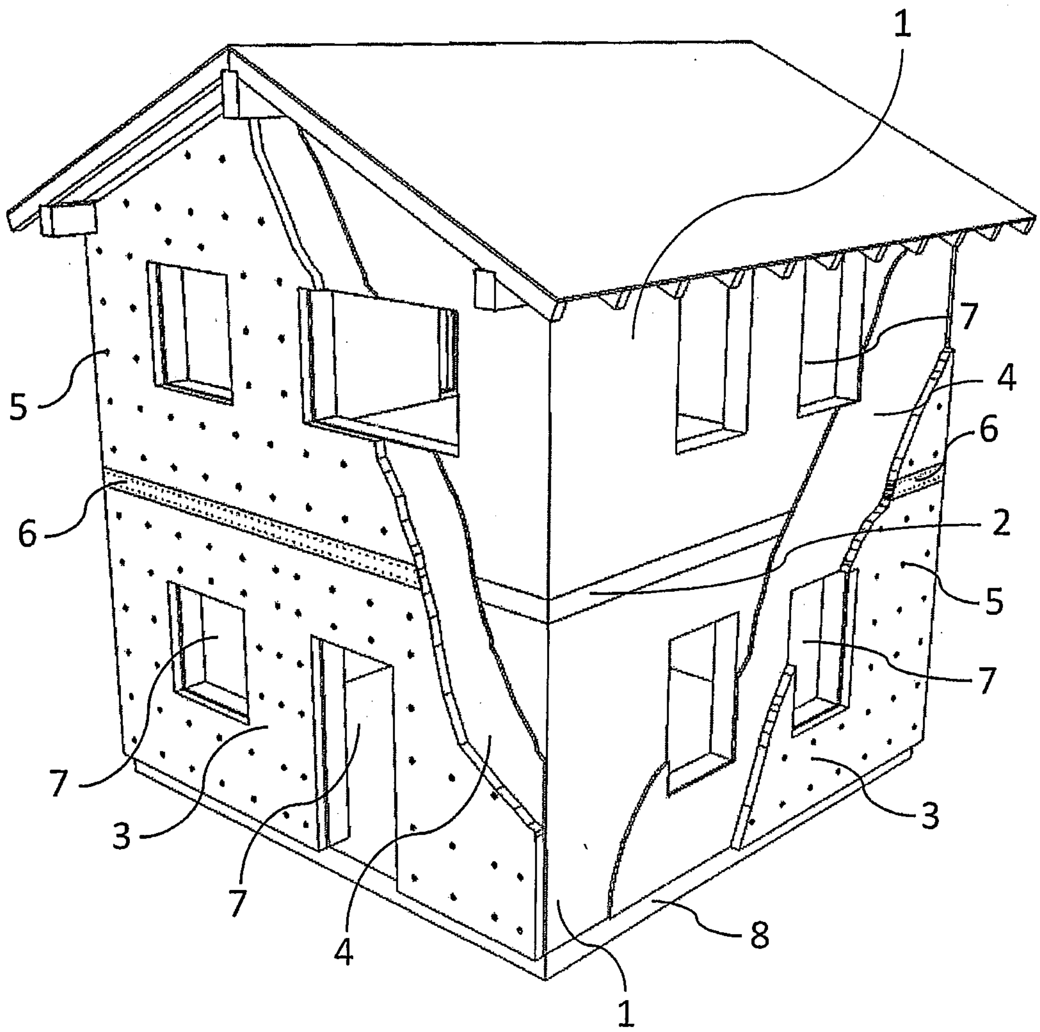

Fig. 1

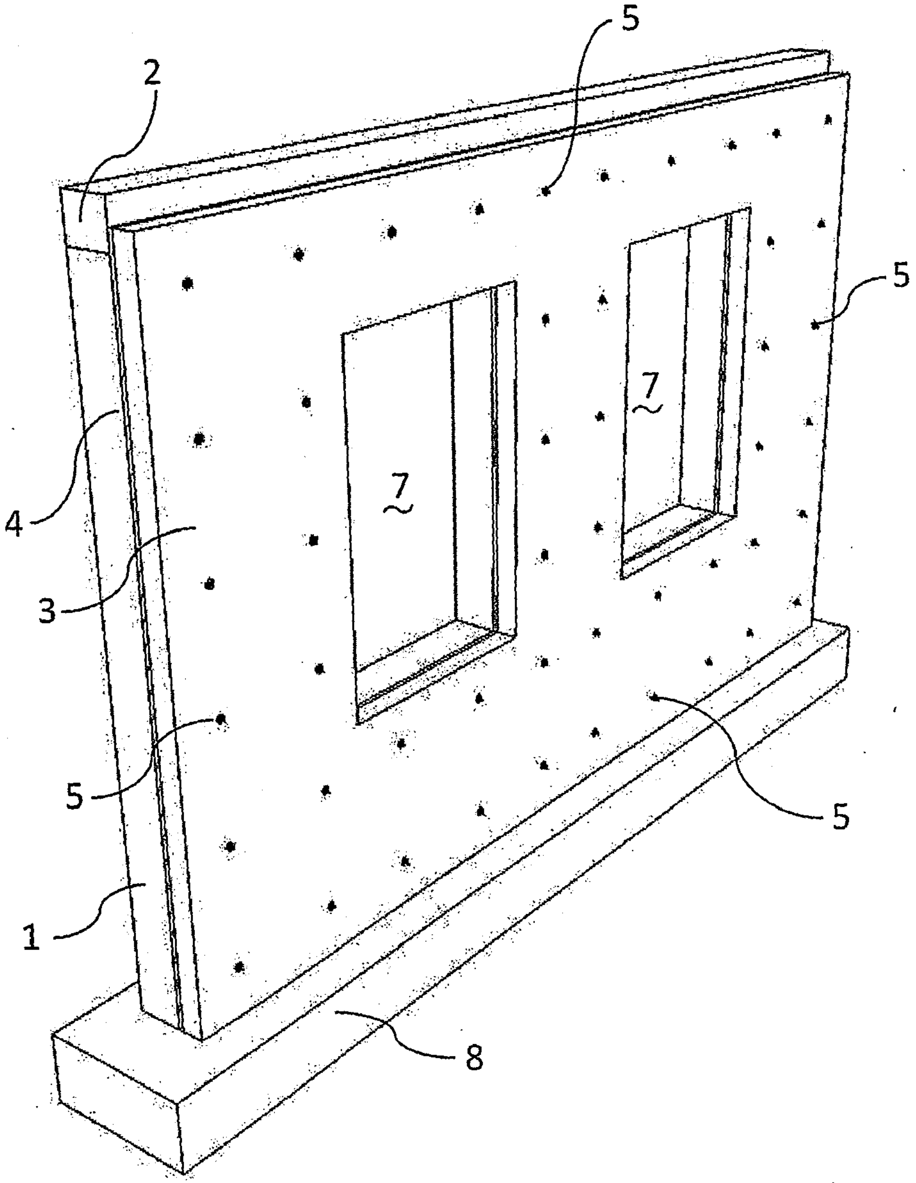

Fig. 2

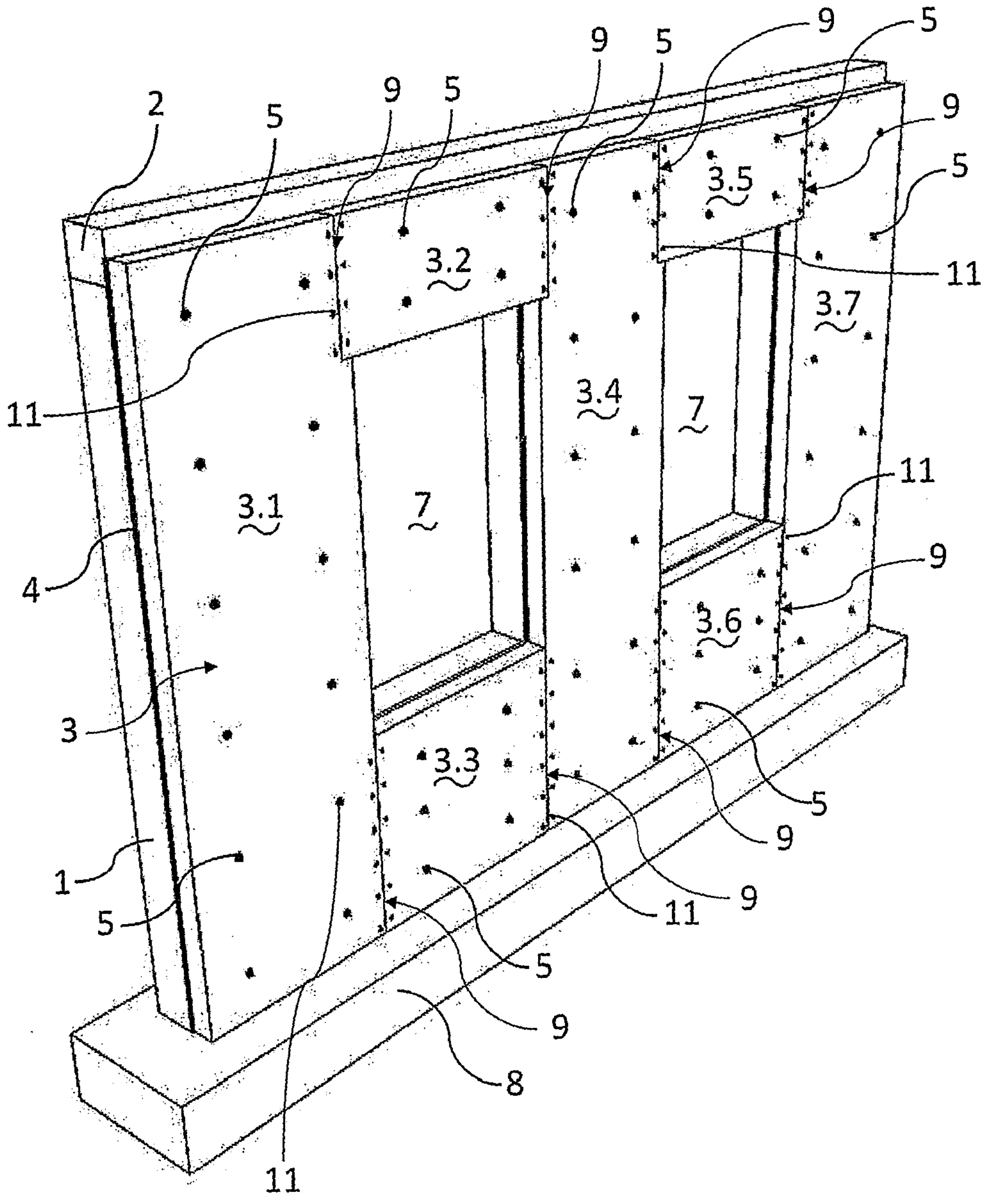

Fig. 3

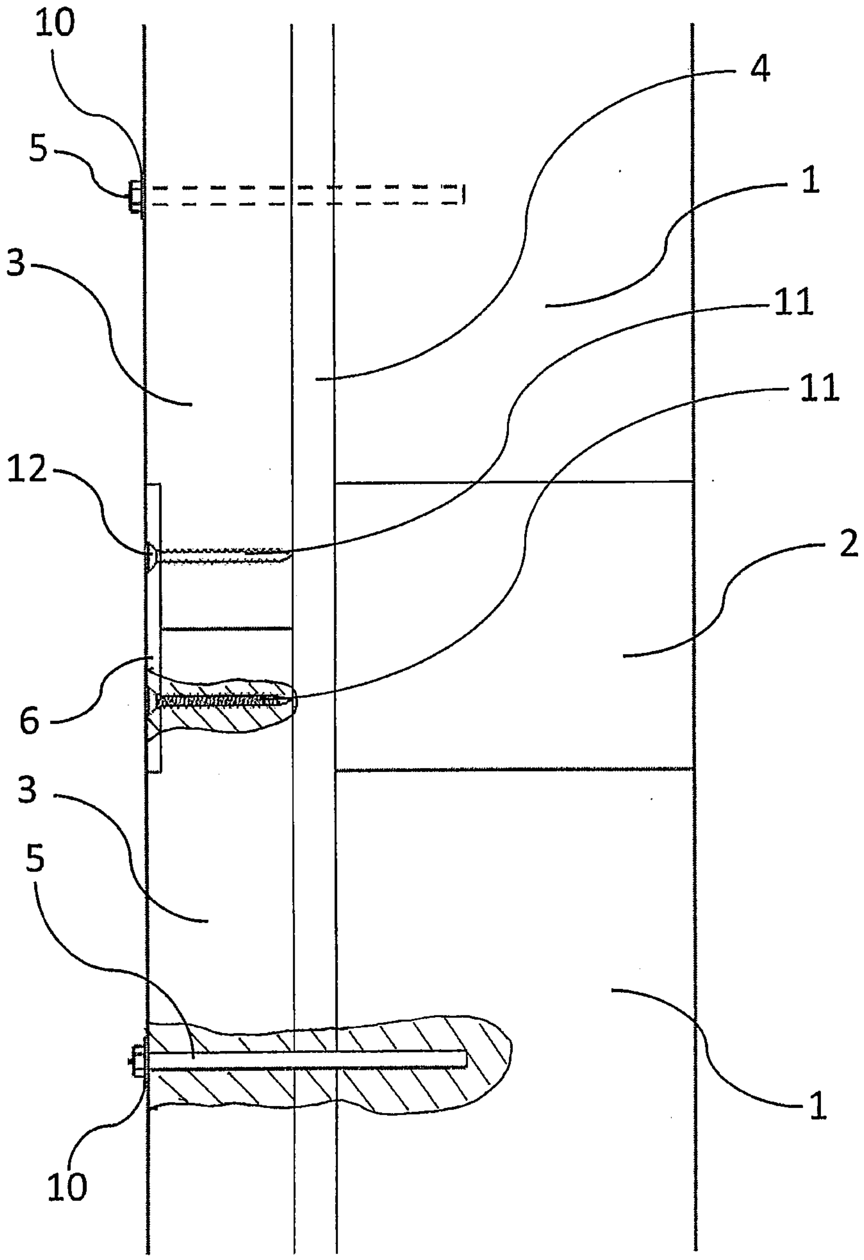

Fig. 4

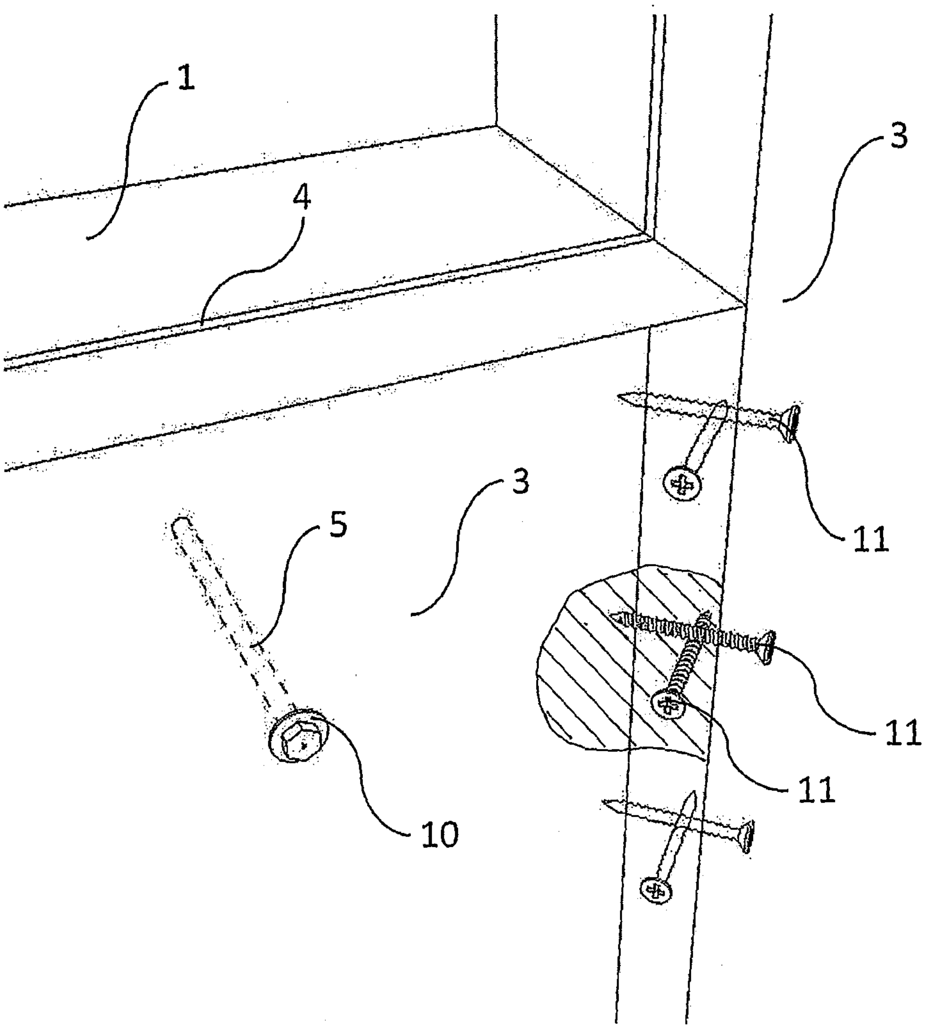

Fig. 5

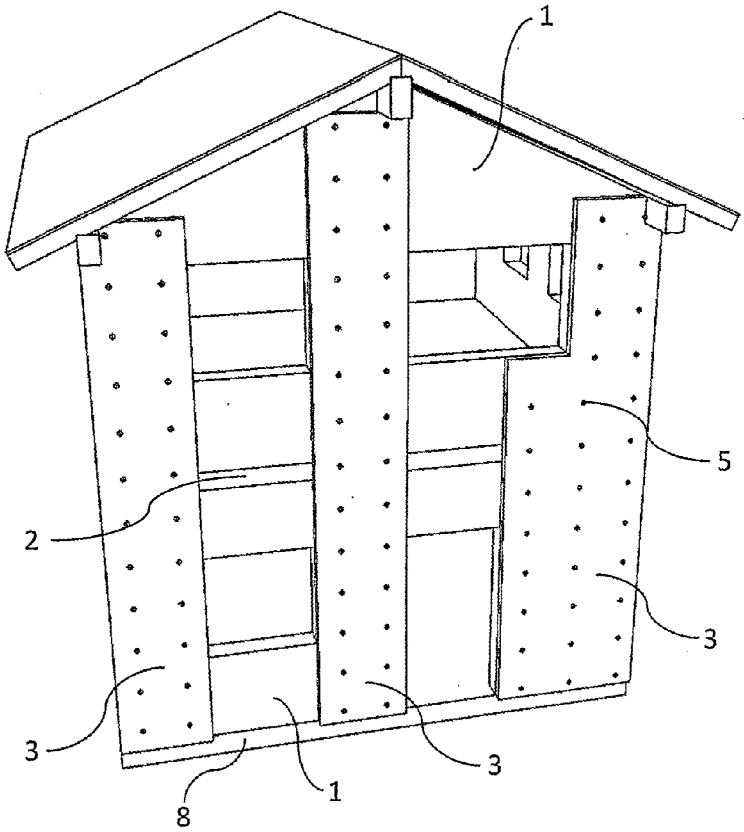

Fig. 6

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- KR 100989218 **[0005]**
- JP 9228658 A **[0006]**
- JP 2009174148 A **[0007]**
- JP 2009097165 B **[0008]**