(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 2 679 748 A2**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
01.01.2014 Bulletin 2014/01

(51) Int Cl.:
E04H 9/02 *(2006.01)*

(21) Application number: **13173716.5**

(22) Date of filing: **26.06.2013**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

(30) Priority: **26.06.2012 SI 201200218**

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(54) **A massive plates connecting system for seismic strengthening of buildings**

(57) The massive plates connecting system for seismic strengthening of buildings according to the invention solves the problem of a simple connection of the massive plates (2) on the outer and/or inner side of the walls (1) of an existing building and is made from flat steel ties (3), steel anchoring brackets (4) and steel angular brackets (5) positioned at the levels of individual floor structures (14) and/or foundation (6). Its main feature is a two-stage connection, which allows the distribution of forces along the complete perimeter of a building in the case of an earthquake. It is useful for all types of walls (1) regardless of the material and construction type.

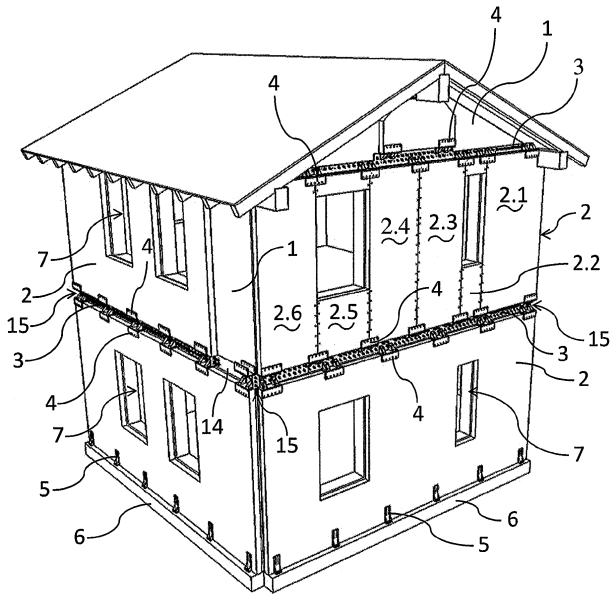

Fig. 1

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Description

The subject of the invention

[0001] The subject of the invention is a massive plates connecting system for seismic strengthening of buildings, or to be more specific, a system for connecting massive cross laminated timber plates and/or massive LVL veneer plates and/or thicker plywood plates onto the walls of existing buildings with specific connections, with the aim of seismically strengthening the walls.

[0002] According to the international patent classification the invention belongs to E 04G 23/02 and to E 04G 17/02 and, additionally, to E 04H 9/02.

Technical problem

[0003] The technical problem solved by this invention is how to conceive a system for connecting massive plates for seismic strengthening of existing buildings that will be simple to install on the outer and/or inner side of buildings, in one or more pieces, regardless of the wall material, and that will ensure the distribution of forces along the building perimeter during an earthquake.

Current state of the art

[0004] There are quite some known systems for connecting the additional strengthening structures onto existing buildings with the aim of their seismic retrofit.

[0005] According to document JP 2009097165 a method for seismic strengthening of partition walls of an existing masonry building, where a steel frame constructed of beams and columns with bolted connections is mounted onto steel brackets attached to the existing structure is known. Weakness and deficiency of this solution is above all in the fact that the strengthening structure can only be installed from the outer side of the building, as the construction of large brackets demands a direct access to the floor structure. Furthermore, weakness and deficiency is in the fact that due to discrete connections high load concentrations occur, hence the solution is not suitable for all types of buildings.

[0006] According to document JP 2005126955 a method for seismically strengthening the walls of an existing building with panels which are installed as infill of existing steel frames and attached to them with a connecting structure and metal connections is known. Viscoelastic elements are connected to one or both sides of a concrete wall and a protective panel, connected to the construction at the top and at the bottom, is placed over them to prevent their delamination. The viscoelastic elements are glued and the protective panel is fixed with steel angular brackets at the top and at the bottom. Weakness and deficiency of this solution is above all in the fact that it is only suitable for concrete walls and that the placement of larger size viscoelastic elements inside the building is difficult or even impossible. Furthermore, weakness and deficiency is in the fact that the attaching of viscoelastic elements onto the walls is complicated as their gluing makes the construction difficult.

[0007] According to document JP 2009249851 a seismic strengthening method of existing buildings where steel beams are bolted in the floor construction at every storey of a concrete building and columns are bolted onto beams. Weakness and deficiency of this solution is above all in the fact that the strengthening structure can only be connected to the outer side of an existing building and that it is only suitable for concrete frame constructions, but not for other types of wall construction of existing buildings.

[0008] The common characteristic of described known solutions is that the walls of existing buildings are cladded with strengthening panels or infills, whereby their construction and connections do not enable sufficient seismic strengthening, because they are not useful for all types of walls and partition walls of a building, they are placed only on the outer sides of buildings and, in case of an earthquake, they cause high local force concentrations on an existing structure.

[0009] 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 plates connecting system for all types of walls, which will be useful for the inner and outer walls of a building and that will allow a sufficient seismic mainly horizontal load transfer and also limit the building's drifts.

The technical problem solution

[0010] According to the invention, the technical problem is resolved with a massive plates connecting system for seismic strengthening of buildings whose main feature is that it is conceived as a two-stage connection characterised by flat steel ties with anchoring brackets and angular brackets with which the massive plates are attached to the existing buildings from the outer and/or inner side in a manner that allows the distribution of forces along the building perimeter in the case of an earthquake. At the same time, the flat steel tie holds the building together at individual storey levels and the system is useful for all types of walls of an existing building, regardless of the material and construction type.

[0011] The invention will be more precisely described in relation to the feasibility example and figures, which show as follows:

Fig. 1 the massive plates connecting system for seismic strengthening of buildings according to the invention, shown in assemblies on the outer envelope of an existing building in an isometric projection;

Fig. 2 same as in Fig. 1, however, only the massive plates connection detail at storey level with a flat steel tie and anchoring brackets along with the edge connection;

Fig. 3 same as in Fig. 1, however, only the massive plates connection detail onto the foundation with an angular bracket;
Fig. 4 same as in Fig. 2, however, only the massive plate connection detail at the observed anchoring bracket;
Fig. 5 same as in Fig. 4, however, only the massive plates connection detail at the observed pair of anchoring brackets, namely the lower and upper anchoring brackets with the anchoring element, in front view;
Fig. 6 same as in Fig. 5, however, in the vertical section A-A;
Fig. 7 the anchoring bracket in an isometric projection;
Fig. 8. same as Fig. 7, however in a side projection;
Fig. 9 flat steel tie.

[0012] The massive plates connecting system for seismic strengthening of buildings according to the invention is conceived as a two-stage connection, which is made from flat steel ties 3 with steel anchoring brackets 4 and steel angular brackets 5 with which the massive plates 2 are connected to the walls 1 of an existing building from the inner and/or outer side of the building so that in the case of an earthquake the forces can be distributed along the complete perimeter of a building, hence tying it together and preventing its collapse. The flat steel ties 3 at the corners of the floor structure 14 are fixedly connected together at angular joints 15, hence forming a continuous loop along the complete perimeter of the building. The system of flat steel ties 3 and anchoring brackets 4 can also be installed only on individual walls 1 of the building and on individual sides of the floor structure 14, respectively. In such cases the flat steel ties 3 are not installed along the complete perimeter of the floor structure 14 of the existing building and do not form a loop, however, they are only installed along one, two or three walls 1. As a general rule, for buildings without a floor structure 14 made from reinforced concrete, the flat steel ties 3 should be placed along the complete perimeter of the building and connected over angular joints 15 in a loop.

[0013] The presented connecting system holds together the existing building and the massive plates 2 or conversely holds together the walls 1 at individual storey levels or floor structures 14 and at the level of foundation 6 and is useful for all types of walls 1 regardless of the material they are made of or the way they are built. In this regard massive plates 2 made from cross laminated timber and /or from the so called LVL veneers and/or thicker plywood made from either one piece or several smaller pieces 2.1, 2.2, 2.3, 2.4, 2.5, 2.6 to 2.n. The openings 7 for the existing windows and doors in walls 1 can be previously cut out of the massive panels 2 or they can be formed on the building itself in case of assembly from smaller pieces.

[0014] As shown in Fig. 1 the connection of the massive panels 2 onto walls 1, at the levels of individual floor structures 14, is preferentially performed with flat steel ties 3 and the appurtenant anchoring brackets 4 and on the level of foundation 6 with angular brackets 5. In some other feasibility example the connection at the foundation 6 level can also be performed with flat steel ties 3 and anchoring brackets 4, individually or in combination with angular brackets 5, which can in some examples also be used for the connection at floor structure 14 levels.

[0015] As a rule, individual connection elements, namely flat steel ties 3, anchoring brackets 4 and angular brackets 5, on individual existing buildings are of coherent shapes.

[0016] At the level of the observed floor structure 14 the anchoring brackets 4 below and above the flat steel tie 3 are placed so that they lie in pairs diametrically one above the other on the same vertical axis or are offset by a certain distance. The combination of both possibilities is arbitrary as is also the number of the anchoring brackets 4 or the number of their pairs, which depends on the given characteristics of the existing building. The described is presented in Fig. 1.

[0017] The connection of massive plates 2 at the intersection of neighbouring walls 1 in the area of the observed angular joint 15 is presented in Fig. 2. The flat steel ties 3 are mounted onto anchors 8, which are previously installed into the floor structure 14 with nuts, which are screwed on unmarked threads at the ends of anchors 8. In individual angular joints 15 the ends of neighbouring flat steel ties 3 are connected over the flaps 28 with bolts 9 inserted through holes 31. With thus formed angular connections 15 all the flat steel ties 3 are connected together preferentially along the complete perimeter of each and every floor structure 14 of the building. It is considered that each flat steel tie 3 has at least one flap 28 with at least two holes 31 on both ends. In some other feasibility example, not shown here, the angular connections 15 can be performed in another way.

[0018] At certain locations along the flat steel ties 3 bolts 16 are welded on or connected on in some other way and onto them above and below anchoring brackets 4 are mounted diametrically to one another, one above the other or offset to one another by an arbitrary distance. The massive plates 2 are mounted into the anchoring brackets 4 so that they are put onto the at least two anchoring elements 12 and connected with self-tapping wood screws 11 from the outer side. The anchoring elements 12 are preferentially placed between the strengthening plates 22 of the attachments 26 and screwed into the massive plates 2 with self-tapping wood screws 11. The described is presented in Fig. 4, Fig.5 and Fig. 6.

[0019] Anchors 8 are previously installed in the area of the foundations 6 and onto them the angular brackets 5 with oblique holes 18 are mounted at arbitrary distances. Massive plates 2 are mounted to angular brackets 5 with self-tapping wood screws11. The number of angular brackets 5 with anchors 8 and their spacing can be arbitrary. The described is presented in Fig.3.

[0020] In Fig. 7 and Fig. 8 the implementation of the anchoring bracket 4 is presented. It consists of the back plate 19 with at least two attachments 26, with a hole 23 at each end, which are spaced to one another at an arbitrary distance and with a series of holes 29 at the opposite edge. Perpendicularly to the back plate 19, at the base of the attachments 26, a steel plate 20 with holes 24 is welded, onto which a plate 21 with a series of holes 25, on the free edge, is also welded. The tie between the attachments 26 of the back plate 19 and the steel plate 20 is additionally strengthened with a pair of triangular-shape strengthening plates 22 which are placed at the edges of attachments 26 so that the holes 23 and 24 are located within them. In this regard, the back plate 19 and plates 20 and 21 form a U-shaped profile channel. The edges of holes 23, 24, 25 and 29 are cropped.

[0021] The flat steel tie 3 is fabricated as a somewhat wider steel strap 27 onto or into which bolts 16 with a thread 30 and holes 13 are implemented in two separate parallel series. Each series namely consists of an arbitrary number of holes 13 and bolts 16. It is important that the bolts 16 are placed in pairs at distances at which the anchoring bolts 4 shall be placed on the flat steel tie 3 and that the distance between a pair of bolts 16 must be such that an individual anchoring bracket 4 is mounted onto them with the attachments 26. The bolts 16 are fabricated as threaded rods with threads 30 at both ends where one end is screwed into unmarked holes in the steel strap 27 and the other end is free. The edges of the holes 13 are cropped. The ends of a steel strap 27 are fabricated as flaps 28 with hoes 31.

[0022] Also the anchors 8 and the anchoring elements 12 are preferentially fabricated with threads at their free ends.

[0023] The massive plates connecting system for seismic strengthening of buildings according to the invention is preferentially executed in accordance with the following described procedure.

[0024] Holes for anchors 8 are drilled into the existing floor structures 14 and the flat steel tie 3 with holes 13 can serve as a stencil. The holes in the floor structure are than completely filled with an epoxy-based injection paste.

[0025] Anchors 8 are inserted into these holes and hence chemically anchored. Flat steel ties 3 are put on the fixed anchors 8 and screwed on with cone-shaped nuts, hence achieving a stiff connection between anchors 8 and flat steel ties 3. The ends of the flat steel ties 3 are connected together with screws 9 over the flaps 28 in angular joints 15 that prevent any wall 1 to collapse out-of-plane in the case of an earthquake which would, especially in the case of floor constructions 14 from timber joists, cause the collapse of ceilings in a building.

[0026] The flat steel ties 3 in some other feasibility example can also be attached into the outermost edge of walls 1, which is very useful in the case of attachment from the inner side of the building.

[0027] The anchoring brackets 4 are attached with anchoring elements 12 and self-tapping wood screws11 onto the massive plates 2, hence forming a combination of tension-shear elements. The number of anchoring brackets 4 and the distance between them depend on the required load resistance. The connection between the anchoring brackets 4 and massive plates 2 has to be as stiff as possible and must behave mostly elastically hence all the gaps between them have to be previously injected.

[0028] The massive plates 2 with anchoring brackets 4 are mounted to the flat steel tie 3 so that the anchoring brackets 4 are placed onto the bolts 16 and screwed onto them with cone-shaped nuts. If the required load resistance is extremely high, the connection between the anchoring brackets 4 and the flat steel tie 3 can also be welded. The connection between the anchoring brackets 4 and the flat steel tie 3 can be effectively used to adjust the behaviour of the connecting system according to the invention, especially its load resistance, stiffness and ductility. It is recommended that the connections between the wall 1, the flat steel ties 3, the anchoring brackets 4 and the massive plates 2 are somewhat over-dimensioned.

[0029] The massive plates 2 are connected at the foundation 6 level with the help of angular brackets 5 with oblique holes 18 as presented in Fig. 1. and Fig. 3. In some other feasibility example, not shown here, they can also be attached to the foundation 6 with the use of flat steel ties 3 and anchoring brackets 4 in a manner previously described for the connecting to floor constructions 14. The choice depends on the state of the existing foundation 6. If it is constructed in stripes with widenings, it is easier to use the angular brackets 5 where the massive plates 2 are mounted 1 to 2 cm above the foundation 6 and the formed gap 10 is later injected to ensure a connection as stiff as possible without any lag.

[0030] The aforementioned examples with flat steel ties 3, anchoring bolts 4 and angular brackets 5 can also be used in combination at the floor construction 14 levels and the foundation 6.

[0031] The massive plate connecting system for seismic strengthening of existing buildings according to the invention is easy to execute as the massive plates 2 can be assembled from several smaller pieces, from 2.1 to 2.n if necessary, and hence carried to the inside of a building. On the other hand, it allows that individual connections or contacts between the assembly parts can exhibit certain characteristics.

[0032] The connection between the flat steel tie 3 and the concrete floor construction 14 can be very fragile, however, it can be easily over-dimensioned so that the walls 1 do not collapse in any case. The connection between the flat steel tie 3 and the anchoring bracket 4 presents the so called control point as here the hysteretic behaviour of steel achieves high dissipation of energy.

[0033] The connection between the massive plate 2 from wood or veneer or plywood and the steel anchoring brackets 4 is ductile, however, slip can be prevented with

additional anchoring elements 12 and self-tapping wood screws 11. Due to this reason, also this connection is intentionally over-dimensioned.

[0034] It applies that the steel-steel connection is the most suitable for the behaviour control of the existing damaged buildings both in the light of mechanical characteristics and the calculation procedure.

Claims

1. The massive plates connecting system for seismic strengthening of buildings is **characterised by** the fact that it is constructed from at least one or more flat steel ties (3), which are attached to the floor structures (14) over the anchors (8) and can be connected together, in a fixed way, with angular joints (15), and from an arbitrary number of anchoring brackets (4) attached to the flat steel ties (3) over the bolts (16), and from an arbitrary number of angular brackets (5) attached to the foundation (6) over the anchors (8), and all of which are intended for connecting the massive plates (2) to the outer and/or inner side of walls (1) of the existing building; that the anchoring brackets (4) are connected at the top and bottom edges of the flat steel tie (3) so that they are placed diametrically in pairs one above the other on the same vertical axis or are offset one to another by an arbitrary distance.

2. The system according to Claim 1 is **characterised by** the fact that the connection of the massive plates (2) to the foundation (6) can also be performed with a flat steel tie (3) and anchoring brackets (4) or in combination with angular brackets (5) if the execution of foundation (6) makes it possible.

3. The system according to Claim 1 is **characterised by** the fact that at the levels of the floor structures (14), the massive plates (2) are put in the anchoring brackets (4) and attached to them with the anchoring elements (12) and self-tapping wood screws (11), whereby within the individual anchoring bracket (4), at least two anchoring elements (12) are placed into the massive plate (2) in the area of the pair of the strengthening plates (22) on the attachments (26).

4. The system according to Claim 1 is **characterised by** the fact that the anchoring bracket (4) is formed by the back plate (19), with at least two attachments (26) and holes (23, 29), onto which a steel plate (20) with at least two holes (24) is welded perpendicularly and onto which a plate (21) with a series of holes (25) is also perpendicularly welded so that the plates (19, 20, 21) form a U-shaped channel where the tie between the attachment (26) and the plate (20) is additionally fixed with a pair of strengthening plates (22) that are spaced one to another by the width of the attachment (26).

5. The system according to Claim 1 is **characterised by** the fact that the flat steel tie (3) is constructed as a steel strap (27) with the flap (28), where onto or into the steel strap (27) the bolts (16) with a thread (30) and holes (13) are implemented in at least two separate parallel series so that the bolts (16) are placed in pairs at a distance equal to the spacing between the holes (23) on the anchoring brackets (4) which are mounted onto them, whereas into the flap (28), at least two holes (31) are constructed.

6. The system according to Claim 1 is **characterised by** the fact that the flat steel tie (3), the anchoring bracket (4) and the angular brackets (5) are made of steel of a proper grade.

7. The system according to Claim 1 is **characterised by** the fact that the massive plates (2) can be made from cross laminated timber and/or LVL veneers and/or thicker plywood that can be placed onto walls (1) in one or several smaller pieces (2.1) to (2.n).

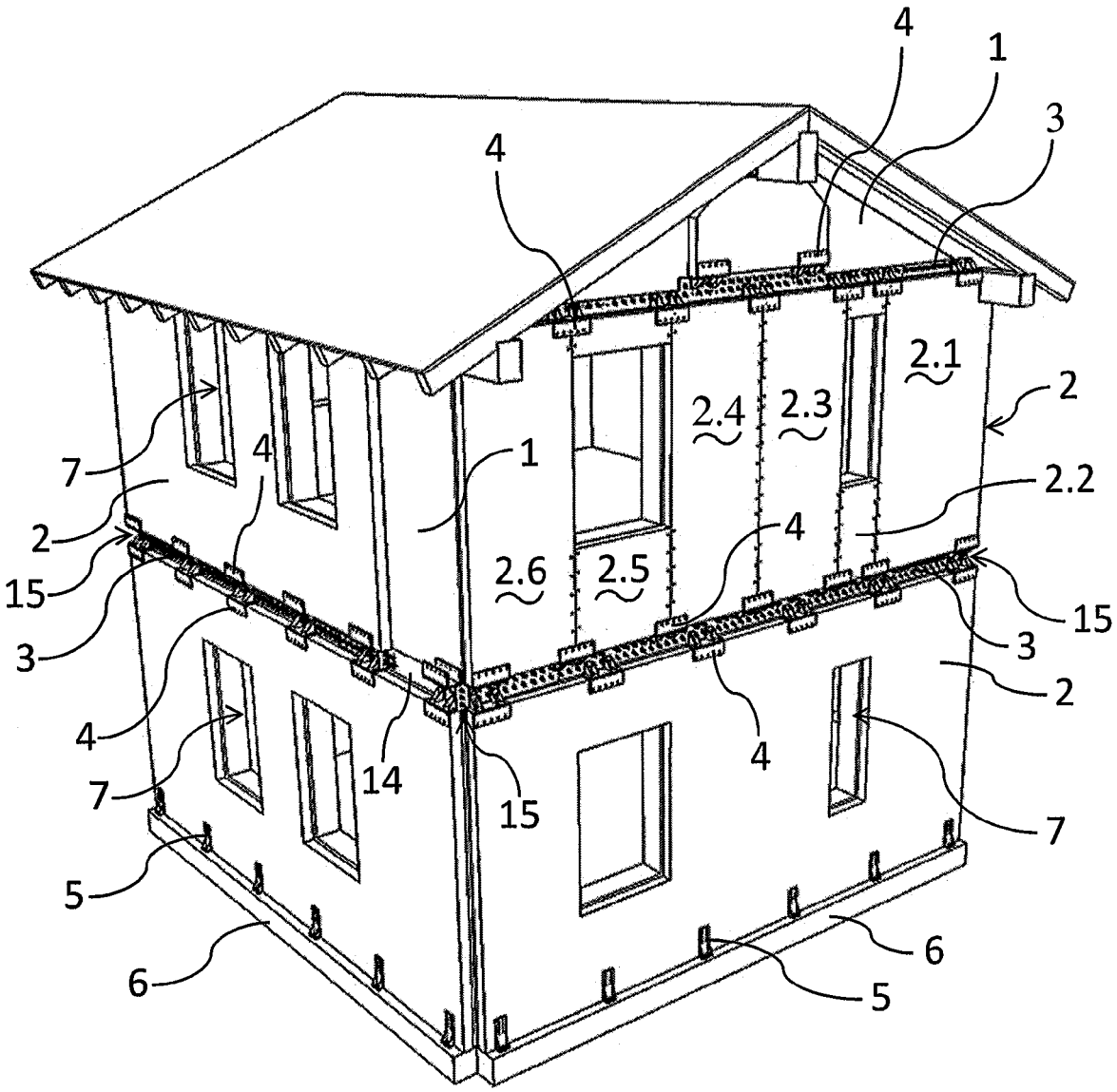

Fig. 1

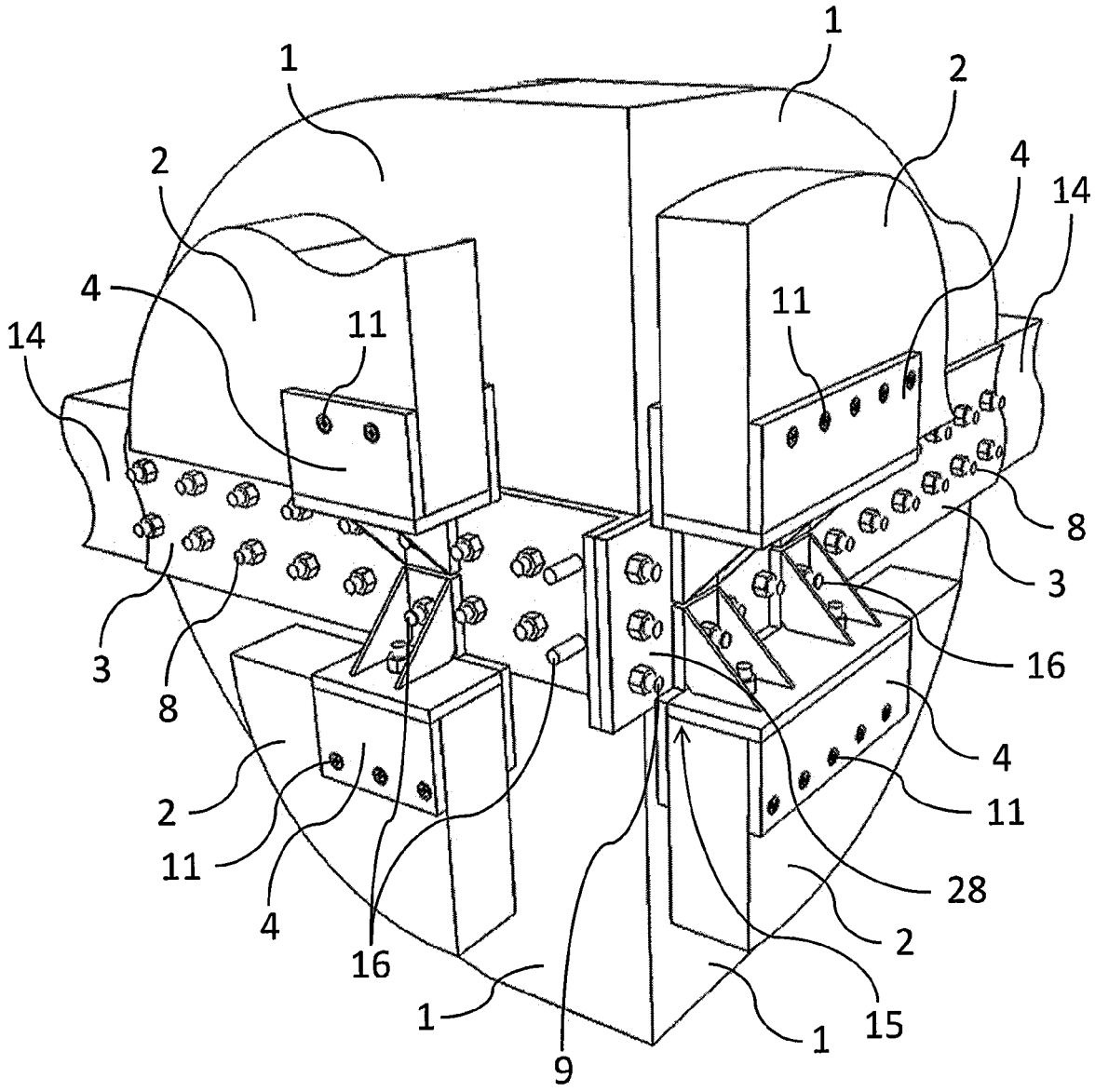

Fig. 2

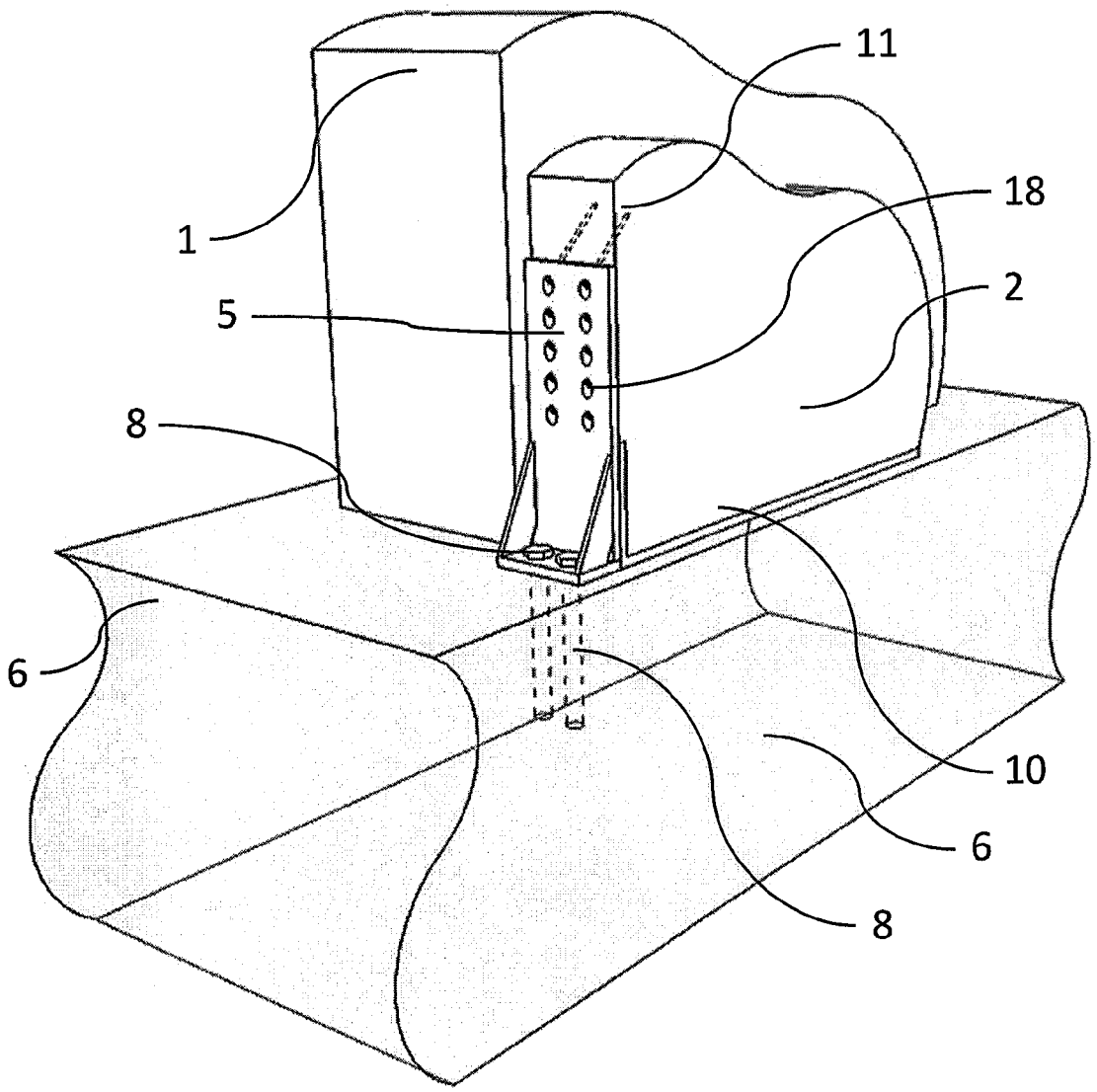

Fig. 3

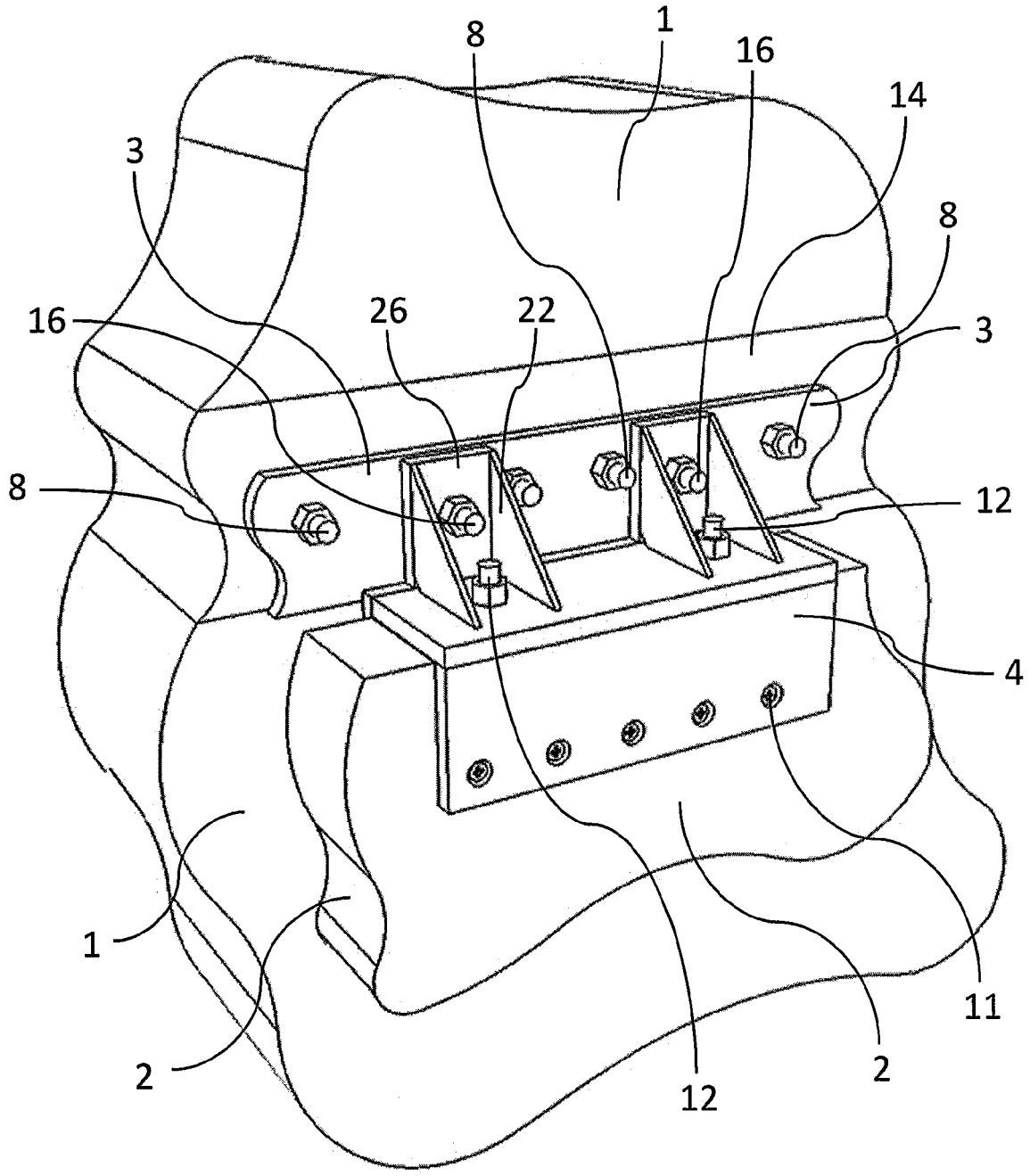

Fig. 4

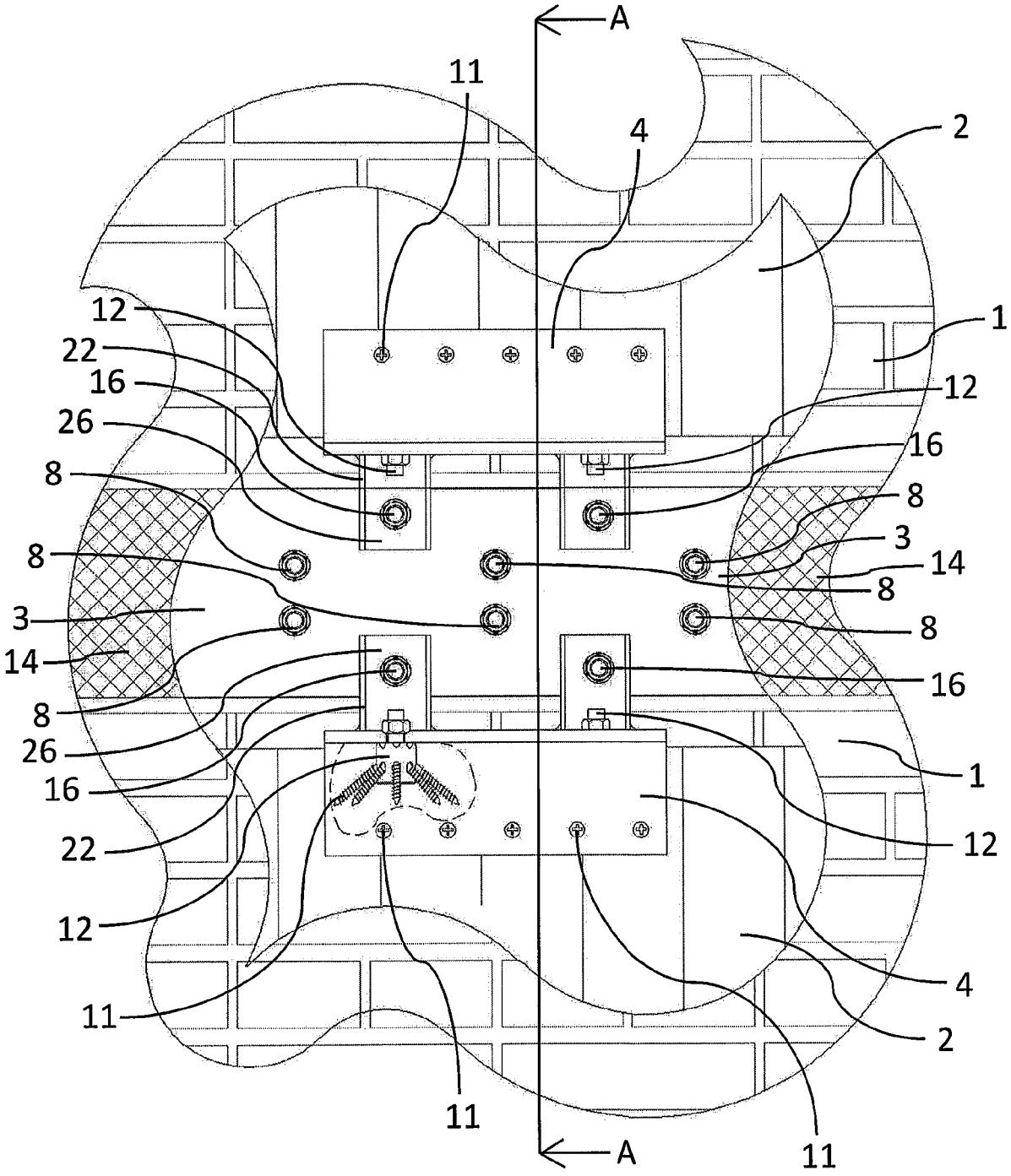
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Fig. 5

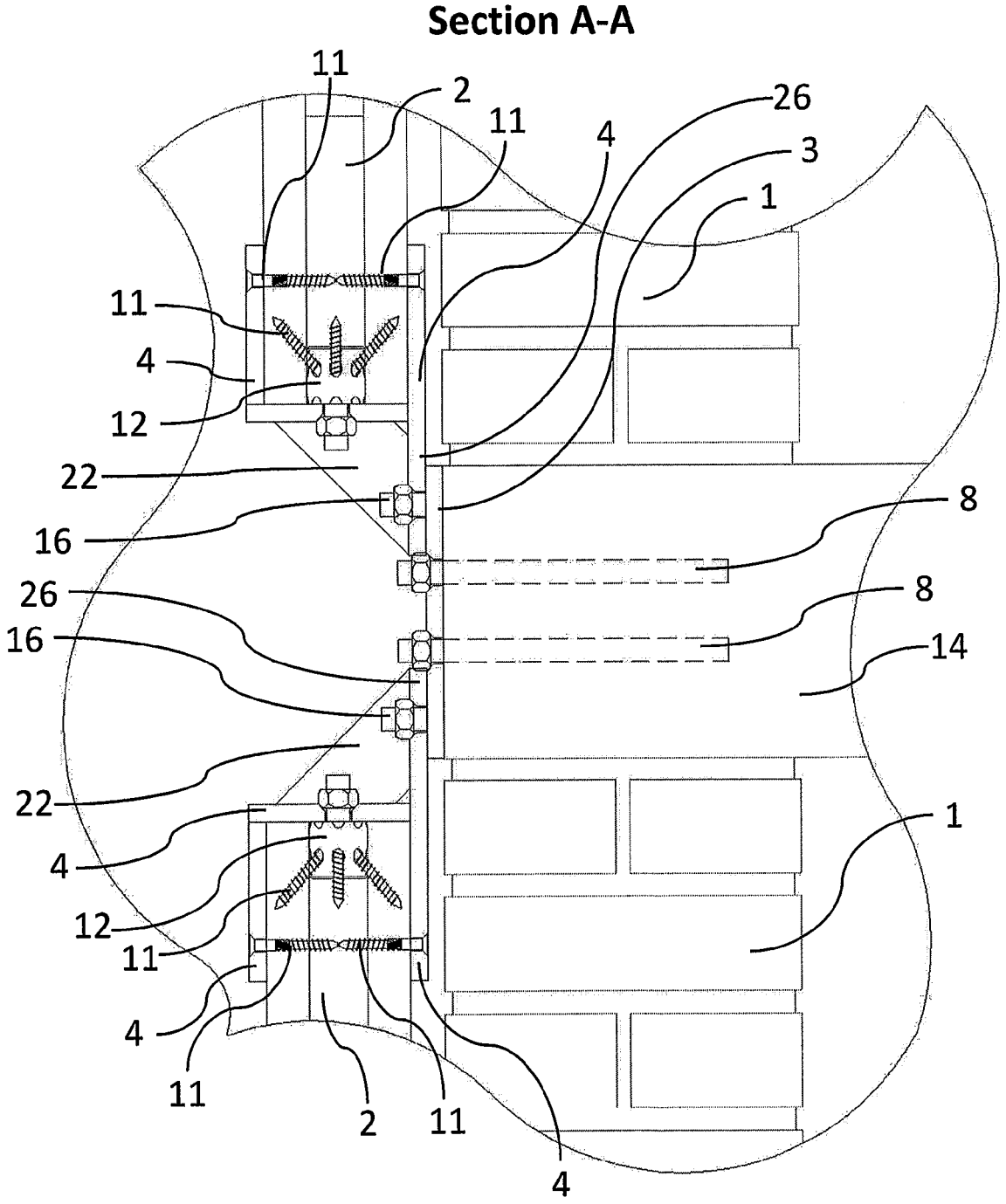
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Fig. 6

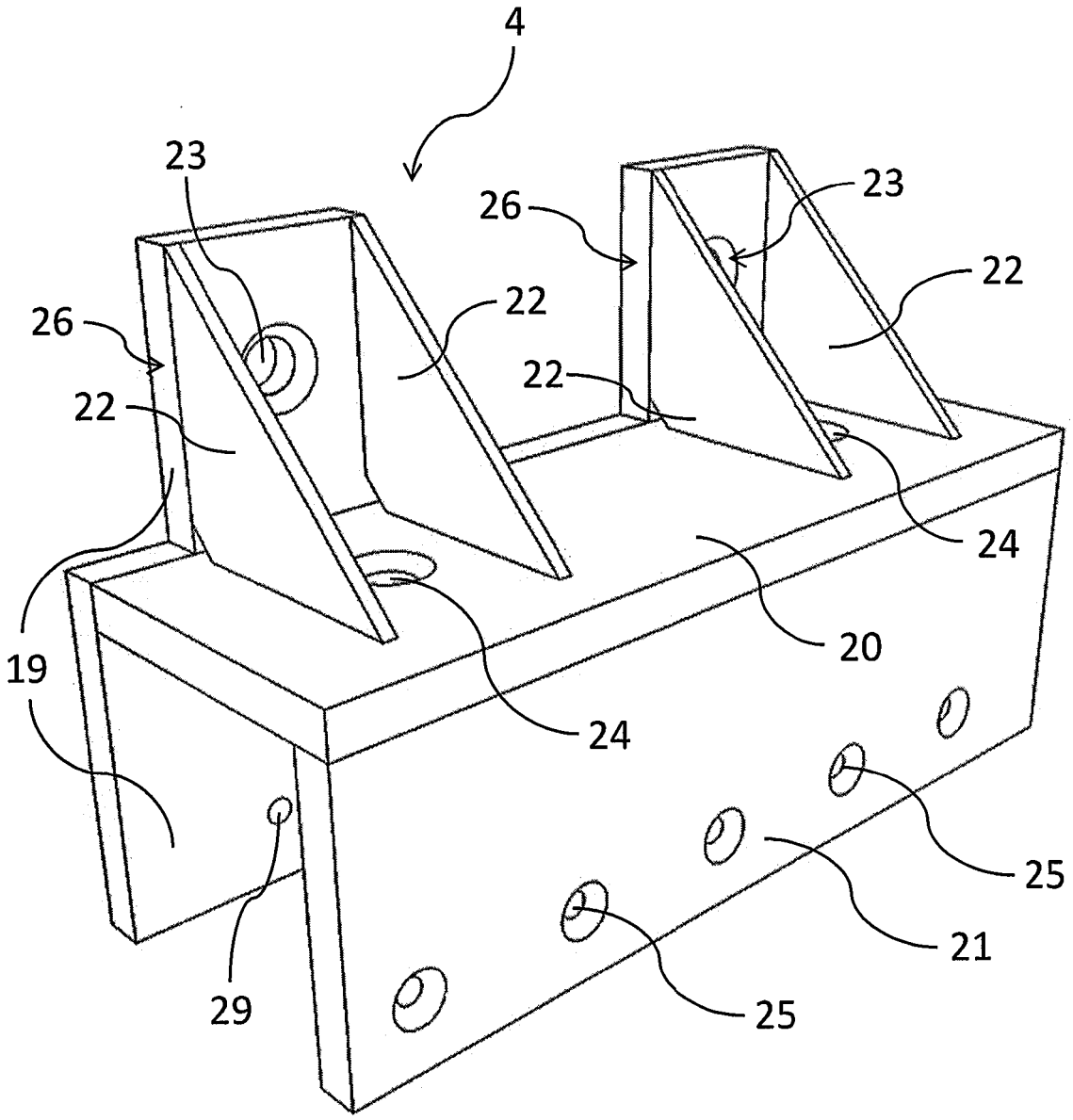

Fig. 7

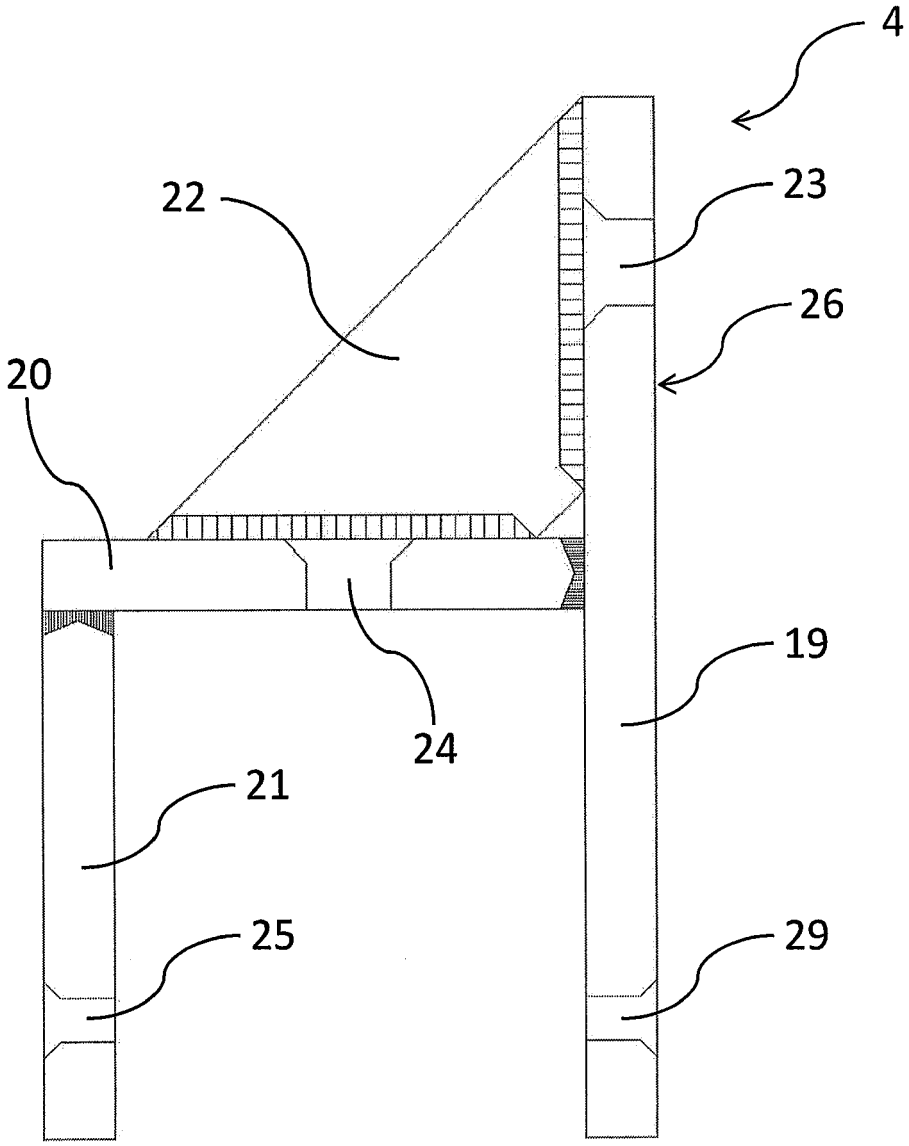

Fig. 8

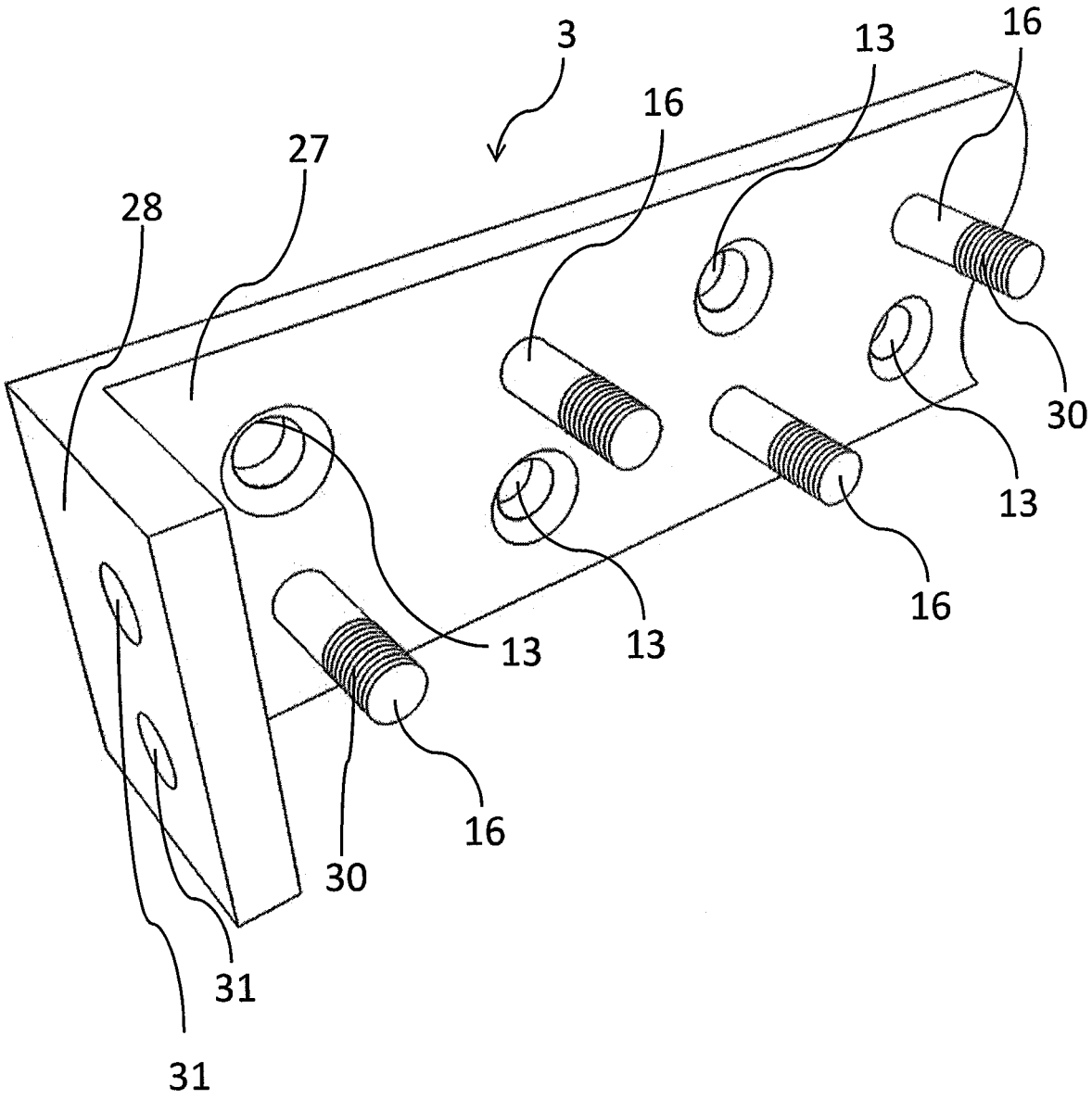

Fig. 9

REFERENCES CITED IN THE DESCRIPTION

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- JP 2005126955 A **[0006]**
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