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(54) **SEISMIC RESTRAINT**

(57) A seismic restraint (106) is configured to be installed between a non-structural component (104) and a structural component (102) of a building. The seismic restraint (106) comprises a deformable fiber rope (108),

and two sockets (110) in which the fiber rope (108) is anchored by its end portions (114). Each socket (110) is configured to be connected to one of the components (102, 104) of the building.

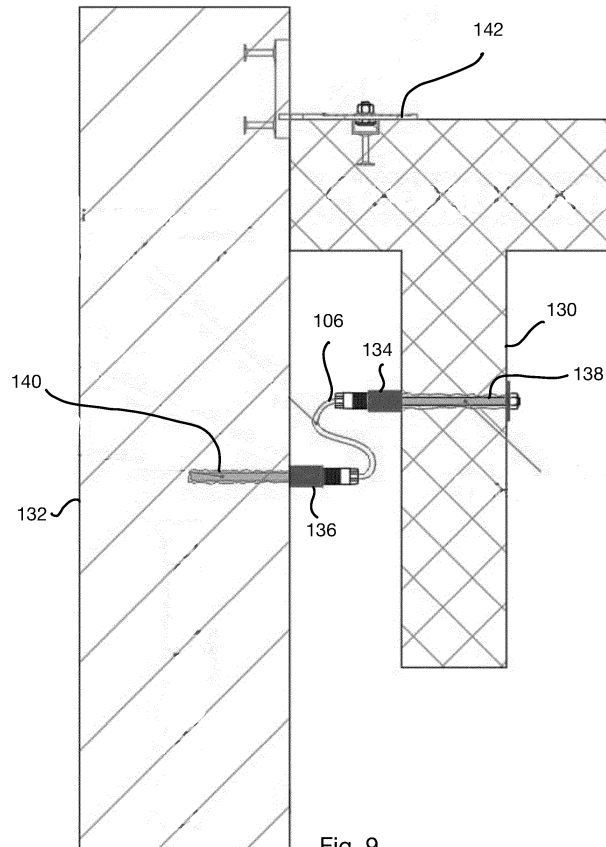


Fig. 9

Description

Technical field

[0001] The present invention relates to a seismic restraint that is configured to be installed between a non-structural component and a structural component of a building. Further, the invention relates to an arrangement comprising a non-structural component and a structural component of a building and a seismic restraint which is installed between the afore-mentioned components of the building.

Background

[0002] An adequate seismic resistance of primary structural components of buildings and engineering structures such as columns, beams, slabs, walls etc. can be well achieved by satisfying the requirements of modern seismic codes. In contrast, the seismic design of connections between non-structural components such as façade panels, electrical and mechanical systems etc., and the primary structure is often neglected. For example, the connections that have been used in Europe to attach heavy precast façade panels to the main structural component in the last fifty years and that are still used today do not have sufficient strength to withstand the seismic demand in case of a strong earthquake. This was empirically confirmed during the Italian earthquakes in 2009 in l'Aquila and in 2012 in Emilia Romagna.

[0003] Consideration could be given to increasing the strength of existing connections between non-structural and structural components of a building. However, this is not a feasible solution since the connections would be impractically massive and impact the response of the primary structural system, which is not desirable. This is why other solutions for seismic protection are urgently sought.

Summary

[0004] It is an object of the present invention to provide a seismic restraint which can be installed between a non-structural component and a structural component of a building to increase a connection therebetween in a simple way.

[0005] This object is achieved by a seismic restraint according to claim 1. Advantageous embodiments are defined in the dependent claims and the following description.

[0006] The invention provides for a seismic restraint which is configured to be installed between a non-structural component and a structural component of a building. The seismic restraint comprises a deformable fiber rope and two sockets, in which the fiber rope is anchored by its end portions. Each socket of the seismic restraint is configured to be connected to one of the components of the building.

[0007] The seismic restraint according to the invention can be used as a back-up system in addition to traditionally used connections which are already present in the building. Th experience shows that the present connections work reasonably well in case of weak earthquakes to prevent claddings or other non-structural components from collapsing. However, in moderate or strong earthquakes, the primary connections would fail due to their inadequate strength or displacement capacity. This is where the seismic restraint according to the present invention comes into effect. Accordingly, immediately after the failure of the primary connections, the seismic restraint is being activated.

[0008] As a result, the seismic restraint disclosed herein forms a back-up device for the seismic strengthening of vulnerable buildings. Being activated upon failure of existing connections between non-structural and structural components of the building, the restraint guarantees additional protection that can effectively prevent human casualties, equipment damage, damage to stored products or any other direct and indirect losses.

[0009] The seismic restraint according to the invention is characterized by a deformable fiber rope which can be easily installed between non-structural and structural building components. Such a deformable fiber rope provides an appropriate strength-to-stiffness ratio. Thus, on the one hand, the fiber rope is strong enough to protect a non-structural component from falling off the primary structural system of the building. On the other hand, the fiber rope is sufficiently flexible to reduce the impact forces exerted onto the seismic restraint when the restraint is activated in the event of an earthquake.

[0010] The length of the deformable fiber rope can be suitably chosen depending on various parameters such as the dynamic characteristics of the primary structure, the geometry of the non-structural components and the primary/secondary structural components, seismicity, and soil type of the location of installation. In any case, the fiber rope can be installed such that the seismic restraint comes into function only when the primary connection fails. In other words, the fiber rope can be installed to be loose in normal operating conditions which means that the length of the fiber rope is chosen to be larger than the shortest distance between the primary structural component and the non-structural component.

[0011] Furthermore, the seismic restraint does not interfere with the architectural appearance of the building, and it does not significantly impact the design of the primary structural components due to relatively small dimensions.

[0012] The fiber rope is anchored by its end portions in two sockets which form end-terminations of the restraint, one of which being connected to the non-structural building component and the other being connected to the structural building component. Thus, the sockets enable the seismic restraint to be installed in a quick and simple manner.

[0013] Preferably, the deformable fiber rope is made

of synthetic fibers having a high strength-to-mass ratio. Needless to say that any other fibers with similar properties can be used.

[0014] For instance, the deformable fiber rope may be made of fibers having a strength-to-mass ratio which is in a range from 5 cN/dtex to 100 cN/dtex.

[0015] In a preferred embodiment, each end portion of the fiber rope is anchored into the respective socket by means of a filler such as a resin. The use of a filler allows a simple yet mechanically stable connection between the fiber rope and the sockets.

[0016] Preferably, each end portion of the fiber rope may have a broom-like structure. In particular, if the fiber rope is anchored into the sockets by means of filler, before the filler is poured into the sockets, the fiber rope may be broomed to increase the contact surface to the filler. This ensures a strong anchorage of the fiber rope in the sockets.

[0017] The sockets may have a specially designed interior which enables adequate anchoring of the fiber rope. For instance, each socket may have a cavity in which the end portion of the rope is anchored, wherein the cavity comprises a conically shaped portion widening along a direction in which the end portion of the fiber rope is inserted into the cavity. Such a conically shaped cavity portion increases the normal contact stresses between the fiber rope and a filler such as a resin within the respective socket when a tension force is applied to the fiber rope. This enables a better transfer of friction forces between the fibers and the filler, which results in a high-efficiency end termination formed by the respective socket. In other words, a high actual strength-to-rope strength ratio is achieved.

[0018] The conically shaped portion may be formed between two cylindrically shaped portions of the cavity. In such an embodiment, the conically shaped portion forms a transition between a first cylindrically shaped cavity portion and a second cylindrically shaped cavity portion, wherein the diameter of the afore-mentioned first cavity portion is smaller than the diameter of the second cavity portion.

[0019] In a preferred embodiment, the seismic restraint may comprise a flexible band which is installed within the conically shaped portion of the cavity. Due to its elasticity, such a band has the function of a spring which reduces an initial tensile stiffness of the restraint and consequently also reduces the shock loads that occur when the restraint is activated during an earthquake. Further, the flexible band can be used as a sealant during the filler pouring process at the stage of manufacture.

[0020] Preferably, each socket of the seismic restraint comprises an external thread which is configured to be engaged with a mating internal thread in order to connect the socket to the respective component of the building. Such a thread may be cut into the exterior of the respective socket in order to enable the socket to be firmly anchored to the building component.

[0021] The seismic restraint may further comprise at

least one adapter which is configured to be connected to at least one of the sockets for connecting said socket with one of the components of the building. Such an adapter can be used to facilitate the installation of the seismic restraint.

[0022] For instance, the adapter may comprise an internal thread mating with the external thread of the respective socket. In addition, the adapter may comprise a further internal thread which is configured to be engaged with a threaded rod to connect the respective socket to one of the components of the building.

[0023] According to another aspect of the invention, an arrangement is provided which comprises a non-structural component and a structural component of a building as well as at least one seismic restraint. As described above, the seismic restraint is installed between the non-structural component and the structural component of the building.

[0024] The non-structural component may comprise at least one of a façade panel, in particular a precast façade panel, an electrical system, and a mechanical system without being limited thereto. The aforementioned systems are meant to cover any kind of installations in buildings such as pipes, ductworks, conduits, switchgears, etc. The structural component may comprise at least one a column, a beam, a slab, and a wall without being limited thereto.

Short Description of the Figures

[0025] Hereinafter, specific embodiments are described referring to the drawings, wherein:

- Figure 1 a perspective view illustrating an arrangement in which a plurality of seismic restraints according to the present invention are installed between non-structural components and a primary structural system of a building;
- Figure 2 a view showing a seismic restraint according to an embodiment of the present invention;
- Figure 3 a front view of a socket of the seismic restraint;
- Figure 4 a view of the socket along section A-A indicated in Figure 3;
- Figure 5 a perspective view of the socket;
- Figure 6 a sectional view of the socket with an end portion of a fiber rope anchored in a cavity of the socket;
- Figure 7 a sectional view illustrating an exemplary installation of the seismic restraint connecting a beam flange with a cladding panel in a precast building;

Figure 8 a plan view of the exemplary installation shown in Figure 6; and

Figure 9 a sectional view illustrating another exemplary installation of the seismic restraint for connecting a beam web and a cladding panel in a precast building.

Detailed Description

[0026] Figure 1 shows an arrangement comprising a primary structural system 100 which comprises structural components 102 to which a plurality of non-structural components 104 such as façade panels are connected. In order to connect the non-structural components 104 to the structural components 102, a plurality of seismic restraints 106 are installed. The seismic restraints 106 are configured to prevent the non-structural components 104 from collapsing during an earthquake. More specifically, the seismic restraints 106 are activated upon failure of existing connections between the structural and non-structural components 102, 104 as illustrated in Figure 1 by dash lines indicating a state before the aforementioned failure.

[0027] As shown in Figure 2, each seismic restraint 106 comprises a deformable fiber rope 108 and two sockets 110. As can be seen in Figure 6, the fiber rope 108 comprises a bundle of synthetic fibers 112. Each end portion 114 of the fiber rope 108 is anchored in one of the sockets 110. Each socket 110 is configured to be connected to one of the structural or non-structural components 102, 104 in order to install the seismic restraint 106 between these building components. It is to be noted that the illustration in Figure 6 is simplified. Thus, Figure 6 shows a sketch where the fibers 112 are straight at the point of entrance into the socket 110. However, in reality, the fibers 112 are braided.

[0028] As shown in Figure 4 and 6, each socket 110 has a cylindrical outer shape enclosing an inner space which forms a cavity 116 in which the respective end portion 114 of the fiber rope 108 is inserted and anchored. According to the present embodiment, the cavity 116 comprises a first cylindrically shaped portion 118, a conically shaped portion 120 and a second cylindrical portion 122 which are arranged in this order with regard to a direction in which the end portion 114 of the fiber rope 108 is inserted into the socket 110. Thus, the cylindrical shaped portion 120 forms a transition from the first cylindrical portion 118 having a relatively small diameter to the second cylindrical portion 122 having a relatively large diameter.

[0029] Each end portion 114 of the fiber rope 108 may be anchored into the respective socket 110 by means of a filler such as a resin. For this, the end portions of the fibers 112 inserted into the cavity 116 of the socket 110 may form a broom-like structure 124 to increase the contact surface of the fibers 112 and the filler when the filler is poured into the cavity 116 at the stage of manufacture.

[0030] As can be seen in Figure 6, the seismic restraint 106 may comprise a flexible band 126 which is installed within the conically shaped portion 120 of the cavity 116. The band 126 forms an elastic spring-like element which reduces the initial tensile stiffness of the seismic restraint 106. As a result, the flexible band 126 can be used to reduce the shock loads that occur when the seismic restraint is activated in the event of an earthquake. Furthermore, the band 126 may serve as a sealant during the process in which the filler is poured into the cavity 116 of the socket 110.

[0031] As shown in Figures 4 to 6, an external thread 128 is formed on the exterior of the respective socket 110. The external thread 128 is to be engaged with a mating internal thread of a mounting element (or an adapter as explained below) during installation of the seismic restraint 106.

[0032] Figures 7 and 8 illustrate an exemplary installation of the seismic restraint 106 in a sectional view and a plan view, respectively. In this specific example, the seismic restraint is used to be installed between a structural precast beam 130 and a non-structural cladding panel 132.

[0033] In order to facilitate this installation, the seismic restraint 106 may comprise special adapters 134, 136 which are adapted to connect each socket 110 to the building component associated therewith, i.e. the precast beam 130 and the cladding panel 132, respectively. In the example shown in Figures 7 and 8, the adapter 134 comprises an internal thread mating with the external thread 128 of the respective socket 110. In addition, the adapter 134 comprises a further internal thread which is engaged with a threaded rod 138 screwed into the precast beam 130. Likewise, the other adapter 136 comprises two internal threads mating with the external thread 128 of the socket 110 and another threaded rod 140, respectively, the threaded rod 140 being screwed into the cladding panel 132.

[0034] Apart from the seismic restraint 106, primary connections are installed between the precast beam 130 and the cladding panel 132. In the example shown in Figure 8, such a primary connection is implemented in form of a hammer-head strap connection 142. In case that the primary hammer-head connections 142 fail during an earthquake, the seismic restraint 106 provided between the precast beam 130 and the cladding panel 132 serves as a back-up protector which prevents the cladding panel 132 from falling off the precast beam 130.

[0035] Figure 9 shows another example for an installation of the seismic restraint 106 between the precast beam 130 and the cladding panel 132. In this example, the installation locations of the seismic restraint 106 and the primary hammer-head strap connections differ from the arrangement shown in Figures 7 and 8. In particular, in Figures 7 and 8, the restraint 106 is attached to a beam flange. In contrast, in Figure 9, the restraint 106 is attached to a beam web. Otherwise, the installations are essentially the same.

List of reference signs

[0036]

100	primary structural system
102	structural component
104	non-structural component
106	seismic restraint
108	fiber rope
110	socket
112	fibers
114	end portion
116	cavity
118	cylindrically shaped portion
120	conically shaped portion
122	cylindrically shaped portion
124	broom-like structure
126	band
128	external thread
130	precast beam
132	cladding panel
134	adapter
136	adapter
138	threaded rod
140	threaded rod
142	primary hammer-head strap connection

Claims

1. A seismic restraint (106) configured to be installed between a non-structural component (104) and a structural component (102) of a building, comprising:
 - a deformable fiber rope (108), and
 - two sockets (110) in which the fiber rope (108) is anchored by its end portions (114), wherein each socket (110) is configured to be connected to one of the components (102, 104) of the building.
2. The seismic restraint (106) according to claim 1, wherein the deformable fiber rope (108) is made of synthetic fibers.
3. The seismic restraint (106) according to claim 1 or 2, wherein the deformable fiber rope (108) is made of fibers having a strength-to-mass ratio in a range from 5cN/dtex to 100 cN/dtex.
4. The seismic restraint (106) according to any one of the preceding claims, wherein each end portion (114) of the fiber rope (108) is anchored into the respective socket (110) by means of a filler.
5. The seismic restraint (106) according to any one of the preceding claims, wherein each end portion (114) of the fiber rope (108) has a broom-like struc-

ture.

6. The seismic restraint (106) according to any one of the preceding claims, wherein each socket (110) has a cavity (116) in which the end portion (114) of the fiber rope (108) is anchored, the cavity (116) comprising a conically shaped portion (120) widening along a direction in which the end portion (114) of the fiber rope (108) is inserted into the cavity (116).
7. The seismic restraint (106) according to claim 6, wherein the conically shaped portion (120) is formed between two cylindrically shaped portions (118, 122) of the cavity (116).
8. The seismic restraint (106) according to claim 6 or 7, comprising a flexible band (126) which is installed within the conically shaped portion (120) of the cavity (116).
9. The seismic restraint (106) according to any one of the preceding claims, wherein each socket (110) comprises an external thread (128) configured to be engaged with a mating internal thread to connect the socket (110) to the component of the building.
10. The seismic restraint (106) according to any one of the preceding claims, comprising at least one adapter (134, 136) configured to be connected to at least one of the sockets (110) to connect said socket (110) with one of the components of the building.
11. The seismic restraint (106) according to the claims 9 and 10, wherein the adapter (134, 136) comprises an internal thread mating with the external thread (128) of the respective socket (110).
12. The seismic restraint (106) according to claim 10 or 11, wherein the adapter (134, 136) comprises a further internal thread configured to be engaged with a threaded rod (138, 140) to connect the respective socket (110) to one of the components of the building.
13. An arrangement comprising a non-structural component (104) and a structural component (102) of a building and at least one seismic restraint (106) according to any one of the preceding claims, the seismic restraint (106) being configured to be installed between the non-structural component (104) and the structural component (102) of the building.
14. The arrangement according to claim 13, wherein the non-structural component (104) comprises at least one of a façade panel, an electrical system, and a mechanical system.
15. The arrangement according to claim 13 or 14, where-

in the structural component (102) comprises at least one of a column, a beam, a slab, and a wall.

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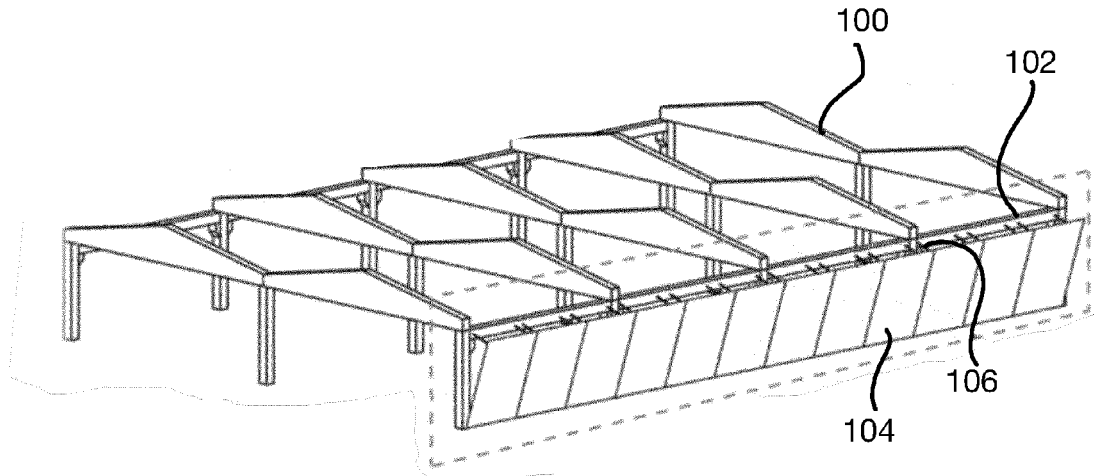


Fig. 1



Fig. 2

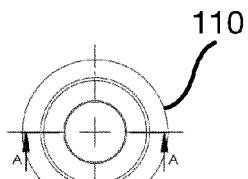


Fig. 3

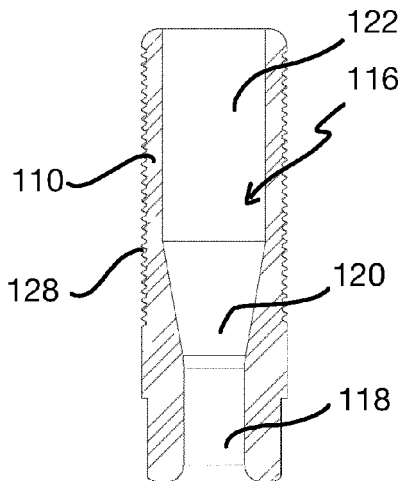


Fig. 4

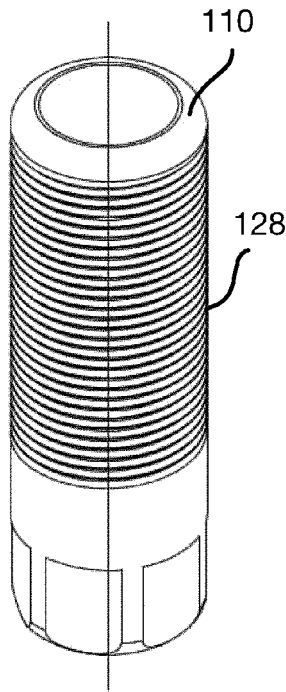


Fig. 5

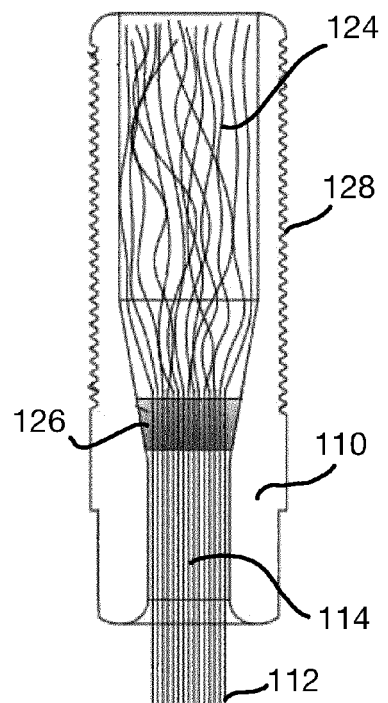


Fig. 6

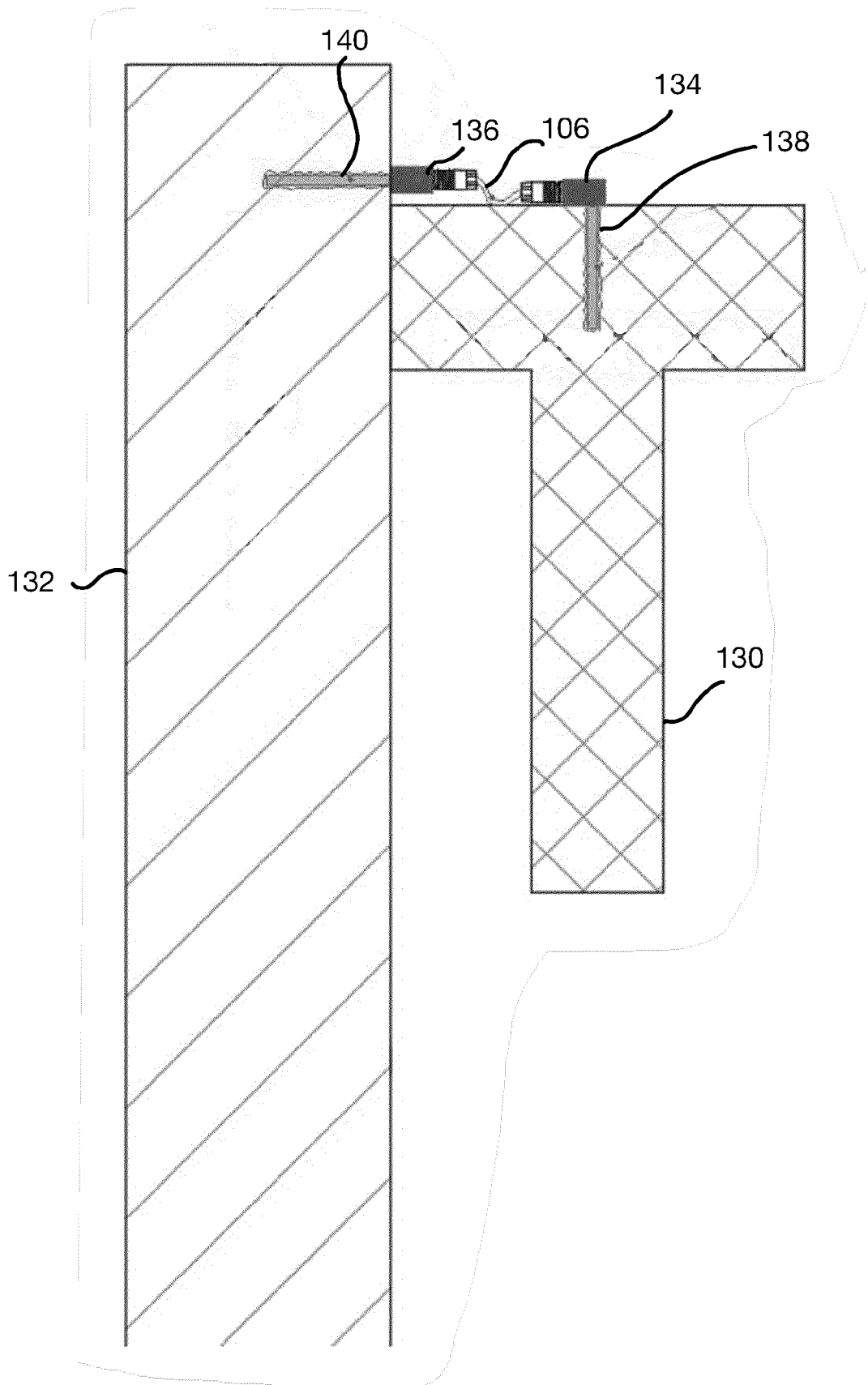


Fig. 7

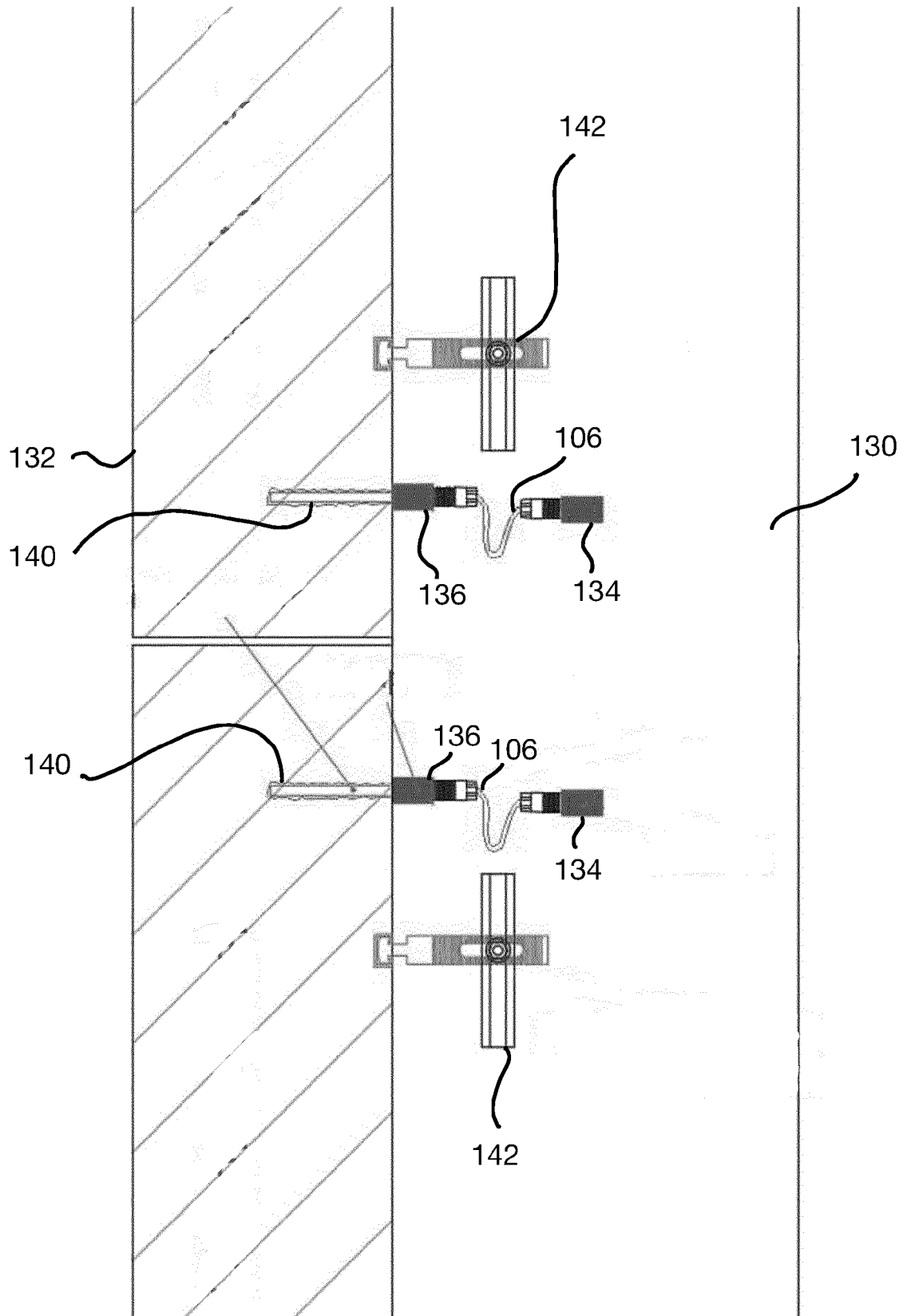


Fig. 8

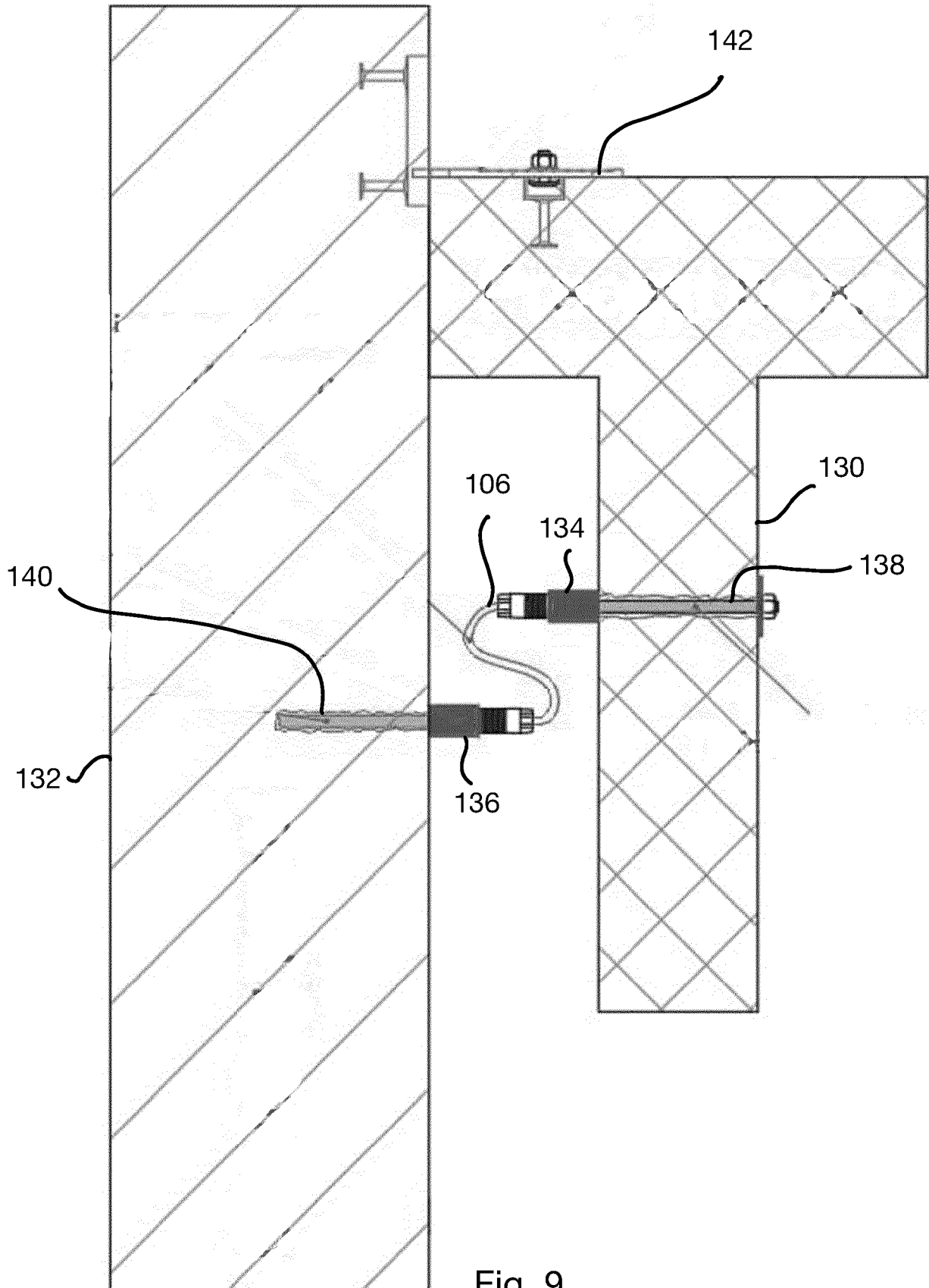


Fig. 9



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Application Number
EP 23 15 2000

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			TECHNICAL FIELDS SEARCHED (IPC)
			E04H E04B
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 30 June 2023	Examiner Valenta, Ivar
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

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