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(72) Inventor: **The designation of the inventor has not yet been filed**

(74) Representative: **Samuels, Lucy Alice**  
**Gill Jennings & Every LLP**  
**Broadgate House**  
**7 Eldon Street**  
**London**  
**EC2M 7LH (GB)**

(71) Applicant: **Rockwool International A/S**  
**2460 Hedehusene (DK)**

(54) **Facade insulation system**

(57) The present invention provides an insulated building wall comprising an external thermal insulation composite system (ETICS) and a building wall, wherein the ETICS is affixed to the building wall, the ETICS comprising:

(i) an insulation sub-system, said insulation sub-system being either

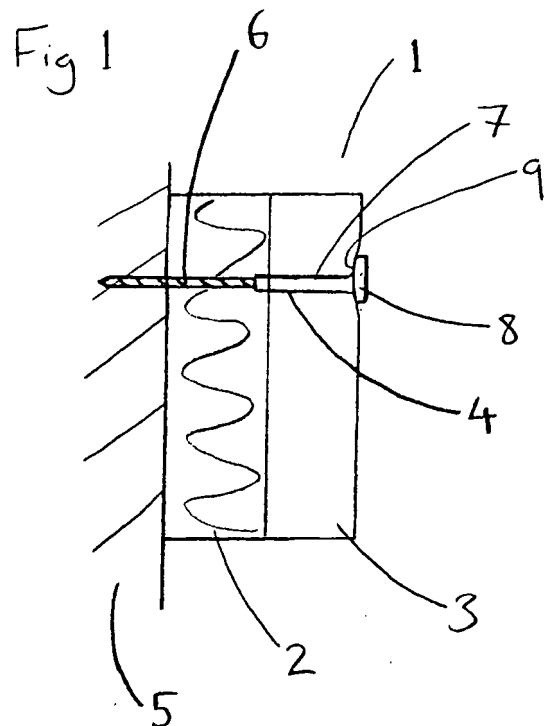
(a) an insulation sub-system comprising at least a first insulating plate which contains from 20 to 90 wt % aerogel and at least a second insulating plate which contains mineral wool, or

(b) an insulation sub-system comprising at least one composite insulating plate containing mineral wool and from 20 to 90 wt % aerogel, and

(ii) at least one mechanical fastener for fastening the at least one insulating plate to the building wall, and

(iii) an outer layer.

A method of providing an external thermal insulation composite system (ETICS) affixed to a building wall and a use of aerogel in an external thermal insulation composite system (ETICS) are also provided.



## Description

**[0001]** The present invention relates to thermal and sound insulation properties of External Thermal Insulation Composite Systems (ETICS). These systems are used for the outside, external insulation of building facades and walls.

An ETICS may conventionally comprise a plurality of insulating elements, which elements are slab or plate shaped with two major surfaces connected with rectangular side surfaces, and which major surfaces are suited for application of a plaster layer; the insulating elements are fastened to the outer facade with the aid of plate fasteners, anchors, profiles etc or a combination of adhesive and mechanical fixing.

**[0002]** External Thermal Insulation Composite Systems (ETICS) are known from the state of the art. To protect the insulating layer and to provide an appealing appearance, the insulating layer is provided with a rendering consisting of one or more layers, e.g. a base coat of plaster, mortar layer or for example a fiber-reinforced filler. Usually the base coat also contains a reinforcement. The final surface is provided by a topcoat, tiles or the like.

**[0003]** The insulation plates are conventionally plates of expanded polystyrol rigid foam (PSE) or mineral fibers, such as rock wool or glass wool. Other insulation plates are made of aerated concrete, foam glass, rigid foams, extruded polystyrene (XPS), or Polyurethane etc. Rigid foam plates have a high stiffness of 80 to 100 kPa and have a sufficiently high tensile strength to withstand and absorb wind load.

**[0004]** The strength characteristics for mineral wool insulation plates depend on the density, the binder content and orientation of the mineral fibres. Commercial known mineral wool insulation plates are having densities of 60 up to 150 kg/m<sup>3</sup>. The insulation boards usually have a length of 800 mm and a width of 625 mm; other dimensions are known as well.

**[0005]** The mechanical strength, especially the compressive strength of insulation plates made of mineral fibers may be increased through a length and height compression of the mineral fibre mat during production. The tensile strength perpendicular to the main surfaces, in the following referred to as the tensile strength is however limited because the mineral fibers in the near-surface zones remain largely parallel to the major sides for plates made by this process type; this mineral wool plate type may be referred to as a "laminar plate". Thus, the tensile strengths for laminar plates are in the range of about 2 to 35 kPa, such as 2 to 20 kPa cf. the EN 1607. The stiffness of the insulation plates parallel to the major surfaces, in the direction of production, is significantly lower than across it.

**[0006]** Another way of changing the mechanical properties of mineral fiber insulation is to cut several strips of mineral wool along the direction of the production line to form lamellas of mineral wool. The lamellas are further

cut crosswise to the production line and the loose lamellas thus obtained are each turned 90 degrees. The loose lamellas are then re-assembled by gluing the lamellas together to form a board with a fibre orientation predominantly perpendicular to the major surface of the plate, a so-called lamella board or "lamella plate". These plates have high compression strength perpendicular to the major surface and high tensile strength.

**[0007]** The thermal insulation properties are however poorer compared to the conventional mineral wool plate made by length and height compression where the fibres have not been re-directed by cutting and turning lamellas. The lamella plates also have a low bending strength.

**[0008]** In addition to these two basic types of mineral wool plates there are the so-called "dual density mineral wool plates" which have a surface layer of 10 to about 20 mm of a compacted mineral wool layer with a density of about 150 to 210 kg/m<sup>3</sup>. The high-density surface layer is usually provided to improve the mechanical properties to these dual density plates. A production method is illustrated in EP1111113.

**[0009]** Furthermore, a mineral wool plate type exists made by moving the uncured mineral wool web with a vertical pendulum motion, in the up-down direction in relation to the production line, and thereby intentionally creating a folded web. This product is also named a pleated mineral wool web and has a meander-like wool structure and thereby a fibre direction predominantly in the direction perpendicular to the major surface of the mineral wool plate and another fibre direction in regions where the folded web bends in the pleats; these bend regions are near the plate surface and this region may be removed by e.g. grinding or sawing and thereby providing a mineral wool plate with a fibre direction predominantly in the direction perpendicular to the major surface of the mineral wool plate.

**[0010]** The insulating plates are adhered to the prepared wall surface by applying adhesive to a part or to the entire surface of the insulating plate. The wall surface may be extensively worked by grinding or other mechanical means to smoothen out any irregularities in the wall surface before application of the plate; sheets or fleeces which aids to even out a more uneven surface may be applied to the wall surface before the application of the plate. A roughness of the surface up to 2 cm will however normally be evened out with the adhesive.

**[0011]** Insulation plates of foam like PSE or mineral wool must be applied with adhesive on minimum 40% of the major surface to fulfil the building regulations. The edges of the surfaces of the plates must in particular be applied with adhesive while two to three adhesive spots on the major surface are sufficient for adhesion and support for the plate.

**[0012]** The wall surface for mounting an ETICS is consequently to be pre-examined and prepared thoroughly before the application of the insulation plates. The use of mechanical fasteners is also made to assure an even higher degree of safety for the application of ETICS; this

is of particular importance when taller buildings are insulated because higher wind loads prevail in the upper part of tall buildings and a higher weight load prevails in the lower part of tall buildings due to the increasing own mass of the ETICS.

**[0013]** The fasteners are conventionally made of polyamide and fibre-reinforced polyamide when higher loads are prevailing. A fastener consists of an elongated element with a round plate shaped head with a diameter between 40 and 140 mm and may be described as a dowel type; the thickness of the head is approx. 2 to 5 mm and it is shaped conically providing re-enforcing ribs. The elongated element is hollow and provides a rawplug with a steel screw or bolt. The fastener is normally mounted after the adhesive mortar has hardened, which of course requires a sufficient resistance of the mounted insulation plates to own mass and wind load. The own mass of thinner plates may be neglected, although thin plates are more susceptible to wind forces and this has to be taken care of.

**[0014]** The adhesion of mechanically fixed ETICS is nowadays not taken into account when calculating the structural stability. However, the adhesion is considered to provide stiffness to the insulation plate.

**[0015]** Holes corresponding to the diameter of the rawplug must be drilled in the wall surface to mount the fastener. The fastener is forced through the insulation material into the wall whereby the rawplug settles when the bolt or screw is fastened. The fastener head with the ribs is in contact with the surface of the insulation and is flush with the surface or at a slightly elevated level above the insulation surface for hard insulation plates; the fastener head tends to be pressed into softer insulation materials such as mineral wool plates causing a depression in the insulation.

**[0016]** Another way of mounting is achieved when the fastener is affixed after a base coat containing a reinforcement e.g. an embedded glass fibre mesh is applied to the outer face of the insulation product. Therefore the holes have to be drilled through the fresh base coat causing an unavoidable pollution of the coat and the equipment; therefore, the installers often try to avoid this way of mounting.

**[0017]** The fasteners must be stronger and thicker upon increase of the insulation thickness and this results in both a less favourable economic solution but also in a deterioration in the insulating properties due to an increase in cold bridges.

**[0018]** The number of fasteners increases substantially with the height of the building. The exact number of fasteners depends on the height of the building and the wind load resistance of the ETICS which is very much related to the mechanical performance of the insulation, e.g. the shear strength, tension strength and especially the pull-through resistance of the insulation material and is generally higher in e.g. the corner areas of a building compared to the surface areas. The number and specification of the fasteners are stated in the Technical Ap-

proval (e.g. European Technical Approval - ETA) of each ETICS.

**[0019]** The final layer of plaster or mortar forming the outermost surface of the ETICS is thinner at the zones of the surface around the fastener heads when the fastener heads are in contact with a rigid hard insulation plate; it is therefore expected that crackings in the mortar may occur in these zones.

**[0020]** DE10211331A1 describes the application of an aerogel material to a vertical surface such as a wall. The aerogel material is provided as particles and are mixed with a binder and the resulting mixture is applied to the wall with a spraying device. The sprayed-on layer seems to be available only in relatively small thicknesses which are not adequate to fulfil the building regulation requirements for insulation performance within ETICS.

**[0021]** EP1408168B1 describes an ETICS with mineral wool plate insulation. A solution with a maximum of 3 dowels per m<sup>2</sup> of insulation area is provided and the minimisation of the number of dowels is done by making restrictions for the transverse tensile strength of the mineral wool plate, the tearing strength of the wall substrate, dowel load, size and shape and taking the adhesive layer into consideration as a load bearing constituent.

**[0022]** Another attempt to improve an ETICS is described in W09813642A1. This document describes an insulating element of mineral wool for the use in an ETICS which may be provided with a layer of densified mineral wool, thus forming a two-layer product, preferably the densified layer has a thickness of 15 to 25 mm. The fibre direction in the densified layer has a higher tendency to be parallel to the major surface than the fibre direction in the non-densified layer. The high density layer results in improved mechanical resistance, e.g. towards the pressure exerted by the head part of a mechanical fastener on the densified layer, when winds are affecting the insulating system. A further densified layer may also be applied facing the wall side. Densifying a layer of mineral wool will in general result in a deterioration of the insulating properties. The multi-layer plates are constructed so that there is a compromise between the insulating properties and the mechanical properties. The high density layer has a cover suitable for application of a mortar layer to enable a marking for the identification of which major surface of the insulating element should be turned to the outside when mounting.

**[0023]** The problem which the invention sets out to solve is how to improve both the mechanical properties and the insulating properties of an insulation sub-system comprising mineral wool in an ETICS.

**[0024]** The solution to these problems is provided with the external thermal insulation composite system (ETICS) comprising: (i) an insulation sub-system, said insulation sub-system being either (a) an insulation sub-system comprising at least a first insulating plate which contains from 20 to 90 wt % aerogel and at least a second insulating plate which contains mineral wool, or (b) an insulation sub-system comprising at least one composite

insulating plate containing mineral wool and from 20 to 90 wt % aerogel, and (ii) at least one mechanical fastener for fastening the at least one insulating plate to the building wall, and (iii) an outer layer.

**[0025]** An "aerogel containing plate" denotes either a first insulating plate which contains from 20 to 90 wt % aerogel or a composite insulating plate containing mineral wool and from 20 to 90 wt % aerogel.

**[0026]** "A first insulating plate" does not necessarily mean that there is only one insulating plate comprised in the insulation sub-system; thus, there may be several and further first insulating plates all having substantially the same characteristics.

**[0027]** As used herein "composite insulating plate" denotes an insulating plate where fibres and aerogel are combined in the insulating plate. For example, "Composite insulating plate" is not intended to include insulating plates where fibres and aerogel are separated into distinct layers.

**[0028]** Generally, gels are described as compositions, wherein a continuous liquid phase is enclosed by a continuous solid three-dimensional network of colloidal particles. An aerogel can be formed by removing the liquid from the gel and replacing it with air as the dispersion medium.

**[0029]** "Aerogel" when used in the broader sense means a gel with air as the dispersion medium. Within that broad description, however, exists three types of aerogel, which are classified according to the conditions under which they have been dried.

**[0030]** Where a wet gel is dried at above the critical point of the liquid, there is no capillary pressure and therefore relatively little shrinkage as the liquid is removed. The product of such a process is very highly porous and is known as an aerogel, the term being used in the narrow sense. On the other hand, if the gel is dried by evaporation under sub-critical conditions, the resulting product is a xerogel. In the production of a xerogel, the material usually retains a very high porosity and a large surface area in combination with a very small pore size.

**[0031]** In the wider sense of the word, aerogels also encompass dried gel products, which have been dried in a freeze-drying process. These products are generally called cryogels.

**[0032]** The term "aerogel" in its broader sense of "gel having air as the dispersion medium" encompasses each of aerogels in the narrower sense, xerogels and cryogels. As used herein, the term "aerogel" denotes aerogels in the broader sense of a gel having air as the dispersion medium.

**[0033]** A number of different aerogel compositions are known in the art. These include both inorganic and organic aerogels. The inorganic aerogels are often based on metal oxides such as silica, carbides and alumina, whereas organic aerogels include carbon aerogel and polymeric aerogels, for instance polyamide aerogels. Silica aerogel melts above 1200 °C and sintering starts at around 700 °C; the difference in fire properties of aerogel

products is primarily ascribed to different aerogel product types like aerogels fibre reinforcement and application of a binder.

**[0034]** Some of the best insulating materials in the solid state are aerogels with a low density, typically from about 0.01 g/cm<sup>3</sup> to 0.3 g/cm<sup>3</sup>; these materials have a thermal conductivity of 12 mW/mK or even lower at ambient temperature and pressure which is to be compared with typically 30-40 mW/mK for mineral wool insulation plates and 25-35 mW/mK for foam insulation plates for an ET-ICS.

**[0035]** Pure aerogels are fragile and this is especially true for aerogels with low densities; thus, they must be handled with great care and their use in most sectors of the insulation market is therefore limited.

**[0036]** The present invention relates, more particularly, to products including aerogel insulation in the form of a mat or plate.

**[0037]** Many different types of aerogel products have been suggested, such as a rigid sandwich layered plate of several aerogel containing layers separated by binder layers of e.g. acrylic binders, cf. W02007/086819.

**[0038]** One type of mat particularly useful in the present invention is an aerogel matrix composite mat. An aerogel matrix composite with fibre reinforcement may be considered as a whole block of monolithic aerogel with fibre embedded into it. The fibres may be eliminated by e.g. combusting the matrix composite which will burn the fibres in case of plastic fibre reinforcement but leave the monolithic block more or less intact as a macroscopic piece of insulation material.

**[0039]** Aerogel matrix composite mats are commercially available from Aspen Aerogels, Inc. and are made by impregnating a matrix of re-enforcing fibres with a flowable sol-gel solution, gelling and then removing the liquid from the gel in a manner that does not destroy the pores of the aerogel. These aerogel matrix composites are mechanically stronger, better insulators and require a shorter processing time than pure aerogels. They are, therefore, suitable for industrial use as insulating material and are commonly used for this purpose. For example US 2002/0094426 describe aerogel matrix composites and their use for insulation purposes.

**[0040]** Elsewhere in the prior art, aerogel mats have been formed in different ways. A number of documents, for example, describe the use of aerogels preformed as particles to produce insulation products. For example, US6485805 describe an insulating composite comprising silica aerogel granules and having a thermally reflective layer, which is preferably a thin aluminium foil layer. The aerogel granules are preferably adhered to the thermally reflective layer with a binder.

**[0041]** It is also possible to incorporate aerogel particles into a composite material comprising fibres. US 6479416, for example, relates to a composite material comprising aerogel particles and thermoplastic fibres. The composite may also contain other types of fibres, but the thermoplastic fibres bind to each other and to the

granules of aerogel to form a cohesive composite material.

**[0042]** WO2006/065904 describes a method for making an insulation blanket comprising adding a wetting agent to aerogel particles before combining them in water with fibres to form slurry. The slurry is then dewatered, and the resulting web dried and calendared to form the blanket. The method may also include providing a layer on at least one side of the blanket to form a plate. This document further describes a product, wherein the blanket is placed between at least two glass layers. The resulting plate may be used as a window, wall, floor or the like.

**[0043]** WO 98/32709 describes a material comprising an aerogel layer with binder and at least one further layer. Further aerogel-based materials are outlined in US 2007/0004306.

**[0044]** All these aerogel containing product types have varying mechanical properties, though they are all characterised by the relatively brittle nature of monolithic aerogel whenever the content of monolithic aerogel is high in the aerogel containing product.

**[0045]** The present inventors have found that by providing an ETICS with one or more insulating plates as stated in claim 1 with aerogel as a part of the insulation sub-system, an improvement in the mechanical properties can be achieved. When the insulating plate is part of the ETICS, the mechanical properties for the entire installed system, namely comprising the insulation plates, fasteners, outer layer and adhesive (if applied) is improved. The insulation sub-system comprising insulation plates with aerogel and with mineral wool results especially in a higher stiffness and pull-through resistance for the mechanical fasteners.

Also, an improved wind load resistance for an ETICS comprising insulation plates containing mineral wool is achieved with the solution according to claim 1.

**[0046]** An ETICS may be grouped into four categories: 1) ETICS relying entirely on adhesion of the insulating plates; the adhesion may be carried out on the entire insulation plate surface or partially in dabs/dots or stripes. 2) ETICS relying on adhesion of the insulating plates assisted by mechanical fastening; the load is entirely distributed with the aid of the adhesion and the mechanical fastening is foremost used for stability against collapse until the adhesive have settled but may also provide for stability against collapse in case of fire. 3) ETICS relying on mechanical fastening assisted by an adhesion. The load is entirely distributed with the aid of the mechanical fastening and the adhesive is foremost used for securing an even distribution. 4) ETICS relying entirely on mechanical fastening.

**[0047]** The present invention is not concerned with the first mentioned category, but is related to the latter three mentioned categories where a mechanical fastening is applied.

**[0048]** In one embodiment, an adhesive is applied between the at least one insulating plate and the building

wall.

**[0049]** In one embodiment, the outer layer forms the outermost surface of the ETICS. The outer layer is preferably a system comprising one or more of the following constituents: 1) a Re-enforcement net, preferably a web of glass-, metal- or polymer-fibres; 2) a mortar layer, preferably of an under mortar layer, an adhesive layer and a final mortar layer.

**[0050]** In one embodiment, it is preferred that the outermost surface is selected from one or more of the materials of the group of tiles, plaster slips.

**[0051]** The mechanical fastener is preferably a dowel or screw-anchor type displaying an elongated element with a round plate shaped head, a fastening element, preferably a pin, spike, peg or sprig or other for the fastening of the insulation to the building wall.

**[0052]** In one embodiment the at least first insulating plate, or the at least one composite insulating plate comprises at least 30 wt.%, such as at least 40 wt.%, and less than 80 wt.%, such as less than 70 wt.%, such as less than 60 wt.%, aerogel.

**[0053]** There is a minimum value for the content of aerogel for which below the effect on the mechanical properties is not sufficient, such as the effect of improving the pull-through resistance or improving the shear strength or the tension strength normal to the plate. On the other hand, there is also a maximum value for the aerogel content for which above the mechanical properties such as bending strength and brittleness are unsatisfactory.

**[0054]** The stated wt.% of aerogel material denotes the content of aerogel in its "pure" form, e.g. without inclusion of any content of binder, fibre or filler, if available in the aerogel containing plate. The stated wt.% does however include substances like hydrophobizing agents and IR opacity substances for the aerogel material. The weight percentages of aerogel described are percentages of the total weight of the respective insulating plate.

**[0055]** It has been found that it is possible to incorporate an amount of at least 20 wt. % aerogel into the aerogel containing plate, which is a relatively high amount of aerogel material which otherwise is known to be a rather brittle material without mechanically weakening the installed ETICS. An aerogel material has very different mechanical properties compared to the conventionally used insulation materials for ETICS, such as foam products like PSE or XPS and mineral fibre products; the difference is mostly pronounced with regard to the brittleness and weight, and these differences become more pronounced upon increasing the content of the aerogel in the aerogel containing plate. The differences in acoustic properties are also pronounced upon increasing the content of the aerogel when compared to conventional insulation plates.

**[0056]** In one embodiment the aerogel containing insulation plate contains an aerogel material based on silica. A silica aerogel shows an improved fire resistance when compared to e.g. organic aerogels.

**[0057]** In one embodiment, the aerogel containing plate has a density of 100-300 kg/m<sup>3</sup>, such as 100-200 kg/m<sup>3</sup>. Conventionally, aerogel containing materials with densities of these magnitudes have better mechanical properties than low-density aerogel materials. In one embodiment, the aerogel containing plate has a density of less than 100 kg/m<sup>3</sup>, such as 30-80 kg/m<sup>3</sup> and these plates are better suited for being used in a sandwich structure between second insulating plates with mineral wool on each side for mechanical stability.

**[0058]** In one embodiment the binder content is at least 2 wt.%, such as at least 4 wt.%, such as at least 6 wt. % and less than 10 wt.%, such as less than 15 wt.%, such as less than 20 wt.% of the weight of aerogel containing plate.

**[0059]** In one embodiment the insulation sub-system comprises at least a first insulating plate which contains from 20 to 90 wt % aerogel and at least a second insulating plate which contains mineral wool, where the first insulating plate comprises fibres of a material selected from the group of organic polymers, such as polyethylenes, polypropylenes, polyacrylonitriles, polyamides, aramids, polyesters and/or the group of carbon, stone, glass and ceramics.

**[0060]** The fibres may be in forms of, wovens, non-wovens, mats, felts, batts, chopped fibers, or a combination thereof; the fibres are preferably used as reinforcement for aerogel composites, such as a fibrous batt.

**[0061]** In one embodiment the insulation sub-system comprises at least a first insulating plate which contains from 20 to 90 wt % aerogel and at least a second insulating plate which contains mineral wool, where the first insulating plate is an aerogel matrix composite.

**[0062]** In one embodiment the insulation sub-system comprises at least a first insulating plate which contains from 20 to 90 wt % aerogel and at least a second insulating plate which contains mineral wool, where the first insulating plate is integral with the second insulating plate. This provides an insulating plate which is less work consuming to mount compared to mounting the first insulating plate and the second insulating plate separately. The mechanical characteristics, such as the resilience of the second insulating plate, which contains mineral wool, may also lend its properties to the integral plate and thereby relieve the brittle character of the first insulating plate containing aerogel.

**[0063]** In one embodiment the second insulating plate is two-layered displaying a first and a second layer integral with each other at respective major surfaces, and the first layer has a higher density than the second layer.

**[0064]** In one embodiment, the first insulating plate and the second insulating plate forming the insulation sub-system of the ETICS have a rectangular major surface; in one embodiment, the first insulating plate and the second insulating plate forming the insulation sub-system of the ETICS have a rectangular major surface having substantially the same length and width, thus the first insulating plate and the second insulating plate being com-

mensurate. When both types of plates have the same geometry, it is easier to calculate the number of mechanical fasteners needed per surface area.

**[0065]** In one embodiment, the first insulating plate and the second insulating plate forming the insulation sub-system of the ETICS have a rectangular major surface having substantially the same length and width, thus the first insulating plate and the second insulating plate being commensurate and furthermore the insulation sub-system displays first insulating plates substantially exactly covering second insulating plates. The mounting of one plate type on top of another in a commensurate relationship represents a straightforward mounting of the second, outer plate because the placement is given by the plate facing the wall.

**[0066]** In one embodiment, the first insulating plate and the second insulating plate forming the insulation sub-system of the ETICS have a rectangular major surface and the insulation sub-system displays first insulating plate covering the edges of second insulating plate. It is also possible to place the second, outer plate in a displaced position relative to the plate facing the wall and thereby covering the edges where the inner plates meet each other to close the edges towards the outside.

**[0067]** In one embodiment, the insulation sub-system comprises at least a first insulating plate which contains from 20 to 90 wt % aerogel and at least a second insulating plate which contains mineral wool, where the first insulating plate is suitable for the application of an outer layer, and the second insulating plate is facing the building wall. An insulation where the first insulating plate, containing aerogel, is the outermost insulation away from the wall, provides an adequate material for fixation of the fastener head of the mechanical fasteners so that the combination of fastener and insulation has a tension strength which gives an improved resistance against wind load on the ETICS. This solution according to the invention does not compromise the insulation properties since the aerogel material in the plate is a highly insulating material, and the mechanical properties are not compromised either for the ETICS when installed.

**[0068]** The first insulating plate may be applied with a surface layer, coating or sheet which has a suitable affinity for the provision of an outer layer, preferably an outer layer comprising mortar or plaster.

**[0069]** In one embodiment the fastener head of the mechanical fastener may be in contact with the first insulating plate with a reinforcement mesh embedded in the base coat.

**[0070]** In one embodiment, the insulation sub-system comprises at least a first insulating plate which contains from 20 to 90 wt % aerogel and at least a second insulating plate which contains mineral wool, where the second insulating plate has a first layer and a second layer integral with each other at respective major surfaces, and the first layer has a higher density than the second layer, the second insulating plate is facing the building wall, and the first insulating plate is facing the first layer.

**[0071]** The provision of both a first insulating plate with aerogel and a high density layer of mineral fibres will result in an even better pull through resistance when compared with a solution without a high density layer of mineral fibres or without a first insulating plate.

**[0072]** In one embodiment, the insulation sub-system comprises at least a first insulating plate which contains from 20 to 90 wt % aerogel and at least a second insulating plate which contains mineral wool, where the first insulating plate is facing the building wall and the second insulating plate is suitable for the application of an outer layer.

**[0073]** The fastener head may be in contact with the second insulating plate with a reinforcement mesh embedded in a base coat of plaster, mortar layer or for example a fiber-reinforced filler.

**[0074]** The second insulating plate with mineral wool may display a zone of depression around the fastener head when mounted, because the mineral wool is resilient. The fastener head is however still prevented from a pull-through due to the underlying aerogel containing plate. In cases where the second insulating plate is lighter than the first insulating plate it may be an advantage to let the first insulating plate face the building wall because the weight contributing of the outermost layers of the total ETICS is thereby reduced.

**[0075]** The total system of dowels, first insulating plate and second insulating plate has improved mechanical properties over a sub-system exclusively consisting of mineral wool plates; the pull-through resistance is in particular improved.

**[0076]** In one embodiment the insulation sub-system comprises at least a first insulating plate which contains from 20 to 90 wt % aerogel and at least a second insulating plate which contains mineral wool, where the second insulating plate has a first layer and a second layer integral with each other at respective major surfaces, and the first layer has a higher density than the second layer, and the second layer is facing the first insulating plate.

**[0077]** The provision of both an aerogel containing plate and a high density layer of mineral fibres will result in an even better pull through resistance when compared with a similar insulation sub-system but without a high density layer of mineral fibres.

**[0078]** In one embodiment the insulation sub-system comprises at least a first insulating plate which contains from 20 to 90 wt % aerogel and at least a second insulating plate which contains mineral wool, where a major surface of the second insulating plate is in contact with at least part of a major surface of the first aerogel plate and the other major surface of the second insulating plate is in contact with at least part of a major surface of a further first insulating plate.

Such an embodiment when being an integral plate shows a better bending strength compared to second insulating plate, especially when comparing with a second insulating plate where the mineral fibre direction is perpendicular to the major surfaces of the plate.

**[0079]** In one embodiment the insulation sub-system comprises at least a first insulating plate which contains from 20 to 90 wt % aerogel and at least a second insulating plate which contains mineral wool, where a major surface of the first insulating plate is in contact with at least part of a major surface of the second insulating plate and the other surface of the first insulating plate is in contact with at least part of the major surface of a further second insulating plate.

**[0080]** The provision of an insulating plate containing mineral wool on each side of the first insulating plate at the major surfaces provides a mechanical protection for the aerogel containing plate. It also provides an improvement in fire properties in the case that the first insulating plate meets lower fire regulation standards than the second insulating plates. The second insulating plates will effectively provide a better fire protection for fires starting from the outside by embedding an aerogel containing plate with a lower fire rating and thereby preventing direct exposure to the fire by means of the outer second insulating plate during the first stage of fire and providing a halt in the fire spread to the building wall by means of the second insulating plate which is innermost.

**[0081]** The provision of a second insulating plate on each side of first insulating plate at the major surfaces provides a mechanical protection for the first insulating plate, and is preferred when a high content of aerogel is present in the first insulating plate, such as a content 40 to 90 wt.% aerogel.

**[0082]** In one embodiment the insulation sub-system comprises at least a first insulating plate which contains from 20 to 90 wt % aerogel and at least a second insulating plate which contains mineral wool, where the insulating plate facing the building wall has a higher density than the insulating plate in contact with at least part of the major surface of the insulating plate facing the building wall.

**[0083]** The weight load contribution of the outer layer will be lower for such a system where the aerogel containing plate is lighter than the mineral wool plate. This will aid to relieve the downward forces on the mechanical fastener and also the intrinsic load which the ETICS provides on the ground, because the force momentum has been diminished by moving the lighter insulating material towards the outside, away from the wall. This is done without compromising the wind load resistance which would have been expected to play a larger role for such a system where low density regions of the ETICS are subjected to wind.

**[0084]** In one embodiment, the insulation sub-system comprises at least a first insulating plate which contains from 20 to 90 wt % aerogel and at least a second insulating plate which contains mineral wool, where the first insulating plate has a thickness of at least 15 mm, such as at least 25 mm, such as at least 40 mm, such as at least 70 mm, such as at least 100 mm, and a thickness less than 200 mm, such as less than 150 mm.

**[0085]** Thicknesses of 15 mm may be enough to pro-

vide the effect of an adequate mechanical strength for the ETICS but it may be preferred to have a higher thickness to enable an improved insulation as well.

**[0086]** The aerogel containing plate may itself be of a layered structure comprising two or more aerogel containing sub-layers which are consolidated to form the aerogel containing plate.

**[0087]** In one embodiment the aerogel containing plate comprises two or more aerogel containing sub-layers consolidated to form an aerogel containing plate, wherein the sub-layers have substantially the same wt. % content of aerogel material.

**[0088]** In one embodiment the aerogel containing plate comprises two or more aerogel containing sub-layers consolidated to form an aerogel containing plate, wherein at least one sub-layer has different aerogel content from the other sub-layers of the aerogel containing plate.

**[0089]** A sub-layer structure may provide improved resilience and/or bending strength to the aerogel containing plate.

**[0090]** Mineral wool denotes a bonded non-woven mineral fibre network, which is obtained by centrifugal spinning of a melt stream, and inclusion of a curable binder and preferably a coupling agent to form a web of fibres; the web of fibres is thereafter cured to form the bonded non-woven mineral fibre network. The mineral wool may contain "shots" obtained during spinning with a cascade spinner or none, or virtually none, when the mineral wool is obtained with e.g. a cup spinner.

**[0091]** The second insulating plate which contains mineral wool may consist essentially of mineral wool.

**[0092]** In one embodiment the insulation sub-system comprises at least a first insulating plate which contains from 20 to 90 wt % aerogel and at least a second insulating plate which contains mineral wool, where the second insulating plate is a mineral wool laminar plate.

**[0093]** The fibre direction in a mineral wool laminar plate is predominantly parallel or deviating with a small amount from parallel to the major surfaces of the plate.

**[0094]** One example of a laminar plate is a glass wool plate, where the glass wool is made with the cup or TEL fibre spinning method. The first insulating plate provides the adequate tensile strength to compensate for the low tensile strength of the mineral wool laminar plate, relative to other types of mineral wool plates. An advantage of using a laminar plate is a high insulation value, relative to other types of mineral wool plates.

**[0095]** In one embodiment the insulation sub-system comprises at least a first insulating plate which contains from 20 to 90 wt % aerogel and at least a second insulating plate which contains mineral wool, where the second insulating plate has a fibre direction predominantly perpendicular to the major surface.

**[0096]** In one embodiment, the second insulating plate is a mineral wool lamella plate.

**[0097]** In one embodiment, the second insulating plate is a mineral wool pleated plate.

**[0098]** A second insulating plate where the fibre direc-

tion is predominantly perpendicular to the major surface like e.g. the lamella plate and the pleated plate infer a relatively high tensile strength, relative to a laminar plate and are preferably used as part of an ETICS where there are particularly high demands to the tensile strength. This may e.g. be the case for ETICS constructed at prevailing high wind loads and/or for the part of an ETICS high above the ground where the wind load is higher than at ground level.

**[0099]** In one embodiment, the insulation sub-system comprises at least one composite insulating plate containing mineral wool and from 20 to 90 wt % aerogel, where the composite is an aerogel matrix composite or an aerogel powder fibre composite.

**[0100]** In one embodiment, the number of mechanical fasteners per m<sup>2</sup> of building wall area is less than 3.

**[0101]** It is an advantage to reduce the number of fasteners since the fastening procedure is labour intensive, and the solution according to the invention makes it possible to reduce the number of fasteners, such as dowels, compared to what is conventionally used.

**[0102]** In another aspect, the present invention provides a method of providing an external thermal insulation composite system (ETICS) affixed to a building wall comprising: 1) providing an insulation sub-system to the wall, preferably by adhering the sub-system to the wall, the sub-system comprising - a first insulating plate containing from 20 to 90 wt % aerogel and a second insulating plate containing mineral wool, or - a composite insulating plate containing mineral wool and from 20 to 90 wt % aerogel, 2) fastening the insulation sub-system to the wall with mechanical fasteners; 3) providing an outer layer on the insulation sub-system.

**[0103]** The insulation sub-system has the benefits of having improved insulation properties due to the content of aerogel and the first insulating plate or the composite plate may therefore be thinner and lighter compared to a pure mineral wool insulation sub-system; this provides an easier handling of the sub-system during installation while at the same time providing an ETICS with improved mechanical properties.

**[0104]** In one embodiment, a net for the outer layer is provided to the insulation sub-system when fastening the insulation sub-system to the wall with mechanical fasteners.

**[0105]** In one embodiment, the insulation sub-system has the features of any one of claims 2 to 18.

**[0106]** The insulation sub-system provides a saving in mechanical fasteners for the fastening of the insulation, and thus the installation of the ETICS is less labour demanding, since preferably the number of mechanical fasteners per m<sup>2</sup> of building wall area is less than 3.

**[0107]** In another aspect, the present invention provides a use of an aerogel in an external thermal insulation composite system (ETICS) affixed to a building wall, said ETICS comprising - an insulation sub-system comprising mineral wool and from 20 to 90 wt % aerogel, and - at least one mechanical fastener for fastening the insulation



sub-system to the building wall, and - an outer layer, for improving the resistance of the insulation sub-system against the pull-through of the mechanical fasteners.

**[0108]** In one embodiment, the use according to claim 22 is provided wherein the aerogel is contained in the insulation sub-system as at least one insulating plate.

**[0109]** In one embodiment, the use according to claim 22 is provided wherein the insulation sub-system has the features of any one of claims 2 to 18.

**[0110]** Several embodiments of the invention are described below by way of example only.

Figure 1 shows a first embodiment of a mounted insulation sub-system being part of an ETICS according to the present invention;

Figure 2 shows a second embodiment of a mounted insulation sub-system being part of an ETICS according to the present invention;

Figure 3 shows a third embodiment of a mounted insulation sub-system being part of an ETICS according to the present invention;

Figure 4 shows a fourth embodiment of a mounted insulation sub-system being part of an ETICS according to the present invention;

Figure 5 shows a fifth embodiment of a mounted insulation sub-system being part of an ETICS according to the present invention;

**[0111]** Figure 1 shows an insulation sub-system (1) comprising mineral wool made by arranging a mineral wool insulating plate (2) at the building wall and arranging an aerogel containing insulating plate (3) on top of the mineral wool plate and mounting a mechanical fastener (4) into the wall (5) holding both the plates (2, 3); the mineral wool plate (2) is glued (not shown) to the wall (5). The part of the ETICS is shown in cross section displaying the mechanical fastener (4). The mechanical fastener is a polyamide based hollow dowel with a metal screw (6) inserted in the hollow element (7) and the dowel has a head (8) in shape of a round plate with a diameter of preferably around 90 mm. The head (8) exerts a pressure on the surface of the aerogel containing plate and there is a slight indentation (9) into the surface due to the static hold force of the mounted screw. The total system of dowels, mineral wool plate (2) and aerogel containing plate (3) is mechanically rigid and has improved properties over a sub-system exclusively consisting of mineral wool plates; the pull-through resistance is in particular improved but also the resistance to wind load is improved with the light aerogel containing plate being placed out-  
ermost.

**[0112]** The insulation shown in figure 1 consists of two plates each having a rectangular major surface of substantially the same length and width as the other plate

and where the two plates are being placed commensurate so that the two plates substantially exactly cover each other. The mineral wool plate (2) is in this example a mineral wool lamella plate which consists of several lamellas of mineral wool glued together in their length direction to form the plate and where the mineral fibre direction is predominantly perpendicular to the major surface as is conventional for such mineral wool lamella plates. The thickness is 100 mm and the width by length is 400 by 1200 mm and the density of the mineral wool plate is 75 kg/m<sup>3</sup>. The aerogel containing plate (3) is in this example an aerogel particle fibre composite comprising stone fibres, aerogel particles and a means for binding the constituents.

**[0113]** Figure 2 shows an insulation sub-system like in figure 1 with the amendment that the mineral wool plate (2) shown in figure 2 is a dual density mineral wool plate which has a surface layer (10) of about 20 mm thickness of a compacted mineral wool layer with a density of about 160 kg/m<sup>3</sup> and a layer (11) of about 120 mm thickness of mineral wool layer with a density of about 90 kg/m<sup>3</sup>; the layer (11) with the lower density is facing the wall and the layer with the higher density (10) is facing the aerogel containing plate (3).

**[0114]** Figure 3 shows an insulation sub-system comprising an aerogel containing insulating plate (3) provided on the building wall and arranging a mineral wool plate (2) on top of the aerogel containing insulating plate (3) and mounting a mechanical fastener (4) into the wall (5) holding both the plates; the aerogel containing plate (3) is glued (not shown) to the wall (5). The part of the ETICS is shown in cross section displaying the mechanical fastener (4). The mechanical fastener (4) is a polyamide based hollow dowel with a metal screw (6) inserted in the hollow element (7) and the dowel has a head (8) in shape of a round plate with a diameter of preferably around 60 mm. The head (8) exerts a pressure on the surface of the mineral wool plate (2) and there is an indentation (9) into the surface due to the static hold force of the mounted screw and the mineral wool is compressed between the fastener head (8) and the surface of the aerogel containing plate (3). The total system of dowels, mineral wool plate (2) and aerogel containing plate (3) is mechanically rigid and has improved properties over a sub-system exclusively consisting of mineral wool plates; the pull-through resistance is in particular improved and the mineral wool plate provides a mechanical protection to the aerogel plate due to its resilient characteristics.

**[0115]** The insulation shown in figure 3 consists of two plates each having a rectangular major surface of substantially the same length and width as the other plate and where the two plates are being placed commensurate so that the two plates substantially exactly cover each other. The mineral wool plate is in this example a mineral wool laminar plate of the stone wool type where the mineral fibre direction is predominantly parallel to the major surface. The thickness of the mineral wool plate is

40 mm and the width by length is 625 by 800 mm and the density of the mineral wool plate is 120 kg/m<sup>3</sup>. The aerogel containing plate is in this example an aerogel matrix composite comprising polymer fibres in an aerogel matrix.

**[0116]** Figure 4 shows an insulation sub-system (1) like in figure 3 with the amendment that the mineral wool plate (2) shown in figure 3 is a dual density mineral wool plate of the stone wool type which has a surface layer (10) of about 20 mm thickness of a compacted mineral wool layer with a density of about 160 kg/m<sup>3</sup> and a layer (11) of about 60 mm thickness of mineral wool layer with a density of about 90 kg/m<sup>3</sup>; the layer (11) with the lower density is facing outwards.

**[0117]** Figure 5 shows an insulation sub-system (1) comprising mineral wool made by arranging a mineral wool insulating plate (2) at the building wall (5) and arranging an aerogel containing insulating plate (3) on top of the mineral wool plate and arranging a further mineral wool plate (2) on top of the aerogel containing insulating plate (3); the three plates are mounted with a mechanical fastener (4) into the wall holding the plates. The part of the ETICS is shown in cross section displaying the mechanical fastener (4). The mechanical fastener is a polyamide based hollow dowel with a metal screw (6) inserted in the hollow element (7) and the dowel has a head (8) in shape of a round plate with a diameter of preferably around 60 mm. The head exerts a pressure on the surface of the mineral wool plate (2) and there is an indentation (9) into the surface due to the static hold force of the mounted screw and the mineral wool is compressed between the fastener head (8) and the surface of the aerogel containing plate (3).

**[0118]** The total system of dowels, mineral wool-aerogel-mineral wool plate sandwich is mechanically rigid and has improved properties over a sub-system exclusively consisting of mineral wool plates; the pull-through resistance is in particular improved but also the overall weight is lowered.

**[0119]** The insulation shown in figure 5 consists of three plates all having a rectangular major surface of substantially the same length and width as the other plates and where the three plates are being placed commensurate so that the three plates substantially exactly cover each other. The mineral wool plates (2) are in this example mineral wool laminar plates of the stone wool type where the mineral fibre direction is predominantly parallel to the major surfaces. The thickness is 80 mm and the width by length is 625 by 800 mm and the density of the mineral wool plate is 100 kg/m<sup>3</sup>. The aerogel containing plate (3) is in this example an aerogel particle fibre composite comprising aerogel particles and a means for binding the constituents.

**[0120]** Figure 6 shows an insulation sub-system (1) comprising an insulating composite plate (12) containing mineral wool and aerogel; the plate is mounted with a mechanical fastener (4) into the wall (5) holding the plate. The part of the ETICS is shown in cross section displaying

the mechanical fastener (4). The mechanical fastener is a polyamide based hollow dowel with a metal screw (6) inserted in the hollow element (7) and the dowel has a head (8) in shape of a round plate with a diameter of preferably around 60 mm.

**[0121]** The head exerts a pressure on the surface of the composite plate (12) and there is an indentation (9) into the surface due to the static hold force of the mounted screw and the plate (12) is compressed between the fastener head (8) and the surface of the composite plate (12).

**[0122]** The total system of dowels, mineral wool-aerogel-composite is mechanically rigid and has improved properties over a sub-system exclusively consisting of mineral wool; the pull-through resistance is in particular improved but also the overall weight is lowered.

**[0123]** The insulation shown in figure 6 has a rectangular major surface. The thickness is 120 mm and the width by length is 625 by 800 mm and the density of the composite plate is 100 kg/m<sup>3</sup>.

## Claims

1. An insulated building wall comprising an external thermal insulation composite system (ETICS) and a building wall, wherein the ETICS is affixed to the building wall, the ETICS comprising:
  - (i) an insulation sub-system, said insulation sub-system being either
    - (a) an insulation sub-system comprising at least a first insulating plate which contains from 20 to 90 wt % aerogel and at least a second insulating plate which contains mineral wool, or
    - (b) an insulation sub-system comprising at least one composite insulating plate containing mineral wool and from 20 to 90 wt % aerogel, and
  - (ii) at least one mechanical fastener for fastening the at least one insulating plate to the building wall, and
  - (iii) an outer layer.
2. An insulated building wall according to claim 1, wherein
  - the at least first insulating plate, or
  - the at least one composite insulating plate
 comprises at least 30 wt.%, such as at least 40 wt.%, and less than 80 wt.%, such as less than 70 wt.%, such as less than 60 wt.% aerogel.
3. An insulated building wall according to any one of the above claims, wherein the insulation sub-system

comprises at least a first insulating plate which contains from 20 to 90 wt % aerogel and at least a second insulating plate which contains mineral wool, where the first insulating plate comprises fibres of a material selected from the group of organic polymers, such as polyethylenes, polypropylenes, polyacrylonitriles, polyamides, aramids, polyesters and/or the group of carbon, stone, glass and ceramics.

4. An insulated building wall according to claim 1, wherein the insulation sub-system comprises at least a first insulating plate which contains from 20 to 90 wt % aerogel and at least a second insulating plate which contains mineral wool, where the first insulating plate is an aerogel matrix composite.
5. An insulated building wall according to claim 1, wherein the insulation sub-system comprises at least a first insulating plate which contains from 20 to 90 wt % aerogel and at least a second insulating plate which contains mineral wool, where the first insulating plate is integral with the second insulating plate.
6. An insulated building wall according to any one of the above claims, wherein the insulation sub-system comprises at least a first insulating plate which contains from 20 to 90 wt % aerogel and at least a second insulating plate which contains mineral wool, where the second insulating plate has a first layer and a second layer integral with each other at respective major surfaces, and the first layer has a higher density than the second layer.
7. An insulated building wall according to any one of the above claims, wherein the insulation sub-system comprises at least a first insulating plate which contains from 20 to 90 wt % aerogel and at least a second insulating plate which contains mineral wool, where the first insulating plate is suitable for the application of an outer layer, and the second insulating plate is facing the building wall.
8. An insulated building wall according to any one of the above claims, wherein the insulation sub-system comprises at least a first insulating plate which contains from 20 to 90 wt % aerogel and at least a second insulating plate which contains mineral wool, where the second insulating plate has a first layer and a second layer integral with each other at respective major surfaces, and the first layer has a higher density than the second layer, the second insulating plate is facing the building wall, and the first insulating plate is facing the first layer.
9. An insulated building wall according to any one of the claims 1 to 6, wherein the insulation sub-system comprises at least a first insulating plate which con-

tains from 20 to 90 wt % aerogel and at least a second insulating plate which contains mineral wool, where the first insulating plate is facing the building wall and the second insulating plate is suitable for the application of an outer layer.

10. An insulated building wall according to any one of the claims 1 to 6 or 9, wherein the insulation sub-system comprises at least a first insulating plate which contains from 20 to 90 wt % aerogel and at least a second insulating plate which contains mineral wool, where the second insulating plate has a first layer and a second layer integral with each other at respective major surfaces, and the first layer has a higher density than the second layer, and the second layer is facing the first insulating plate.
11. An insulated building wall according to any one of the claims 1 to 6 or 9, wherein the insulation sub-system comprises at least a first insulating plate which contains from 20 to 90 wt % aerogel and at least a second insulating plate which contains mineral wool, where a major surface of the second insulating plate is in contact with at least part of a major surface of the first aerogel plate and the other major surface of the second insulating plate is in contact with at least part of a major surface of a further first insulating plate.
12. An insulated building wall according to any one of the claims 1 to 7, wherein the insulation sub-system comprises at least a first insulating plate which contains from 20 to 90 wt % aerogel and at least a second insulating plate which contains mineral wool, where a major surface of the first insulating plate is in contact with at least part of a major surface of the second insulating plate and the other surface of the first insulating plate is in contact with at least part of the major surface of a further second insulating plate.
13. An insulated building wall according to any one of claims 1 to 10, wherein the insulation sub-system comprises at least a first insulating plate which contains from 20 to 90 wt % aerogel and at least a second insulating plate which contains mineral wool, where the insulating plate facing the building wall has a higher density than the insulating plate in contact with at least part of the major surface of the insulating plate facing the building wall.
14. An insulated building wall according to any one of the above claims, wherein the insulation sub-system comprises at least a first insulating plate which contains from 20 to 90 wt % aerogel and at least a second insulating plate which contains mineral wool, where the first insulating plate has a thickness of at least 15 mm, such as at least 25 mm, such as at least 40 mm, such as at least 70 mm, such as at least 100

mm, and a thickness less than 200 mm, such as less than 150 mm.

15. An insulated building wall according to any one of the above claims, wherein the insulation sub-system comprises at least a first insulating plate which contains from 20 to 90 wt % aerogel and at least a second insulating plate which contains mineral wool, where the second insulating plate is a mineral wool laminar plate.

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16. An insulated building wall according to any one of the above claims, wherein the insulation sub-system comprises at least a first insulating plate which contains from 20 to 90 wt % aerogel and at least a second insulating plate which contains mineral wool, where the second insulating plate has a fibre direction predominantly perpendicular to the major surface.

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17. An insulated building wall according to any one of the above claims, wherein the insulation sub-system comprises at least one composite insulating plate containing mineral wool and from 20 to 90 wt % aerogel, where the composite is an aerogel matrix composite or an aerogel powder fibre composite.

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18. An insulated building wall according to any one of the above claims, wherein the number of mechanical fasteners per m<sup>2</sup> of building wall area is less than 3.

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19. A method of providing an external thermal insulation composite system (ETICS) affixed to a building wall comprising:

1) providing an insulation sub-system to the wall, preferably by adhering the sub-system to the wall, the sub-system comprising

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- a first insulating plate containing from 20 to 90 wt % aerogel and a second insulating plate containing mineral wool, or
- a composite insulating plate containing mineral wool and from 20 to 90 wt % aerogel,

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2) fastening the insulation sub-system to the wall with mechanical fasteners;

3) providing an outer layer on the insulation sub-system.

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20. A method according to claim 19, wherein a net for the outer layer is provided to the insulation sub-system when fastening the insulation sub-system to the wall with mechanical fasteners.

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21. A method according to claim 19 or 20, wherein the insulation sub-system has the features of any one of claims 2 to 18.

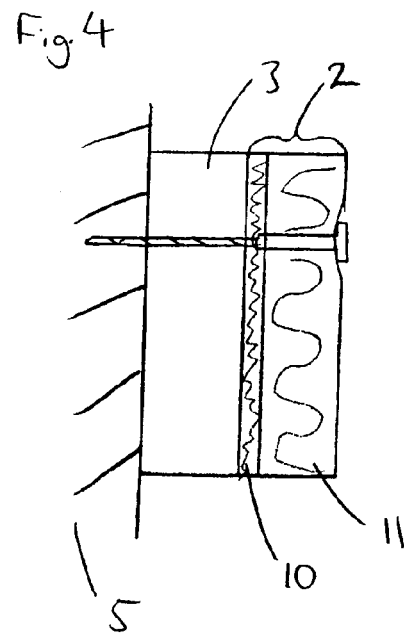
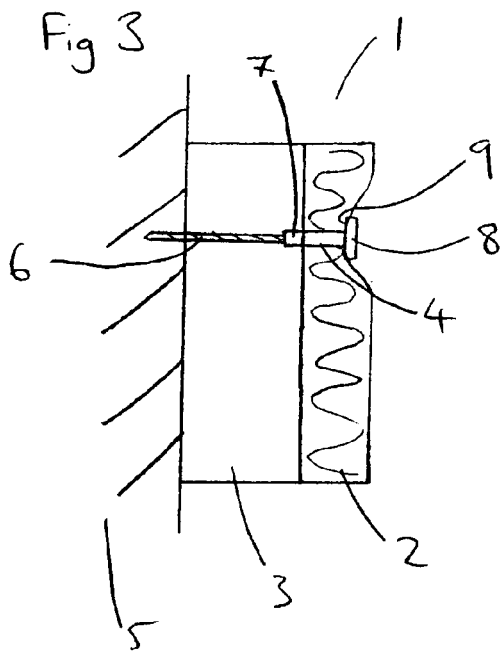
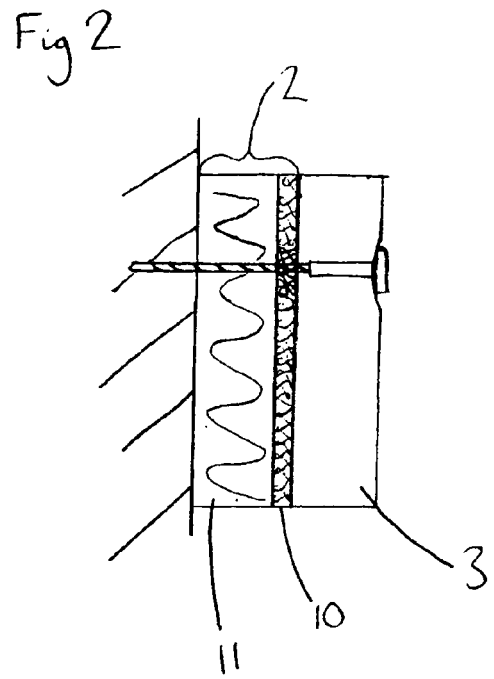
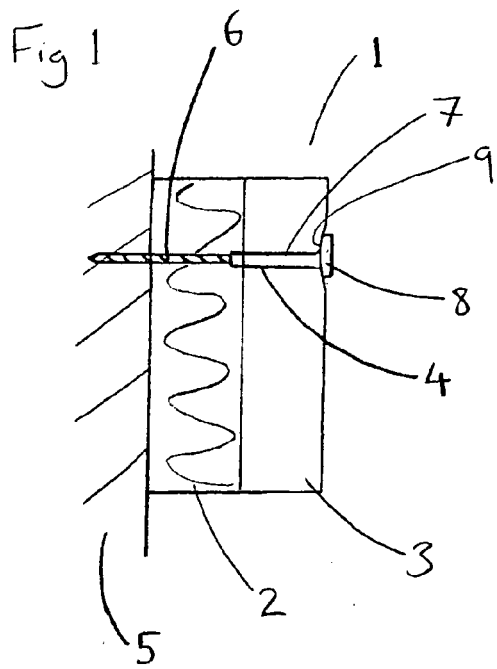
22. Use of an aerogel in an external thermal insulation composite system (ETICS) affixed to a building wall, said ETICS comprising

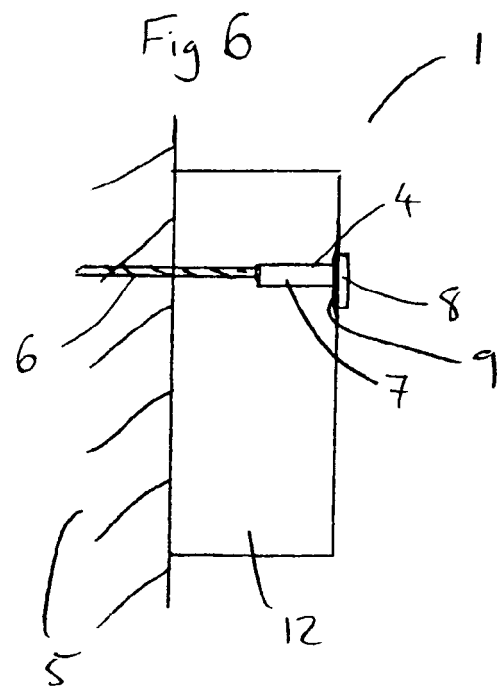
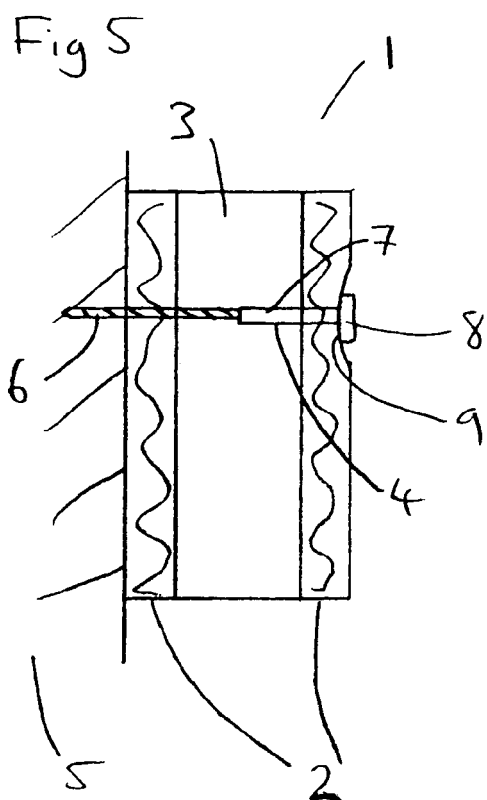
- an insulation sub-system comprising mineral wool and from 20 to 90 wt % aerogel, and
- at least one mechanical fastener for fastening the insulation sub-system to the building wall, and
- an outer layer,

for improving the resistance of the insulation sub-system against the pull-through of the mechanical fasteners.

23. Use according to claim 22, wherein the aerogel is contained in the insulation sub-system as at least one insulating plate.

24. Use according to claim 22 or 23, wherein the insulation sub-system has the features of any one of claims 2 to 18.







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Application Number  
EP 08 25 3406

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