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DRY BUILDING MATERIAL MIXTURE AND THERMAL INSULATION PLASTER PRODUCED THEREFROM

The invention in question relates to the technical field of thermal insulation, particularly the thermal insulation of buildings.

In particular, the invention in question relates to a dry building material mix, particularly a plaster mortar, and its use for manufacturing an insulating plaster.

Furthermore, the invention in question relates to an insulating plaster and a insulating plaster system, which contains the insulating plaster.

In addition, the invention in question relates to a thermal insulation composite system (ETICS), which has a thermal insulation panel and an insulating plaster system.

Finally, the invention in question relates to an insulating plaster panel, which is particularly suitable for internal insulation.

While the thermal insulation of buildings was seen as secondary for new builds and the acquisition of real estate until the 1980s, it has increasingly moved back into focus due to rising energy prices, an increased environmental awareness and not least due to legislative measures, such as the German Energy Saving Regulation (EnEV).

New builds and old buildings are predominantly insulated by means of a so-called external insulation, i.e. the external sides of the building are equipped with insulation material.

Normally, thermal insulation composite systems (ETICS) are preferably used for thermal insulation, said systems being constructed of a panel-shaped insulation material, a reinforcement layer being applied to the exterior of this and consisting of a reinforcement mortar and a reinforcement fabric and a finishing plaster. The insulation panels are usually designed on the basis of plastics, particularly rigid polystyrene foams (PS), such as polystyrene particle foam (EPS), extruded polystyrene foam (XPS) or on the basis of rigid polyurethane foams (PUR). Thermal composite systems based on the above plastic insulation panels have outstanding insulating properties in ideal conditions, but have the disadvantage that they form a moisture barrier and moisture from the brickwork cannot be released into the environment, which often leads to the formation of mould and algae. In addition, the moisture increases the thermal conductivity of the system, which is why the theoretical heat transfer coefficients (U-values) according to EN ISO 6946 are often not achieved in practice.

In addition, such thermal insulation composite systems (ETICS) have thicknesses of 15 to 20 cm in order to achieve sufficient thermal insulation, which often leads to an optical impairment of the insulated facade and reduced incidence to light into the building through the windows. To reduce the thickness of the thermal composite systems (ETICS), vacuum insulation panels (VIP) are being used increasingly in recent times, which enable effective thermal insulation with thermal insulation composite systems of a thickness of approx. 10 cm. However, these thermal insulation composite systems also have the crucial disadvantage that they are not open to diffusion, i.e. moisture from the brickwork cannot be emitted into the environment.

On the other hand, the alternatively used insulation materials that are open to diffusion, for example those based on mineral wool or natural, organic fibres such as wood, cork, hemp and reed fibres, are often lacking the necessary mechanical stability and structural integrity; these systems are in fact designed flexibly and not dimensionally stably. In addition, these systems have a considerably lower insulating effect in comparison with plastic panels and vacuum insulation panels.

Thermal insulation composite systems based on organic polymers or contain organic natural products all have in common the fact that they are flammable and must be treated with special chemicals to reduce combustibility and flammability in general, which in turn however is often associated with increased environmental pollution and risk to health.

Insulating plasters are also used, which contain a binder and heat-insulating additives. Such insulating plasters are generally open to diffusion, i.e. moisture from the brickwork can be emitted to the environment; however, the insulating effect and mechanical load capacity of such insulating plasters is considerably reduced in comparison to thermal insulation composite systems, restricting the use of thermal insulating plasters to a few uses.

For this reason, there has been no lack of effort made in the prior art to improve existing thermal insulation systems for the thermal insulation of buildings:

For example, DE 10 2012 101 931 A1 relates to a facade insulating system with a substructure in the timber frame construction, an insulating layer formed from mineral wool panels and a plaster layer, wherein a support fabric exists on the insulating layer which is intended to provide the insulation with an increased mechanical load capacity.

Furthermore, DE 10 2010 029 513 A1 relates to a thermal insulating powder mixture, which is made into thermal insulating moulded bodies and consists of a mixture of silicic acid and at least one fibrous material.

DE 10 2011 109 661 A1 relates to an insulating board and a special arrangement of a number of insulating boards on a building wall, which are connected by means of a capillary-active adhesive for moisture control.

While the aforementioned systems can improve at least specific individual aspects of conventional thermal insulation systems, they however do not make it possible to overcome the principle disadvantages of conventional thermal insulation systems.

Attempts have also been made as it were to improve the efficiency of thermal insulation systems by using special materials. In particular, attempts have been made to incorporate aerogels into insulation or insulation systems in order to increase their insulating effect. Aerogels are highly porous solids, more than 90 vol% of which consists of pores. Due to the extremely high porosity, aerogels are outstandingly suited, at least in theory, to thermal insulation and have thermal conductivity figures $\lambda$ in the range of 0.012 to 0.020 W/(mK). The aerogel that are usually used for insulating purposes are made up of silicon dioxide or condensed silicic acid and are extracted from silicates by means of the sol-gel process. As well as the good thermal insulating properties, aerogels are also characterised by good sound insulation and non-flammability. Due to the high porosity, aerogels however only have an extremely low mechanical stability and are destroyed even under low mechanical loads.

Due to the good thermal insulation properties of silicate-based aerogels in particular, a number of attempts to incorporate aerogels into insulation have been carried out nonetheless. Aerogels are incorporated into insulation panels made of mineral wool among other things; a corresponding product is commercially available under the trade name Aerowolle®.

In addition, attempts have also been made to incorporate aerogels into insulating plasters, wherein the mechanical workability, particularly the application of the insulating plaster by means of plastering machines has proven to be difficult as the fragile aerogel particles are usually destroyed when being applied under pressure to the building wall.

DE 10 2011 119 029 A1 and EP 2 597 072 A1 relate to an insulation for the production of an insulating element, wherein the insulation contains aerogel particles and at least one inorganic or organic binder. The binder content should be less than 3 vol%, with regard to the entire volume of the insulation, and the insulation also contains expanded or extruded polystyrene particles.

WO 2010/126792 A1 discloses compositions with an aerogel component, which has a slight, thermal conductivity. In addition, methods for manufacturing suspensions and compositions are disclosed, which for example include the displacement of the aerogel component with a tenside, a binder and other ingredients, such as fibres. The compositions can be suspensions, which can be used in coating applications or as self-supporting solid composite materials.

US 6,217,646 B1 relates to a mortar composition for pressure application by means of spraying to even out a surface. The mortar composition contains hydraulic lime, Portland cement and vinyl acetate dry polymer as active ingredients. In addition, the composition has as the filler and as the main weight component a mineral filler, preferably quartz sand. After applying the mortar to a surface, this can still be surface modelled after an initial hardening process. In addition, a wide range of additives can be used to improve the characteristics profile of the mortar composition. These optional additives include hollow glass or ceramic balls, defoamers, water retaining agents, rheology suspension agents, hydrophobic agents, dewatering agents and catalysts.

Furthermore, EP 2 722 319 A2 relates to an insulating plaster composition for forming a sound and/or thermal insulation of a building wall or ceiling, comprising aerogel particles and at least one binder. The composition contains at least one cementitious binder, particularly a cementitious binder combination. In addition, a method for forming a sound and/or thermal insulation is described as well as a sound and/or thermal insulation from an insulating plaster composition. Furthermore, a thermal insulation system comprising a sound and/or thermal insulation from an insulating plaster composition is described.

EP 2 799 409 A1 relates to a dry mix for manufacturing high-performance insulating materials, which exist substantially of 60 to 90 vol% of a water-repellent, particulate silica aerogel, 0.5 to 30 vol% of a purely mineral binder, 0.2 to 20 vol% of a porous, insoluble or slowly soluble additive, up to 5 vol% of reinforcing fibres and up to 5 vol% of processing agents. After mixing the dry composition with water, the resulting suspension can be applied to a surface or formed as self-supporting moulded bodies, wherein high pressure can be applied without the thermal insulation capacity being impaired.

However, even the aforementioned systems have not yet managed to decisively improve the principle disadvantages of using aerogels, namely the lower mechanical load capacity and the resulting lowered stability as well as the insulating effect of the insulation being considerably reduced in practice.

For this reason, the object of the present invention is to provide thermal insulating systems, wherein the previously described problems and disadvantages arising in connection with the prior art should be at least largely avoided or at least attenuated.

In particular, it is the object of the present invention to provide a dry building material mix for manufacturing thermal insulating plasters, which can be processed as conventional thermal insulating plaster but have considerably improved thermal insulation properties.

In addition, another object of the present invention is to provide thermal insulation systems, particularly thermal insulation composite systems, which are open to diffusion, have a considerably reduced thickness in comparison to conventional systems while simultaneously exhibiting improved thermal insulation properties.

The above described task will be solved according to the invention by a dry building material compound according to claim 1; further advantageous refinements and embodiments of the inventive dry building material compound are the object of the respective dependent claims.

A further object of the present invention is the use of the inventive dry building material mix according to the invention for manufacturing an insulating plaster according to claim 4.

A further object of the present invention is an insulating plaster according to claim 5 or according to claim 6.

Another further object of the present invention is a multi-layered insulating plaster system according to claim 7; further advantageous further refinements and embodiments of this invention are the subject of the respective dependent claims.

A further object of the present invention is a thermal insulation composite system, comprising a thermal insulation panel and an insulating plaster system, as per claim 10; further advantageous refinements and embodiments of this aspect of the invention are the subject of the respective dependent claims.

Finally, a further object of the present invention is an insulating plaster panel according to claim 12.

It is understood that the subsequent specification of values, figures and ranges are not intended to be limiting in this respect of values, figures and range information; rather, it is obvious to the person skilled in the art that there may be deviations from the stated ranges or information in a particular case or relating to the use without the context of the present invention being left.

Moreover, all values, parameters or similar mentioned below can basically be determined or defined using standard or standardized or explicitly specified determination methods or using determination methods commonly used by the person skilled in the art.

On this basis, the invention in question will be described in detail below.

The object of the present invention – according to a **first** aspect of the present invention – is thus a dry building material mix for manufacturing an insulating plaster, wherein the dry building material mix contains

(A) an aerogel in quantities of 5 to 35 wt.-%, in relation to the dry building material mix,

(B) at least one lightweight aggregate, particularly perlite, in quantities of 40 to 75 wt.-%, in relation to the dry building material mix,

(C) at least one lime-based binder, particularly hydraulic lime, in quantities of 8 to 40 wt.-%, in relation to the dry building material mix,

(D) at least one cement-based binder, particularly white cement, in quantities of 1.5 to 10 wt.-%, in relation to the dry building material mix, and

(E) at least one additive in quantities of 0.1 to 5 wt.-%, in relation to the dry building material mix,

wherein the dry building material mix contains the aerogel and the lightweight aggregate in a

weight-based ration of aerogel to lightweight aggregate of 1 : 1 to 1 : 13 and wherein the dry building material mix contains the lime-based binder and the cement-based binder in a weight-based ratio of lime-based binder to cement-based binder of 1 : 1 to 15 : 1.

Within the scope of the present invention, it is thereby preferable if the aerogel is designed on a silicate basis, consists particularly at least substantially of silicon dioxide, is preferably a pure silicon dioxide aerogel.

The aerogel can be made water-repellent if applicable, which positively influences the hydrophobic properties of the insulation on one hand, but also reduces the porosity of the aerogel on the other hand, thus attenuating the insulating effect – albeit only slightly. In addition, a water-repellent aerogel no longer conforms to the fuel class A1 as per DIN EN 13501-1 and DIN 4102-1, being instead class A2, i.e. evidence of the actual non-flammability of the aerogel must be produced.

The aerogel can be made water-repellent using conventional methods, which are familiar to the person skilled in the art such that further embodiments can be dispensed with at this point. Exemplary reference can be made, for example, to U. K. H. Bangi, A. V. Rao und A. P. Rao "A new route for preparation of sodium-silicate-based hydrophobic silica aerogels via ambient-pressure drying", Sci. Technol. Adv. Mater. 9, 2008.

With the dry building material mix according to the invention, insulating plasters are available that exhibit a considerably improved mechanical stability as compared to conventional aerogel-containing insulating plasters.

As with conventional, aerogel-free plaster systems, the dry building material mix according to the invention can be made into an insulating plaster by simply mixing with water, said insulating plaster can be mechanically applied to building walls and has considerably improved thermal insulation properties alone and as part of the thermal insulation composite system as compared with the prior art.

In addition, the insulating plaster according to the invention is open to diffusion, i.e. moisture from the brickwork can be emitted to the environment, whereby the purely theoretically achievable heat transfer coefficients of the insulation are actually also achieved.

Preferably, the dry building material mix contains the aerogel in quantities of 10 to 30 wt.-%, very particularly preferably 15 to 25 wt.-%, in relation to the dry building material mix. Specifically in the above mentioned mixture ranges, particularly stable and durable insulating plasters are obtained, which have considerably improved insulating properties as compared to conventional insulating plaster systems.

Particularly good results are obtained within the scope of the present invention if the aerogel contained in the dry building material mix has a particle size of 0.01 to 10 mm, specifically 0.05 to 8 mm, preferably 0.1 to 7 mm, more preferably 0.2 to 6 mm, particularly preferably 0.5 to 5 mm, very particularly preferably 0.5 to 4 mm, extremely preferably 0.5 to 2 mm. The aerogels used within the scope of the present invention with particle sizes in the aforementioned ranges generally have a relatively high mechanical stability on one hand and are particularly compatible with the other particles contained within the dry building material mix on the other hand.

The aerogel usually has a bulk density of 0.05 to 0.320 g/cm$^3$, particularly 0.08 to 0.27 g/cm$^3$, preferably 0.12 to 0.25 g/cm$^3$, more preferably 0.13 to 0.22 g/cm$^3$, particularly preferably 0.14 to 0.20, very particularly preferably 0.15 to 0.16 g/cm$^3$.

Particularly good results are obtained within the scope of the present invention if the aerogel has an absolute pore diameter in the range of 2 to 400 nm, particularly 5 to 300 nm, preferably 8 to 200 nm, more preferably 10 to 130 nm, particularly preferably 10 to 70 nm. Aerogels which have pore sizes in the aforementioned range exhibit an extremely low thermal conductivity on one hand and a comparatively high mechanical stability on the other.

According to a preferred embodiment of the present invention, the aerogel is at least substantially dimensionally stable under the contract conditions of the prepared dry building material mix, i.e. particularly as insulating plaster. It is thereby particularly advantageous if at least 70 wt.-%, preferably at least 80 wt.-%, more preferably at least

90 wt.-%, particularly preferably at least 95 wt.-% of the used aerogel particles remain dimensionally stable under contract conditions. It is a feature of the aerogel used according to the invention that the aerogel particles, particularly upon mechanical application specifically with the help of plastering machines effecting a pressure of up to 7 or 8 bar on the aerogel particles, remain dimensionally stable and are not destroyed, which leads to the particularly good thermal insulation properties with simultaneously high mechanical residence of the insulating plaster according to the invention.

With aerogels that have the aforementioned parameters and properties, a particularly more mechanically resistant, durable and outstanding heat-insulating insulating plaster can be obtained. In particular, the aerogel particles exhibit a considerably higher mechanical load capacity and resistance when incorporated into the plaster or into the dry building material mix than is the case with comparable products of prior art to date.

Within the scope of the present invention, preferably used water-repellent aerogels also have a contact angle with water of 110 to 165°. Furthermore, the thermal conductivity of such preferably used water-repellent aerogels can be in the range of 0.015 to 0.032 W/(mK), particularly 0.019 to 0.025 W/(mK), preferably 0.020 to 0.022 W/(mK). Particularly good results are also obtained within the scope of the present invention if the thermal conductivity of the aerogels is within the range of 0.015 to 0.016 W/(mK).

In addition, it is provided within the scope of the present invention that the dry building material mix also contains at least one lightweight aggregate.

The additives applied or used within the scope of the present invention are known as such to the person skilled in the art. The term “additive” should be taken to mean particularly concrete aggregates according to DIN 1045 within the scope of the present invention. The additives are fillers with particle sizes that are suitable for the respective production of binders. For further information about the term “aggregate”, reference can be made particularly to Römpp Chemielexikon, 10th Edition, Georg-Thieme-Verlag, Stuttgart/New York, Volume 1, 1998, Pages 419 and 420, keyword: “Concrete aggregate” and to the literature referenced there, the particular content is hereby completely implicit by its reference.

The aggregate is generally selected from natural or artificial stones, metals or glasses. In this context, particularly good results are obtained within the scope of the present invention if the aggregate is a lightweight aggregate, particularly with a gross grain density of maximum 2.0 $kg/dm^3$. It has hereby been proven to be preferable if the lightweight aggregate is selected from the group of volcanic rock, perlite, vermiculite, pumice, glass foam or expanded glass, expanded clay, expanded shale, polystyrene, tuff, expanded mica, lava rock, lava sand, foam plastics and their compounds, preferably perlite.

At the same time, particularly good results are obtained within the scope of the present invention if the lightweight aggregate has a particle size of maximum 4 mm, particularly maximum 3 mm. Lightweight aggregates with the aforementioned particle sizes, specifically in the case of perlite, can interact with aerogel particles – without being bound by this theory –, wherein the aerogel is embedded particularly in the cavities existing between the individual perlite particles in the dry building material mix and in the insulating plaster and protected there from mechanical destruction.

Within the scope of the present invention, it can be provided that the dry building material mix contains the lightweight aggregate in quantities of 45 to 70 wt.-%, particularly preferably 50 to 65 wt.-%, in relation to the dry building material mix.

Particularly good results are obtained within the scope of the present invention if the dry building material mix contains the aerogel and the lightweight aggregate in a weight-based ration of aerogel to lightweight aggregate of 1 : 2 to 1 : 6, very particularly preferably 1 : 2 to 1 : 4.

Particularly in the aforementioned weight-based ratios of aerogel to lightweight aggregate, it can be seen that the aerogel particles are preserved in the insulating plaster, particularly even during mechanical application.

The dry building material mix contains binder according to the invention. In particular, particularly good results are achieved if the dry building material mix contains the binder in quantities of 10 to 50 wt.-%, preferably 12 to 40 wt.-%, particularly preferably 15 to 35 wt.-%. The dry building material mix according to the invention and the thermal insulating plaster according to the invention contain the binders thereby preferably in a rather lessor amount, while the aerogel and aggregates exist in a considerably higher amount, which leads to considerably improved thermal insulation properties.

Within the scope of the present invention, the dry building material mix has at least two different binders. According to the invention, the dry building material mix has a lime-based binder, particularly hydraulic lime, and a cement-based binder, particularly white cement. Mixtures of the aforementioned binders have a particularly good binding behaviour, have a consistency and viscosity that guarantees good applicability of the insulating plaster and leads to an outstanding final stability despite the high proportion of aggregates. In addition, the lime content also inhibits the formation of mould and algae due to its high alkalinity. The insulating plaster according to the invention, which can be obtained with the dry building material mix, is open to diffusion such that a formation of mould is countered from the outset, but the use of a lime-based binder also suppresses the formation of mould and algae in the case that the insulating plaster system is applied under unfavourable conditions.

A hydraulic lime is to be understood within the scope of the present invention as a mixture of burnt lime (calcium hydroxide) with hydraulic factors, such as calcium silicates and calcium aluminates or iron oxide. The hydraulic proportion of the binder hardens through hydration and requires no carbon dioxide for binding. The binder hereby obtains a high initial strength, while the non-hydraulic part of the lime slowly hardens or binds by means of diffusion of carbon dioxide into the insulating plaster.

According to the invention, the dry building material mix contains the lime-based binder in quantities of 8 to 40 wt.-%, particularly preferably 10 to 30 wt.-%, very particularly preferably 15 to 30 wt.-%, in relation to the dry building material mix.

Within the scope of the present invention, it is further provided that the dry building material mix contains the cement-based binder in quantities of 1.5 to 10 wt.-%, particularly preferably 2 to 8 wt.-%, very particularly preferably 2 to 5 wt.-%, in relation to the dry building material mix.

According to a particularly advantageous embodiment of the present invention, the dry building material mix contains the lime-based binder and the cement-based binder in a weight-based ratio of lime-based binder to cement-based binder of 2 : 1 to 10 : 1, particularly preferably 3 : 1 to 8 : 1, very particularly preferably 4 : 1 to 7 : 1.

Furthermore, it is provided within the scope of the present invention that the dry building material mix contains at least one additive, particularly at least one admixture. It can hereby be provided that the additive is selected from the group of plasticizers, thickeners, delayers, activators, stabilising agents (stabilisers), rheological suspending agents, admixtures for adjusting the water retention capacity (water retention agents), dispersing agents, sealing agents, air-entraining agents and their compounds.

According to the invention, it is provided that the dry building material mix contains the additive in quantities of 0.1 to 5 wt.-%, preferably 0.3 to 3 wt.-%, more preferably 0.5 to 1 wt.-%, in relation to the dry building material mix.

In addition, it can be provided within the scope of the present invention that the dry building material mix has a bulk density in the range of 100 to 400 kg/m$^3$, particularly 150 to 350 kg/m$^3$, preferably 175 to 300 kg/m$^3$, more preferably 200 to 250 kg/m$^3$.

A further object of the present invention – according to a **<u>second</u>** aspect of the present invention – is the use of a dry building material mix, particularly a plaster mortar, as described above, for manufacturing an insulating plaster, particularly a thermal insulating plaster, for the thermal insulation of structures, particularly of buildings.

For further details of this inventive aspect, reference can be made to the preceding embodiments of the dry building material mix according to the invention, which apply accordingly in relation to the use according to the invention.

A further object of the present invention – according to a **third** aspect of the present invention – is an insulating plaster, particularly a thermal insulating plaster, for the thermal insulation of structures or buildings, which from a previously described dry building material mix by means of mixing with water the dry building material mix is obtainable in quantities of 70 to 150 wt.-%, in relation to the dry building material mix, wherein the hardened insulating plaster has a compressive strength of 0.4 to 2.5 $N/mm^2$.

Within the scope of the present invention, particularly good results are obtained if the insulating plaster is obtainable by mixing with water in quantities of 80 to 130 wt.-%, preferably 90 to 110 wt.-%, relating to the dry building material mix. The insulating plaster according to the invention can thus be mixed and handled like a conventional insulating plaster as known from the prior art.

Generally, the hardened insulating plaster already has an outstanding barrier effect against running water without further coating, whereas water vapour can diffuse relatively easily through the hardened insulating plaster. Thus the hardened insulating plaster within the scope of the present invention usually has a water absorption coefficient w in the range of 1.0 to 1.8 $kg/(m^2 \cdot h^{0.5})$, particularly 1.10 to 1.80 $kg/(m^2 \cdot h^{0.5})$, preferably 1.20 to 1.70 $kg/(m^2 \cdot h^{0.5})$.

In general, the insulating plaster is applied to the surface face to be treated by means of conventional methods, particularly by means of mechanical spraying methods. It is a feature of the insulating plaster according to the invention that it can be applied despite its high content of aerogel by means of mechanical spraying methods, particularly by means of plastering machines onto the surface face to be insulated, particularly house walls. As previously stated within the context of the first inventive aspect, the insulating plaster according to the invention is characterised in that the aerogel contained therein is at least substantially dimensionally stable under contract conditions, particularly during mechanical application, wherein at least 70 wt.-%, particularly at least 80 wt.-%, preferably at least 90 wt.-%, more preferably at least 95 wt.-% of the used aerogel particles remain dimensionally stable.

For further details of this inventive aspect, reference can be made to the preceding embodiments of the dry building material mix according to the invention and to the use according to the invention, which apply in relation to the insulating plaster according to the invention.

A further object of the present invention – according to a **fourth** aspect of the present invention – is an insulating plaster, containing at least one aerogel, which is particularly obtainable from a previously described dry building material mix, wherein the hardened insulating plaster has a thermal conductivity in the range of 0.02 to 0.055 W/(mK), particularly 0.022 to 0.050 W/(mK), preferably 0.024 to 0.045 W/(mK), more preferably 0.026 to 0.040 W/(mK), particularly preferably 0.028 to 0.032 W/(mK). The insulating plaster according to the invention thereby has thermal conductivities as are usually observed only in thermal insulation composite systems.

Generally, the hardened insulating plaster has a compressive strength of 0.4 to 2.5 $N/mm^2$, particularly 0.4 to 2.0 $N/mm^2$, preferably 0.45 to 1.6 $N/mm^2$, more preferably, 0.45 to 1.4 $N/mm^2$. The aerogel-containing insulating plaster according to the invention thus has an extremely high compressive strength for thermal insulating plasters.

Within the scope of the present invention, it is advantageous if the hardened insulating plaster has a water vapour diffusion resistance coefficient $\mu$, determined in accordance with DIN EN ISO 12542, in the range of 2 to 9, particularly 3 to 7, preferably 4 to 6. As previously mentioned, the insulating plaster according to the invention is characterised in that it is open to diffusion and moisture can be emitted from the brickwork into the environment, which counteracts the formation of mould and algae and also increases the stability of the thermal insulating system.

Generally, the hardened insulating plaster has a dry bulk density in the range of 200 to 350 $kg/m^3$, particularly 225 to 325 $kg/m^3$, preferably 250 to 300 $kg/m^3$.

With regard to the layer thickness, with which the insulating plaster is applied to a surface, particularly to a building wall, this can vary over a wide range. Particularly good results are however obtained within the scope of the present invention if the hardened insulating plaster is applied with a layer thickness of 1 to 14 cm, particularly 1 to 10 cm, preferably 1 to 8 cm, more preferably 2 to 7 cm, particularly preferably 3 to 6 cm, to the surface to be insulated, particularly the internal or external surface of a building wall. It is thus further advantageous if the hardened insulating plaster is applied to the external surface of a building wall, i.e. is used as external insulation. The thermal insulating plaster according to the invention can thereby be applied particularly directly to the brickwork, or the brickwork can be specifically prepared in advance, for example by applying a primer coat. Primer coats, which reinforce the brickwork or improve the adhesion of plaster to the brickwork, are readily known to the person skilled in the art such that further embodiments can be dispensed with at this point.

With regards the layer thickness of the hardened insulating plaster, the aforementioned value ranges only apply for a single application of the inventive insulating plaster or insulating plaster system, which contains the insulating plaster according to the invention, whereas when using the insulating plaster according to the invention in a thermal insulation composite system (ETICS), particularly in a thermal insulation composite system (ETICS) containing a thermal insulation panel, considerably lesser layer thicknesses of the insulating plaster according to the invention are used, as described below.

It is a feature of the insulating plaster according to the invention that it can be used both for the internal and external area, particularly wherein outstanding heat insulating results with simultaneously very good mechanical load capacity are achieved even with the sole use of the inventive insulating plaster or an insulating plaster system containing this in the field of external insulation. The sole application of the thermal insulating plaster according to the invention or an insulating plaster system is recommended, for example, when the contours of a building need to be reproduced in exact detail. Otherwise a thermal insulation composite system (ETICS) is preferred, as an even better thermal insulation can be achieved with this.

Within the scope of the present invention, it can also be provided that the hardened insulating plaster has the flammability A1 or A2 as per DIN 4102. As the insulating plaster according to the invention preferably has a purely mineral basis, it is not flammable and has the flammability A1 as per DIN 4102. When using water-repellent aerogels and organic additives, the insulating plaster according to the invention is still not flammable, for which however proof must be provided, which corresponds to flammability A2 as per DIN 4102.

For further details of this inventive aspect, reference can be made to the preceding embodiments relating to the other inventive aspects, which apply in relation to the insulating plaster according to the invention.

The object of the present invention – according to a **fifth** aspect of the present invention – is a multi-layered insulating plaster system, which has at least one insulating plaster system consisting of at least an at least one aerogel-containing insulating plaster, as previously described, and a surface coating, wherein the surface coating is arranged at least on one side of the insulating plaster layer facing away from the surface, particularly a building wall, being provided with the insulating plaster system. Hereby, it is preferred if the surface coating at least substantially covers the side of the insulating plaster layer facing away from the surface provided with the insulating plaster system.

The application of the surface to be insulated can thereby occur continuously or only in sections, wherein a continuous surface coating is preferred particularly on the external side of the insulating plaster system, i.e. on the side of the insulating plaster system facing away from the surface to be insulated.

In general, the surface coating is watertight, particularly impervious to driving rain, and/or open to diffusion. Preferably used surface coatings according to the invention thus prevent the penetration of liquid water into the insulating plaster system, but facilitate on the other hand the diffusion of water vapour from the brickwork into the environment, whereby the brickwork is constantly dehumidified.

Particularly good results are obtained within the scope of the present invention if the surface coating has a layer thickness of 50 to 400 µm, particularly 100 to 300 µm, preferably 150 to 250 µm. The surface coating can be thus produced by one-time or optionally by repeated application, i.e. the surface coating within the scope of the invention can exist of several layers, wherein the total thickness of the surface coating is however preferably within the aforementioned range.

Surface coatings on a polymer basis, specifically on an acrylate basis, have proven themselves to be particularly suitable. These are in fact permeable for water vapour, but still impermeable by liquid water and have an outstanding expandability of up to 150%. Such surface coatings thereby has a crack bridging effect, i.e. if cracks occur in the insulation, the surface coating will not inevitably crack in the same way and thus allow water to enter the insulating system, but rather its protective function will be maintained. This increases the stability of the insulating system or insulating plaster system considerably. Particularly suitable acrylate dispersions are available as water-based dispersions with a solid content of up to 60% and contain no organic solvent. Such acrylate dispersions are commercially available and readily familiar to the person skilled in the art.

In addition, it can be provided within the scope of the present invention that at least one primer coat is arranged between the aerogel-containing insulating plaster layer and the surface coating. The primer coat can likewise consist of one or several layers and has particularly a layer thickness of 25 to 100 µm, specifically 35 to 75 µm, preferably 45 to 60 µm. In principle, all primers guaranteeing an improved adhesion of the surface coating to the material to be coated and also reinforcing the predominantly mineral-based plaster system are suitable as a primer. Such primer systems are known and familiar to the person skilled in the art. It is however preferred if the used primer is also open to diffusion, i.e. does not prevent dehumidification of the brickwork.

According to a preferred embodiment of the present invention, at least one additional insulating plaster layer particularly not containing aerogel is arranged between the insulating plaster layer containing one aerogel and the primer coat or the surface coating. In this connection, it is also preferred if the additional insulating plaster layer is arranged on the side of the one aerogel-containing insulating plaster facing away from the surface provided with the insulating plaster system.

The use of a further thermal insulating plaster particularly increases the mechanical load capacity, such as the compressive strength of the entire insulating plaster system and also specifically protects the aerogel-containing insulating plaster when arranged on an external side.

If the insulating plaster system contains an additional thermal insulation plaster layer, this generally has a layer thickness in the range of 0.1 to 2 cm, particularly 0.2 to 1.5 cm, preferably 0.3 to 1.0 cm, more preferably 0.4 to 0.7 cm. Within the scope of the present invention, the additional insulating plaster layer, which particularly does not contain an aerogel, is therefore only applied to the external side of the insulating plaster layer containing one aerogel with an extremely thin layer thickness in order to protect said aerogel-containing insulating plaster layer from mechanical influences.

In addition, within the scope of the present invention, it is preferable if the additional insulating plaster layer has a thermal conductivity in the range of 0.02 to 0.12 W/(mK), particularly 0.03 to 0.10 W/(mK), preferably 0.05 to 0.09 W/(mK), more preferably 0.06 to 0.08 W/(mK).

Likewise, particularly good results are obtained within the scope of the present invention if the additional insulating plaster layer has a compressive strength of 1.3 to 4.0 $N/mm^2$, particularly 1.4 to 3.5 $N/mm^2$, preferably 1.5 to 3.2 $N/mm^2$, more preferably 1.6 to 3.0 $N/mm^2$.

In general, the additional insulating plaster layer has a water vapour diffusion resistance coefficient µ, determined in accordance with DIN EN ISO 12542, in the range of 3 to 10, particularly 4 to 8, preferably 5 to 7.

Furthermore, it can be provided that the additional insulating plaster layer has a dry bulk density in the range of 200 to 350 kg/m$^3$, particularly 250 to 325 kg/m$^3$, preferably 290 to 310 kg/m$^3$.

By using the additional insulating plaster layer, particularly not containing aerogel, the mechanical properties of the insulating plaster system can be improved, wherein at the same time the insulation efficiency and the water vapour diffusion resistance of the insulating plaster system are only slightly influenced due to the low layer thickness of the additional insulating plaster layer.

According to a preferred embodiment of the present invention, the additional insulating plaster layer contains a lightweight aggregate. With regard to the quantity of lightweight aggregate in the additional insulating plaster layer, this can vary over a wide range. Particularly good results are however obtained if the additional insulating plaster layer contains a lightweight aggregate in quantities of 30 to 90 wt.-%, particularly 40 to 85 wt.-%, preferably 50 to 80 wt.-%, in relation to the additional insulating plaster or a corresponding dry building material mix.

In addition, the additional insulating plaster layer generally contains at least one binder. Within the scope of the present invention, it is however preferred when the additional insulating plaster layer contains at least one lime-based binder, particularly hydraulic lime, and at least one cement-based binder, particularly white cement. Thereby, it is preferable according to the invention if the additional insulating plaster layer contains the lime-based binder in quantities of 5 to 60 wt.-%, particularly 10 to 40 wt.-%, preferably 10 to 30 wt.-%, in relation to the additional insulating plaster or a corresponding dry building material mix and contains the cement-based binder in quantities of 1 to 15 wt.-%, particularly 2 to 10 wt.-%, preferably 3 to 5 wt.-%, in relation to the additional insulating plaster or a corresponding dry building material mix.

The lightweight aggregate used for the additional insulating plaster layer has particularly a gross grain density of maximum 2.0 kg/dm$^3$ and is particularly selected from the group of volcanic rock, perlite, vermiculite, pumice, glass foam or expanded glass, expanded clay, expanded shale, polystyrene, tuff, expanded mica, lava rock, lava sand, foam plastics and their compounds, preferably perlite, particularly with a grain density of maximum 3 mm, particularly maximum 2 mm.

With the above named weight ratios, very good resistances and a very good and consistent binding of the additional insulating plaster layer can be observed for one thing. In addition, the adhesion to the insulating plaster layer containing one aerogel is also increased, as similar binder systems are preferably used in each case.

If the insulating plaster system has a further insulating plaster layer, particularly not containing aerogel, in addition to the insulating plaster layer containing one aerogel, a supporting layer is generally arranged between the one aerogel-containing insulating plaster layer and the additional insulating plaster layer. The supporting layer is particularly designed in the form of a reinforcement and is preferably a fibreglass fabric or a fibreglass network. The use of a supporting layer, particularly in the form of a reinforcement, also lends the insulating plaster system according to the invention further mechanical load capacity and avoids the formation of cracks, as stresses are compensated. Furthermore, a reinforcement enables the two insulating plaster layers to be directly in contact with each other and so they can form a particularly deep bond, wherein both insulating plaster layers are anchored on and in the reinforcement. The use of fibreglass fabrics or fibreglass networks is particularly advantageous as these are both alkali-resistant and non-flammable. Preferably, reinforcements, particularly fibreglass fabrics, are used with mesh sizes or a size of the mesh openings in the range of 16 $mm^2$ to 400 $mm^2$, particularly 49 $mm^2$ to 300 $mm^2$, preferably 100 $mm^2$ to 200 $mm^2$.

A preferred insulating plaster system according to the invention has the following structure based on a surface provided with the insulating plaster system, i.e. from internal to external:

Insulating plaster layer, containing at least an aerogel,
Support layer,
Additional insulating plaster layer,
Primer coat and
Surface coating.

Such insulating plasters combine both a high insulation efficiency and a high mechanical load capacity.

The insulating plaster system within the scope of the present invention preferably has a water vapour diffusion resistance coefficient μ, determined in accordance with DIN EN ISO 12542 in the range of 4 to 12, particularly 5 to 10, preferably 6 to 8.

In addition, it is preferred within the scope of the present invention if the insulating plaster system has the flammability A1 or A2 as per DIN 4102. The insulating plaster system according to the invention is thus non-flammable and consequently satisfies the highest fire protection regulations, which is why it can also be installed without problems in sensitive areas.

In general, the insulating plaster system has a layer thickness of 1.5 to 14 cm, particularly 2.5 to 9 cm, preferably 3.5 to 8 cm.

However, the aforementioned layer thicknesses or thicknesses of the insulating plaster system only apply if the insulating plaster system is applied directly onto a building wall, particularly a brickwork. If the insulating plaster system according to the invention is used as part of a thermal insulation composite (ETICS), it can have considerably lesser layer thicknesses. The insulating plaster system according to the invention thus allows an effective thermal insulation with lesser layer thicknesses and an outstanding mechanical load capacity.

For further details of this inventive aspect, reference can be made to the preceding embodiments relating to the other inventive aspects, which apply in relation to the insulating plaster system according to the invention.

The object of the present invention – according to a **sixth** aspect of the present invention – is a thermal insulation composite system (ETICS), which has a thermal insulation panel and a previously described insulating plaster system. It is thereby particularly provided according to the invention that the thermal insulation panel is arranged on a surface to be insulated and hereafter the insulating plaster system is arranged, i.e. on the external side or on the side of the thermal insulation panel facing away from the surface to be insulated.

The thermal insulation composite system according to the invention is particularly characterised in that it only has an extremely slight thickness, is open to diffusion for water vapour and also has a very high mechanical resilience, wherein comparable or even improved insulating properties are achieved despite the slight layer thickness as compared to conventional thermal insulation composite systems.

In general, the thermal insulation composite system has a thickness of 4 to 12 cm, particularly 5 to 10 cm, preferably 5.5 to 9 cm, more preferably 6 to 8 cm. The layer thickness is thereby dependant on the site conditions, such as the condition of the brickwork and the surroundings.

As a result of the thermal insulation composite system according to the invention, as compared to conventional thermal insulation composite systems having layer thicknesses in the range of 18 to 20 cm, efficient thermal insulation can be achieved with a thickness of the thermal insulation composite system being reduced by more than two-thirds. According to a preferred embodiment of the present invention, the thermal insulation composite system has a water vapour diffusion resistance coefficient μ, determined in accordance with DIN EN ISO 12542 in the range of 4 to 12, particularly 5 to 10, preferably

6 to 8.

In addition, within the scope of the present invention, it is preferred if the thermal insulation composite system has a thermal conductivity in the range of 0.015 to 0.045 W/(mK), particularly 0.017 to 0.040 W/(mK), preferably 0.020 to 0.035 W/(mK), more preferably 0.022 to 0.027 W/(mK).

As previously mentioned, the insulating plaster system according to the invention has as the component of a thermal insulation composite system other layer thicknesses than when used alone. With regard to the layer thickness of the insulating plaster system in the thermal insulation composite system, this can vary over a wide range. Particularly good results are however obtained if the insulating plaster system has a thickness of 0.5 to 6 cm, particularly 1 to 5 cm, preferably 1.5 to 4 cm, more preferably 2 to 3 cm.

In this context, it can be particularly provided that the aerogel-containing insulating plaster layer has a layer thickness in the range of 0.5 to 4 cm, particularly 1 to 3 cm, preferably 1.5 to 3 cm, more preferably 1.5 to 2.5 cm.

At the same time, it can be provided that the additional insulating plaster layer, particularly not containing aerogel, has a layer thickness in the range of 0.1 to 2 cm, particularly 0.2 to 1.5 cm, preferably 0.3 to 1.0 cm, more preferably 0.4 to 0.7 cm. With the aforementioned layer thicknesses of the insulating plaster system or the insulating plaster layers as part of the thermal insulation composite system according to the invention, outstanding results are obtained within the scope of the present invention.

According to a preferred embodiment of the present invention, the thermal insulation composite system has the following layer structure, starting from the surface to be insulated towards the exterior:

Thermal insulation panel,

Insulating plaster layer, containing at least one aerogel,

Support layer,

Additional insulating plaster layer,

Primer coat and

Surface coating.

Particularly good results are obtained with the thermal insulation composite system according to the invention, if a specific thermal insulation panel containing one aerogel, as described below, is used as part of the thermal composite system.

The preferably used thermal insulation panel, particularly for the thermal insulation of structures and buildings, is characterised by the fact that the thermal insulation panel contains at least one aerogel and is open to diffusion along its principal insulation direction. The preferably used thermal insulation panel according to the invention thus permits a transportation of water vapour from the brickwork to the environment. The principal insulation direction of the preferably used thermal insulation panel according to the invention thus runs vertically to the main surface, i.e. the largest surface of the thermal insulation panel, which is synonymously described as the flat surface or broad surface.

The aerogel is arranged in loose filling in the thermal insulation panel. A particularly low water vapour diffusion resistance can thereby be achieved, as no binder prevents the diffusion of the water vapour.

In general, the thermal insulation panel has an aerogel with absolute particle sizes in the range of 1 to 8 mm, particularly 2 to 6 mm, preferably 3 to 5 mm. The use of aerogel with the above particle sizes permits a particularly good water vapour diffusion on one hand, while allowing a very effective insulating effect, wherein the particles are robust enough to withstand with damage vibrations during storage and transportation, cutting and assembling of the thermal insulation panel.

With regard to the water vapour diffusion resistance of the used thermal insulation panel, this can vary over a wide range. However, it is preferable if the thermal insulation panel has a water vapour diffusion resistance coefficient μ, determined in accordance with DIN EN ISO 12542 in the range of 1 to 8, particularly 1 to 6, preferably 2 to 5.

Thermal insulation panels made of polymer foams have considerably higher water vapour diffusion resistance coefficients, determined in accordance with DIN EN ISO 12542. In this way, rigid polyurethane foams and expanded polystyrene foam have μ-values in the range of 50 to 80, while extruded polystyrene foam has μ-values in the range of 80 to 180.

The thermal insulation panels have a thermal conductivity in the range of 0.008 to 0.040 W/(mK), particularly 0.010 to 0.035 W/(mK), preferably 0.011 to 0.030 W/(mK), more preferably 0.012 to 0.020 W/(mK). The preferably used thermal insulation panel thereby virtually achieves the extremely low thermal conductivity of pure aerogel.

The thermal insulation panel has an at least substantially cuboid structure. This makes both the storage and assembly of the thermal insulation panels easier.

In general, the used thermal insulation panel has a thickness in the range of 1 to 8 cm, particularly 2 to 7 cm, preferably 2.5 to 6 cm, more preferably 3 to 5 cm. The used thermal insulation panel has thereby a considerably reduced thickness in comparison with conventional thermal insulation panels based on polystyrene or polyurethane, wherein a

3-fold to 4-fold reduction is possible.

It is preferred that the thermal insulation panel has a base plate, consisting of the narrow sides of the thermal insulation panel and an internal structure with gaps, particularly cavities. The base body can be formed as one piece or several pieces.

The thermal insulation panel preferably has an internal structure parallel to the principal insulation direction with gaps, particularly cavities, being open on at least one side, for receiving the aerogel. In doing so, it can be provided that the gaps are open on both sides and extend over the entire thickness of the thermal insulation panel. As a result of the internal structure with the cavities for receiving the aerogel, the thermal insulation panel receives an increased mechanical stability on one hand; on the other hand, the loose filling of the aerogel in the thermal insulation panel used according to the invention is divided into smaller units, whereby fewer strong forces act upon the aerogel particles during transportation and assembly, i.e. due to vibrations, and these are thus preserved.

The gaps are preferably formed n-sided, particularly four-sided to eight-sided, preferably six-sided. As a result of the internal structure, alveolar cavities are thus preferably created in the thermal insulation panel, which are preferably completely opened vertically to the diffusion direction or to the principal thermal insulation direction.

Particularly good results are obtained thereby if the openings of the gaps have surface areas parallel to the main surface in the range of 1 to 64 $cm^2$, particularly 3 to 36 $cm^2$, preferably 4 to 16 $cm^2$. A grid is preferably therefore formed within the thermal insulation panel as a result of the internal construction, in particular as a result of supports. This rasterization of the thermal insulation panel protects – as mentioned above – the aerogel on one hand, but also facilitates simple assembly of the thermal insulation panel at the building site or an adjustment of the dimensions of the thermal insulation panel in size and shape to the surface to be insulated.

In general, the base body of the thermal insulation panel has wood, plastics or mineral materials or exists at least substantially from this. A plurality of thermoplastic or thermoset plastics are suitable for forming the base body of the used thermal insulation panel according to the invention, in particular plastics based on (i) polyolefin, more preferably polyethylene (PE) or polypropylene (PP); (ii) polymethacrylates (PMA); (iii) polymethylmethacrylates (PMMA); (iv) polyvinyl chloride (PVC); (v) polyvinylidene halide, particularly polyvinylidene fluoride (PVDV) or polyvinylidene chloride (PVDC); (vi) acrylonitrile/butadiene/styrene copolymer (ABS); (vii) polyamides (PA), polycarbonates (PC); (viii) melamine formaldehyde resins; (ix) epoxy resins; (x) phenolic resins or (xi) urea resins can be used.

It is however preferable if the base body of the thermal insulation panel is made of mineral materials, as the thermal insulation panel exhibits the flammability class of A1 or A2 in accordance with DIN 4102 in this case. According to another preferred embodiment, the base body of the thermal insulation panel exists at least substantially of wood; this has the advantage that a high stability is achieved with a relatively low weight and also a further improved permeability for gases, in particular water vapour, is achieved.

In general, the openings of the gaps are at least partially sealed, in particular by means of a trickle guard. In this context, it can be particularly provided that a surface structure being open to diffusion, specifically open to flow, is arranged on the broad surfaces of the thermal insulation panel, wherein it is preferable that the surface structure covers the broad surfaces of the thermal insulation panel. An at least partial or sectional sealing of the opening of the gaps by means of a trickle guard, in particular with a surface structure, prevents an unwanted dropping of the aerogel from the gaps of the thermal insulation panel on one hand. On the other hand, an only sectional covering of the opening ensures an unobstructed diffusion of water vapour through the thermal insulation panel. The surface structure preferably completely covers the broad surface of the thermal insulation panel.

It is preferred if the surface structure is a textile or mineral, preferably a mineral, surface structure, in particular a fabric, woven fabric, knitted fabric, meshwork, stitch-bonded fabric, fleece and/or a felt, or a lattice. In this context, it is preferred if the surface structure is a fabric with a mesh size or lattice spacing of 0.5 to 5 mm, particularly 1 to 4 mm, preferably 1.5 to 3 mm, more preferably 1.7 to 2.5 mm, wherein a fibreglass fabric is preferably used.

The above mentioned surface structures are all open to diffusion or open to flow and allow an unobstructed passage of water vapour. In addition, the use of a surface structure, particularly a fibreglass fabric, with the aforementioned mesh sizes serves not only as a trickle guard against unintended dropping of the aerogel from the gaps of the thermal insulation panel but also in fact as a reinforcement at the same time for a coating being applied to the thermal insulation panel or to a plaster being applied to the thermal insulation panel, particularly a thermal insulating plaster, wherein this can be anchored to the surface structure when using a plaster but does not penetrate the panel. The used thermal insulation panel thereby provides a thermal insulation composite system into which it is integrated with an increased mechanical stability.

The thermal insulation panel is generally applied to the surface to be insulated by means of an adhesive, particularly by means of a 2-component adhesive, especially with a methyl methacrylate basis or polyurethane basis. The use of adhesives in comparison to the use of insulation fixings has the advantage that the thermal insulation panel and consequently a thermal insulation composite system into which it is integrated is not damaged and the formation of a thermal bridge through the insulation fixing is also prevented.

For further aspects of this inventive aspect, reference can be made to the preceding embodiments relating to the other inventive aspects, which apply in relation to the thermal insulating composite system according to the invention.

Finally, a further object of the present invention - according to a **seventh** aspect of the present invention - is an insulating plaster panel, which consists of a previously described insulating plaster containing at least one aerogel or an insulating plaster system as described above.

The insulating plaster panel according to the invention is particularly suitable for interior construction, particularly for roof constructions, especially for under-rafter and inter-rafter insulations.

If used in the interior area, different primers and coatings are usually used than in the field of external insulation. However, this is familiar to the person skilled in the art such that no further embodiments are required for this purpose.

With regard to the thickness of the insulating plaster panel according to the invention, this can vary over a wide range. Particularly good results are also obtained within the scope of the present invention if the insulating plaster panel has a thickness in the range of 1 to 6 cm, particularly 1.5 to 5.5 cm, preferably 1.5 to 5 cm, more preferably 2 to 4 cm.

For further details of this inventive aspect, reference can be made to the preceding embodiments relating to the other inventive aspects, which apply in relation to the insulating plaster panel according to the invention.

Further advantages, features, aspects and characteristics of the present invention will become apparent from the following description of a preferred embodiment according to the invention depicted in the drawings.

Whereby the figures show the following:

Fig. 1 shows a schematic representation of the insulating plaster layer 1 according to the invention, which is attached to a building wall 2;

Fig. 2 shows a schematic representation of the insulating plaster system 3 according to the invention, which is attached to a building wall 2;

Fig. 3 shows a schematic representation of a thermal insulation composite system 8 according to the invention, which is attached to a building wall 2;

Fig. 4 shows the schematic structure of a preferably used thermal insulation panel 9 according to the invention.

In particular, Fig. 1 shows a schematic representation of the insulating plaster layer 1 according to the invention, which is attached to a wall of a building 2 to be insulated. Contrary to what the figures show, it can be particularly provided that the house wall has been pretreated before application of the insulating plaster layer 1 according to the invention, particularly with a primer.

In particular, Fig. 2 shows a preferred embodiment of the insulating plaster system 3 according to the invention, which is attached to a house wall. The insulating plaster system 3 according to the invention particularly has an insulating plaster layer 1 containing at least one aerogel and a surface coating 4 being impervious to driving rain and open to diffusion. Between the surface coating 4 and the insulating plaster layer 1, a primer coat 5 is provided, which provides a good adhesion between the surface coating 4 and the underlying layers of the insulating plaster system 3. Between the primer coat 5 and the insulating plaster layer 1, an additional insulating plaster layer 6 containing no aerogels is arranged and between the insulating plaster layers 1 and 6, there is a supporting layer 7, which preferably consists of a fibreglass fabric with a mesh width of 13 x 13 mm. The insulating plaster system 3 according to the invention is designed to be open to diffusion and impervious to driving rain.

Fig. 3 shows particularly a schematic representation of a preferred thermal insulation composite system 8 according to the invention, which consists of an insulating plaster system 3 and an insulating plaster panel 9. The insulating plaster panel 9 is attached to the house wall 2 by means of a 2-component adhesive 10. The insulating plaster system 3 according to the invention is applied directly onto the thermal insulation panel 9 in the direction of the principal insulation direction, i.e. onto the main surface or broad surface of the thermal insulation panel 9, wherein the at least one aerogel-containing insulating plaster layer 1 directly adjoins the insulating plaster panel 9. A supporting layer 7 and a further insulating plaster layer not containing aerogel 6 follows on the insulating plaster layer 1. Attached to the outside of the insulating plaster layer 6, there is a primer coat 5, onto which the surface coating 4 is then applied. The thermal composite system according to the invention is designed to be open to diffusion in the principal insulation direction, i.e.

vertical to the house wall 2, and impervious to driving rain.

In particular, Figure 4 shows a preferred embodiment of the used thermal insulation panel 9 according to the invention. The thermal insulation panel 9 has a base plate, which is formed from the narrow sides 11 of the thermal insulation panel and an internal structure 12. The internal structure 12 forms hexagonal, particularly alveolar cavities 13, which extend homogeneously over the entire thickness of the thermal insulation panel 9 and contain an aerogel. The main surfaces or broad surfaces of the thermal insulation panel 9 are covered with a surface structure 14, particularly with a fibreglass fabric having a mesh width of 2 x 2 mm, particularly the broad surfaces of the thermal insulation panel 9 are covered with a surface structure. The fibreglass fabric serves on one hand as a trickle guard against unintended falling of the aerogel from the gaps 12 of the thermal insulation panel 9 and on the other hand as an anchor or reinforcement of plaster layers, wherein the plaster does not penetrate into the interior of the panel, at least not substantially into the interior of the panel.

**Exemplified embodiments**

**1. Method for manufacturing the aerogel**

The aerogel used within the scope of the present invention is produced in a multi-stage method, comprising the following procedural steps:

1. Production of the hydrosol

   A commercial sodium-silicate solution is diluted with deionised water and then guided through a strongly acidic cation exchanger resin on the basis of sulfonated and divinyl benzene-crosslinked polystyrene. A hydrosol is obtained as a reaction product, in which the sodium ions of the silicate are almost completely replaced by protons. The completeness of the ion exchange reaction is checked by means of a conductivity measurement.

2. Production of a hydrogel

   The hydrosol obtained in procedural step 1 is heated to 50°C and displaced with N, N-Dimethylformamide with continuous stirring. To accelerate the applicable condensation reaction, molar aqueous ammonia solution is added to the mixture 6, until the solution reaches a weakly acidic pH value in the range of 4.2 to 4.9. The hydrosol is aged for several hours at a constant temperature to form the gel. Then the arising hydrogel is reduced to particle sizes in the range of 0.5 to 1 cm by adding deionised water at a consistent temperature and while stirring. The mixture containing the hydrogel is cooled to 35°C and aged again for several hours.

3. Production of the alcogel

   The hydrogel obtained in procedural step 3 is displaced with methanol until the volume rations of water and methanol are about the same. Then the gel rests for several hours. Afterwards, a majority of the solvent is separated from the reaction mixture by means of filtration. The remaining residue is then displaced with methanol again. A slow solvent replacement takes place, during which water is replaced by methanol. The separation of the solvent mixture and the addition of methanol are repeated as necessary. An alcogel is developed, which matures at a constant temperature for several hours.

   The separated solvent mixture is transferred into a distillation apparatus and separated by means of distillation.

4. Surface modification

   The alcogel obtained in procedural step 3 is displaced with a mixture of hexamethyldisilazane and n-hexane at a constant temperature by means of stirring, wherein nitric acid is used as the catalyst. After 20 hours of reaction time, the surface reaction is largely complete.

5. Solvent replacement

The reaction mixture obtained in procedural step 4 is separated from a majority of the solvent by means of filtration and the remaining residue is displaced with n-hexane. The step is repeated several times as necessary. In this way, the methanol is largely replaced by n-hexane.

The separated solvent mixture is transferred into a distillation apparatus and separated by means of distillation.

6. Drying

The remaining solvent – mainly n-hexane – is removed by means of distillation and the alcogel granulate that is still moistened with solvent residue is dried for several hours from the reaction vessel and in a vacuum at 50°C while carefully stirring and agitating.

In this way, a silica aerogel with the following properties is obtained:

| | |
|---|---|
| Particle size: | 0.5 to 5 mm, |
| Density: | 0.18 to 0.20 g/cm$^3$, |
| Contact angle: | 110 to 150°, |
| Thermal conductivity: | 0.024 to 0.026 W/(mK), |
| Pore diameter: | 100 to 300 nm, |
| Light transmittance: | None |

The obtained aerogel is divided into the designed size fractions by means of sieving.

**2. Production of an aerogel-containing thermal insulating plaster**

A plaster mortar, consisting of

Hydraulic lime (21 parts by weight),

White cement (3 parts by weight),

Perlite (55 parts by weight),

Aerogel with a particle size in the range of 0.5 to 3 mm (20 parts by weight) and additives (1 part by weight),

with a bulk density of 250 kg/m$^3$is made into an insulating plaster by mixing with water.

50 litres of the plaster mortar are mixed with 15 litres of water, wherein 40 litres of fresh mortar are obtained.

The aerogel-containing thermal insulating plaster has a thermal conductivity of 0.034 W/(mK). The water absorption coefficient w is 1.24 kg/($m^2$ • $h^{0.5}$), i.e. the plaster is water-repellent.

**3. Production of a thermal insulation composite system**

a) Production of a thermal insulation panel

A panel-shaped 1 m x 0.5 m wooden construction with an alveolar internal construction, which has an alveolus width of 2 x 2 cm, is sealed on one side by means of a fibreglass fabric with a mesh with of 2 x 2 mm using adhesion. The alveoli of the internal construction are filled with a coarse-grained aerogel with particle sizes in the range of 3 to 5 mm and the second surface of the base construction is also sealed by means of adhesion with a fibreglass fabric with an alveolus width of 2 x 2 mm.

b) Application of a thermal insulation composite system

In total 9 of the thermal insulation panels are attached in an arrangement of 3 x 3 thermal insulation panels, i.e. three thermal insulation panels above each other and three thermal insulation panels next to each other, on a wall by means of a 2-component polyurethane adhesive. The adhesive is applied in a punctiform manner. The thickness of the thermal insulation panel is 5 cm. Then a 2 cm thick layer of the one aerogel-containing insulating plaster as produced in 2. is applied and then provided with a fibreglass reinforcement from a fibreglass fabric with a mesh width of 10 x 10 mm. After drying the thermal insulating plaster layer, a further thermal insulating plaster layer containing no aerogel is applied, with a layer thickness of 0.5 cm. This further thermal insulating plaster is a purely mineral plaster based on perlite, which is obtained from a plaster mortar, containing 50 to 80 vol% perlite, 10 to 30 vol% limestone, 3 to 5 vol% cement and 0.1 vol% cellulose by means of mixing with water.

After drying the further thermal insulating plaster layer, the surface of the thermal insulation composite system is provided with a primer. Then a surface coating based on acrylate is applied in the form of an aqueous acrylate dispersion with a dry layer thickness of 200 to 300 µm. The surface coating is water-repellent and impervious to driving rain as well as open to diffusion.

**4. Production of a thermal insulating plaster panel**

The thermal insulating plaster produced in step 2.) is moulded into a 35 to 37 mm thick panel. The hardened thermal insulating plaster panel has a dry bulk density of 0.25 $g/cm^3$ and a thermal conductivity of 0.034 W/(mK). The compressive strength is 0.6 $N/mm^2$.
The water absorption coefficient w is 1.24 $kg/(m^2 \cdot h^{0.5})$ and the water vapour diffusion resistance μ is 6.1. The thermal insulating plaster panel according to the invention is thus open to water vapour diffusion and water-resistant without any further treatment.
The thermal insulating plaster panel can be stored and transported easily, i.e. it is stable enough to withstand the mechanical stresses arising during transportation. In addition, the thermal insulating plaster panel according to the invention can be cut and tailored outstandingly, which is why it is particularly suitable for interior fitting.

**List of reference signs:**

1 Insulating plaster layer, containing aerogel

2 Building wall

3 Insulating plaster system

4 Surface coating

5 Primer coat

6 Additional insulating plaster layer

7 Support layer

8 Thermal insulation composite system

9 Thermal insulation panel

10 Adhesive

11 Narrow edges of the thermal insulation panel

12 Internal structure of the thermal insulation panel

13 Gaps

14 Surface structure

# Varmeisoleringspuds

## Patentkrav

1. Byggemateriale-tørblanding til fremstilling af isoleringspuds,
**kendetegnet ved,**
at byggemateriale-tørblandingen
(A) indeholder et aerogel i mængder på 5 til 35 vægt-%, baseret på byggemateriale-tørblandingen,
(B) indeholder mindst et letvægtstilslag, navnlig perlit, i mængder på 40 til 75 vægt-%, baseret på byggemateriale-tørblandingen,
(C) inderholder mindst et kalkbaseret bindemiddel, navnlig hydraulisk kalk, i mængder på 8 til 40 vægt-%, baseret på byggemateriale-tørblandingen,
(D) indeholder mindst et cementbaseret bindemiddel, navnlig hvid cement, i mængder på 1,5 til 10 vægt-%, baseret på byggemateriale-tørblandingen, og
(E) indeholder mindst et additiv i mængder på 0,1 til 5 vægt-%, baseret på byggemateriale-tørblandingen,
hvor byggemateriale-tørblandingen indeholder aerogelet og letvægtstilslaget i et vægtbaseret forhold mellem aerogel og letvægtstilslag på 1: 1 til 1 : 13, og
hvor bygningsmateriale-tørblandingen indeholder det kalkbaserede bindemiddel og det cementbaserede bindemiddel i et vægtbaseret forhold mellem kalkbaseret bindemiddel og cementbaseret bindemiddel på 1: 1 til 15 : 1.
2. Byggemateriale-tørblanding ifølge krav 1, kendetegnet ved,
at byggemateriale-tørblandingen indeholder aerogelet i mængder på 10 til 30 vægt-%, mest fortrinsvis 15 til 25 vægt-%, baseret på byggemateriale-tørblandingen og/eller
aerogelet har en partikelstørrelse på 0,01 til 10 mm, navnlig 0,05 til 8 mm, fortrinsvis 0,1 til 7 mm, mere fortrinsvis 0,2 til 6 mm, særligt fortrinsvis 0,5 til 5 mm, endnu mere fortrinsvis 0,5 til 4 mm, allermest fortrinsvis 0,5 til 2 mm.
3. Byggemateriale-tørblanding ifølge krav 1 eller 2, kendetegnet ved, at byggemateriale-tørblandingen desuden indeholder mindst et tilslag, navnlig valgt fra naturlige eller kunstige sten, metaller eller glas, navnlig hvor tilslaget er et letvægtstilslag, navnlig med en partikeldensitet på højst 2,0 kg/dm$^3$, navnlig valgt fra gruppen af vulkansk sten, perlit, vermikulit, pimpsten, skum- og ekspanderet glas, ekspanderet ler, ekspanderet skifer, polystyren, tuf, ekspanderet glimmer, lavagrus, lavasand,

skumplast og blandinger deraf, fortrinsvis perlit.

4. Anvendelse af en bygningsmateriale-tørblanding, navnlig en pudsmørtel, ifølge et af de foregående krav til fremstilling af en isoleringspuds, navnlig en varmeisoleringspuds, til varmeisolering af bygninger, navnlig huse.

5. Isoleringspuds, navnlig varmeisoleringspuds til varmeisolering af bygninger, der kan tilvejebringes ud fra en byggemateriale-tørblanding ifølge et af kravene 1 til 3, hvor isoleringspudsen kan tilvejebringes via udrøring med vand af bygningsmateriale-tørblandingen i mængder på 70 til 150 vægt-% baseret på byggemateriale-tørblandingen, og hvor den hærdede Isoleringspuds har en trykbrudstyrke på 0,4 til 2,5 N/mm$^2$.

6. Isoleringspuds ifølge krav 5, kendetegnet ved,
at den hærdede isoleringspuds har en termisk ledningsevne i området fra 0,02 til 0,055 W/(mK), navnlig 0,022 til 0,050 W/(mK), fortrinsvis 0,024 til 0,045 W/(mK), mere fortrinsvis 0,026 til 0,040 W/(mK) særligt fortrinsvis 0,028 til 0,032 W/(mK), og/eller
at den hærdede isoleringspuds har en vanddampdiffusionsmodstandskoefficient μ, som er bestemt i henhold til DIN EN ISO 12542, i området fra 2 til 9, navnlig 3 til 7, fortrinsvis 4 til 6.

7. Flerlags-isoleringspudssystem (3), som indeholder mindst ét isoleringspudslag (1), der består af en isoleringspuds ifølge krav 5 eller 6, og en overfladebelægning (4), hvor belægningen i det mindste er anbragt på en overflade (2), som er forsynet med isoleringspudssystemet (3), navnlig en bygningsvæg, som vender bort fra siden med isoleringspudslaget (1), fortrinsvis i det mindste i alt væsentligt dækker denne.

8. Isoleringspudssystem (3) ifølge krav 7, kendetegnet ved den følgende lagstruktur, som går ud fra en overflade (2), der er forsynet med isoleringspudssystemet (3):
Isoleringspudslag (1),
bærelag (7),
yderligere isoleringspudslag (6),
grundingslag (5) og
overfladebelægning (4).

9. Isoleringspudssystem (3) ifølge krav 7 eller 8, kendetegnet ved, at isoleringspudssystemet (3) har en lagtykkelse på 1,5 til 14 cm, navnlig 1,5 til 10 cm, fortrinsvis 2,5 til 9 cm, mere fortrinsvis fra 3,5 til 8 cm.

10. Varmeisoleringskompositsystem (8), der indeholder en varmeisoleringsplade (9) og et isoleringspudssystem (3) ifølge et af kravene 7 til 9, navnlig hvor først

varmeisoleringspladen (9) og derefter isoleringspudssystemet (3) er placeret på en overflade (2), der skal isoleres,
navnlig hvor varmeisoleringskompositsystemet (8) har en tykkelse på 4 til 12 cm, navnlig 5 til 10, fortrinsvis 5,5 til 9 cm, mere fortrinsvis 6 til 8 cm, og/eller
navnlig hvor varmeisoleringskompositsystemet (8) har en varmeledningsevne i området fra 0,015 til 0,045 W/(mK), navnlig 0,017 til 0,040 W/(mK), fortrinsvis 0,020 til 0,035 W/(mK), mere fortrinsvis 0,022 til 0,027 W/(mK).

11. Varmeisoleringskompositsystem (8) ifølge krav 10, kendetegnet ved følgende lagopbygning:
Varmeisoleringsplade (9),
isoleringspudslag (1),
bærelag (7),
yderligere isoleringspudslag (6),
grundingslag (5) og
overfladebelægning (4).

12. Isoleringspudsplade, der består af en isoleringspuds ifølge ef af kravene 5 eller 6, eller et isoleringspudssystem ifølge kravene 7 til 9.

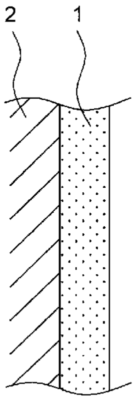


Fig. 1

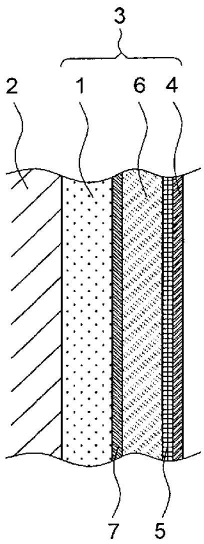


Fig. 2

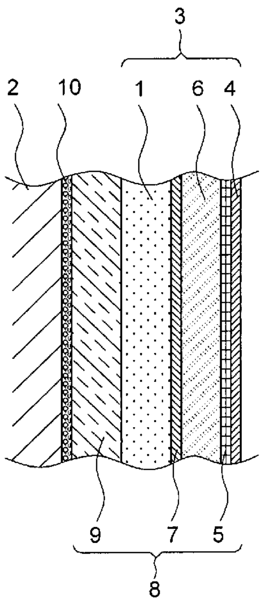


Fig. 3

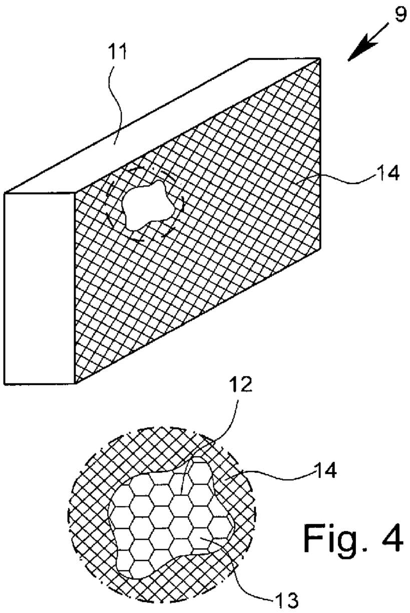


Fig. 4