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Fire Protection Panel and Method for Producing the Same

The present invention relates to a cement-bound fire protection panel for preventive structural fire protection and a method for the production thereof.

Fire protection panels are used for example in the field of ventilation and smoke extraction channels and in tunnel construction. Their resistance, particularly on exposure to long-term high-temperature stress, is important.

EP 1 326 811 B1 discloses a fire protection material for structures made of concrete and pre-stressed concrete, in particular for tunnels, which can be in the form of panels. The fire protection material is produced from a hydraulically setting mixture containing aluminous cement, wherein the set material comprises less than 5 wt.-% ettringite. In the unset state, the material comprises 50 to 200 parts by weight of aluminous cement and 10 to 250 parts by weight of xonotlite, wherein the xonotlite is in the form of felted pellets. The setting mixture can also contain wollastonite, tobermorite and/or aluminium hydroxide as fillers.

DE 197 04 961 C2 discloses a composite building panel with a core layer coated on both sides with a cover layer, wherein the core layer is composed of lightweight concrete produced as a premix. Expanded clay beads made from clay granules fired at over 1,000°C are mixed into the core layer as a lightweight aggregate material. Moreover, a reinforcement composed of alkali-resistant glass or synthetic fibres is also contained therein.

EP 1 685 932 A1 discloses a sandwich panel with a cement-bound core layer and two cement-bound cover layers and a method for the production thereof. According to a preferred embodiment, the fresh concrete for producing the core layer comprises 18-22 wt.-% Portland cement, 18-22 wt.-% pozzolan, 12-18 wt.-% water, 35-45 wt.-% expanded clay granules, 0.1-0.3 wt.-% air-entraining agent, 0.2-0.5 wt.-% flow agent and 1-2 wt.-% a dispersant. According to a preferred embodiment, the fresh mortar for the production of the two cover layers comprises 25-32 wt.-% Portland cement, 25-32

wt.-% pozzolan, 25-32 wt.-% water, 10-15 wt.-% foam glass granules, 0.2-0.5 wt.-% a flow agent, 0.1-0.3 wt.-% stabiliser, 2-3.5 wt.-% dispersing agent and 0.2-0.4 wt.-% air-entraining agent.

US 2002/0139082 A1 also discloses a sandwich panel with two cover layers and a core layer. According to an embodiment, the core layer is composed of 25-40 wt.-% binder, 25-50 vol.-% pores, 45-65 wt.-% filler, 0.5-1 wt.-% fibres and 0 to 6 wt.-% additives and further substances. Among other substances, Portland cement is listed as one of the preferred binders, and high-alumina cement is also mentioned. Moreover, expanded perlite and expanded vermiculite are listed as possible lightweight aggregate materials. According to US 2002/0139082 A1, substances such as gypsum, glass or wollastonite fibres or mineral aggregates such as unexpanded vermiculite can be added in order to increase fire resistance. The lower cover layer is a fibre cement layer. The upper cover layer is composed according to an embodiment of 25-40 wt.-% hydraulic binder, 45-65 wt.-% filler, 5-12 wt.-% fibres and 0 to 6 wt.-% additives. Among other substances, Portland cement is listed as one of the preferred binders, and high-alumina cement is also mentioned. Moreover, hollow ceramic beads are mentioned as a possible lightweight aggregate material. Moreover, wood shavings are preferably used as fibres, and ceramic fibres are mentioned.

The EP 1184522 A2 discloses a flexible fire protection panel with a plastic matrix and a coarse-grained inorganic filler, which can be a substance such as perlite, vermiculite or porous concrete. Metal fibres may also be contained therein. The fire protection panel is a one-layer panel.

DE 10 2007 026 970 A1 discloses zeolite-containing fire protection panel, which in addition to lightweight mineral aggregates such as vermiculite can also comprise mineral fibres and tobermorite or xonotlite as a mineral carrier material. Phosphoric acid or cement are disclosed as examples of binders.

The EP 2 045 227 A1 discloses a fire protection mass for filling cavities that can also be configured as a moulded body. The fire protection mass comprises a rapid-setting cement and inorganic fillers, including calcium silicates, perlite and fibres, e.g. of glass, rock wool or mineral wool.

US 2004/0211338 A1 discloses a construction material that can be processed into panels. The construction materials can comprise Portland cement and high-alumina cement and glass fibres and mineral lightweight aggregate particles composed of a high-melting-point material such as perlite.

DE 20 2005 021 073 U1 discloses a flat fire protection element, which according to an embodiment can comprise two cover layers and a core layer. The cover layers are produced from a fibre network impregnated with cement paste. The core layer is a perlite lightweight concrete. Suitable as a binder are cements based on aluminous cements with added Portland cement.

In known fire protection panels, there is a risk that when the panels are subjected to stress from all sides, which for example is the case in ventilation and smoke extraction channels, they may lose their functionality. In particular, the insulating and protective action can be lost due to deformation and shrinkage or melting.

The object of the present invention is therefore to provide a cement-bound, lightweight, high-temperature-resistant, non-flammable fire protection panel for preventive structural fire protection, in particular for use in ventilation and/or smoke extraction channels and/or in tunnel construction, that can be manufactured inexpensively and in an energy-efficient manner.

A further object is to provide an inexpensive and energy-efficient method for producing such a fire protection panel.

These objects are achieved by a fire protection panel with the features of Claim 1 and a method with the features of Claim 10. Advantageous improvements of the invention are included in the respective subsequent dependent claims.

In the following, the invention is explained by way of example by means of a drawing. The drawing shows the following:

Figure 1: A schematic sectional cross section of a fire protection panel according to the invention

The sandwich-like fire protection panel 1 according to the invention (Fig. 1) is composed of a core layer 2 that is covered on both sides on its two main surfaces with one cover layer 3a; 3b. The core layer 2 and the two cover layers 3a; 3b are firmly connected with each other. The fire protection panel 1 preferably has a cuboidal configuration.

The core layer 2 is cement-bound and comprises a hardened cement paste matrix 4 in which are embedded lightweight mineral aggregate particles 5 of a lightweight mineral aggregate, individual mineral fibres 6 for reinforcement, and according to the invention, CSH aggregate particles 7 composed of steam-hardened or autoclaved or hydrothermally hardened, tobermorite-containing CSH-material.

The hardened cement paste matrix 4 of the core layer 2 is composed of a set hydraulic binder, which according to the invention contains calcium aluminate cement clinker and optionally Portland cement clinker as well. The unset binder preferably also contains, in a manner known *per se*, a setting regulator, preferably calcium sulphate or lithium-containing compounds.

Cement is a hydraulically hardening mass construction material used in the non-metallic minerals industry that is produced from naturally occurring raw materials. In some cases, by-products of other industries are added. Cement hardens even under water, and the resulting hardened cement paste is also stable under water. In general, a distinction is made according to

DIN EN 197-1 among five main types of cement, namely Portland cements (CEM I), Portland composite cements (CEM II), blast furnace cements (CEM III), pozzolan cements (CEM IV), and composite cements (CEM V). All of the aforementioned cements according to DIN EN 197-1 contain Portland cement clinker. For the production of Portland cement clinker, the raw materials, mainly limestone and clay or marl, are first prepared by comminution, grinding and dosed mixing and then fired at approx. 1,450°C. The most important clinker materials produced in this process are C_3S (alite or tricalcium silicate), C_2S (belite or dicalcium silicate), C_3A (tricalcium aluminate) and C_4AF (brownmillerite or calcium aluminate ferrite). After firing, the products produced are milled. The milled cement clinker is then used as a binder.

As explained above, cement is a hydraulic binder. When cement clinker is mixed with water, various reactions of the cement and the water begin that are generally referred to as hydration. The various clinker minerals differ with respect to their reaction products. The reaction of the clinker minerals C_3S and C_2S with water at room temperature produces calcium silicate hydrate and $Ca(OH)_2$ (portlandite). C_3A and C_4AF react in the presence of a setting regulator, in particular calcium sulphate, to form AFm, ettringite and calcium aluminate hydrates (CAH) or calcium ferrite hydrates (CFH).

Calcium aluminate cements differ fundamentally in their phase composition from the silicate-rich standard cements according to DIN EN 197-1. They are standardized in DIN EN 14647. An essential component of calcium aluminate cement is monocalcium aluminate (CA), in addition to $C_{12}A_7$ in high-calcium and CA_2 in lower-calcium calcium aluminate cements. The SiO_2 component is bound either as C_2S or C_2AS (gehlenite), and the iron oxide, as in the case of Portland cement clinker, forms calcium aluminate ferrite (C_4AF). On this basis, calcium aluminate cement is hydrated significantly more rapidly than Portland cement, binds approximately twice as much water, and cleaves off virtually no $Ca(OH)_2$. At hydration temperatures below 25°C, the phases monocalcium aluminate (CAH_{10}) and/or dicalcium aluminate hydrate (C_2AH_8), which impart strength but are metastable, are formed

from the CA. Depending on the storage conditions, CAH_{10} and C_2AH_8 are converted more or less rapidly into the stable phases hydrogarnet (C_3AH_6) and gibbsite (AH_3) (conversion). At temperatures of 40°C and above, hydration leads directly to the formation of the stable phases C_3AH_6 and AH_3.

As explained above, the core layer 2 also comprises lightweight mineral aggregate particles 5. The lightweight aggregate particles 5 are evenly distributed in the hardened cement paste matrix 4 and are embedded therein. The lightweight aggregate particles 5 of the core layer 2 are composed according to the invention of high-melting-point material with a melting point of ≥ 700°C, and preferably ≥ 1,100°C. The lightweight aggregate particles 5 are grains of a lightweight aggregate according to DIN 1045-2/DIN EN 13055-1. The lightweight aggregate particles 5 thus have a grain bulk density ρ_a of < 2.0 kg/dm^3, and preferably < 1.0 kg/dm^3, according to DIN EN 1097-6. The bulk density ρ_S of the lightweight aggregate particles 5 used is preferably < 400 kg/m^3, preferably < 250 kg/m^3 according to DIN EN 1097-3. In particular, the lightweight aggregate particles 5 are composed of expanded perlite or expanded vermiculite or foam glass or mixtures thereof. Moreover, the lightweight aggregate particles 5 preferably have a grain size of < 2.5 mm, and preferably < 1.6 mm.

The mineral fibres 6 of the core layer 2 are glass fibres and/or rock wool fibres. The mineral fibres 6 are also embedded in the hardened cement paste matrix 4 and evenly distributed in the hardened cement paste matrix 4. This thus provides individual fibre reinforcement. The mineral fibres 6 serve to reinforce the core layer 2, in particular at high temperatures in the case of fire. For this purpose, the mineral fibres 6 of the core layer 2 preferably have a melting point of > 850°C, preferably > 1000°C. Moreover, the glass fibres preferably have a fibre length of < 20 mm, preferably 10 to 15 mm, and a fibre diameter of 10 to 20 µm, preferably 14 to 16 µm. The rock wool fibres preferably have a fibre length of < 10 mm, preferably 2 to 5 mm, and a fibre diameter of 3 to 10 µm, preferably 5 to 8 µm.

As explained above, according to the invention, the core layer 2 comprises CSH aggregate particles 7 composed of tobermorite-containing, steam-hardened or autoclaved or hydrothermally hardened CSH (calcium silicate hydrate) material.

Hydrothermally hardened CSH-material is produced from aqueous mixtures of at least one mineral binder, which comprises at least one CaO-component capable of reacting in the hydrothermal process, e.g. cement or quicklime or lime hydrate, and at least one SiO_2-component capable of reacting in the hydrothermal process, e.g. quartz powder or fly ash, and optionally additives, in particular inert additives. Moreover, the aqueous mixture can comprise at least one aggregate and/or common additives and a calcium sulphate component. The aqueous mixture is poured into casting moulds, allowed to stiffen, optionally cut, and then subjected to steam hardening.

If a blowing agent, in particular aluminium powder and/or paste, is added to the aqueous mixture, the result is then porous concrete material or CSH material produced according to cellular concrete technology. Porous concrete material is hydrothermally hardened, porous calcium silicate hydrate material. For the production of hydrothermally hardened foam concrete material, pre-prepared foam is mixed in instead of the blowing agent.

Consequently, hydrothermally hardened CSH material is essentially composed of a solid skeleton of calcium silicate hydrate phases (CSH phases), residual quartz grains, optionally inert additives and/or aggregates and further secondary components, such as e.g. anhydrite. The residual quartz grains, inert additives and aggregates are embedded in the CSH phases. In porous and foam concrete material, the solid skeleton also comprises bridges that surround the pores (= macropores) artificially formed by porosification or addition of foam. Moreover, the solid skeleton always comprises micropores that are embedded in the CSH-phases or distributed therein. The micropores are a component part of the solid skeleton. The CSH phases of the solid skeleton thus function as a binding phase in the solid skeleton.

They are predominantly crystalline and semi-crystalline, and in general these are tobermorite-11 Å and CSH(I).

The CSH-aggregate grains 7 according to the invention are preferably grains produced by comminution, e.g. crushing, of hydrothermally hardened CSH-material, and preferably porous concrete material. Preferably, the starting material is recycled material, i.e. in particular waste products from the production of CSH-material, preferably porous concrete material. Meals from dry post-processing, e.g. by means of sawing or grinding, of hydrothermally hardened CSH-material can also be used.

Moreover, the grain size of the CSH aggregate particles 7 is preferably < 1 mm, wherein preferably 50 m-% of the grains have a grain size of < 200 µm.

Preferably, the CSH-material, in particular the porous concrete material, of the CSH aggregate particles 7 is mass-hydrophobed. The advantage of the mass-hydrophobed material is that it absorbs less mixing water during production of the core layer. Moreover, this also causes the finished fire protection panel 1 according to the present invention to absorb less water, thus improving its elongation and shrinking behaviour.

The CSH-material, in particular the porous concrete material, of the CSH aggregate particles 7 is composed primarily of tobermorite-11 Å and secondarily of CSH(I). It contains virtually no xonotlite, at the most < 2 m-% from impurities. Calcite can be contained as a filler in amounts of up to 25 m-%.

The CSH material, in particular the porous concrete material, of the CSH aggregate particles 7 also preferably has a residual quartz content determined by means of differential scanning calorimetry (DSC) of < 10 m-%, preferably < 5 m-%, and particularly preferably < 3 m-%.

The core layer 2 also preferably comprises inert or reactive mineral concrete additives according to DIN EN 206/DIN 1045-2. Inactive additives do not react with cement and water and are therefore evenly distributed in the hardened cement paste matrix 4 and embedded therein. Reactive, pozzolanic or latent hydraulic additives react at least partially on hydration to form hydrate phases, which then form a part of the hardened cement paste matrix 4. Depending on the w/c value (water/cement value) and the degree of hydration, however, a portion of the reactive additives can be embedded as unreacted or partially reacted additive grains in the hardened cement paste matrix 4. Preferably, the reactive additives are pozzolanic additives, in particular fly ash according to DIN EN 450-1. In the context of the invention, reactive additives are preferred.

In particular, if the fire protection panel 1 is a fire protection panel 1 for ventilation and smoke extraction channels, the core layer 2 also comprises organic natural fibres 8. The individual natural fibres 8 are also evenly distributed in the core layer 2 and embedded in the cement matrix 4. The natural fibres 8 serve to reinforce the fire protection panel 1 in a cold state, i.e. when the fire protection panel 1 is not exposed to fire stress. The natural fibres provide favourable ductility of the fire protection panel 1 in a cold state, primarily during assembly. This allows the fire protection panel 1, for example, to be attached without problems to the respective substrate by means of screws. Preferably, the natural fibres are cellulose fibres, e.g. paper fibres.

The core layer 2 or the mortar mixture for producing the core layer 2 preferably also comprises common concrete admixtures, in particular according to DIN EN 934-2. Concrete admixtures are liquid, powdered, or granular substances that influence the properties of the fresh and/or hardened mortar by means of their chemical and/or physical action. Preferably, the core layer 2 or the mortar mixture for producing the core layer 2 comprise flow agents and/or water retention agents, e.g. methylcellulose and/or air-entraining agents. Because of the action of the air-entraining agent, the core layer 2 comprises spherical air pores 13 formed by the air-entraining agent, which

are also distributed in the hardened cement paste matrix 4 and embedded therein.

The two cover layers 3a; 3b, which are preferably identically configured, are also cement-bound and each comprise a hardened cement paste matrix 9 in which are also embedded lightweight mineral aggregate particles10 of a light, mineral aggregate, mineral fibres 11 for reinforcement or armouring, and according to the invention, CSH aggregate particles 12 composed of steam-hardened or autoclaved or hydrothermally hardened, tobermorite-containing CSH material.

According to the invention, the hardened cement paste matrix 9 of the cover layers 3a; 3b is also composed of a set hydraulic binder, which in an unset state comprises calcium aluminate cement clinker and preferably Portland cement clinker as well. The unset binder preferably also comprises, in a manner known *per se*, a setting regulator, preferably calcium sulphate and/or lithium-containing compounds.

The lightweight aggregate particles 10 of the cover layers 3a; 3b are also evenly distributed in the hardened cement paste matrix 9 and are embedded therein. The lightweight aggregate particles 10 of the cover layers 3a; 3b are also composed according to the invention of high-melting-point mineral material with a melting point of $\geq$ 700°C, preferably $\geq$ 1,100°C. The lightweight aggregate particles 10 are again grains of a lightweight aggregate according to DIN 1045-2/DIN EN 13055-1. Accordingly, the lightweight aggregate particles 10 have a grain bulk density of < 2.0 kg/dm^3, preferably < 1.0 kg/dm^3, according to DIN EN 1097-6. The bulk density ρ_S of the lightweight aggregate particles 10 used is again preferably < 400 kg/m^3, preferably < 250 kg/m^3, according to DIN EN 1097-3. In particular, the lightweight aggregate particles 10 of the cover layers 3a; 3b are composed of expanded perlite or expanded vermiculite or foam glass or mixtures thereof. Moreover, the lightweight aggregate particles 5 preferably have a grain size of < 2.5 mm, preferably < 1.6 mm.

The mineral fibres 11 of the two cover layers 3a; 3b are also glass fibres and/or rock wool fibres. The mineral fibres 11 are also evenly distributed in the hardened cement paste matrix 9 and are embedded in the hardened cement paste matrix 9. The mineral fibres 11 serve to reinforce the cover layers 3a; 3b, in particular at high temperatures in the case of fire. Accordingly, the mineral fibres 11 of the cover layers 3a; 3b also preferably have a melting point of > 850°C, preferably > 1,000°C. Moreover, the fibres 11 of the cover layers 3a; 3b have a greater length and a greater diameter than the fibres 6 of the core layer 2. For this reason, among others, the two cover layers 3a; 3b comprise higher strengths than the core layer 2. Preferably, the fibres 11 of the cover layers 3a; 3b, which in particular are glass fibres, have a fibre length of 20 to 40 mm, and preferably 25 to 35 mm. Moreover, they preferably have a fibre diameter of 0.7 to 2 mm, and preferably 1 to 1.5 mm. Because of their greater length and thickness, the individual fibres 11 of the cover layers 3a; 3b can in some cases also become entangled with one another or form fibre bundles, thus improving the strength properties of the cover layers 3a; 3b.

As explained above, the two cover layers 3a; 3b according to the invention also comprise CSH aggregate particles 12 composed of hydrothermally hardened CSH material, preferably porous concrete material. The CSH aggregate particles 12 of the cover layers 3a; 3b are also grains produced by comminution, in particular breaking, sawing, or grinding, from hydrothermally hardened CSH material, preferably porous concrete material. Preferably, the starting material used is in turn recycled material, i.e. in particular waste products from the production of CSH material, preferably porous concrete material.

Preferably, the CSH material, in particular the porous concrete material, of the CSH aggregate particles 12 of the two cover layers 3a; 3b is also mass-hydrophobed.

The CSH material of the CSH aggregate particles 12 of the two cover layers 3a; 3b preferably has the same properties with respect to grain size, tobermorite content, calcite content, quartz content and xonotlite content as the CSH material of the CSH aggregate particles 7 of the core layer 2.

The cover layers 3a; 3b can also additionally contain further components, e.g. inert or preferably reactive concrete additives according to DIN EN 206/DIN 1045-2. Preferably, the reactive additives of the two cover layers 3a; 3b are pozzolanic additives, in particular fly ash according to DIN EN 450-1.

The two cover layers 3a; 3b or the mortar mixtures for producing the two cover layers 3a; 3b preferably also comprise common concrete admixtures according to DIN EN 934-2. Preferably, the two cover layers 3a; 3b or the mortar mixtures for producing the two cover layers 3a; 3b comprise flow agents and/or water retention agents, e.g. methylcellulose. The cover layers 3a; 3b preferably contain no air-entraining agent.

The total thickness D of the fire protection panel 1 of the invention is preferably 10 to 60 mm, particularly preferably 20 to 40 mm. The core layer 2 preferably has a thickness D_K of 8 to 55 mm, particularly preferably 30 mm. Moreover, the two cover layers 3a; 3b preferably have a thickness D_D of 0.5 to 3 mm, particularly preferably 2 mm. The cover layers 3a; 3b are therefore thinner than the core layer 2.

Production of the fire protection panel 1 of the invention is explained in further detail below:

Production of the fire protection panel 1 of the invention is carried out by the "fresh on fresh" method. This means that a core layer fresh mortar for the core layer 2 and a core layer fresh mortar for the two cover layers 3a; 3b are produced, and the individual fresh mortars are then applied to one another to produce the individual layers 2; 3a; 3b. The panel is then allowed to set or harden. This takes place not hydrothermally, but under ambient pressure at room temperature or a temperature slightly elevated to approx.

80°C, preferably 65°C. In particular, production is carried out as follows, essentially as described in EP 1685932 A1:

Metal moulds having a U-shaped cross-section are positioned, open toward the top and front, on a main conveyor belt moving in a secondary conveying direction. The metal moulds are adjacent to one another on the front side. A first cover layer production device is arranged above the main conveyor belt for producing the first cover layer 3a. The first cover layer production device comprises a vessel that contains the fresh mortar of the first cover layer 3a. Moreover, the first cover layer production device comprises means for transporting the cover layer fresh mortar for the first cover layer 3a into the metal moulds. Preferably, this is an injection device comprising an oscillating injection head.

The fresh mortar of the first cover layer 3a is manufactured by producing a cover layer dry mortar mixture in a dry mixer and mixing the cover layer dry mortar mixture with water in a final mixer. Preferably, the fresh mortar of the first cover layer 3a has a w/s value (water/solid value) of 0.5 to 0.9, preferably 0.8. The fresh mortar bulk density according to DIN EN 1015-6 is preferably 1.0 to 1.2 g/cm^3. The slump according to DIN EN 1015-3 is preferably 19 to 23 cm. The pore content according to DIN EN 1015-7 is preferably 5-15 vol.-%.

The fresh mortar of the first cover layer 3a comprises as dry components at least calcium aluminate cement clinker, preferably Portland cement clinker, the lightweight aggregate particles 10, the mineral fibres 11, according to the invention the CSH aggregate particles 12, and optionally at least one inert and/or reactive concrete additive material, and preferably at least one concrete admixture agent.

Preferably, the fresh mortar of the first cover layer 3a comprises the following dry components, based on total dry matter (the values total 100 wt.-%):

	wt.-%
Calcium aluminate cement clinker	40 to 70
Portland cement clinker	0 to 20
Lightweight aggregate particles	5 to 20
CSH aggregate particles	5 to 20
Mineral fibres	1 to 5
Organic natural fibres	0 to 3
Inert and/or reactive concrete additive(s)	0 to 20
Concrete admixture(s)	< 2
Other components, including setting regulators(s)	< 5

If the fire protection panel 1 is to be used for ventilation and smoke extraction channels, the fresh mortar of the first cover layer 3a preferably comprises the following dry components, based on total dry matter (the values total 100 wt.-%):

	wt.-%
Calcium aluminate cement clinker	55 to 65
Portland cement clinker	12 to 18
Foam glass	12 to 18
CSH aggregate particles	6 to 10
Glass fibres	1.5 to 3
Organic natural fibres	0.5 to 2
Pozzolanic additives	0 to 10
Concrete admixture(s)	< 2

Other components, including setting regulators(s)	< 5

If the fire protection panel 1 is to be used for tunnel construction, the fresh mortar of the first cover layer 3a preferably comprises the following dry components, based on total dry matter (the values total 100 wt.-%):

	wt.-%
Calcium aluminate cement clinker	60 to 70
Portland cement clinker	12 to 18
Expanded perlite	3 to 7
CSH aggregate particles	10 to 15
Glass fibres	1.5 to 3
Pozzolanic additives	0 to 10
Concrete admixture(s)	< 2
Other components, including setting regulators(s)	< 5

The fresh mortar of the core layer 2 is now applied to the fresh first cover layer 3a. For this purpose, a core layer production device is arranged above the main conveyor belt. This device is arranged downstream of the first conveying layer production device in the secondary conveying direction. The core layer production device comprises a vessel that contains the fresh mortar of the core layer. Moreover, the core layer production device comprises means for introducing the fresh mortar of the cover layer onto the fresh first cover layer 3a. Preferably, this is a cellular wheel sluice.

The fresh mortar of the core layer is produced by mixing a core cover layer dry mortar mixture with water in a core layer mixer. Preferably, the fresh mortar of the core layer has a w/s value of 0.6 to 1, preferably 0.8. The fresh mortar bulk density of the fresh mortar of the cover layer according to DIN

EN 1015-6 is lower than the fresh mortar bulk density of the fresh mortar of the cover layers. It is preferably 0.8 to 1.1 g/cm^3. The slump of the fresh mortar of the cover layer according to DIN EN 1015-3 is also less than the slump of the fresh mortar of the cover layer. It is preferably 14 to 17 cm. The pore content of the fresh mortar of the cover layer according to DIN EN 1015-7 is greater than the pore content of the fresh mortar of the cover layers. It is preferably 15-30 vol.-%.

The fresh mortar of the core layer comprises as dry components at least calcium aluminate cement clinker, the lightweight mineral aggregate particles 5, the mineral fibres 6, according to the invention the CSH aggregate particles CSH aggregate particles 7, optionally the natural fibres 8 and preferably at least one inert and/or reactive concrete additive, preferably at least one concrete admixture.

The fresh mortar of the core layer preferably comprises the following dry components, based on total dry matter (the values total 100 wt.-%):

	wt.-%
Calcium aluminate cement clinker	30 to 65
Portland cement clinker	0 to 20
Lightweight aggregate particles	15 to 40
CSH aggregate particles	5 to 20
Mineral fibres	1 to 5
Organic natural fibres	0 to 3
Inert and/or reactive concrete additive(s)	0 to 20
Concrete admixture(s)	< 3
Other components, including setting regulators(s)	< 5

If the fire protection panel 1 is to be used for ventilation and smoke extraction channels, the fresh mortar of the core layer preferably comprises the following dry components, based on total dry matter (the values total 100 wt.-%):

	wt.-%
Calcium aluminate cement clinker	40 to 50
Portland cement clinker	6 to 15
Foam glass	20 to 30
Expanded vermiculite	5 to 10
CSH aggregate particles	5 to 8
Glass fibres	0.8 to 1.5
Rock wool fibres	1.5 to 2,0
Organic natural fibres	0.5 to 2,0
Pozzolanic additives	5 to 15
Concrete admixture(s)	< 3
Other components, including setting regulators(s)	< 5

If the fire protection panel 1 is to be used for tunnel construction, the fresh mortar of the core layer preferably comprises the following dry components, based on total dry matter (the values total 100 wt.-%):

	wt.-%
Calcium aluminate cement clinker	55 to 65
Portland cement clinker	0 to 5
Expanded perlite	8 to 15
CSH aggregate particles	10 to 20
Glass fibres	1.5 to 3
Pozzolanic additive	8 to 15
Concrete admixture(s)	< 3
Other components, including setting regulators(s)	< 5

The fresh mortar of the second cover layer 3b is now applied to the fresh core layer 2. The fresh mortar of the second cover layer 3b preferably has a composition like that of the fresh mortar of the first cover layer 3a.

In order to produce the second cover layer 3b, a second cover layer production device is arranged above the main conveyor belt. This device is arranged upstream of the core layer production device in the primary conveying direction. The second cover layer production device comprises a vessel containing the fresh mortar of the second cover layer 3b. Moreover, the second cover layer production device comprises a plastic film track that moves in a secondary conveying direction opposite to the primary conveying direction. Suitable means are used to apply the fresh mortar of the second cover layer 3b to the plastic film track. The plastic film track with the fresh second cover layer 3b is then deflected by 180° so that the fresh second cover layer 3b is applied to the fresh core layer 2 opposite to the first fresh cover layer 3a and the plastic film is arranged in the uppermost position. This gives rise to an endless unset plate strand.

The endless unset plate is now divided in a cutting device into individual unset panels, and the individual forms are allowed to hydraulically set with

the panels in setting device. This preferably takes place at ambient pressure and room temperature or at a temperature slightly elevated to 80°C, preferably 65°C. The setting process lasts approx. 14 to 24 h. The plastic film is then peeled off, and the individual panels are dried to moisture content equilibrium for 10 to 16 h at 40 to 65°C.

The fire protection panel 1 according to the present invention is high-temperature-resistant. Even in the case of fire stress on all sides, its function is not impaired by shrinkage, deformation, or melting.

This results from the targeted selection and composition of the individual mineral components of the fire protection panel 1 according to the present invention, which are all high-temperature-resistant. The content of calcium aluminate cement in the still-unset binder of the core layer 2 and the two cover layers 3a; 3b causes a hardened cement paste matrix 4; 9 to be formed that is also stable in the high temperature range. The reason is that the CAH phases formed are stronger than the CSH phases of the Portland cement stone. It was found in the context of the invention that the tobermorite-containing CSH aggregate particles 7; 12 show an outstanding cooling action in the case of fire. The reason for this is that tobermorite contains an extremely high concentration of water of crystallization (approx. 12-20 wt.-%), in particular significantly more than xonotlite (approx. 2.5 wt.-%), which is vaporized and expelled in case of fire. Energy is absorbed in this process. Moreover, considerable thermal energy is also required to decompose the tobermorite into the final product wollastonite, which also contributes to the high resistance of the fire protection panel 1 of the invention.

At the same time, the fire protection panel 1 according to the present invention, in particular because of the lightweight mineral aggregate particles 5; 10 and the pores formed by the air-entraining agent 13 in the core layer 2, is very light in weight and shows favourable insulating properties with simultaneously low panel thickness. This allows the coating thickness to be reduced and the type and number of fixing agents to be optimized or minimized.

In particular, the fire protection panel 1 according to the present invention has a dry bulk density ρ_0 according to DIN EN ISO 12570 of 500 to 800 kg/m^3, preferably 600 to 750 kg/m^3.

Despite this, the fire protection panel 1 according to the present invention comprises excellent strength properties. The combination of the favourable strength properties with simultaneously low weight and outstanding fire protection properties is ensured in particular by the combination of the two thin cover layers 3a; 3b with the thicker core layer 2. The reason is that the cover layers 3a; 3b have longer mineral fibres 11, a higher hardened cement paste content and a higher dry bulk density and lower pore content than the core layer 2. This allows them to provide sufficient strength of the fire protection panel 1 according to the present invention. In contrast, the core layer 2 provides the low weight and favourable fire protection properties.

The cover layers 3a; 3b preferably have a dry bulk density ρ_0 according to DIN EN ISO 12570 of 900 to 1000 kg/m^3. The core layer 2, in contrast, preferably has a dry bulk density ρ_0 according to DIN EN ISO 12570 of 400 to 700 kg/m^3. The dry bulk density ρ_0 of the individual layers can be determined for example by sawing the fire protection panel 1.

Moreover, the fire protection panel 1 according to the invention is weather-resistant and shows high durability.

In particular, the fire protection panel 1 according to the present invention has a freeze-thaw resistance DIN EN 12467 of A, the highest category.

Because of the mineral fibres 6; 11, the fire protection panel 1 according to the present invention also comprises good strength in the case of fire. The fibres 6; 11 serve to bridge cracks and absorb deformation forces. The fire behaviour of the fire protection panel 1 of the invention is classified according to DIN EN 13501 in category A1. Moreover, the fire protection panel 1 according to the present invention meets the standards of the common international tunnel temperature-time curves for tunnel construction, such as

HCM (hydrocarbon Mayor curve) 120 min or RWS (Rijkswaterstaat curve) 180 min and the tests according to DIN EN 1366.

The fire protection panel 1 according to the present invention can also be produced in a simple, inexpensive, and energy-efficient manner, in particular when recycled CSH material is used.

Because of the content of Portland cement clinker in the fresh mortar of the cover layer, generation of heat during setting is reduced. The reason is that this generation of heat is significantly greater with calcium aluminate cement than with slower-setting Portland cement. By using Portland cement, it is thus also possible to synchronize the setting of the cover layers 3a; 3b with the setting of the core layer 2. Moreover, the content of CSH aggregate particles 7; 12 makes it possible to regulate heat generation, as the content of cement can be proportionately reduced/increase thereby.

It is also within the scope of the invention for the core layer 2, instead of or in addition to the individual mineral fibres 6, to comprise, for reinforcing purposes, one or a plurality of fibre mats, in particular fabrics composed of mineral fibres.

The indicated DIN standards are the respective DIN standards in force on the priority date.

Patentkrav

1. Brandbeskyttelsesplade (1) til forebyggende, strukturel brandbeskyttelse, især til installation i tunneler eller i ventilations- og/eller røgudsugningskanaler, hvilket panel omfatter et cementbundet kernelag (2) og to cementbundne dæklag (3a; b) der dækker kernelaget (2),

hvilket kernelag (2) har de følgende træk:

a) kernelaget (2) omfatter en cementstenmatrix (4) der er sammensat af et hærdet, hydraulisk bindemiddel, som indeholder lercementklinker,

b) lette mineralske aggregerede partikler (5) der er indlejret i cementstenmatrixen (4), og som er sammensat af materialer med højt smeltepunkt der har et smeltepunkt på ≥ 700 °C, fortrinsvis ≥ 1100 °C, mineralske fibre (6), og CSH-aggregerede partikler (7) der er sammensat af hydrotermisk hærdet, tobermoritholdigt CSH-materiale,

og hvilke to dæklag (3a; 3b) hver har følgende træk:

c) de to dæklag (3a; 3b) har hver en cementstenmatrix (9) der er sammensat af et hærdet, hydraulisk bindemiddel som indeholder lercementklinker og fortrinsvis portlandcementklinker,

d) lette mineralske aggregerede partikler (10) der er indlejret i cementstenmatrixen (9), og som er sammensat af materialer med højt smeltepunkt der har et smeltepunkt på ≥ 700 °C, fortrinsvis ≥ 1100 °C, mineralske fibre (11), og CSH-aggregerede partikler (12) der er sammensat af hydrotermisk hærdet, tobermoritholdigt CSH-materiale,

e) de to dæklag (3a; 3b) har en højere tør bulkdensitet ρ_0 ifølge DIN EN ISO 12570 end kernelaget (2).

2. Brandbeskyttelsespladen (1) ifølge krav 1,

kendetegnet ved, at

de CSH-aggregerede partikler (7; 12) af kernelaget (2) og/eller de to dæklag (3a; 3b) er massehydrofoberet.

3. Brandbeskyttelsesplade (1) ifølge krav 1 eller 2,

kendetegnet ved, at

de CSH-aggregerede partikler (7; 12) af kernelaget og/eller de to dæklag (3a; 3b) består af genanvendt CSH-materiale, fortrinsvis porebetonmateriale.

4. Brandbeskyttelsesplade (1) ifølge et af de foregående krav,
kendetegnet ved, at
de CSH-aggregerede partikler (7; 12) af kernelaget og/eller de to dæklag (3a; 3b) består af knust CSH-materiale, især knust porebetonmateriale, og/eller savsmuld og/eller slibestøv fra den tørre efterbehandling af CSH-materiale, især porebetonmateriale.

5. Brandbeskyttelsesplade (1) ifølge et af de foregående krav,
kendetegnet ved, at
de lette aggregerede partikler (5; 10) af kernelaget (2) og/eller de to dæklag (3a; 3b) har en partikeldensitet på < 2,0 kg/dm^3, fortrinsvis < 1,0 kg/dm^3, ifølge DIN EN 1097-6.

6. Brandbeskyttelsesplade (1) ifølge et af de foregående krav,
kendetegnet ved, at
de lette aggregerede partikler (5; 10) af kernelaget (2) og/eller af de to dæklag (3a; 3b) består af ekspanderet perlit eller ekspanderet vermiculit eller skumglas eller blandinger deraf.

7. Brandbeskyttelsesplade (1) ifølge et af de foregående krav,
kendetegnet ved, at
kernelaget (2) omfatter individuelle organiske naturlige fibre (8), især cellulosefibre, som er indlejret i cementstenmatrixen (4).

8. Brandbeskyttelsesplade (1) ifølge et af de foregående krav,
kendetegnet ved, at
de mineralske fibrene (6; 11) af kernelaget (2) og/eller dæklagene (3a; 3b) er glasfibre og/eller mineraluldsfibre.

9. Brandbeskyttelsesplade (1) ifølge et af de foregående krav,
kendetegnet ved, at

det hydrauliske bindemiddel af kernelaget (2) og/eller dæklagene (3a; 3b) indeholder mindst en fortrinsvis reaktiv tilsætning, især flyveaske, og/eller brandbeskyttelsespladen (1) har en tør bulkdensitet ρ_0 ifølge DIN EN 12570 på 500 til 800 kg/m^3, fortrinsvis 600 til 750 kg/m^3, og/eller dæklagene (3a; 3b) har et højere indhold (vægt-%) cementsten end kernelaget (2).

10. Fremgangsmåde til fremstilling af en brandbeskyttelsesplade (1) ifølge et af de foregående krav, hvilken fremgangsmåde har følgende fremgangsmådetrin:

a) at fremstille en frisk mørtel til et kernelag til fremstilling af kernelaget (2) og at fremstille et frisk kernelag deraf,

b) at fremstille et frisk mørtel til et dæklag til fremstilling af de to dæklag (3a; 3b) og at fremstille to friske dæklag deraf,

c) at sammenføje de to friske dæklag og det friske kernelag,

d) at afbinde kernelaget og de to dæklag.

11. Fremgangsmåden ifølge krav 10,

kendetegnet ved, at

den friske mørtel til dæklaget til fremstilling af de to dæklag (3a; 3b) omfatter følgende tørre komponenter, der er baseret på det totale tørstof (værdierne udgør op til 100 vægt-%):

	Vægt-%
Lercementklinker	40 to 70
Portlandcementklinker	0 to 20
Lette aggregerede partikler	5 to 20
CSH-aggregerede partikler	5 to 20
Mineralske fibre	1 to 5
Organiske naturlige fibre	0 to 3
Inert og/eller reaktiv betontilsætning eller -tilsætninger	0 to 20
Betontilsætningsmiddel	< 2

	Vægt-%
Andre komponenter, herunder størkningsregulator	< 5

og den friske mørtel til kernelaget omfatter følgende tørre komponenter, der er baseret på det totale tørstof (værdierne giver op til 100 vægt-%):

	Vægt-%
Lercementklinker	30 til 65
Portlandcementklinker	0 til 20
Lette aggregerede partikler	15 til 40
CSH-aggregerede partikler	5 til 20
Mineralske fibre	1 til 5
Organiske naturlige fibre	0 til 3
Inert og/eller reaktiv betontilsætning eller -tilsætninger	0 til 20
Betontilsætningsmiddel	< 3
Andre komponenter, herunder størkningsregulator	< 5

12. Fremgangsmåde ifølge krav 10 eller 11,

kendetegnet ved, at

den friske mørtel til dæklaget til fremstilling af de to dæklag (3a; 3b) omfatter følgende tørre komponenter, der er baseret på det totale tørstof (værdierne udgør op til 100 vægt-%):

	Vægt-%
Lercementklinker	55 til 65
Portlandcementklinker	12 til 18
Skumglas	12 til 18

	Vægt-%
CSH-aggregerede partikler	6 til 10
Glasfibre	1,5 til 3
Organiske naturlige fibre	0,5 til 2
Pozzolaniske tilsætninger	0 til 10
Betontilsætningsmiddel	< 2
Andre komponenter, herunder størkningsregulator	< 5

og den friske mørtel til kernelaget omfatter følgende tørre komponenter, der er baseret på det totale tørstof (værdierne giver op til 100 vægt-%):

	Vægt-%
Lercementklinker	40 til 50
Portlandcementklinker	6 til 15
Skumglas	20 til 30
Ekspanderet vermiculit	5 til 10
CSH-aggregerede partikler	5 til 8
Glasfibre	0,8 til1,5
Mineraluldsfibre	1,5 til 2,0
Organiske naturlige fibre	0,5 to 2,0
Pozzolaniske tilsætninger	5 til 15
Betontilsætningsmiddel	< 3
Andre komponenter, herunder størkningsregulator	< 5

13. Fremgangsmåde ifølge krav 10,

kendetegnet ved, at

den friske mørtel til dæklaget for de to dæklag (3a; 3b) omfatter følgende tørre

komponenter, der er baseret på det totale tørstof (værdierne giver op til 100 vægt-%):

	Vægt-%
Lercementklinker	60 til 70
Portlandcementklinker	12 til 18
Ekspanderet perlit	3 til 7
CSH-aggregerede partikler	10 til 15
Glasfibre	1.5 til 3
Pozzolaniske tilsætninger	0 til 10
Betontilsætningsmiddel	< 2
Andre komponenter, herunder størkningsregulator	< 5

og den friske mørtel til kernelaget omfatter følgende tørre komponenter, der er baseret på det totale tørstof (værdierne giver op til 100 vægt-%):

	Vægt-%
Lercementklinker	55 til 65
Portlandcementklinker	0 til 5
Ekspanderet perlit	8 til 15
CSH-aggregerede partikler	10 til 20
Glasfibre	1,5 til 3
Pozzolaniske tilsætninger	8 til 15
Betontilsætningsmiddel	< 3
Andre komponenter, herunder størkningsregulator	< 5

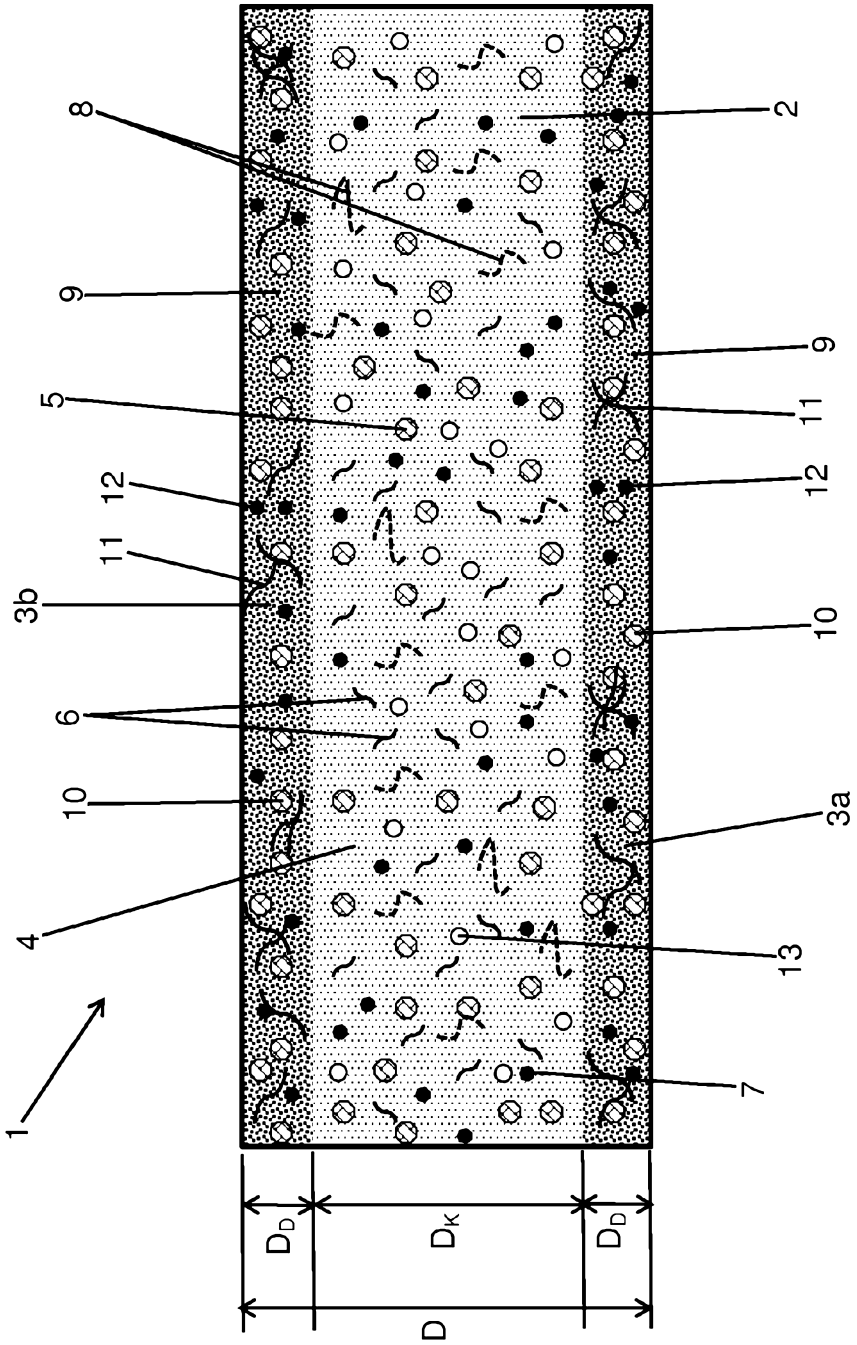
14. Fremgangsmåde ifølge et af kravene 10 til 13,

kendetegnet ved, at

den friske mørtel til dæklaget for de to dæklag (3a; 3b) har et højere cementindhold (vægt-%) end den friske mørtel af kernelaget.

15. Fremgangsmåde ifølge et af kravene 10 til 14,

kendetegnet ved, at

den friske mørtel til dæklaget for de to dæklag (3a; 3b) har 5 til 20 vægt-%, fortrinsvis 6 til 10 vægt-% CSH-aggregerede partikler (12), der er baseret på det totale tørstof, og/eller den friske mørtel til kernelaget har 5 til 20 vægt-%, fortrinsvis 10 til 15 vægt-% CSH-aggregerede partikler (7), der er baseret på det totale tørstof.

Figur 1: