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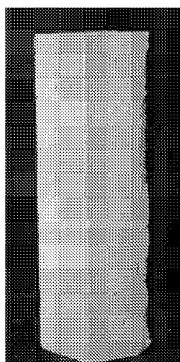
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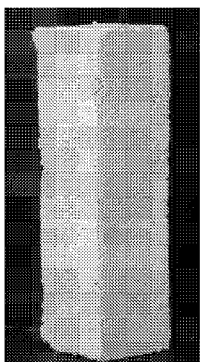
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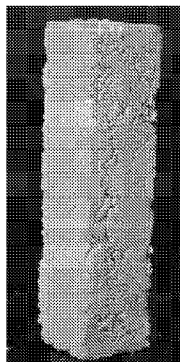
Figure 1.



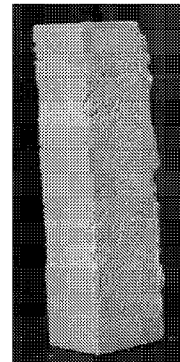
Sample 1



Sample 2



Sample A<sup>†</sup>



Sample B<sup>†</sup>

<sup>†</sup> not according to the invention

(57) Abstract: The present invention provides a mould for shaping a sulphur cement product, which mould has an inner surface describing an inner volume for receiving a cast material, an outer surface and a barrier comprised between the inner surface and the outer surface, which barrier has a thermal conductance per unit area of at most 100 W/m<sup>2</sup> K in a direction perpendicular to the inner surface. The invention further provides a process for shaping a sulphur cement product.

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## MOULD AND PROCESS FOR SHAPING A SULPHUR CEMENT PRODUCT

Field of the invention

This invention relates to a mould for shaping a sulphur cement product and a process for shaping a sulphur cement product using such mould.

5 Background of the invention

Sulphur may be used as an alternative for Portland cement as binder material in construction materials. Sulphur based construction materials, such as sulphur cement and sulphur concrete have distinctive advantages over their Portland cement based counterparts. Sulphur based construction materials are strong, acid and salt resistant and thus applicable in many fields of industry including those where contact with aggressive environments is anticipated. Typical fields of application include building blocks, bricks, tiles, floors, coatings, foundations, acid reservoirs, etc.

Sulphur cement is a thermoplastic material that typically melts at temperatures in the range of from 115 to 125 °C, depending on its exact composition. Upon cooling, the liquid sulphur cement re-solidifies at temperatures below the melting temperature.

The ability to melt and subsequently re-solidify allows for the convenient shaping of sulphur cement. A typical process for shaping sulphur cement is moulding.

25 In CA2267860 is disclosed a process for preparing sulphur comprising concrete blocks, wherein a mixture of powdered sulphur and sand having temperature of 110°C (230°F) are moulded and compressed in a urethane mould.

FR2773340 discloses a process for preparing concrete elements using a mould. The mould is formed out of a

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deformable, flexible plastic material such as polyurethane, silicone or others. FR2773340 does not disclose the dimensions of the mould or its use at elevated temperatures. According to FR2773340, the  
5 obtained concrete elements show surface defects and irregularities similar to traditionally produced elements.

Moulded sulphur cement or concrete based structures can suffer a deterioration of compression and flexural  
10 strength due to the intrusion of water, as for instance shown in US4256499. Water intrusion occurs due a bad surface finish, which results in the presence of micro cracks and porosity on the outer surface of the structure. As a consequence, the compression strength of  
15 the sulphur cement or concrete structures decreases.

In US4256499 is disclosed a method of producing a shaped sulphur concrete article with a good surface finish. In the method of US4256499, adhesion to the mould is prevented by removing the mould prior to melting the  
20 sulphur. In the method of US4256499, a mouldable mixture comprising a mineral binding agent and a sulphur component is compressed in a steel mould under high pressure. The thus formed compressed shaped body of the mixture is removed from the mould and subsequently heated  
25 to a temperature sufficient to melt the sulphur and cooled to obtain a shaped article. The obtained articles showed post-production water intrusion, exhibiting a reduction in compression strength up to 20% after being soaked in water of 25 °C for 1 hour. The method of  
30 US4256499 requires the formation of a self-supporting compressed shaped body prior to melting the sulphur. Furthermore the method of US4256499 requires that the mould be removed prior to melting the sulphur.

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In US4981740 is disclosed a method for producing sulphur concrete pipes using casting moulds. To prevent sticking of the sulphur concrete to the mould, US4981740 suggests to preheat the mould and to apply a release agent, i.e. form oil or a polytetrafluoroethylene (PTFE or Teflon™) coating on the surface of casting mould. Applicants have found that sulphur based objects moulded by the process of US4981740 have a rough surface.

There is a need in the art for a mould and an improved process for producing shaped objects of sulphur cement and/or sulphur concrete with a good surface finish, i.e. a smooth surface.

#### Summary of the invention

It has now been found that shaped objects of a sulphur cement product with a good surface finish, i.e. a smooth surface, can be obtained by using a mould having a low thermal conductance per unit area.

Accordingly, the present invention provides a mould for shaping a sulphur cement product, which mould has an inner surface describing an inner volume for receiving a cast material, an outer surface and a barrier comprised between the inner surface and the outer surface, which barrier has a thermal conductance per unit area of at most 100 W/m<sup>2</sup>K in a direction perpendicular to the inner surface.

Reference herein to a sulphur cement product is to sulphur cement or to a sulphur cement containing material, i.e. to a material at least containing elemental sulphur and a filler. Examples of sulphur cement containing materials are sulphur cement premix compositions and sulphur cement-aggregate composites such as sulphur mortar, sulphur concrete or sulphur-extended asphalt.

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Reference herein to thermal conductance per unit area is to the quantity of heat that passes in unit time through unit area of a barrier of particular thickness when its opposite faces differ in temperature by one  
5 degree. The thermal conductance per unit area is expressed in  $\text{W/m}^2\text{K}$ .

Reference herein to a direction perpendicular to the inner surface is to a direction perpendicular to the tangent plane of the inner surface. It will be  
10 appreciated that if the inner surface is curved, the tangent plane may differ depending of the position on the inner surface.

Not being bound to any theory, applicants believe that the formation of a rough surface and of micro cracks and porosity on the outer surface of shaped objects of a  
15 sulphur cement product is the result of inhomogeneous temperature profile in the sulphur cement product during cooling. The temperature profile in the sulphur cement product may be influenced by the heat properties of the mould. It has now been found that homogeneity of the  
20 temperature profile in the sulphur cement product during cooling can be improved by using a mould having a thermal conductance per unit area of at most  $100 \text{ W/m}^2\text{K}$  in a direction perpendicular to the inner surface. The mould  
25 according to the invention has the advantage that the rate of heat transfer from the molten sulphur cement product to the mould at the interface between the sulphur cement product and the inner surface of the mould is regulated. If the rate of heat transfer is too high, the  
30 interfacial temperature decreases faster than the bulk temperature of the sulphur cement product. When the interfacial temperature decreases below the re-solidification temperature, the sulphur cement product at

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the interface may become solid while the bulk of the sulphur cement product remains liquid. As a consequence, rough structures, micro cracks and porosity may evolve at the interface induced by internal stresses and material shrinkage.

In another aspect, the invention provides a process for shaping a sulphur cement product comprising cooling a molten sulphur cement product in a mould having an inner surface in contact with the molten sulphur cement product to obtain a shaped solid sulphur cement product and wherein at most  $100 \text{ W/m}^2\text{K}$  is diffused per unit area through the mould in a direction perpendicular to the inner surface.

The process according to the invention has the advantage that shaped objects of sulphur cement product may be prepared with a surface that is smooth and essentially free of micro cracks and surface porosity.

#### Brief description of the drawings

Figure 1 displays sulphur cement products.

#### Detailed description of the invention

The mould of the present invention has an inner surface and an outer surface. The inner surface describes an inner volume set to receive a cast material, typically a sulphur cement product. A barrier is comprised between the inner and the outer surface of the mould. The barrier has a thermal conductance per unit area of at most  $100 \text{ W/m}^2\text{K}$ , preferably in the range of from 0.1 to  $100 \text{ W/m}^2\text{K}$ , more preferably 0.1 to  $60 \text{ W/m}^2\text{K}$ , even more preferably in the range of from 0.1 to  $10 \text{ W/m}^2\text{K}$ , still more preferably of from 0.1 to  $5 \text{ W/m}^2\text{K}$ , in a direction perpendicular to the inner surface.

Among others, the barrier provides a heat contact between the volume described by the inner surface and an

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outer atmosphere surrounding the outer surface. In case, the temperature in the inner volume differs from the temperature of the outer atmosphere, heat may be transported through the barrier. As mentioned herein above where the use of the mould for shaping a sulphur cement product is described, it may be desired to regulate the transfer of heat from the interface of the mould and the inner volume to the outer atmosphere. The rate at which heat is transported through the barrier, i.e. the thermal conductance per unit area of the barrier, depends on the thermal properties of the material(s) of which the barrier is comprised and the thickness of the barrier in a direction perpendicular to the inner surface. The correlation between the thermal conductance per unit area and the thickness of the barrier is given by the thermal conductivity in a direction perpendicular to the inner surface of the material(s) of which the barrier is comprised. Reference herein to the thermal conductivity is to the quantity of heat transmitted, due to unit temperature gradient, in unit time under steady conditions in a direction normal to a surface of unit area, when the heat transfer is dependent only on the temperature gradient. The thermal conductivity is expressed in W/mK and is obtained by multiplying the thermal conductance per unit area with the thickness. It will be appreciated that although the thickness of the barrier may have any hypothetical value, in reality the thickness will be limited due to practical restraints such as weight or size of the mould. Typically, the thickness of the barrier will not exceed 0.1 m.

It is preferred that independent of the thickness of the barrier, the barrier has a thermal conductivity of at

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most 1 W/mK, more preferably in the range of from 0.01 to 1 W/mK, more preferably 0.01 to 0.5 W/mK, in a direction perpendicular to the inner surface.

When the barrier is in heat contact with a heat source such as a hot cast material, the temperature of the barrier may change. The temperature change is induced by the transport of heat between the barrier and the heat source. The amount of heat necessary to change the temperature of the barrier, i.e. the volumetric specific heat capacity per unit area of the barrier depends on the thermal properties of the material(s) of which the barrier is comprised and the thickness of the barrier in a direction perpendicular to the inner surface. Reference herein to the volumetric specific heat capacity per unit area is to the heat required to raise a unit area of substance by one degree of temperature. The volumetric specific heat capacity per unit area is expressed in J/m<sup>2</sup>K. Preferably, the volumetric specific heat capacity per unit area of the barrier is at least 1,000 J/m<sup>2</sup>K, more preferably at least 10,000 J/m<sup>2</sup>, even more preferably in the range of from 10,000 to 10,000,000 J/m<sup>2</sup>K, in a direction perpendicular to the inner surface. The correlation between the volumetric specific heat capacity per unit area and the thickness of the barrier is given by the volumetric specific heat capacity in a direction perpendicular to the inner surface of the material(s) of which the barrier is comprised. Reference herein to the volumetric specific heat capacity is to the heat required to raise a unit volume of substance by one degree of temperature. The volumetric specific heat capacity is expressed in J/m<sup>3</sup>K and is obtained by dividing the volumetric specific heat capacity per unit area by the thickness.

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It is preferred that independent of the thickness of the barrier, the barrier has a volumetric specific heat capacity of at least  $10,000 \text{ J/m}^3\text{K}$ , more preferably at least  $1,000,000 \text{ J/m}^3\text{K}$ , even more preferably in the range of from  $1.000,000$  to  $100,000,000 \text{ J/m}^3\text{K}$ , in a direction perpendicular to the inner surface.

The advantage of a high specific heat capacity per unit area, preferably over  $10,000 \text{ J/m}^2\text{K}$ , is that this may allow the barrier to absorb significant amounts of heat before the temperature of the barrier is significantly changed. Although, heat is constantly transported through the barrier, the barrier in fact may act as a temperature buffer. When, in addition, the specific heat capacity is over  $1,000,000 \text{ J/m}^3\text{K}$ , this advantage, i.e. allowing the barrier to absorb significant amounts of heat before the temperature of the barrier is significantly changed, is obtained and in addition the required thickness of the barrier is kept to a minimum.

The mould may have any suitable shape known in the art, such as curved, cubical, spherical, cylindrical, triangular or an elongated derivative shape thereof. Typically, the mould may have an essentially cylindrical, cubical or elongated cubical shape. Examples of such shapes include a block with provided therein on or more inner volumes or any other support structure provided with one or more inner volumes. It will be appreciated that when two or more inner volumes are comprised in a single mould, the outer surface, i.e. the surface in contact with the outer atmosphere, may have a normal vector that is inclined in a plane perpendicular to the tangent plane of the inner surface.

The inner volume may have any shape that is known in the art. Typically, the shape of the inner volume may be

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determined by the desired shape of the cast material. Examples of such shapes include curved, cubical, spherical, triangular or an elongated derivative shape thereof. Such shapes may serve as tiles, bricks, building components or works of art.

The barrier may be comprised of one or more layers, whereby each layer may be comprised of the same or different materials. If there are two or more layers, such layers preferably extend in a direction parallel to the inner surface. Reference herein to a direction parallel to the inner surface is to a direction parallel to the tangent plane of the inner surface. It will be appreciated that if the inner surface is curved, the tangent plane may differ depending on the position on the inner surface. This has the advantage that a uniform thermal behaviour is obtained in the barrier in a direction perpendicular to the inner surface. Preferably, the barrier is comprised of two or more layers extending in a direction parallel to the inner surface. The use of more than one layer may provide a synergy effect. For instance a mechanically and thermally stable mould may be obtained by using mechanically strong outer layer combined with a thermally stable the inner layer. Typically, each layer may be comprised of a material independently having a thermal conductivity and/or volumetric specific heat capacity. Depending on the thickness of each layer, each layer may independently have a thermal conductance per unit area or volumetric specific heat capacity per unit area. Preferably, the layer forming the inner surface has a thermal conductivity of at most 1 W/mK in a direction perpendicular to the inner surface. This prevents a high

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rate of heat transfer at the interface between the barrier and the inner volume.

Preferably, the inner surface, outer surface and barrier are comprised of one or more metals, polymeric materials, silicon comprising materials or combinations thereof, preferably polymeric materials, silicon comprising materials or combinations thereof, more preferably polymeric materials. The materials may be dense or porous, such as polymeric or inorganic foams. The materials may be homogeneous or heterogeneous composites. It will be appreciated that the choice of material forming the inner surface should be such that a good surface finish can be obtained. Polyurethanes were found to be unsuitable as the moulds prepared using polyurethane showed significant deterioration and decomposition of the mould due to melting and decomposition of the polyurethane. It is known that polyurethane may start to decompose at temperature between 120 to 180°C. Consequently, the moulds have a reduced lifetime and the surface finish of the prepared sulphur cement products may be affected.

Typically, metals have a thermal conductivity above 5 W/mK, more typically in the range of from 20 to 450 W/mK. For example aluminium has a thermal conductivity of 237 W/mK, copper 398 W/mK, iron 80,3 W/mK and titanium 21,9 W/mK. It will therefore be appreciated that the mould should preferably not consist predominately out of a metal. For instance, the use of an iron mould would require a barrier thickness of at least 0.8 m.

Polymers, however, typically have a thermal conductivity below 1 W/mK. Furthermore, polymers may have volumetric specific heat capacities, which are typically

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in the range of from 1,000,000 to 10,000,000 J/m<sup>3</sup>K.  
 Therefore, a layer having a thickness of approximately  
 0.01 m of silicone rubber is sufficient to prepare a  
 mould according to the invention. Approximate values for  
 thermal conductivity and volumetric specific heat  
 capacities of generally known polymers are:

Material	Thermal conductivity (W/mK)	Volumetric specific heat capacity (J/m <sup>3</sup> K)
PVC	0.16	1,950,000
PTFE	0.25	2,200,000
Polydimethylsiloxane	0.86	2,704,000
Polyethylene	0.35	2,116,000
Polystyrene	0.035	39,000
Polyurethane	0.027	168,000
Polyimide	0.1	1,547,800
Polymethylmethacrylate	0.19	1,652,000
Polyamide	0.26	2,415,000
Resol type Foam	0.029	120,000
Novolac type Foam	0.024	30,144

It will be appreciated that depending on polymer  
 properties such as monomer composition, chain length and  
 the degree of cross-linking, the actual thermal  
 properties of a particular polymer may deviate from the  
 approximate values given hereinabove.

When the barrier is comprised out of two or more  
 layers comprising different materials, it will be  
 appreciated that the thermal conductance per unit area  
 (U) of the total barrier may be determined following  
 equation (1):

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$$1/U = 1/U_1 + 1/U_2 + \dots + 1/U_n \quad (1)$$

Examples of barriers include barriers comprised of silicon rubber, polycarbonate, glass or combination thereof with sand. In the later example the rubber, polycarbonate or glass form the most inner layer and the sand and may form an outer insulating layer. Such can be obtained for instance by embedding the inner layer in an amount of sand.

The invention further provides a process for shaping a sulphur cement product. In the process according to the invention a molten sulphur cement product is cooled in a mould and the heat flow through the mould is controlled such that at most 100 W/m<sup>2</sup>K is diffused per unit area through the mould in a direction perpendicular to the inner surface.

Reference to a molten sulphur cement product is to a sulphur cement product comprising molten sulphur. Sulphur melts in a temperature in a range of from 115 to 130 °C.

Preferably, the molten sulphur cement product has a temperature in the range of from 120 to 180 °C, more preferably 120 to 145 °C. At temperatures below this range the sulphur may not melt not melt or melt incompletely and the viscosity is too low and at higher, i.e. above 180°C, temperatures the sulphur has a tendency to polymerise, resulting in an undesired increased viscosity.

The cooling of the sulphur cement product is controlled by limiting the heat flow through the mould in a direction perpendicular to the inner surface. When the sulphur cement product is in contact with the inner surface of the mould at most 100 W/m<sup>2</sup>K is diffused

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through the mould in a direction perpendicular to the inner surface. Preferably, in the range of from 0.1 to 100 W/m<sup>2</sup>K, more preferably 0.1 to 60 W/m<sup>2</sup>K, even more preferably in the range of from 0.1 to 10 W/m<sup>2</sup>K, still more preferably of from 0.1 to 5 W/m<sup>2</sup>K is diffused through the mould in a direction perpendicular to the inner surface.

In the process according to the invention, a reduced temperature difference between the bulk of the sulphur cement product and the sulphur cement product contacting the inner surface may be obtained. This is in contrast to a process wherein more than 100 W/m<sup>2</sup>K is diffused through the mould, e.g. by using an iron or steel mould. The process according to invention may allow the bulk of the molten and the sulphur cement product contacting the inner surface to solidify approximately at the same time. As a consequence, the internal stress due to shrinkage induced by the solidification at the inner surface prior to the solidification of the bulk is reduced. It will be appreciated that these internal stresses play an important role in the formation of micro cracks and porosity on the surface of the solid sulphur cement product.

The mould may be any mould known in the art allowing at most 100 W/m<sup>2</sup>K to diffuse through the mould in a direction perpendicular to the inner surface. Preferably, a mould according to the invention is used.

The mould may be filled with a solid or a molten sulphur cement product. Preferably, the mould is filled with a molten sulphur cement product prior to cooling. It will be appreciated that when the mould is filled with a solid sulphur cement product, heat must be applied to the sulphur cement product to induce the sulphur to melt.

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Preferably, when the mould is filled with molten sulphur cement product, the mould is heated or preheated to a temperature close to the temperature at which the sulphur cement product is molten, preferably to a temperature in the range of from 90 to 150 °C, more preferably of from 100 to 140 °C. Preferably, the mould is heated before the mould is filled with molten sulphur cement product. Especially, when a mould is used with a high volumetric specific heat capacity per unit area, i.e. of from 1,000 J/m<sup>2</sup>K, more preferably for from 10,000 J/m<sup>2</sup>K, even more preferably in the range of from 10,000 to 10,000,000 J/m<sup>2</sup>K, in a direction perpendicular to the inner surface, the mould may act as a temperature buffer. When such a mould is preheated to a temperature in the range of the melt temperature of sulphur, premature solidification of the sulphur cement product at the inner surface of the mould may be prevented.

Preferably, the inner surface of the mould is comprised of a polymeric material, a silicon-based glass or a combination thereof. Such materials may allow for an easy release of the solid shaped sulphur cement product, without the use of release agents, such as form oil.

It will be appreciated that when the inner surface is comprised of a polymeric material, the polymeric material has a thermal decomposition temperature and/or melting temperature of at least 120°C, preferably of at least 200°C. Reference herein to melting temperature is to a temperature above which the viscosity of the polymer becomes so low that the structural integrity of the inner surface is compromised. It will be appreciated that some polymers do not melt as the polymer thermally decomposes prior to melting. Such polymers, however, may show a decrease in viscosity when reaching a temperature above

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their glass transition temperature the structural integrity of the inner surface may become compromised.

It will further be appreciated that the inner surface should not react chemically with the sulphur.

5            Preferably, the polymeric material is a silicon-based rubber, polycarbonate, poly(ethylene terephthalate), polyimide, polyamide, fluoropolymer or a combination thereof, preferably a silicon-based rubber. Silicon-based rubbers are well known in the art. Examples  
10 of silicon-based rubbers include polydimethylsiloxane (PDMS). More preferably, the mould is essentially in its entirety formed from a silicon-based rubber. The use of silicon-based rubber moulds may improve the release of solid sulphur cement products even further due to the  
15 flexible nature of silicon-based rubbers.

          Polyurethanes were found to be unsuitable as the moulds prepared using polyurethane showed significant deterioration and decomposition of the mould due to melting and decomposition of the polyurethane. It is  
20 known that polyurethane may start to decompose at temperature between 120 to 180°C. Consequently, the moulds have a reduced lifetime and the surface finish of the prepared sulphur cement products may be affected.

          The sulphur cement product may be any sulphur cement  
25 containing material, i.e. a material at least containing elemental sulphur and a filler. Examples of sulphur cement containing materials are sulphur cement premix compositions and sulphur cement-aggregate composites such as sulphur mortar, sulphur concrete or sulphur-extended  
30 asphalt.

          Sulphur cement is known in the art and at least comprises sulphur, usually in an amount of at least 50 wt%, and a filler.

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Usual sulphur cement fillers are particulate inorganic materials with an average particle size in the range of from 0.1  $\mu\text{m}$  to 0.1 mm. Examples of such sulphur cement fillers are fly ash, limestone, quartz, iron oxide, alumina, titania, graphite, gypsum, talc, mica or combinations thereof. The filler content of sulphur cement may vary widely, but is typically in the range of from 5 to 50 wt%, based on the total weight of the cement.

Sulphur cement may be plasticised by the addition of a sulphur cement modifier in the sulphur cement preparation process. Such modifiers are known in the art. Examples of such modifiers are aliphatic or aromatic polysulphides or compounds that form polysulphides upon reaction with sulphur. Examples of compounds that form polysulphides are olefinic compounds such as 5-ethylene-2-norbornene, dicyclopentadiene, limonene, styrene or naphthalene. Modifiers may be added in an amount in the range of from 0.05 to 25 wt% based on the weight of sulphur, usually in the range of from 0.1 to 10 wt%.

Reference herein to a sulphur cement premix composition is to a composition comprising a pre-reacted mixture of sulphur and a sulphur cement modifier that can suitably be used for the preparation of sulphur cement by adding sulphur and/or filler to it in the required amounts.

Reference herein to sulphur cement-aggregate composites is to a composite comprising both sulphur cement and aggregate. Examples of sulphur cement-aggregate composites are sulphur mortar, sulphur concrete and sulphur-extended asphalt. Mortar comprises fine aggregate, typically with particles having an average diameter between 0.1 and 5 mm, for example sand. Concrete

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comprises coarse aggregate, typically with particles having an average diameter between 5 and 40 mm, for example gravel or rock. Sulphur-extended asphalt is asphalt (typically aggregate with a binder containing  
5 filler and a residual hydrocarbon fraction), wherein part of the binder has been replaced by sulphur.

It has been found that the shaped solid sulphur cement products prepared by the process according to the invention show a good surface finish and exhibit  
10 reflectory properties. This enables the preparation of shaped sulphur cement products with a coloured glossy surface finish. A pigment may be applied on the inner surface of the mould prior to introducing the cast material into the inner volume. After the cast material  
15 is introduced, the pigment may subsequently be transferred to the surface of the sulphur cement product. After cooling, a coloured shaped solid sulphur cement product is obtained.

#### Examples

20 The following non-limiting experiments serve to illustrate the invention.

#### Experiment 1

A cast mixture was used comprising 25 wt% sulphur, 28 wt% quartz as filler and 47 wt% dried sand (Normsand)  
25 as aggregate. Both the quartz filler and the sand aggregate were preheated for 12 hours at 150 °C. The cast mixture was prepared by mixing the molten sulphur with the sand aggregate. Subsequently, the quartz filler was mixed into the mixture.

30 A silicon rubber mould (mould 1) having properties as shown in table 1 was preheated to a temperature of approximately 100 °C for at least 12 hours. Bars of 40x40x160 mm were prepared by casting the molten cast

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mixture into the preheated mould and allowing the mould and cast mixture to cool to a temperature below 60 °C. The sulphur cement bar could be removed from the mould without the need to apply excessive force due to the flexible nature of the silicon rubber mould.

The sulphur cement bar produced according to experiment 1 is shown in Figure 1 as Sample 1. The produced sulphur cement bar had a very smooth surface finish.

#### Experiment 2

A sulphur cement product was produced following the method of experiment 1, with the exception that the silicon rubber mould was preheated to 55 °C. Again, the sulphur cement bar could be removed from the silicon rubber mould without the need to apply excessive force due to the flexible nature of the silicon rubber mould.

The sulphur cement bar produced according to experiment 2 is shown in Figure 1 as Sample 2. The produced sulphur cement bar had a smooth surface finish.

#### Comparative Experiment A

A sulphur cement product was produced following the method of experiment 1, with the exception that the silicon rubber mould was replaced by a stainless steel mould as described in NEN-EN-196 (mould A, see Table 1 for the mould properties).

After cooling the sulphur cement bar was removed from the mould by dismantling the mould.

The sulphur cement bar produced according to comparative experiment A is shown in Figure 1 as Sample A. The produced sulphur cement bar had a very rough surface texture compared to the sulphur cement bars produced in experiments 1 and 2. Large deformations were visible on the surface of the sulphur cement bar.

Comparative Experiment B

A sulphur cement product was produced following the method of comparative experiment A, with the exception that the inner surface of the stainless steel mould was coated with a PTFE (polytetrafluorethylene) layer (mould B, see table 1 for the mould properties). The PTFE layer had a thickness of approximately 100  $\mu\text{m}$ .

After cooling the bar was removed from the mould by dismantling the mould. It was visually observed that part of the PTFE layer was transferred from the mould to the sulphur cement bar. To repeat the experiment it was necessary to remove the remaining part of the PTFE layer and apply a new PTFE layer to the inner surface of the stainless steel mould.

The sulphur cement bar produced according to comparative experiment B is shown in Figure 1 as Sample B. The produced sulphur cement bar had a rough surface texture compared to the sulphur cement bars produced in experiments 1 and 2.

Table 1

Mould	thickness barrier	thermal conductance per unit area	volumetric specific heat capacity per unit area
	[ $\times 10^{-3}$ m]	[W/m <sup>2</sup> K]	[J/m <sup>2</sup> K]
1	15	57	27075
A	15	933	54510
B*	15.1	697	54730

\*For the calculations a thickness of the PTFE coating of  $1 \times 10^{-4}$  m was used

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C L A I M S

1. Mould for shaping a sulphur cement product, which mould has an inner surface describing an inner volume for receiving a cast material, an outer surface and a barrier comprised between the inner surface and the outer  
5 surface, which barrier has a thermal conductance per unit area of at most  $100 \text{ W/m}^2\text{K}$  in a direction perpendicular to the inner surface.
2. Mould according to claim 1, wherein the barrier has a thermal conductance per unit area of at most  $60 \text{ W/m}^2\text{K}$ ,  
10 preferably in the range of from  $0.1$  to  $10 \text{ W/m}^2\text{K}$ , more preferably of from  $0.1$  to  $5 \text{ W/m}^2\text{K}$ .
3. Mould according to claim 1 or 2, wherein the barrier has a thermal conductivity of at most  $1 \text{ W/mK}$ , preferably at most  $0.5 \text{ W/mK}$ , in a direction perpendicular to the  
15 inner surface.
4. Mould according to any one of claims 1 to 3, wherein the barrier further has a volumetric specific heat capacity per unit area of at least  $10,000 \text{ J/m}^2\text{K}$  in a direction perpendicular to the inner surface.
- 20 5. Mould according to claim 4, wherein the barrier has a volumetric specific heat capacity of at least  $1,000,000 \text{ J/m}^3\text{K}$ , in a direction perpendicular to the inner surface.
6. Mould according to any one of claims 1 to 5, wherein the barrier comprises two or more layers extending in a  
25 direction parallel to the inner surface.
7. Mould according to claim 6, wherein the layer forming the inner surface has a thermal conductivity of

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at most 1 W/mK in a direction perpendicular to the inner surface.

8. Mould according to any one of claims 1 to 7, wherein the inner surface, outer surface and barrier are  
5 comprised of one or more metals, polymeric materials, silicon comprising materials or combinations thereof, preferably polymeric materials, silicon comprising materials or combinations thereof, more preferably polymeric materials.

10 9. Process for shaping a sulphur cement product comprising cooling a molten sulphur cement product in a mould having an inner surface in contact with the molten sulphur cement product to obtain a shaped solid sulphur cement product, wherein at most 100 W/m<sup>2</sup>K is diffused per  
15 unit area through the mould in a direction perpendicular to the inner surface.

10. Process according to claim 9, wherein at most 60 W/m<sup>2</sup>K, preferably in the range of from 0.1 to 10 W/m<sup>2</sup>K, more preferably of from 0.1 to 5 W/m<sup>2</sup>K is  
20 diffused per unit area through the mould in a direction perpendicular to the inner surface.

11. Process according to claim 9 or 10, wherein the mould is a mould according to any one of claims 1 to 8.

12. Process according to any one of claims 9 to 11,  
25 wherein the mould is filled with a molten sulphur cement product prior to cooling.

13. Process according to claim 12, wherein prior to filling the mould with the molten sulphur cement product, the mould is heated to a temperature in the range of from  
30 90 to 150 °C, more preferably of from 100 to 140 °C.

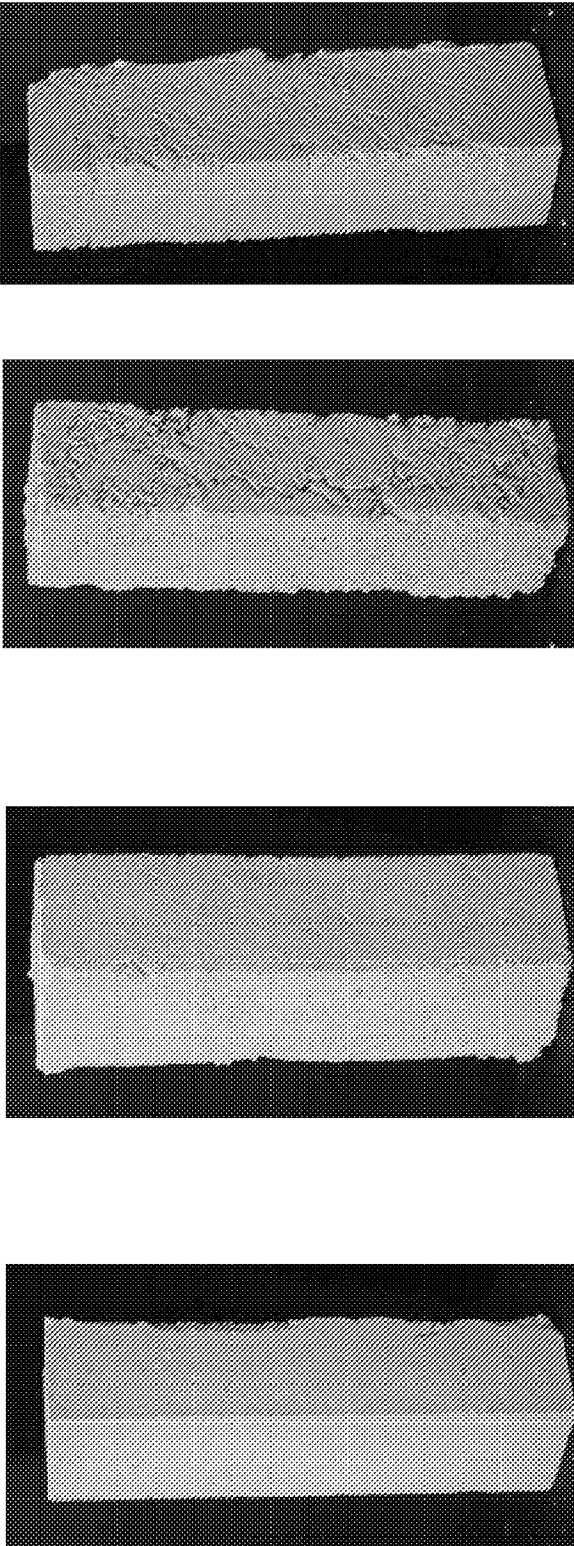
14. Process according to any one of claims 9 to 13, wherein the inner surface is a polymeric material, a silicon-based glass or a combination thereof.

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15. Process according to claim 14, wherein the inner surface is a polymeric material and the polymeric material has a thermal decomposition temperature and/or melting temperature of at least 120 °C, preferably of at least 200 °C.

16. Process according to claim 15, wherein the polymeric material is a silicon-based rubber, polycarbonate, poly(ethylene terephthalate), polyimide, polyamide, fluoropolymer or a combination thereof, preferably a silicon-based rubber.

Figure 1.



Sample B<sup>#</sup>

Sample A<sup>#</sup>

Sample 2

Sample 1

<sup>#</sup> not according to the invention

# INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2008/050363

## A. CLASSIFICATION OF SUBJECT MATTER

INV. B28B7/34 C04B28/36 B28B1/54

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B28B C04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 37 40 682 A1 (DONATH GABRIELE [DE]) 15 June 1989 (1989-06-15)	1-5
Y	column 3, line 19 - line 33; claim 5; figures 2,3	6-8
X	FR 2 773 340 A1 (CONST IND RATIONNELLES [FR]) 9 July 1999 (1999-07-09)	1-5
Y	page 4, line 12 - line 13; figure 2	
Y	WO 2006/013589 A (TONCELLI DARIO [IT]) 9 February 2006 (2006-02-09)	6-8
A	claims 1,2,6-8; figures	1-5
X	CA 2 267 860 A1 (EMPIRICAL DEV INC [CA]) 30 September 2000 (2000-09-30)	1-5, 8-12, 14-16
Y	page 10, line 1 - page 11, line 16; claims 19-22,26	13
	-/--	

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

\* Special categories of cited documents:

\*A\* document defining the general state of the art which is not considered to be of particular relevance

\*E\* earlier document but published on or after the international filing date

\*L\* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

\*O\* document referring to an oral disclosure, use, exhibition or other means

\*P\* document published prior to the international filing date but later than the priority date claimed

\*T\* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

\*X\* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

\*Y\* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

\*Z\* document member of the same patent family

Date of the actual completion of the international search

9 May 2008

Date of mailing of the international search report

23/05/2008

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# INTERNATIONAL SEARCH REPORT

International application No  
PCT/EP2008/050363

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	<p>US 4 981 740 A (LARSEN LEIF H A [DK])  1 January 1991 (1991-01-01)  claims 7-13; example 4</p>	13

## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/EP2008/050363

### Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:  
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

### Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers allsearchable claims.
2. ☒ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search reportcovers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

#### Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

**FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210**

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-8

mould with a barrier between inner and outer surface  
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2. claims: 9-16

process for shaping a sulphur cement product  
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# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2008/050363

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 3740682	A1	15-06-1989	NONE
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