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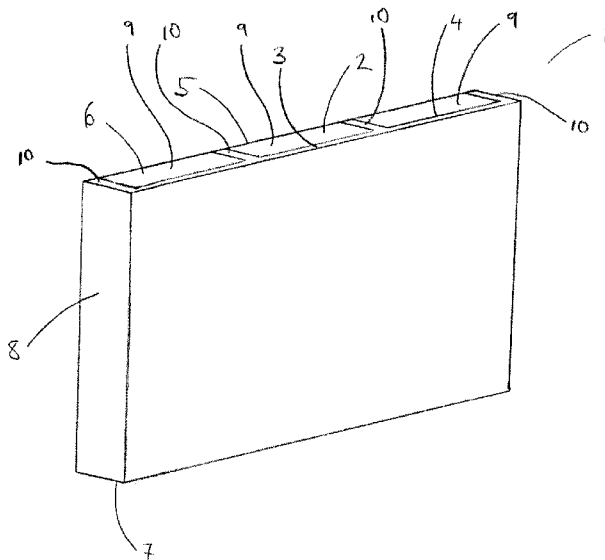
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(54) Title: **FACADE ELEMENT**

Figure 1



(57) Abstract: A façade element comprising: an insulating layer having a first major face, a second major face, an upper edge and a lower edge, and two side edges, each edge connecting the first and second major faces, wherein the insulating layer comprises a coherent man-made vitreous fibre-containing insulating material and at least one stud extending substantially from the upper edge to the lower edge and substantially from the first major face to the second major face of the insulating layer; and a face plate disposed on the first major face of the insulating layer; wherein both the stud and the face plate comprise a polymeric foam composite material, the polymeric foam composite material comprising a polymeric foam and discontinuous man-made vitreous fibres, wherein at least 50% by weight of the man-made vitreous fibres present in the polymeric foam composite material have a length less than 100 micrometres.

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Façade Element

Field of the Invention

The invention relates to a façade element useful in the construction of building walls. The invention also relates to a building wall including such a
5 façade element and a building including such a building wall.

Background to the Invention

The invention relates to façade elements that can be used in external walls that include vertical posts and horizontal joists that form the basic
10 framework of the building. Traditionally, in light-frame construction, a framework is built up from horizontal joists and vertical studs. This framework is then covered on its outside with thermally insulating cladding and a waterproofing material and on its inside with plaster board, for example. This system has the advantage of being quick to construct, but, since the wall is insulated outside the
15 framework, the overall wall thickness is high for the level of insulation provided.

Instead of providing an outer insulating cladding, insulation material can instead be provided in between the joists and studs in the framework, decreasing the thickness of the insulating cladding required. However, the load-bearing studs are generally constructed from wood or metal, so have a high
20 thermal conductivity and can form thermal bridges through the wall. Furthermore, installation of insulating material between the studs and joists in the framework can be time-consuming in comparison with installation of thermally insulating outer cladding.

Therefore, it is an object of the invention to provide a façade element with
25 a high level of thermal insulation and which is light and allows quick and economic construction of the building. It is also an object of the invention to provide a façade element that can act as a load-bearing structure in a building wall, thereby reducing the complexity of the building framework that is required. It is also an object of the invention to provide a façade element on which it is
30 easy to apply render and which has an increased dimensional stability under specific temperature and humidity conditions. Finally, it is an object of the invention to achieve excellent fire resistance.

Summary of the Invention

To solve the above-mentioned problems, the invention provides a façade element comprising:

an insulating layer having a first major face, a second major face, an upper edge and a lower edge, and two side edges, each edge connecting the first and second major faces, wherein the insulating layer comprises a coherent man-made vitreous fibre-containing insulating material and at least one stud extending substantially from the upper edge to the lower edge and substantially from the first major face to the second major face of the insulating layer; and

a face plate disposed on the first major face of the insulating layer; wherein both the stud and the face plate comprise a polymeric foam composite material, the polymeric foam composite material comprising a polymeric foam and discontinuous man-made vitreous fibres, wherein at least 50% by weight of the man-made vitreous fibres present in the polymeric foam composite material have a length less than 100 micrometres.

The invention also provides a building wall comprising a façade element according to the invention, positioned such that the face plate is substantially vertical, a lower joist that supports the façade element at its edge corresponding to the lower edge of the insulating layer and an upper joist that abuts the façade element at its edge that corresponds to the upper edge of the insulating layer.

The invention also provides a building comprising a wall according to the invention.

The façade elements of the invention can be used in construction of a building wall by positioning them between the horizontal joists that make up the framework of the building.

By using the polymeric foam composite material for the studs, it is possible for the façade element to be load-bearing, because the polymeric foam composite material has a high level of compressive strength and resistance to compression and is also dimensionally stable in hot or humid conditions. The polymeric foam composite material is also highly insulating, which reduces the degree of thermal bridging through the façade element. By including load-bearing and thermally insulating studs within the façade element itself, it is possible to reduce the number of metal or timber studs used in the building framework. Reducing the number of metal or timber studs reduces the level of thermal bridging and also means that fewer, larger, façade elements make up

the building wall. This, in turn, increases the speed of construction. In some cases, metal and timber studs can be excluded entirely, with a single façade element extending from one corner of the building to another.

5 The provision of a coherent man-made vitreous fibre-containing insulating material in the insulating layer ensures that the façade element has a high level of thermal insulation and that the overall density of the façade element is not too high, which allows for easier installation.

The provision of a face plate of polymeric foam composite material contributes to the load-bearing capacity of the façade element and also provides
10 a surface that is highly suited to the application of render.

Detailed Description of the Invention

The invention is described in more detail below with reference to the
15 Figures.

Figure 1 shows an outer perspective view of a façade element according to the invention.

Figure 2 shows an inside perspective view of a façade element according to the invention.

20 Figure 3 shows a horizontal sectional view of a façade element according to the invention.

Figure 4 shows a horizontal sectional view of a preferred embodiment of the invention.

25 Figure 5 shows a perspective view of part of a building wall according to the invention.

Figure 6 shows a perspective view of a building wall according to the invention.

Figure 7 is a photograph showing the effect of heating on the composite materials of Examples 6 and 7.

30 Figure 8 is an environmental scanning electron microscope image of a polyurethane foam composite material as used according to the invention.

The façade element 1 shown in Figures 1, 2 and 3 comprises an insulating layer 2 and a face plate 3. The insulating layer 2 has a first major face

4, of which only the edges are visible in Figures 1 and 2, and a second major face 5, which is fully visible in Figure 2. The insulating layer also has an upper edge 6, a lower edge 7 and side edges 8, wherein each edge connects the first major face 4 and the second major face 5 of the insulating layer 2. The face plate 3 is disposed on the first major face 4 of the insulating layer 2.

The insulating layer 2 comprises a coherent man-made vitreous fibre-containing insulating material 9 and at least one stud 10. The stud or studs 10 extend substantially from the upper edge 6 to the lower edge 7 of the insulating layer 2 and substantially from the first major face 4 to the second major face 5 of the insulating layer 2. Both the stud or studs 10 and the face plate 3 comprise a polymeric foam composite material as described in more detail below.

The height of the façade element is generally such that it can span a single storey of a building. Therefore, the height is generally between 2 m and 4 m, although taller and shorter façade elements 1 can also be made according to the invention. In some cases, the width of the façade element 1 may be so as to span the entire width of a building. However, more usually, a plurality of façade elements 1 are positioned side-by-side on each side of each storey of the building. The width of each façade element 1 is advantageously greater than façade elements that have been used previously, for example in the range 2 m to 15 m. However, the façade elements according to the invention are also useful when they have a more conventional width of from 0.5m to 1.5m or from 0.6 m to 1m, for example.

The depth of the façade element 1 is determined by the amount of insulation and the level of structural support that the façade element 1 is required to contribute. Generally, the thickness of the façade element 1 is in the range 10 to 60 cm, preferably 15 to 50 cm, more preferably 20 to 40 cm.

Generally, the insulating layer 2 and the face plate 3 each span the majority of, or almost the entire height and width of the façade element 1. It is possible, however, for the façade element 1 to have additional plates (not shown) at any of the edges 6, 7, 8. Such plates could surround the insulating layer 2 to form a frame. Such a frame could be useful to distribute any loads across the edges of the façade element 1 and to protect it from damage during storage and installation. Moreover, such additional plates might be shaped or

profiled in order to secure a tight fit and sealing between adjacent elements. This can contribute to providing a building envelope that is air-tight.

The insulating layer 2 of the façade element 1 of the invention comprises a coherent man-made vitreous fibre-containing insulating material 9. The term
5 "coherent" means that the man-made vitreous fibre-containing insulating material 9 is not in the form of a granulate or any other loose insulating material.

The coherent man-made vitreous fibre-containing insulating material 9 is preferably mineral wool. The man-made vitreous fibres in the coherent man-made vitreous fibre-containing insulating material 9 can be glass fibres, ceramic
10 fibres, slag wool fibres or any other type of man-made vitreous fibre, but they are preferably stone fibres. Stone fibres have a composition, expressed as weight percent of oxides as follows:

SiO₂ 25 to 50%, preferably 38 to 48%
Al₂O₃ 12 to 30%, preferably 15 to 28%
15 TiO₂ up to 2%
Fe₂O₃ 2 to 12%
CaO 5 to 30%, preferably 5 to 18%
MgO up to 15%, preferably 4 to 10%
Na₂O up to 15%
20 K₂O up to 15%
P₂O₅ up to 3%
MnO up to 3%
B₂O₃ 0 to 3%.

These values are all quoted as oxides, with iron quoted as Fe₂O₃, as is
25 conventional.

The man-made vitreous fibres present in the coherent man-made vitreous fibre-containing insulating material 9 can be produced by standard methods such as with a cascade spinner or a spinning cup. Usually, the fibres are treated with a binder and collected as a web before being cured.

30 In order to provide a façade element 1 having as low weight and overall density as possible, and because the coherent man-made vitreous fibre-containing insulating material 9 does not contribute significantly to the strength of the insulating layer 2, it is possible for this material to have a low density. It is preferred that the coherent man-made vitreous fibre-containing insulating

material 9 has a density less than 80 kg/m^3 , preferably less than 60 kg/m^3 , more preferably less than 50 kg/m^3 . Usually the density of the coherent man-made vitreous fibre-containing insulating material 9 is at least 20 kg/m^3 , more usually at least 30 kg/m^3 .

5 The primary purpose of the coherent man-made vitreous fibre-containing insulating material 9 is to provide a high level of thermal insulation. Therefore, it is preferred that the coherent man-made vitreous fibre-containing insulating material 9 has a thermal conductivity of less than $40 \text{ mW/(m}\cdot\text{K)}$, more preferably less than $35 \text{ mW/(m}\cdot\text{K)}$ and more preferably less than $33 \text{ mW/(m}\cdot\text{K)}$.

10 The coherent man-made vitreous fibre-containing insulating material 9 can be fixed in place with an adhesive. However, preferably, the coherent man-made vitreous fibre-containing insulating material 9 is bonded to the stud or studs 10 and/or to the face plate 3 without the use of any extrinsic fixing means. This can be achieved by forming the face plate 3 or the stud or studs 10 in the
15 presence of the coherent man-made vitreous fibre-containing insulating material 9.

 As shown in the Figures, the coherent man-made vitreous fibre-containing insulating material 9 is usually arranged in blocks that fill the gaps between the studs 10. Preferably the blocks fill substantially all of the space
20 between successive studs 10.

 In order to provide a good level of insulation to the building, the insulating layer 2 usually forms the majority of the thickness of the façade element 1. However, as the face plate 3 also has a good level of insulation, this is not essential. Nevertheless, it is preferable for the insulating layer 2 to form the
25 majority of the thickness of the façade element 1 in order to keep the density of the façade element 1 to a minimum. Therefore, the thickness of the insulating layer 2 is preferably from 8 cm to 50 cm, more preferably from 13 cm to 45 cm, most preferably from 18 cm to 35 cm.

 The insulating layer 2 also includes at least one stud 10, which extends
30 substantially from the first face 4 to the second face 5 of the insulating layer 2 and from the upper edge 6 to the lower edge 7 of the insulating layer 2. Whilst the invention allows for façade elements 1 including only a single stud 10, it is more usual for the insulating layer 2 to comprise a plurality of studs 10 extending from the upper edge 6 to the lower edge 7 and substantially from the first major

face 4 to the second major face 5 of the insulating layer 2. The studs 10 comprise a polymeric foam composite material as discussed below.

The studs 10 can be load-bearing. The precise number of studs 10, the distance between each stud and the dimensions of each stud can be selected according to the circumstances, depending on the level of structural support required, the density and weight desired for the façade element 1 and the dimensions of the façade element 1. Typically, the studs 10 are separated by a distance in the range 30 cm to 1.25 m, more usually in the range 30 cm to 90 cm. The width of each stud in the plane of the insulating layer is generally in the range 1 cm to 15 cm, more preferably from 2 cm to 10 cm. The studs 10 usually run parallel to each other and perpendicular to the upper edge 6 and the lower edge 7 of the insulating layer 2. The height and depth of the studs 10 depend directly on the dimensions of the insulating layer 2.

In a particularly advantageous embodiment, a stud 10 forms a side edge 8 of the insulating layer 2. Preferably each side edge 8 of the insulating layer 2 is formed by a stud 10. This ensures that the side edges 8 of the insulating layer 2 are rigid, so can be handled easily with a low risk of damage.

The face plate 3 is formed from a polymeric foam composite material as discussed below. This material has been found to be particularly suited for construction of the face plate 3 due to its high compressive strength and resistance to compression, its increased dimensional stability under specific temperature and humidity conditions, its high level of fire resistance and because it is easy to apply render to this material. Dimensional stability of the face plate 3 in hot or humid conditions is particularly important. The façade element is usually separated from the elements only by a layer of render. Therefore, where the render is exposed to direct sunlight, in particular when it is darkly coloured, the render and the face plate 3 can reach temperatures of 70 or 80°C. If the face plate 3 were to shrink under these conditions, as would be the case with traditional polymeric foams such as polyurethane and expanded polystyrene, it could result in the render cracking and the façade element no longer being able to provide the same level of structural support. The polymeric foam composite used in the invention, however, retains its shape more effectively when subjected to heat and moisture.

A face plate 3 of a polymeric foam composite material according to the present invention provides a high receptiveness and/or adhesion for a rendering system without using any additional surface primer, coating and/or additive. Such high receptiveness and/or adhesion for the rendering system results in a high bond strength between the base coat of a rendering and the face plate 3 of the façade element 1. The bond strength between a layer of render, especially a base coat, which is the layer of render applied directly to an insulation element (such as a façade element) in a rendering system, and the insulating (façade) element is measured in accordance with the Guideline for European Technical Approval ETAG No. 004 (e.g. edition 03/2000), paragraph 5.1.4.1.1. The results are expressed in N/mm² (MPa). Preferably, in the building wall or building of the invention, at least a base coat of render is applied to the face plate 3 and the bond strength between the face plate 3 and a the base coat is at least 0,010 N/mm², more preferably at least 0,020 N/mm² and even more preferably at least 0,040 N/mm².

Preferably, the face plate 3 covers the entire first major face 4 of the insulating layer 2. The face plate 3 generally contributes to the strength of the façade element 1 so its depth can be selected on the basis of the level of structural support required. Usually, the face plate 3 has a depth in the range 1 cm to 10 cm, preferably in the range 1.5 cm to 8 cm, more preferably in the range 2 cm to 6 cm.

It is often advantageous, as in the embodiment shown in Figures 1, 2 and 3 for the face plate 3 and the studs 10 to be bonded together without any extrinsic attachment means, such as adhesive. This can be achieved by forming the studs 10 and the face plate 3 simultaneously in position relative to each other, so that the studs 10 and the face plate 3 essentially form a single piece of polymeric foam composite material. Alternatively the bond could be formed by pre-forming the face plate 3 and forming the studs 10 *in situ* on the face plate 3. It is also within the scope of the invention, however, for the studs 10 and the face plate 3 to be separate elements bonded together with an adhesive.

In one embodiment of the invention (not shown), the façade element also comprises reinforcing plates extending horizontally between the studs 10. For example, a plurality of reinforcing plates could be arranged to extend horizontally between the studs 10 at intermediate levels within the façade element 1. This

arrangement has the effect of further improving the load-bearing capacity and/or to act as an additional bracing, e.g. when arranged between vertical posts. The horizontal reinforcement plates are preferably formed of the polymeric foam composite material described below.

5 Figure 4 shows a preferred embodiment of the invention in which a back plate 11 is disposed on the second major face 5 of the insulating layer 2. The back plate 11 forms the inside surface of the building wall. Preferably, the back plate 11 is a gypsum board or a plyboard.

Figure 5 shows part of a building wall 12 according to the invention. The
10 façade element 1 is shown in position such that the face plate 3 is substantially vertical. A lower joist 13 supports the façade element 1 at its edge corresponding to the lower edge 7 of the insulating layer 2. This edge of the façade element 1 could be formed by the lower edge 7 of the insulating layer 2 itself (as shown) or by a plate that covers the lower edge 7 of the insulating layer
15 2. An upper joist 14 abuts the façade element 1 at its edge that corresponds to the upper edge 6 of the insulating layer 2. This edge of the façade element 1 could be formed by the upper edge 6 of the insulating layer 2 itself (as shown) or by a plate that covers the upper edge 6 of the insulating layer 2

Any façade element according to the invention can be used to form a
20 building wall in this way. The particular façade element 1 shown in Figure 5 is of the preferred embodiment comprising a back plate 11 disposed on the second major face 5 of the insulating layer 2.

The upper joist 14 and the lower joist 13 are preferably steel joists. However, it is also possible for the upper joist 14 and the lower joist 13 to be
25 manufactured from another material such as timber. Where the joists 13, 14 are steel joists, they can have a variety of different profiles depending on the circumstances. Joists 13 and 14 shown in Figure 5 are C-profile joists, but the use of H-profile joists is, of course, also possible. The joists 13, 14 are generally supported at either end by vertical posts (not shown).

30 A wider section of a building wall according to the invention is shown in Figure 6. In the particular building wall 12 shown, a plurality of façade elements 1 are disposed adjacent to one another. Each façade element 1 is substantially vertical and a lower joist 13 supports each façade element at its edge corresponding to the lower edge 7 of the insulating layer 2. An upper joist 14

abuts each façade element 1 at its edge that corresponds to the upper edge 6 of the insulating layer 2. Where there is more than one storey, as in Figure 6, at least one joist can act as both a lower joist 13 and an upper joist 14 with respect to different façade elements 1. The joists 13 and 14 are affixed at their ends to vertical posts 15. One advantage of the façade element according to the invention is that, often, the façade element provides such a high degree of structural support that no further stud-work is necessary. However, sometimes, in order to provide additional structural support, external studs 16, which are affixed to the lower joist 13 and the upper joist 14, are disposed between adjacent façade elements 1. Even when such external studs 16 are necessary, the number of the studs is usually low in the context of the invention, which reduces the amount of thermal bridging through the building wall. The external studs 16 are usually steel studs, but could also be timber studs.

15 Polymeric Foam Composite Material

The invention makes use of the polymeric foam composite material described in our earlier application filed on 18 August 2011 and having the application number EP 11177971.6 and in our international application PCT/EP2012/066196 filed on 20 August 2012. The disclosure of those applications is incorporated herein by reference.

The polymeric foam composite material used in the present invention can be produced from a foamable composition comprising a foam pre-cursor and discontinuous man-made vitreous fibres, wherein at least 50% by weight of the man-made vitreous fibres have a length of less than 100 micrometres.

25 The term "discontinuous man-made vitreous fibres" is well understood by those skilled in the art. Discontinuous man-made vitreous fibres are, for example, those produced by internal or external centrifugation, for example with a cascade spinner or a spinning cup.

30 The weight percentage of fibres in the polymeric foam composite material or in the foamable composition above or below a given fibre length is measured with a sieving method. A representative sample of the man-made vitreous fibres is placed on a wire mesh screen of a suitable mesh size (the mesh size being the length and width of a square mesh) in a vibrating apparatus. The mesh size can be tested with a scanning electron microscope according to DIN ISO 3310.

The upper end of the apparatus is sealed with a lid and vibration is carried out until essentially no further fibres fall through the mesh (approximately 30 mins). If the percentage of fibres above and below a number of different lengths needs to be established, it is possible to place several screens with incrementally increasing mesh sizes on top of one another. The fibres remaining on each screen are then weighed.

In order to measure the length of fibres present in a polymeric foam composite of the invention, it is possible to burn off the foam from a representative sample of the foam composite by placing it in a 590°C furnace for 20 min. This method is according to ASTM C612-93. The remaining fibres can then be analysed using a wire mesh screen as set out above.

According to the invention, the discontinuous man-made vitreous fibres present in the polymeric foam composite must have at least 50% by weight of the fibres with a length less than 100 micrometres as measured by the method above.

By reducing the length of man-made vitreous fibres that are present in the foamable composition and in the polymeric foam composite, a larger quantity of fibres can be included in the foamable composition before an unacceptably high viscosity is reached. As a result, the compressive strength, fire resistance, and in particular the compression modulus of elasticity and dimensional stability in hot or humid conditions of the resulting foam can be improved. Previously, it had been thought that ground fibres having such a low length would simply act as a filler, increasing the density of the foam. However, by using mineral fibres with such a high proportion of short fibres, far higher levels of fibres can be incorporated into the foam precursor and the resulting foam. The result of this is that significant increases in the compressive strength and, in particular, the compression modulus of elasticity of the foam can be achieved. The dimensional stability in hot or humid conditions can also be increased.

Preferably, the length distribution of the man-made vitreous fibres present in the polymeric foam composite or foamable composition is such that at least 50% by weight of the man-made vitreous fibres have a length of less than 75 micrometres, more preferably less than 65 micrometres.

Preferably, at least 60% by weight of the man-made vitreous fibres present in the polymeric foam composite or foamable composition have a length

less than 100 micrometres, more preferably less than 75 micrometres and most preferably less than 65 micrometres.

Generally, the presence of longer man-made vitreous fibres in the polymeric foam composite or foamable composition is found to be a disadvantage in terms of the viscosity of the foamable composition and the ease of mixing. Therefore, it is preferred that at least 80%, or even 85 or 90% of the man-made vitreous fibres present in the polymeric foam composite or foamable composition have a length less than 125 micrometres. Similarly, it is preferred that at least 95%, more preferably at least 97% or 99% by weight of the man-made vitreous fibres present in the polymeric foam composite or foamable composition have a length less than 250 micrometres.

The greatest compressive strength and highest dimensional stability can be achieved when at least 90% by weight of the fibres have a length less than 100 micrometres and at least 75% of the fibres by weight have a length less than 65 micrometres.

Man-made vitreous fibres having the length distribution discussed above have been found generally to sit within the walls of the cells of the foam composite, without penetrating the cells to a significant extent. Therefore, it is believed that a greater percentage by weight of the fibres in the composite contribute to increasing the strength of the composite rather than merely increasing its density.

It is also preferred that at least some of the fibres present in the foam composite material, for example at least 0.5% or at least 1% by weight, have a length less than 10 micrometres. These very short fibres are thought to be able to act as nucleating agents in the foam formation process. The action of very short fibres as nucleating agents can favour the production of a foam with numerous small cells rather than fewer large cells.

The fibres present in the polymeric foam composite or in the foamable composition can be any type of discontinuous man-made vitreous fibres, but are preferably stone fibres. In general, stone fibres have a content by weight of oxides as follows:

SiO₂ 25 to 50%, preferably 38 to 48%

Al₂O₃ 12 to 30%, preferably 15 to 28%

TiO₂ up to 2%

Fe_2O_3 2 to 12%

CaO 5 to 30%, preferably 5 to 18%

MgO up to 15% preferably 4 to 10%

Na_2O up to 15%

5 K_2O up to 15%

P_2O_5 up to 3%

MnO up to 3%

B_2O_3 up to 3%.

10 These values are all quoted as oxides, with iron expressed as Fe_2O_3 , as is conventional.

An advantage of using fibres of this composition in the polymeric foam composite material, especially in the context of polyurethane foams, is that the significant level of iron and alumina in the fibres can act as a catalyst in formation of the foam. This effect is particularly relevant when at least some of the iron in the fibres is present as ferric iron, as is usual and/or when the level of Al_2O_3 is particularly high such as 15 to 28% or 18 to 23%.

An alternative stone wool composition useful in the invention has oxide contents by weight in the following ranges:

20 SiO_2 37 to 42%

Al_2O_3 18 to 23%

$\text{CaO} + \text{MgO}$ 34 to 39%

Fe_2O_3 up to 1%

$\text{Na}_2\text{O} + \text{K}_2\text{O}$ up to 3%

25 Again, the high level of alumina in fibres of this composition can act as a catalyst in the formation of a polyurethane foam. Whilst stone fibres are preferred, the use of discontinuous glass fibres or slag fibres is also possible.

The man-made vitreous fibres present in the polymeric foam composite and foamable composition are discontinuous man-made vitreous fibres. The term "discontinuous man-made vitreous fibres" is well understood by those skilled in the art. Discontinuous man-made vitreous fibres are, for example, those produced by internal or external centrifugation, for example with a cascade spinner or a spinning cup.

Traditionally, fibres produced by these methods have been used for insulation, whilst continuous glass fibres have been used for reinforcement in

composites. Continuous fibres (e.g. continuous E glass fibres) are known to be stronger than discontinuous fibres produced by cascade spinning or with a spinning cup (see "Impact of Drawing Stress on the Tensile Strength of Oxide Glass Fibres", *J. Am. Ceram. Soc.*, 93 [10] 3236-3243 (2010)). Nevertheless, it has been found that foam composites comprising short, discontinuous fibres have a compressive strength that is at least comparable with foam composites comprising continuous glass fibres of a similar length. This unexpected level of strength is combined with good fire resistance, a high level of thermal insulation and cost efficient production.

In order to achieve the required length distribution of the fibres, it will usually be necessary for the fibres to be processed further after production. The further processing will usually involve grinding or milling of the fibres for a sufficient time for the required length distribution to be achieved.

Usually, the fibres present in the polymeric foam composite and foamable composition have an average diameter of from 1.5 to 7 micrometres. Preferably, the fibres have an average diameter of from 2 to 6 micrometres, more preferably the fibres have an average diameter of from 3 to 6 micrometres. Thin fibres as preferred in the invention are believed to provide a higher level of thermal insulation to the composite than thicker fibres, but without a significant reduction in strength as compared with thicker fibres as might be expected. The average fibre diameter is determined for a representative sample by measuring the diameter of at least 200 individual fibres by means of the intercept method and scanning electron microscope or optical microscope (1000x magnification).

The foamable composition that can be used to produce the polymeric foam composite comprises a foam precursor and man-made vitreous fibres. The foam precursor is a material that either polymerises (often with another material) to form a polymeric foam or is a polymer that can be expanded with a blowing agent to form a polymeric foam. The composition can be any composition capable of producing a foam on addition of a further component or upon a further processing step being carried out.

Preferred foamable compositions are those capable of producing polyurethane foams. Polyurethane foams are produced by the reaction of the polyol with an isocyanate in the presence of a blowing agent. Therefore, in one embodiment, the foamable composition comprises, in addition to the man-made

vitreous fibres, a polyol as the foam precursor. In another embodiment, the foamable composition comprises, in addition to the man-made vitreous fibres, an isocyanate as the foam precursor. In another embodiment, the composition comprises a mixture of an isocyanate and a polyol as the foam precursor.

- 5 If the foam precursor is a polyol, then foaming can be induced by adding a further component comprising an isocyanate. If the foam precursor is an isocyanate, foam formation can be induced by the addition of a further component comprising a polyol.

10 Suitable polyols for use either as the foam precursor or to be added as a further component to the foamable composition to induce foam formation are commercially available polyol mixtures from, for example, Bayer Material Science, BASF or DOW Chemicals. Commercially available polyol compositions are often supplied as a pre-mixed component that comprises polyol and any or all of catalyst(s), flame retardant(s), surfactants and water, the latter which can
15 act as a chemical blowing agent in the foam formation process. Generally it comprises all of these. Such a pre-formed blend of polyol with additives is commonly known as a pre-polyol.

20 The isocyanate for use either as the foam precursor or to be added as a further component to the foamable composition to induce foam formation is selected on the basis of the density and strength required in the foam composite as well as on the basis of toxicity. It can, for example, be selected from methylene polymethylene polyphenol isocyanates (PMDI), methylene diphenyl diisocyanate (MDI), toluene diisocyanate (TDI), hexamethylene diisocyanate (HDI) and isophorone diisocyanate (IPDI), PMDI or MDI being preferred. One
25 particularly suitable example is diphenylmethane-4,4'-diisocyanate. Other suitable isocyanates are commercially available from, for example, Bayer Material Science, BASF or DOW Chemicals.

30 In order to form a foam composite, a blowing agent is required. The blowing agent can be a chemical blowing agent or a physical blowing agent. In some embodiments, the foamable composition comprises a blowing agent. Alternatively, the blowing agent can be added to the foamable composition together with a further component that induces foam formation.

In the context of polyurethane foam composites, in a preferred embodiment, the blowing agent is water. Water acts as a chemical blowing agent, reacting with the isocyanate to form CO₂, which acts as the blowing gas.

When the foam-precursor is a polyol, in one embodiment, the foamable
5 composition comprises water as a blowing agent. The water is usually present in such a foamable composition in an amount from 0.3 to 2 % by weight of the foamable composition.

As an alternative, or in addition, a physical blowing agent, such as liquid CO₂ or liquid nitrogen could be included in the foamable composition or added to
10 the foamable composition as part of the further component that induces foam formation.

The foamable composition, in an alternative embodiment, is suitable for forming a phenolic foam. Phenolic foams are formed by a reaction between a phenol and an aldehyde in the presence of an acid or a base. A surfactant and
15 a blowing agent are generally also present to form the foam. Therefore, the foamable composition could comprise, in addition to the man-made vitreous fibres, a phenol and an aldehyde (the foam precursor), a blowing agent and a surfactant. Alternatively, the foamable composition could comprise as the foam precursor, a phenol but no aldehyde, or an aldehyde but no phenol.

20 Whilst foamable compositions suitable for forming polyurethane or phenolic foams are preferred, it is also possible to use foamable compositions suitable for forming polyisocyanurate, expanded polystyrene and extruded polystyrene foams.

In an alternative embodiment, the polyurethane foam composite is
25 especially a polyisocyanurate foam composite, where the blowing agent is preferably pentane. Pentane has the advantage over other blowing agents that it is more environmentally friendly and cost effective than for instance HFC blowing agents.

Pentane can be c-pentane, i-pentane, or n-pentane or a mixture of two or
30 more of these. The choice between c-pentane, i-pentane and n-pentane is dependent on the production method. They are quite different in boiling point, initial thermal conductivity, aged thermal conductivity and price. The preferred pentane in this invention is n-pentane based on the price and aged thermal conductivity.

The foamable composition that can be used to make the foam composite used in the invention can contain additives in addition to the foam precursor and the man-made vitreous fibres. When it is desired to include additives in the foam composite, as an alternative to including the additives in the foamable composition comprising man-made vitreous fibres, the additive can be included with a further component that is added to the foamable composition to induce foam formation.

As an additive, it is possible for the composition or the foam composite to comprise a fire retardant such as expandable powdered graphite, aluminium trihydrate or magnesium hydroxide. The amount of fire retardant in the composition is preferably from 3 to 20% by weight, more preferably from 5 to 15% by weight and most preferably from 8 to 12 % by weight. The total quantity of fire retardant present in the polymeric foam composite material is preferably from 1 to 10%, more preferably from 2 to 8% and most preferably from 3 to 7 % by weight.

Alternatively, or in addition, the foamable composition or foam composite can comprise a flame retardant such as nitrogen- or phosphorus-containing polymers.

The fibres used in the polymeric foam composite can be treated with binder, which, as a result, can be included in the composition and the resulting foam composite as an additive if it is chemically compatible with the composition. The fibres used usually contain less than 10% binder based on the weight of the fibres and binder. The binder is usually present in the foamable composition at a level less than 5% based on the total weight of the foamable composition. The foam composite usually contains less than 5% binder, more usually less than 2.5% binder. In a preferred embodiment, the man-made vitreous fibres used are not treated with binder.

In some circumstances, it is advantageous, before mixing the man-made vitreous fibres into the foamable composition, to treat the fibres with a surfactant, usually a cationic surfactant. The surfactant could, alternatively, be added to the composition as a separate component. The presence of a surfactant, in particular a cationic surfactant, in the composition and as a result in the polymeric foam composite material has been found to provide easier mixing and,

therefore, a more homogeneous distribution of fibres within the foamable composition and the resulting foam.

One advantage of the described polymeric foam composite is that it is possible to incorporate larger percentages of fibres into the foamable composition, and therefore into the resulting foam, than would be the case with longer fibres. This allows higher levels of fire resistance, dimensional stability and compressive strength to be achieved. Preferably, the composition comprises at least 15% by weight, more preferably at least 20% by weight, most preferably at least 35% by weight of man-made vitreous fibres. The polymeric foam composite material itself preferably comprises at least 10% by weight, more preferably at least 15% by weight, most preferably at least 20% by weight of man-made vitreous fibres.

Usually the foamable composition comprises less than 85% by weight, preferably less than 80%, more preferably less than 75% by weight man-made vitreous fibres. The resulting foam composite usually contains less than 80% by weight, preferably less than 60%, more preferably less than 55% by weight man-made vitreous fibres.

The polymeric foam composite used in the invention comprises a polymeric foam and man-made vitreous fibres. The foam composite can be formed from the foamable composition as described above. It is preferred that the polymeric foam is a polyurethane foam or a phenolic foam. Polyurethane foams are most preferred due to their low curing time.

The first step in the production of the polymeric foam composite material is to form the foamable composition comprising the foam precursor and the mineral fibres. The fibres can be mixed into the foam precursor by a mechanical mixing method such as use of a rotary mixer or simply by stirring. Additives as discussed above can be added to the foamable composition.

Once the fibres and foam precursor have been mixed, the formation of a foam can then be induced. The manner in which the foam is formed depends on the type of foam to be formed and is known to the person skilled in the art for each type of polymeric foam. In this respect, reference is made to "Handbook of Polymeric Foams and Foam Technology" by Klempner et al.

For example, in the case of a polyurethane foam, the man-made vitreous fibres can be mixed with a polyol as the foam precursor. The foamable

composition usually also comprises water as a chemical blowing agent. Then foaming can be induced by the addition of an isocyanate.

In the case where a further component is added to the foamable composition to induce foaming, this can be carried out in a high pressure mixing head as commercially available.

In one embodiment, foam formation is induced by the addition of a further component and the further component comprises further man-made vitreous fibres, wherein at least 50% by weight of the further man-made vitreous fibres have a length of less than 100 micrometres. Including man-made vitreous fibres in both the foamable composition and the further component can increase the overall quantity of fibres in the foam composite, by circumventing the practical limitation on the quantity of fibres that can be included in the foamable composition itself.

For example in the context of polyurethane foam composites a foamable composition could comprise a polyol, man-made vitreous fibres and water. Then foaming could be induced by the addition, as the further component, of a mixture of isocyanate and further man-made vitreous fibres, wherein at least 50% of the man-made vitreous fibres have a length of less than 100 micrometres.

In essentially the same process, the mixture of isocyanate and man-made vitreous fibres could constitute the foamable composition, and the mixture of polyol, water and man-made vitreous fibres could constitute the further component.

The quantity of man-made vitreous fibres in the further component is preferably at least 10 % by weight, based on the weight of the further component. More preferably the quantity is at least 20% or at least 30% based on the weight of the further component. Usually, the further component comprises less than 80% by weight, preferably less than 60%, more preferably less than 55% by weight man-made vitreous fibres.

The polymeric foam composite is the material that provides compressive strength and resistance to compression to the thermal insulating element. Therefore, preferably the polymeric foam composite has a compressive strength of at least 1500 kPa and a compression modulus of elasticity of at least 60000 kPa as measured according to European Standard EN 826:1996.

The following are examples of the polymeric foam composite materials as used in the invention as compared with other polymeric foam composite materials.

5 Example 1 (comparative)

100.0 g of a commercially available composition of diphenylmethane-4,4'-diisocyanate and isomers and homologues of higher functionality, and 100.0 g of a commercially available polyol formulation were mixed by propellers for 20 seconds at 3000 rpm. The material was then placed in a mold to foam, which
10 took about 3 min. The following day, the sample was weighed to determine its density and the compression strength and compression modulus of elasticity were measured according to European Standard EN 826:1996.

Compressive strength: 1100 kPa

15 Compression modulus of elasticity: 32000 kPa

Example 2

100.0 g of the same commercially available polyol formulation as used in Example 1 was mixed with 200.0 g ground stone wool fibres, over 50% of which
20 have a length less than 64 micrometres, for 10 seconds. Then 100.0 g of the commercially available composition of diphenylmethane-4,4'-diisocyanate was added and the mixture was mixed by propellers for 20 seconds at 3000 rpm. The material was then placed in a mold to foam, which took about 3 min. The following day, the sample was weighed to determine its density and the
25 compression strength and compression modulus of elasticity were measured according to European Standard EN 826:1996.

Compressive strength: 1750 kPa

Compression modulus of elasticity: 95000 kPa

30

Example 3 (comparative)

100.0 g of the same commercially available polyol formulation as used in Examples 1 and 2 was mixed for 10 seconds with 50.0 g stone fibres having a different chemical composition from those used in Example 2 and having an

average length of 300 micrometres. 100.0 g of the commercially available composition of diphenylmethane-4,4'-diisocyanate was added. The mixture was then mixed by propellers for 20 seconds at 3000 rpm. The material was placed in a mold to foam, which takes about 3 min. The following day, the sample was weighed to determine its density and the compression strength and compression modulus of elasticity were measured according to European Standard EN 826:1996.

Compressive strength: 934 kPa

10 Compression modulus of elasticity: 45000 kPa

Example 4

Example 3 was repeated, but the fibres were ground such that greater than 50% of the fibres had a length less than 64 micrometres. Following this grinding it became possible to mix 200g of the fibres with the polyol mixture.

Compressive strength: 1785 kPa

Compression modulus of elasticity: 115000 kPa.

20 Example 5

Small flame tests were carried out according to ISO/DIS 11925-2 to establish the fire resistance of polymeric foam composites as used in the invention compared with the fire resistance of composites comprising quartz sand rather than fibres according to the invention. The foam used was polyurethane foam. The fibres used had a composition within the following ranges.

SiO₂ 38 to 48wt%

Al₂O₃ 17 to 23wt%

TiO₂ up to 2wt%

30 Fe₂O₃ 2 to 12wt%

CaO 5 to 18wt%

MgO 4 to 10wt%

Na₂O up to 15wt%

K₂O up to 15wt%

P₂O₅ up to 3wt%

MnO up to 3wt%

B₂O₃ up to 3wt%

- 5 The quartz sand used had a particle size up to 2mm. In each composite tested, expanding graphite was included as a fire retardant. The test involved measuring the height of a flame from each composite under controlled conditions. The results were as follows:

Fibre Content (wt%)	Sand Content (wt%)	Graphite Content (wt%)	Flame height (cm)
25	0	8	12-17
25	0	10	7
31	0	10	5
0	25	8	22
0	25	10	11
0	31	10	12

10

Example 6 (comparative)

- 240g of a commercially available polyol formulation and 340 g of a commercially available composition of diphenylmethane-4,4'-diisocyanate and isomers and homologues of higher functionality, were mixed by propellers for 20 seconds at 3000 rpm. The material was then transferred into a mold and allowed to foam. The next day, samples measuring 80mm x 30mm x 30mm was cut and weighed and the density was calculated to 41kg/m³. Then the sample was placed in a heating cupboard at 200°C. After 24 hours, the foam had shrunk to a length of 56,5mm and the sample had lost its initial cuboid shape.

20

Example 7

- 240g of the same commercially available polyol formulation as used in Example 6 was mixed with 480g ground stone wool fibres with over 50% having a length less than 64 micrometers. The mixture was mixed by propeller for 30 seconds at 3000 rpm. Then 340g of the commercially available composition of diphenylmethane-4,4'-diisocyanate was added and the mixture was mixed by

25

propellers for 20 seconds at 3000 rpm. The material was then transferred to a mold and allowed to foam. The next day, samples measuring 80mm x 30mm x 30mm was cut and weighed and the density was calculated to 84kg/m³. Then the sample was placed in a heating cupboard at 200°C. After 24 hours, the foam
5 had shrunk to a length of 75,5mm and the sample had maintained its initial cuboid shape.

The cut samples of Examples 6 and 7 are shown in Figure 7, both before heating and after heating.

10 Figure 8 is an environmental scanning electron microscope image of a polyurethane foam composite material as used according to the invention, in which the fibres have a length distribution such that 95% by weight of the fibres have a length below 100 micrometres and 75% by weight of the fibres have a length below 63 micrometres. The composite contains 45% fibres by weight of
15 the composite. The instrument used was ESEM, XL 30 TMP (W), FEI/Philips incl. X-ray microanalysis system EDAX. The sample was analysed in low vacuum and mixed mode (BSE/SE).

CLAIMS

1. A façade element comprising:
an insulating layer having a first major face, a second major face, an
5 upper edge and a lower edge, and two side edges, each edge connecting the
first and second major faces, wherein the insulating layer comprises a coherent
man-made vitreous fibre-containing insulating material and at least one stud
extending substantially from the upper edge to the lower edge and substantially
from the first major face to the second major face of the insulating layer; and
10 a face plate disposed on the first major face of the insulating layer;
wherein both the stud and the face plate comprise a polymeric foam
composite material, the polymeric foam composite material comprising a
polymeric foam and discontinuous man-made vitreous fibres, wherein at least
50% by weight of the man-made vitreous fibres present in the polymeric foam
15 composite material have a length less than 100 micrometres.
2. A façade element according to claim 1 wherein a plurality of studs extend
substantially from the upper edge to the lower edge and substantially from the
first major face to the second major face of the insulating layer and wherein the
20 studs comprise a polymeric foam composite material, the composite material
comprising a polymeric foam and discontinuous man-made vitreous fibres,
wherein at least 50% by weight of the man-made vitreous fibres present in the
polymeric foam composite material have a length less than 100 micrometres.
- 25 3. A façade element according to claim 2, wherein the studs are
substantially parallel to each another.
4. A façade element according to any preceding claim, wherein the face
plate and the stud or studs are bonded together without any extrinsic attachment
30 means.
5. A façade element according to any preceding claim, further comprising a
back plate disposed on the second major face of the insulating layer.

6. A façade element according to claim 5, wherein the back plate is a gypsum board or a plyboard.
7. A façade element according to any preceding claim, wherein the
5 insulating layer is surrounded at its upper, lower and side edges by a frame.
8. A façade element according to any preceding claim, wherein at least 60% by weight of the man-made vitreous fibres present in the polymeric foam composite material have a length less than 65 micrometres.
- 10
9. A façade element according to any preceding claim, wherein at least 80% by weight of the man-made vitreous fibres present in the polymeric foam composite material have a length less than 125 micrometres.
- 15
10. A façade element according to any preceding claim, wherein at least 95% by weight of the man-made vitreous fibres present in the polymeric foam composite material have a length less than 250 micrometres.
- 20
11. A façade element according to any preceding claim, wherein at least 0.5%, preferably at least 1% by weight of the man-made vitreous fibres present in the polymeric foam composite material have a length less than 10 micrometres.
- 25
12. A façade element according to any preceding claim, wherein the man-made vitreous fibres present in the polymeric foam composite material have an average diameter of from 1.5 to 7, preferably from 2 to 6, more preferably from 3 to 6 micrometres.
- 30
13. A façade element according to any preceding claim, wherein the man-made vitreous fibres present in the polymeric foam composite material have a content of oxides by weight as follows:
- SiO₂ 25 to 50%, preferably 38 to 48%
- Al₂O₃ 12 to 30%, preferably 15 to 28%
- TiO₂ up to 2%

Fe_2O_3 2 to 12%

CaO 5 to 30%, preferably 5 to 18%

MgO up to 15%, preferably 1 to 8% or 4 to 10%

Na_2O up to 15%

5 K_2O up to 15%

P_2O_5 up to 3%

MnO up to 3%

B_2O_3 0 to 3%.

10 14. A façade element according to any preceding claim, wherein the polymeric foam is a polyurethane foam.

15 15. A façade element according to any preceding claim, wherein the polymeric foam composite material comprises at least 10% by weight, preferably at least 15% by weight, more preferably at least 20% by weight of man-made vitreous fibres.

20 16. A façade element according to any preceding claim, wherein the polymeric foam composite material comprises less than 80% by weight, preferably less than 60%, more preferably less than 55% by weight of man-made vitreous fibres.

25 17. A façade element according to any preceding claim, wherein the density of the coherent man-made vitreous fibre-containing insulating material is less than 80 kg/m^3 , preferably less than 60 kg/m^3 , more preferably less than 50 kg/m^3 .

30 18. A building wall comprising a façade element according to any of claims 1 to 17, positioned such that the face plate is substantially vertical, a lower joist that supports the façade element at its edge corresponding to the lower edge of the insulating layer and an upper joist that abuts the facade element at its edge that corresponds to the upper edge of the insulating layer.

19. A building wall according to claim 18, wherein the upper and lower joists are each affixed at both ends to a vertical post.
20. A building wall according to claim 18 or claim 19, wherein the joists are
5 steel joists.
21. A building wall according to any of claims 18 to 20, wherein a base coat of render is applied to the face plate of the façade element and the bond strength between the face plate 3 and a the base coat is at least 0,010 N/mm²,
10 more preferably at least 0,020 N/mm² and even more preferably at least 0,040 N/mm².
22. A building comprising a wall according to any of claims 18 to 21.

Figure 1

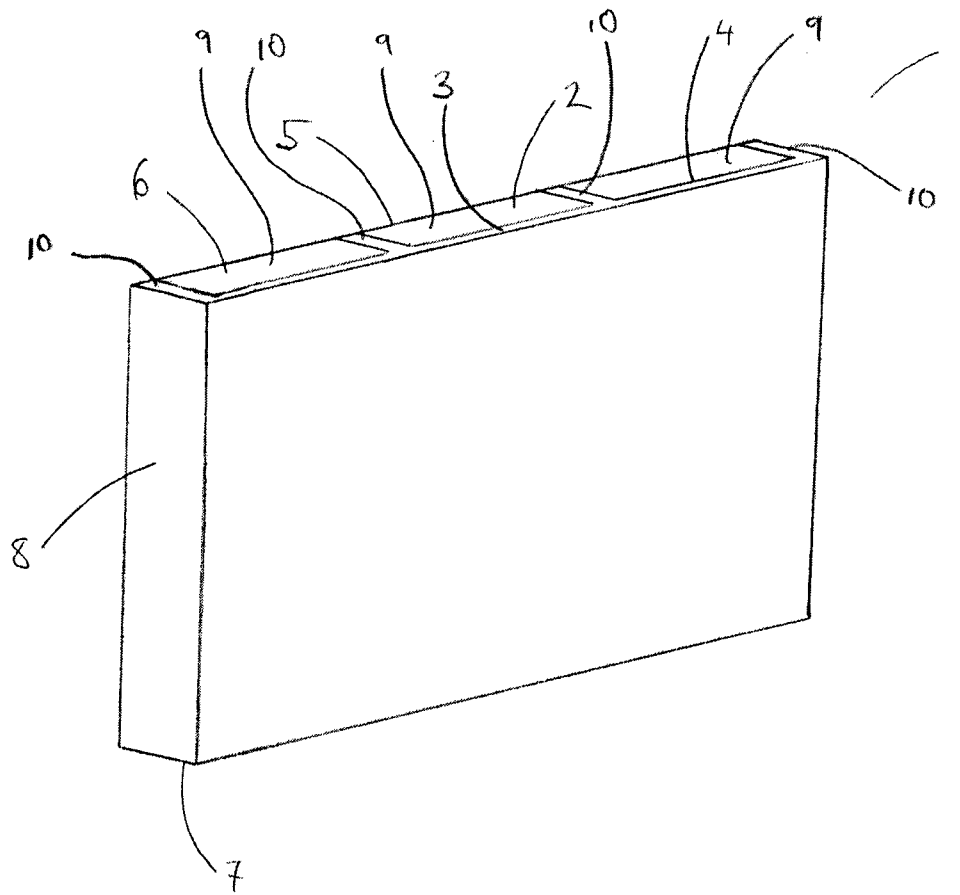


Figure 2

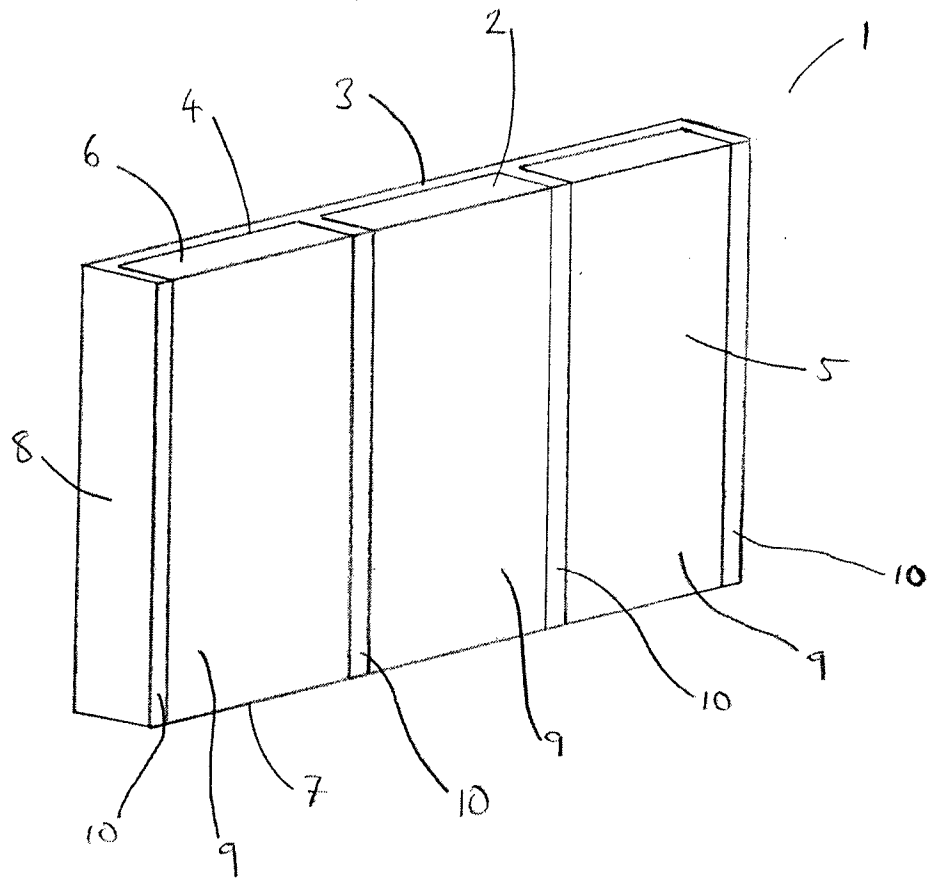


Figure 3

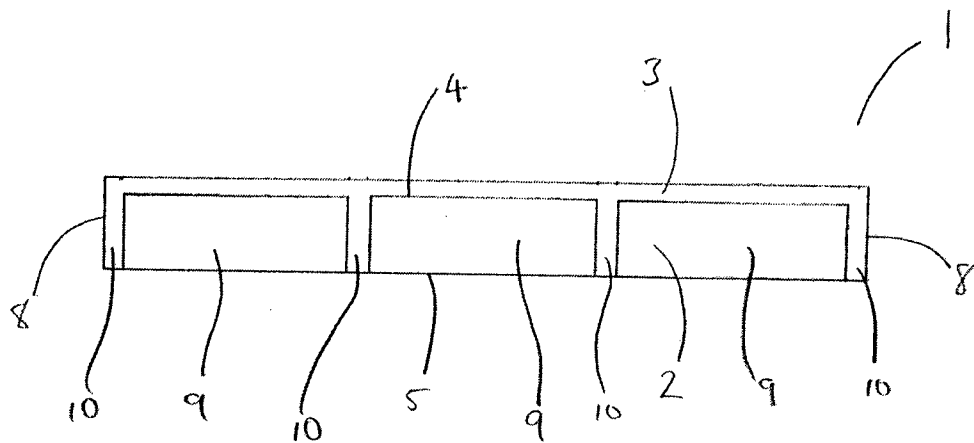


Figure 4

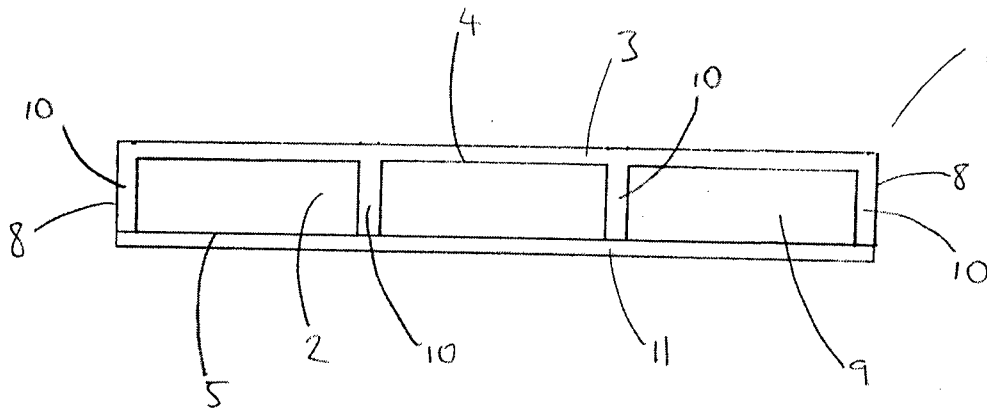


Figure 5

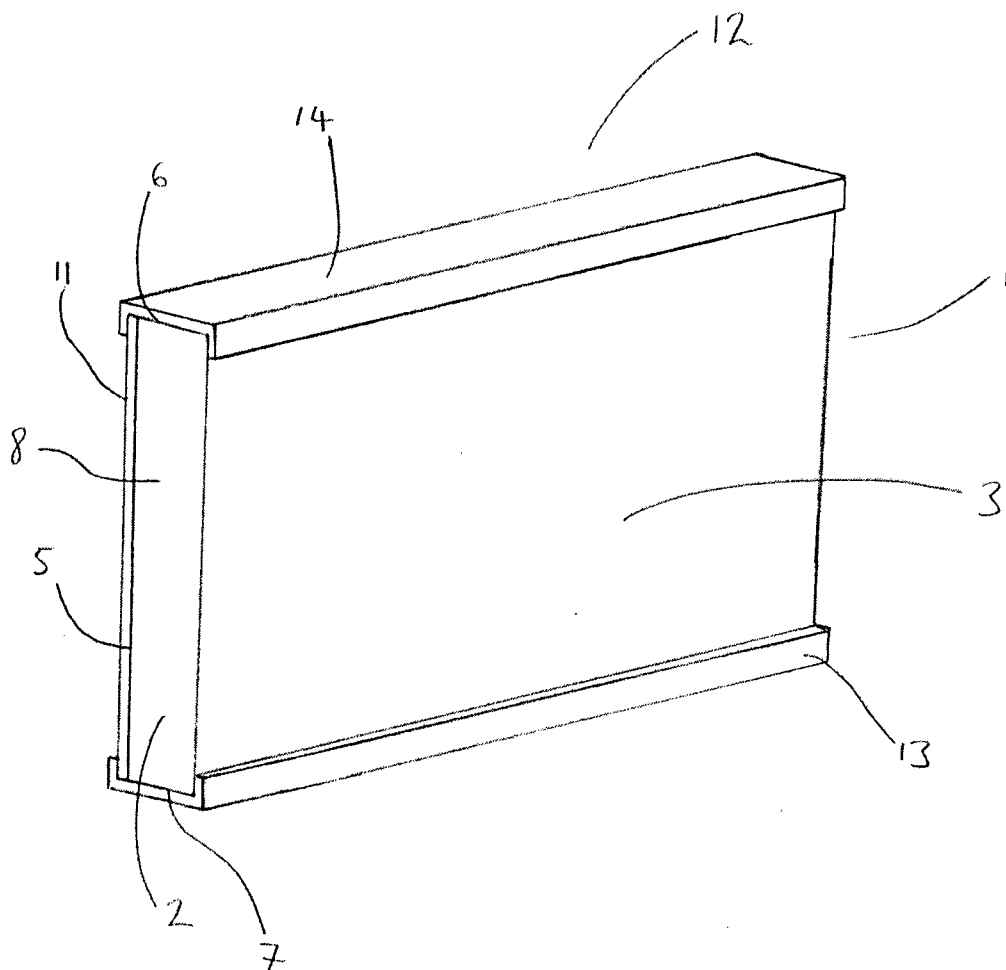


Figure 6

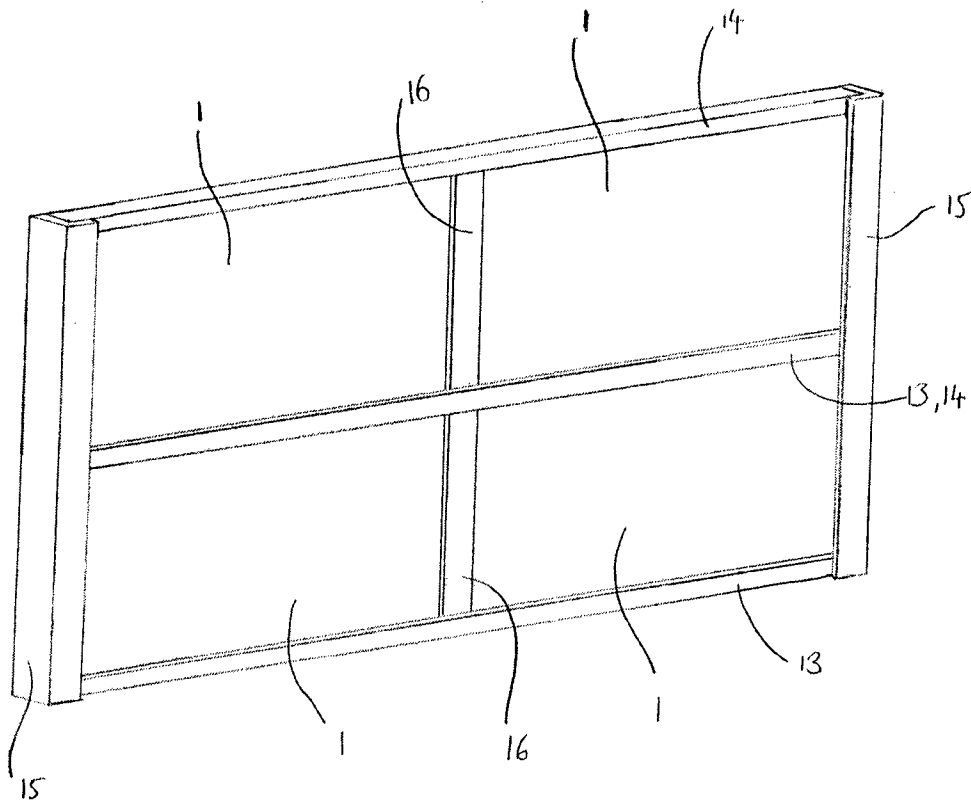
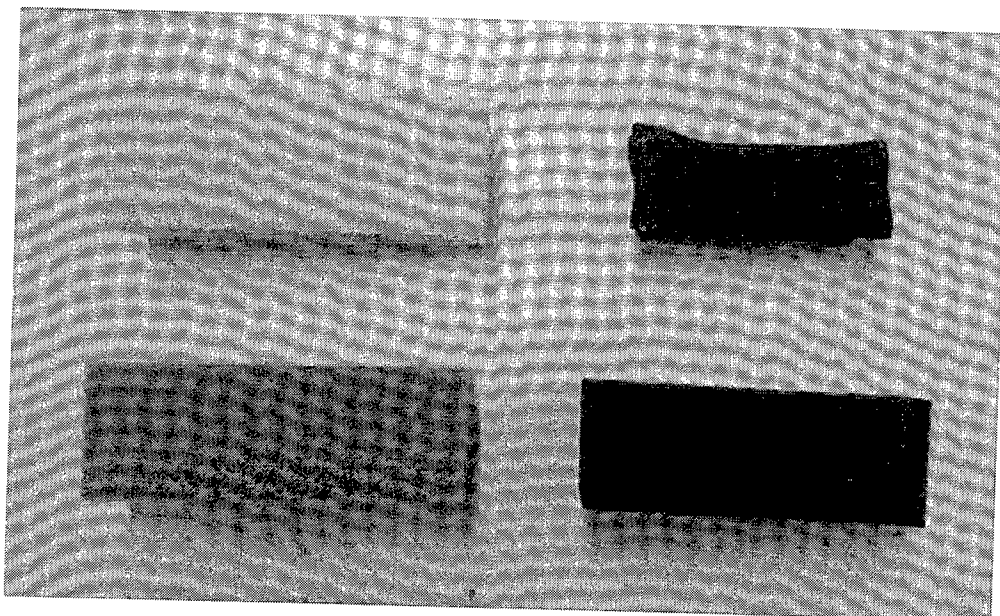


Figure 7

Before heating

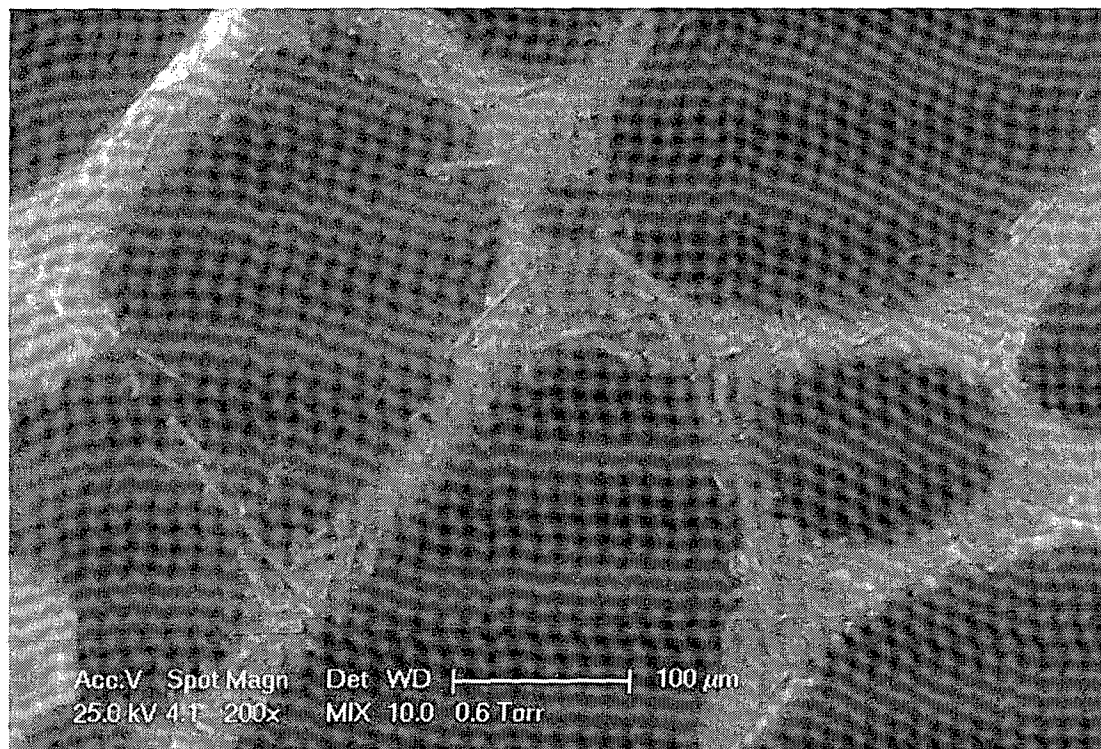
After heating



Example 6

Example 7

Figure 8



INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2014/000174

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

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)

IPC: B32B, C08J, E04B, E04C

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

SE, DK, FI, NO classes as above

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

EPO-Internal, PAJ, WPI data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 3783082 A (ALMOG E), 1 January 1974 (1974-01-01); column 1, line 1 - column 1, line 62; column 2, line 16 - column 2, line 19; column 4, line 24 - column 4, line 27; claims --	1-22
Y	GB 1045848 A (DU PONT), 19 October 1966 (1966-10-19); page 1, line 11 - page 1, line 60; page 4, line 1 - page 4, line 8; claims 1, 2, 6; Page 3, Table I (b) --	1-22
Y	US 20110047908 A1 (BRUSMAN BRYAN DANIEL ET AL), 3 March 2011 (2011-03-03); paragraphs [0012], [0023]-[0024], [0029]; claim 1 --	1-22



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

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“O” document referring to an oral disclosure, use, exhibition or other means

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“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

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“&” document member of the same patent family

Date of the actual completion of the international search

13-05-2014

Date of mailing of the international search report

14-05-2014

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2014/000174

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	SHAMOV, I. V. et al: 'Anwendung zerkleinerter Glasfasern als modifizierender Zusatz für Polyurethanharzschaumstoffe', Plaste und Kautschuk, 1979, vol. 26. no. 1, pp. 23-25. ISSN 0048-4350.; whole document --	1-22
P, Y	WO 2013024176 A1 (ROCKWOOL INT ET AL), 21 February 2013 (2013-02-21); whole document --	1-22
A	DE 20108294 U1 (GEFINEX JACKON GMBH), 20 June 2002 (2002-06-20); whole document --	1-22
A	EP 1518972 A1 (HENDRIKS JOANNES AUGUSTINUS AN), 30 March 2005 (2005-03-30); abstract; claims 1, 10 --	1-22
A	GB 2491414 A (ALBERTELLI ALDINO ET AL), 5 December 2012 (2012-12-05); abstract; page 30, line 10 - page 30, line 20 -- -----	1-22

Continuation of: second sheet

International Patent Classification (IPC)

E04B 1/76 (2006.01)
B32B 5/18 (2006.01)
B32B 27/00 (2006.01)
E04B 1/14 (2006.01)
E04B 1/30 (2006.01)
E04B 1/80 (2006.01)
E04B 2/56 (2006.01)
E04C 2/22 (2006.01)
E04C 2/24 (2006.01)
E04C 3/08 (2006.01)
C08J 9/35 (2006.01)
E04C 2/26 (2006.01)

INTERNATIONAL SEARCH REPORT

Information on patent family members

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PCT/IB2014/000174

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