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(54) Title: A BONDED NON-WOVEN FIBROUS MAT

(57) **Abstract:** The present invention provides a bonded non-woven fibrous mat, the bonded non-woven fibrous mat comprising: (a) a precursor mat comprising: a non-woven web of fibers comprising a blend of glass fibers and polyester fibers, and a first binder; and (b) a composition which substantially or completely impregnates the precursor mat, the composition comprising: a second binder, and a filler; wherein: the first binder is selected from the group consisting of a polycarboxylic acid binder, a polyvinyl alcohol binder, or a combination thereof; and the second binder is a polycarboxylic acid binder which is prepared from an unsaturated carboxylic acid compound and an aryl vinyl compound; provided the bonded non-woven fibrous mat does not comprise a filler which is calcium carbonate. The invention also provides methods for manufacturing the bonded non-woven fibrous mat, as well as a construction board comprising the bonded non-woven fibrous mat, in particular, a ceiling tile. The invention also relates to a fluid filter comprising the bonded non-woven fibrous mat, the use of the fluid filter in air or liquid filtration, and a filtration process.

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A Bonded Non-Woven Fibrous Mat

The present invention relates to a bonded non-woven fibrous mat, in particular, a bonded non-woven fibrous mat which is stiff but which is also capable of being repeatedly folded or pleated without cracking. The invention also relates to methods for manufacturing the bonded non-woven fibrous mat, as well as a construction board comprising the bonded non-woven fibrous mat, in particular, a ceiling tile. The invention also relates to a fluid filter comprising the bonded non-woven fibrous mat, the use of the fluid filter in air or liquid filtration, and a filtration process.

Background

Fibrous insulation and construction panels are typically manufactured by fiberizing a molten composition of polymer, glass, or other mineral material to form fine fibers and depositing the fibers on a collecting conveyor to form a batt or a blanket. Mineral fibers, such as glass fibers or mineral wool, are typically used in insulation products. A binder composition is then applied to bind the fibers together where they contact each other. During the manufacturing process, some insulation products are formed and cut to provide sizes generally dimensioned to be compatible with standard construction practices, e.g. ceiling boards having widths and/or length adapted for specific building practices. Ceiling board products may also incorporate a facing layer or material on at least one of the major surfaces, forming ceiling tiles or panels. In some applications, the facer may be an aesthetic or decorative surface and is often painted.

Ceiling tiles are often used to impart both structural and aesthetic value, while also providing acoustical absorbency and attenuation, to building interiors. Ceiling tiles may be used in areas that require noise control, such as public areas and are also used in residential buildings.

One of the challenges in developing improved ceiling tiles is being able to provide a facer which is simultaneously stiff but also capable of being repeatedly folded or pleated without cracking. These properties are very different from each other because, while it is possible to prepare facers which have the required level of stiffness, these facers are typically brittle. Likewise, while it is possible to prepare a facer exhibiting suitable flexibility, such facers are typically not sufficiently rigid.

US2002/0020142 (Swiszcz et al) describes a structural panel comprising spaced dividers. The spaced dividers are compressible.

US7547375, US8283266, and US8758563 (all to Johns Manville) describe non-woven fibrous mats which may be used in ceiling panels. US7547375, US8283266, and US8758563 do not describe non-woven fibrous mats in which one binder is used in the formation of a precursor mat, and an impregnation composition comprising a second binder and a filler is used to substantially or completely impregnate the precursor mat. Instead, each of US7547375, US8283266, and US8758563 describes the use of one binder to bind the fibers of the mat.

It is an object of the present invention to overcome or mitigate at least some of the problems of the prior art. In particular, it is an object of the invention to provide a bonded non-woven veil which is stiff but which is also capable of being repeatedly folded or pleated without cracking.

Definitions

The point of attachment of a repeat unit, moiety, or substituent is represented by "-". For example, -COOH is attached through the carbon atom.

The term “about” or “approximately” means an acceptable error for a particular value as determined by a person of ordinary skill in the art, which depends in part on how the value is measured or determined. In certain embodiments, the term “about” or “approximately” means within 1, 2, 3 or 4 standard deviations. In certain embodiments, the term “about” or “approximately” means within 30%, 25%, 20%, 15%, 10%, 9%, 8%, 7%, 6%, 5%, 4%, 3%, 2%, 1%, or 0.5% of a given value or range.

Unless otherwise specified, “a,” “an,” “the,” and “at least one” are used interchangeably. Furthermore, as used in the description of the application and the appended claims, the singular forms “a,” “an,” and “the” are inclusive of their plural forms, unless contradicted by the context surrounding such.

An “aliphatic” group is an acyclic or cyclic, saturated or unsaturated carbon group, excluding aryl groups (see *IUPAC Compendium of Chemical Terminology*, 3rd ed. International Union of Pure and Applied Chemistry; 2006. Online version 3.0.1, 2019. https://doi.org/10.1351/goldbook.A00217). An “aliphatic-aryl” group therefore is an aliphatic group attached to an aryl group.

“Aryl” refers to an aromatic carbocylic group or aromatic heterocarbocyclic group. When the aryl group is an aromatic carbocylic group, the aryl group may have a single ring or multiple condensed rings. In certain embodiments, the aryl group can have from 5-20 carbon atoms, in certain embodiments from 6-20 carbon atoms, in certain embodiments from 6-15 carbon atoms, in certain embodiments 6-12 carbon atoms. The aryl group may be substituted or unsubstituted. In certain embodiment, the aryl group is unsubstituted. In certain embodiments, the aryl group is substituted. Unless otherwise specified, the aryl group may be attached to any suitable carbon atom and, if substituted, may be substituted at any suitable atom. Examples of aryl groups include, but are not limited to, phenyl, tolyl (o-, m-, or p-), naphthyl, anthracenyl, and the like.

When the aryl group is an aromatic heterocarbocyclic group, one or more (e.g. 1, 2, 3, or more) of the carbon atoms in an aromatic carbocylic group is independently substituted with a heteroatom provided aromaticity is maintained. An aromatic heterocarbocyclic group may also be known as a heteroaryl group. The heteroaryl group may have a single ring or multiple condensed rings. The or each heteroatom may be independently selected from the group consisting of nitrogen, oxygen, phosphorus, sulfur. In one embodiment, the or each heteroatom is selected from nitrogen. In certain embodiments,

the heteroaryl group may have from 4-20 carbon atoms, in certain embodiments from 5-20 carbon atoms, in certain embodiments from 5-15 carbon atoms. The heteroaryl group may be unsubstituted. Alternatively, the heteroaryl group may substituted. Unless otherwise specified, the heteroaryl group may be attached at any suitable atom and, if substituted, may be substituted at any suitable atom. Examples of heteroaryl groups include but are not limited to thienyl, furanyl, pyrrolyl, imidazolyl, pyrazolyl, thiazolyl, isothiazolyl, oxazolyl, isoxazolyl, triazolyl, thiadiazolyl, thiophenyl, oxadiazolyl, pyridinyl, pyrimidyl, benzoxazolyl, benzthiazolyl, benzimidazolyl, indolyl, quinolinyl, and the like.

The term “consisting” is closed and excludes additional, unrecited elements or method steps in the claimed invention.

The term “consisting essentially of” is semi-closed and occupies a middle ground between “consisting” and “comprising”. “Consisting essentially of” does not exclude additional, unrecited elements or method steps which do not materially affect the essential characteristic(s) of the claimed invention.

The term “comprising” is inclusive or open-ended and does not exclude additional, unrecited elements or method steps in the claimed invention. The term is synonymous with “including but not limited to”. The term “comprising” encompasses three alternatives, namely (i) “comprising”, (ii) “consisting”, and (iii) “consisting essentially of”.

The terms “mat”, “veil”, and “facer” are used interchangeably herein and refer to a bound web of fibers.

The term “substantially free” means that the selected composition contains less than a functional amount of the stated ingredient or component, typically less than about 0.1 wt%, such as less than about 0.05 wt%, for example, less than about 0.03 wt% of the total solids of the composition.

“Substituted” refers to a group in which one or more (e.g. 1, 2, 3, 4, or 5) hydrogen atoms are each independently replaced with substituents which may be the same or different. The substituent may be any group which does not adversely affect the bonded non-woven mat of the invention, the precursor mat, the glass fibers, the polyester fibers, the first binder, the second binder, or the filler. Examples of substituents include, but are not limited to, $-R^a$, $-O-R^a$, $-NR^aR^b$, -CN, $-COOR^a$, and $-CONR^aR^b$, preferably $-R^a$. R^a and R^b are independently selected from the groups consisting of H, alkyl, and aryl, such as phenyl, tolyl (o-, m-, or p-), naphthyl, anthracenyl, methyl, ethyl, n-propyl, i-propyl, n-butyl, i-butyl, t-butyl, pentyl, cyclo-pentyl, hexyl, cyclo-hexyl and the like.

The term “saturated” means a compound or group that has only single bonds in its structure i.e. the compound or group does not have double or triple bonds in its structure (see the Oxford Dictionary of Chemistry, 6th Edition, 2008).

The term “unsaturated” means a compound or group having double or triple bonds in its structure (see the Oxford Dictionary of Chemistry, 6th Edition, 2008). In one embodiment, the compound or group has at least one double bond in its structure.

Brief Description of the Figures

Certain aspects of the embodiments described herein may be more clearly understood by reference to the drawings, which is intended to illustrate but not limit, the invention, and wherein:

Figure 1 shows a representative bonded non-woven fibrous mat, which is according to the invention. The mat exhibits the required level of stiffness, and does not crack after repeated folding.

Description of the Invention

Bonded Non-Woven Fibrous Mat

In one aspect, the present invention provides a bonded non-woven fibrous mat, the bonded non-woven fibrous mat comprising:

(a) a precursor mat comprising:

- a non-woven web of fibers comprising a blend of glass fibers and polyester fibers, and
- a first binder;

and

(b) a composition which substantially or completely impregnates the precursor mat, the composition comprising:

- a second binder, and
- a filler;

wherein:

the first binder is selected from the group consisting of a polycarboxylic acid binder, a polyvinyl alcohol binder, or a combination thereof; and

the second binder is a polycarboxylic acid binder which is prepared from an unsaturated carboxylic acid compound and an aryl vinyl compound;

provided the bonded non-woven fibrous mat does not comprise a filler which is calcium carbonate.

The bonded non-woven mat of the present invention is stiff but is capable of being repeatedly folded or pleated without cracking, for example, twenty times or more. In this respect, a fold is when the bonded non-woven mat is bent over on itself so that one part of it covers another, and is then substantially straightened out. The action of folding and straightening is carried out multiple times i.e. twenty times or more. The bonded non-woven mat of the present invention may be repetitively pleated by producing two or more folds in the bonded non-woven mat, and then extending the folds or pleats out. In other words, the pleat may be concertinaed multiple times by compressing or collapsing folds in the non-woven mat, and then extending the folds.

Without wishing to be bound by theory, it is believed that the first binder, or combination thereof, which binds the blend of glass and polyester fibers, provides a base strength to the bonded non-woven fibrous mat, and the second binder provides flexibility to the bonded non-woven fibrous mat. Furthermore and also without wishing to be bound by theory, it is believed that there is a synergistic effect between the first binder, the polyester fibers, and the second (impregnation) binder that allows the mat to demonstrate its beneficial performance characteristics.

If desired, the bonded non-woven mat may be pre-creased and folded into a desired configuration before use. Alternatively or in addition, the bonded non-woven mat may be scored along a predetermined pattern to partially cut through the thickness of the bonded non-woven mat, and then folded into a desired configuration before use if desired.

The bonded non-woven fibrous mat comprises a precursor mat. The precursor mat comprises (a) a non-woven web of fibers comprising a blend of glass fibers and polyester fibers, and (b) a first binder, or combination thereof.

A non-woven web of fibers means that the glass and polyester fibers are randomly orientated.

The glass fibers may be formed by conventional methods known to those skilled in the art. In this respect, the glass fibers may be formed by a continuous manufacturing process in which molten glass passes through the holes of a bushing, the streams of molten glass thereby formed are solidified into filaments, and the filaments are combined together to form a fiber, “roving,” “strand,” or the like.

After the glass fibers are drawn from the bushing, an aqueous sizing composition (also referred to as a size) may optionally be applied to the fibers. The sizing composition is not limited, and may be any sizing composition known to those of skill in the art. Generally sizing compositions contain a lubricant to protect the fibers from damage by abrasion. The sizing composition may be applied by conventional methods such as by an application roller or by spraying the size directly onto the fibers. The size protects the glass fibers from breakage during subsequent processing, helps to retard interfilament abrasion, ensures the integrity of the strands of glass fibers, promotes the interconnection of the glass filaments that form the strand, etc.

After the glass fibers are treated with the sizing composition, they may be chopped for subsequent processing into a wet-laid, non-woven mat as described below. The chopped fibers may have varying lengths from each other within the non-woven mat.

The glass fibers may have a mean fiber diameter as described below and a mean fiber length as described below.

The glass fibers may have a mean fiber diameter in the range of ≥ about 6.5 μm and ≤ about 15 μm. In one embodiment, the glass fibers may have a mean fiber diameter in the range of ≥ about 8 μm and ≤ about 13 μm. In another embodiment, the glass fibers may have a mean fiber diameter of ≥ about 8.5 μm. In one embodiment, the glass fibers may have a mean fiber diameter of ≥ about 9 μm. In another embodiment, the glass fibers may have a mean fiber diameter of ≥ about 9.5 μm.

In one embodiment, the glass fibers may have a mean fiber diameter ≤ about 12.5 μm. In another embodiment, the glass fibers may have a mean fiber diameter of ≤ about 12 μm. In another embodiment, the glass fibers may have a mean fiber diameter of ≤ about 11.5 μm. In another embodiment, the glass fibers may have a mean fiber diameter of ≤ about 11 μm. In another embodiment, the glass fibers may have a mean fiber diameter of ≤ about 10.5 μm.

In one embodiment, the glass fibers may have a mean fiber diameter of about 10 μm.

The glass fibers may have a mean fiber length in the range of ≥ about 5 mm and ≤ about 15 mm. In one embodiment, the glass fibers may have a mean fiber length in the range of ≥ about 8 mm and ≤ about 13 mm. In another embodiment, the glass fibers may have a mean fiber length of ≥ about 8.5 mm. In one embodiment, the glass fibers may have a mean fiber length of ≥ about 9 mm. In another embodiment, the glass fibers may have a mean fiber length of ≥ about 9.5 mm.

In one embodiment, the glass fibers may have a mean fiber length ≤ about 12.5 mm. In another embodiment, the glass fibers may have a mean fiber length of ≤ about 12 mm. In another embodiment, the glass fibers may have a mean fiber length of ≤ about 11.5 mm. In another embodiment, the glass fibers may have a mean fiber length of ≤ about 11 mm. In another embodiment, the glass fibers may have a mean fiber length of ≤ about 10.5 mm.

In one embodiment, the glass fibers may have a mean fiber length of about 10 mm.

The glass fibers may comprise SiO_2 in a range from about 50 to about 65 wt% of the total wt% of the glass composition. In one embodiment, the glass fibers may comprise SiO_2 in a range from about 51 to about 62 wt% of the total wt% of the glass composition. In another embodiment, the glass fibers may comprise SiO_2 in a range from about 52 to about 62 wt% of the total wt% of the glass composition, such as about 52 to about 56 wt% of the total wt% of the glass composition or about 55 wt% to about 60.4 wt% of the total wt% of the glass composition. In another embodiment, the glass fibers may comprise SiO_2 in a range from about 54 to about 62 wt% of the total wt% of the glass composition. In another embodiment, the glass fibers may comprise SiO_2 in about 58 wt% of the total wt% of the glass composition. In another embodiment, the glass fibers may comprise SiO_2 in about 59 wt% of the total wt% of the glass composition. In another embodiment, the glass fibers may comprise SiO_2 in about 60 wt% of the total wt% of the glass composition, such as about 60.1 wt%.

The glass fibers may comprise Al_2O_3 in a range from about 7 to about 25 wt% of the total wt% of the glass composition. In one embodiment, the glass fibers may comprise Al_2O_3 in a range from about 7 to about 20 wt% of the total wt% of the glass composition. In another embodiment, the glass fibers may comprise Al_2O_3 in a range from about 19 to about 25 wt% of the total wt% of the glass composition. In another embodiment, the glass fibers may comprise Al_2O_3 in a range from about 9 to about 15 wt% of the total wt% of the glass composition. In one embodiment, the glass fibers may comprise Al_2O_3 in a range from about 12 to about 16 wt% of the total wt% of the glass composition, such as about 12 to about 15 wt% of the total wt% of the glass composition. In another embodiment, the glass fibers may comprise Al_2O_3 in a range from about 17 to about 20 wt% of the total wt% of the glass composition. In another embodiment, the glass fibers may comprise Al_2O_3 in about 11.5 wt% of the total wt% of the glass composition, such as about 11.6 wt%. In another embodiment, the glass fibers may comprise Al_2O_3 in about 12 wt% of the total wt% of the glass composition, such as about 12.1 wt%. In another embodiment, the glass fibers may comprise Al_2O_3 in about 13 wt% of the total wt% of the glass composition, such as about 13.2 wt%.

The glass fibers may contain B_2O_3 i.e. the glass fibers are boron-containing glass fibers. The glass fibers may comprise B_2O_3 in a range from about 1 wt% to about 12 wt% of the total wt% of the glass composition. In one embodiment, the glass fibers may comprise B_2O_3 in a range from about 4 to about 6 wt% of the total wt% of the glass composition. In another embodiment, the glass fibers may comprise B_2O_3 in a range from about 5 to about 10 wt% of the total wt% of the glass composition. In another embodiment, the glass fibers may comprise B_2O_3 in a range from about 7 to about 12 wt% of the total wt% of the glass composition. Without wishing to be bound by theory, boron-containing glass fibers typically have lower softening points than boron-free glass fibers. The process for preparing the fibers typically utilise less energy than the boron-free fibers (because the glass melt typically has a lower softening point). The lower softening point of the boron-containing glass fibers may be of use in the application of the fibers.

The glass fibers may comprise substantially no B_2O_3 i.e. the glass fibers may be substantially boron-free fibers. The glass fibers may comprise no B_2O_3 i.e. the glass fibers may be boron-free fibers. Without wishing to be bound by theory, boron-free or substantially boron-free glass fibers are more environmentally friendly than the boron-containing glass fibers as melts from which the fibers are made do not emit boron into the environment during processing. The fibers themselves typically have higher softening points than boron-containing fibers which may be of use in the application of the fibers.

The glass fibers may comprise CaO in a range from about 7 to about 30 wt% of the total wt% of the glass composition. In one embodiment, the glass fibers may comprise CaO in a range from about 7 to about 12 wt% of the total wt% of the glass composition. In another embodiment, the glass fibers may comprise CaO in a range from about 12 to about 30 wt% of the total wt% of the glass composition. In another embodiment, the glass fibers may comprise CaO in a range from about 16 to about 25 wt% of the total wt% of the glass composition, such as about 17 to about 25 wt% of total wt% of the glass

composition. In another embodiment, the glass fibers may comprise CaO in a range from about 21 to about 23 wt% of the total wt% of the glass composition. In another embodiment, the glass fibers may comprise CaO in a range from about 24 to about 30 wt% of the total wt% of the glass composition. In another embodiment, the glass fibers may comprise CaO in about 21.7 wt% of the total wt% of the glass composition. In another embodiment, the glass fibers may comprise CaO in about 22 wt% of the total wt% of the glass composition. In another embodiment, the glass fibers may comprise CaO in about 22.1 wt% of the total wt% of the glass composition. In another embodiment, the glass fibers may comprise CaO in about 22.6 wt% of the total wt% of the glass composition.

The glass fibers may comprise MgO in a range from about 0.1 to about 15 wt% of the total wt% of the glass composition. In one embodiment, the glass fibers may comprise MgO in a range from about 0.1 to about 8 wt% of the total wt% of the glass composition. In another embodiment, the glass fibers may comprise MgO in a range from about 8 to about 15 wt% of the total wt% of the glass composition. In another embodiment, the glass fibers may comprise MgO in a range from about 0.1 to about 5 wt% of the total wt% of the glass composition. In one embodiment, the glass fibers may comprise MgO in a range from about 0.4 to about 4 wt% of the total wt% of the glass composition. In another embodiment, the glass fibers may comprise MgO in about 2 wt% of the total wt% of the glass composition. In another embodiment, the glass fibers may comprise MgO in about 3.1 wt% of the total wt% of the glass composition. In another embodiment, the glass fibers may comprise MgO in about 3.4 wt% of the total wt% of the glass composition.

The glass fibers may comprise substantially no MgO i.e. the glass fibers may be substantially magnesium-free fibers. The glass fibers may comprise no MgO i.e. the glass fibers may be magnesium-free fibers.

The glass fibers may comprise ZnO in a range from about 0.1 to about 4 wt% of the total wt% of the glass composition. In one embodiment, the glass fibers may comprise ZnO in a range from about 0.5 to about 1 wt% of the total wt% of the glass composition, such as about 1 wt%. In another embodiment, the glass fibers may comprise ZnO in a range from about 2 to about 5 wt% of the total wt% of the glass composition. In another embodiment, the glass fibers may comprise ZnO in a range from about 1 to about 4 wt% of the total wt% of the glass composition, such as about 1.1 to about 3 wt%. In one embodiment, the glass fibers may comprise ZnO in about 2.9 wt% of the total wt% of the glass composition.

The glass fibers may comprise substantially no ZnO i.e. the glass fibers may be substantially zinc-free fibers. The glass fibers may comprise no ZnO i.e. the glass fibers may be zinc-free fibers.

The glass fibers may comprise BaO in a range from about 0.1 to about 3 wt% of the total wt% of the glass composition. In one embodiment, the glass fibers may comprise BaO in a range from about 0.5 to about 1 wt% of the total wt% of the glass composition, such as about 1 wt%. In another embodiment,

the glass fibers may comprise BaO in a range from about 1 to about 3 wt% of the total wt% of the glass composition, such as about 1.1 to about 3 wt%.

The glass fibers may comprise substantially no BaO i.e. the glass fibers may be substantially barium-free fibers. The group of glass fibers may comprise no BaO i.e. the glass fibers may be barium-free fibers.

The glass fibers may comprise Li_2O in a range from about 0.1 to about 1 wt% of the total wt% of the glass composition. In one embodiment, the glass fibers may comprise Li_2O in a range from about 0.1 to about 0.4 wt% of the total wt% of the glass composition. In another embodiment, the glass fibers may comprise Li_2O in a range from about 0.5 to about 1 wt% of the total wt% of the glass composition.

The glass fibers may comprise substantially no Li_2O i.e. the glass fibers may be substantially lithium-free fibers. The glass fibers may comprise no Li_2O i.e. the glass fibers may be lithium-free fibers.

The glass fibers may comprise Na_2O and K_2O in a range from about 0.1 to about 5 wt% of the total wt% of the glass composition. In one embodiment, the glass fibers may comprise Na_2O and K_2O in a range from about 0.1 to about 4 wt% of the total wt% of the glass composition, such as about 0.5 to about 4 wt% of the total wt% of the glass composition. In another embodiment, the glass fibers may comprise a total of Na_2O and K_2O in a range from about 0.1 to about 2 wt% of the total wt% of the glass composition, such as about 0.1 to about 1 wt% of the total wt% of the glass composition. In another embodiment, the glass fibers may comprise a total of Na_2O and K_2O in a range from about 0.1 to about 0.3 wt% of the total wt% of the glass composition. In another embodiment, the glass fibers may comprise Na_2O and K_2O in about 0.1 to about 0.2 wt% of the total wt% of the glass composition. In another embodiment, the glass fibers may comprise Na_2O and K_2O in about 0.9 wt% of the total wt% of the glass composition. In another embodiment, the glass fibers may comprise Na_2O and K_2O in about 0.8 wt% of the total wt% of the glass composition. In another embodiment, the glass fibers may comprise Na_2O and K_2O in about 1.2 wt% of the total wt% of the glass composition.

The glass fibers may comprise substantially no Na_2O or K_2O i.e. the glass fibers may be substantially sodium- and potassium-free fibers. The glass fibers may comprise no Na_2O or K_2O i.e. the glass fibers may be sodium- and potassium-free fibers.

The glass fibers may comprise TiO_2 in a range from about 0.1 to about 5 wt% of the total wt% of the glass composition. In one embodiment, the glass fibers may comprise TiO_2 in a range from about 0.1 to about 4 wt% of the total wt% of the glass composition. In another embodiment, the glass fibers may comprise TiO_2 in a range from about 0.1 to about 0.2 wt% of the total wt% of the glass composition, such as about 0.1 to about 1.5 wt%. In another embodiment, the glass fibers may comprise TiO_2 in a range from about 0.2 to about 0.5 wt% of the total wt% of the glass composition. In another embodiment, the glass fibers may comprise TiO_2 in about 0.5 wt% of the total wt% of the glass

composition. In another embodiment, the glass fibers may comprise TiO_2 in about 1.5 wt% of the total wt% of the glass composition. In another embodiment, the glass fibers may comprise TiO_2 in about 2.5 wt% of the total wt% of the glass composition.

The glass fibers may comprise substantially no TiO_2 i.e. the glass fibers may be substantially titanium-free fibers. The glass fibers may comprise no TiO_2 i.e. the glass fibers may be titanium-free fibers.

The glass fibers may comprise ZrO_2 in a range from about 0.1 to about 1 wt% of the total wt% of the glass composition. In one embodiment, the glass fibers may comprise ZrO_2 in a range from about 0.1 to about 0.4 wt% of the total wt% of the glass composition. In another embodiment, the glass fibers may comprise ZrO_2 in a range from about 0.5 to about 1 wt% of the total wt% of the glass composition.

The glass fibers may comprise substantially no ZrO_2 i.e. the glass fibers may be substantially zirconium-free fibers. The glass fibers may comprise no ZrO_2 i.e. the glass fibers may be zirconium-free fibers.

The glass fibers may comprise Fe_2O_3 in a range from about 0.1 to about 2 wt% of the total wt% of the glass composition. In one embodiment, the glass fibers may comprise Fe_2O_3 in a range from about 0.1 to about 0.8 wt% of the total wt% of the glass composition. In another embodiment, the glass fibers may comprise Fe_2O_3 in a range from about 0.2 to about 0.4 wt% of the total wt% of the glass composition. In another embodiment, the glass fibers may comprise Fe_2O_3 in about 0.1 wt% of the total wt% of the glass composition. In another embodiment, the glass fibers may comprise Fe_2O_3 in about 0.2 wt% of the total wt% of the glass composition.

The glass fibers may comprise substantially no Fe_2O_3 i.e. the glass fibers may be substantially iron-free fibers. The glass fibers may comprise no Fe_2O_3 i.e. the glass fibers may be iron-free fibers.

The glass fibers may comprise F_2 in a range from about 0.1 to about 2 wt% of the total wt% of the glass composition. In one embodiment, the glass fibers may comprise F_2 in a range from about 0.1 to about 1 wt% of the total wt% of the glass composition. In another embodiment, the glass fibers may comprise F_2 in a range from about 0.2 to about 0.7 wt% of the total wt% of the glass composition. In another embodiment, the glass fibers may comprise F_2 in about 0.1 wt% of the total wt% of the glass composition.

The glass fibers may comprise substantially no F_2 i.e. the glass fibers may be substantially fluoride-free fibers. The glass fibers may comprise no F_2 i.e. the glass fibers may be fluoride-free fibers. Without wishing to be bound by theory, fluoride-free or substantially fluoride-free fibers are more environmentally friendly than fluoride-containing fibers.

The glass fibers may comprise a composition comprising:

Oxide	Wt%
SiO_2	50-65
Al_2O_3	7-25
B_2O_3	0-12
CaO	7-30
MgO	0-15
ZnO	0-4
BaO	0-3
Li_2O	0-1
Na_2O+K_2O	0-5
TiO_2	0-5
ZrO_2	0-1
Fe_2O_3	0-2
F_2	0-2

While various components in the glass may be expressed as a range, the total wt% of the composition adds up to 100 wt%.

The glass fibers may comprise boron-containing E-glass, boron-free E-glass, ECR-glass, H glass, or a mixture thereof. In one embodiment, the glass fibers may comprise boron-containing E-glass fibers. In another embodiment, the glass fibers may comprise boron-free E-glass fibers. In another embodiment, the glass fibers may comprise ECR-glass fibers. In another embodiment, the glass fibers may comprise a mixture of boron-containing E-glass, and boron-free E-glass fibers. In another embodiment, the glass fibers may comprise a mixture of boron-containing E-glass, and ECR-glass fibers. In another embodiment, the glass fibers may comprise a mixture of boron-free E-glass fibers, and ECR-glass fibers. In another embodiment, the glass fibers may comprise a mixture of boron-containing E-glass, boron-free E-glass fibers, and ECR-glass fibers. In another embodiment, the glass fibers may comprise H glass.

The composition of boron-containing E-glass may comprise:

Oxide	Wt%
SiO_2	52-56
Al_2O_3	12-16
B_2O_3	5-10, such as 4-6
CaO	16-25, such as 21-23
MgO	0-5, such as 0.4-4
ZnO	0
BaO	0

Li_2O	0
Na_2O+K_2O	0-2, such as 0.1-0.2
TiO_2	0-1.5, such as 0.2-0.5
ZrO_2	0
Fe_2O_3	0-0.8, such as 0.2-0.4
F_2	0-1, such as 0.2-0.7

While various components in the E-glass may be expressed as a range, the total wt% of the composition adds up to 100 wt%.

The composition of boron-free E-glass may comprise:

Oxide	**Wt%**
SiO_2	59
Al_2O_3	12.1
B_2O_3	0
CaO	22.6
MgO	3.4
ZnO	0
BaO	0
Li_2O	0
Na_2O+K_2O	0.9
TiO_2	1.5
ZrO_2	0
Fe_2O_3	0.2
F_2	0

While various components in the E-glass may be expressed as a range, the total wt% of the composition adds up to 100 wt%. In this instance, the boron-free E-glass does not comprise F_2.

Alternatively or in addition, the composition of boron-free E-glass may comprise:

Oxide	**Wt%**
SiO_2	60.1
Al_2O_3	13.2
B_2O_3	0
CaO	22.1
MgO	3.1
ZnO	0

BaO	0
Li_2O	0
Na_2O+K_2O	0.8
TiO_2	0.5
ZrO_2	0
Fe_2O_3	0.2
F_2	0.1

While various components in the E-glass may be expressed as a range, the total wt% of the composition adds up to 100 wt%. In this instance, the boron-free E-glass comprises F_2.

The composition of ECR-glass may comprise:

Oxide	**Wt%**
SiO_2	54-62
Al_2O_3	9-15
B_2O_3	0
CaO	17-25
MgO	0-4
ZnO	2-5
BaO	0
Li_2O	0
Na_2O+K_2O	0-2
TiO_2	0-4
ZrO_2	0
Fe_2O_3	0-0.8
F_2	0

While various components in the ECR-glass may be expressed as a range, the total wt% of the composition adds up to 100 wt%. In this instance, the ECR-glass comprises no or substantially no B_2O_3 nor F_2. Boron-free ECR-glass fibers are commercially available from Owens Corning as Advantex™ glass fibers.

H glass and the method by which it can be prepared is disclosed in US11214512, the content of which is incorporated herein by reference in its entirety. The composition of H glass may comprise:

SiO_2 in an amount from 55.0 to 60.4% by weight;

Al_2O_3 in an amount from 19.0 to 25.0% by weight;

CaO in an amount from 7 to 12.0% by weight;

MgO in an amount from 8.0 to 15.0% by weight;

Na_2O in an amount from 0 to 1.0% by weight; and

TiO_2 in an amount from 0.0 to 1.5% by weight, expressed as percentages by weight based on the weight of the entire composition,
wherein the weight percent ratio of Al_2O_3/MgO is less than 2.0, wherein the combined amounts of SiO_2, Al_2O_3, MgO, and CaO is at least 98% by weight and less than 99.5% by weight, wherein the sum of the amounts of B_2O_3, Li_2O, and fluorine is less than 0.2% by weight, and wherein said glass composition has a fiberizing temperature no greater than 2,500° F.

In one embodiment, the composition of H glass may comprise 19.5 to 21% by weight Al_2O_3.

In one embodiment, the combined amounts in H glass of MgO and CaO is greater than 20% by weight.

In one embodiment, the combined amounts in H glass of MgO and CaO is less than 22% by weight.

In one embodiment, the weight percent ratio in H glass of Al_2O_3/MgO is no greater than 1.8.

In one embodiment, the combined amounts in H glass of Fe_2O_3, TiO_2, K_2O, and Na_2O is below 1.5% by weight.

In one embodiment, the composition of H glass is free or substantially free of B_2O_3.

In one embodiment, the composition of H glass is free of Li_2O.

Any suitable polyester fibers may be used provided the final bonded non-woven fibrous mat retains its stiffness, and crack resistance when the mat is repeatedly folded or pleated. The polyester fibers may be aliphatic-aryl polyester fibers which are known to the skilled person, such as poly(ethylene terephthalate) (PET) fibers, poly(butylene terephthalate) (PBT) fibers, poly(hexamethylene terephthalate) (PHT) fibers, poly(propylene terephthalate) (PTT) fibers.

In one embodiment, the polyester fibers do not comprise recycled polyester fibers i.e. the polyester fibers have not been subjected to any processing other than for their production.

The polyester fibers may have a mean fiber diameter as described below and a mean fiber length as described below.

The polyester fibers may have a mean fiber diameter in the range of ≥ about 1 μm and ≤ about 15 μm. In one embodiment, the polyester fibers may have a mean fiber diameter in the range of ≥ about 3 μm and ≤ about 10 μm. In another embodiment, the polyester fibers may have a mean fiber diameter of ≥ about 3.5 μm. In one embodiment, the polyester fibers may have a mean fiber diameter of ≥ about 4 μm. In another embodiment, the polyester fibers may have a mean fiber diameter of ≥ about 4.5 μm. In another embodiment, the polyester fibers may have a mean fiber diameter of ≥ about 5 μm. In

another embodiment, the polyester fibers may have a mean fiber diameter of ≥ about 5.5 μm. In another embodiment, the polyester fibers may have a mean fiber diameter of ≥ about 6 μm.

In one embodiment, the polyester fibers may have a mean fiber diameter ≤ about 9.5 μm. In another embodiment, the polyester fibers may have a mean fiber diameter of ≤ about 9 μm. In another embodiment, the polyester fibers may have a mean fiber diameter of ≤ about 8.5 μm. In another embodiment, the polyester fibers may have a mean fiber diameter of ≤ about 8 μm. In another embodiment, the polyester fibers may have a mean fiber diameter of ≤ about 7.5 μm. In another embodiment, the polyester fibers may have a mean fiber diameter of ≤ about 7 μm.

In one embodiment, the polyester fibers may have a mean fiber diameter of about 6-7 μm, such as about 6 μm.

The polyester fibers may have a mean fiber length in the range of ≥ about 1 mm and ≤ about 15 mm. In one embodiment, the polyester fibers may have a mean fiber length in the range of ≥ about 3 mm and ≤ about 10 mm. In another embodiment, the polyester fibers may have a mean fiber length of ≥ about 3.5 mm. In one embodiment, the polyester fibers may have a mean fiber length of ≥ about 4 mm. In another embodiment, the polyester fibers may have a mean fiber length of ≥ about 4.5 mm. In another embodiment, the polyester fibers may have a mean fiber length of ≥ about 5 mm. In another embodiment, the polyester fibers may have a mean fiber length of ≥ about 5.5 mm. In another embodiment, the polyester fibers may have a mean fiber length of ≥ about 6 mm.

In one embodiment, the polyester fibers may have a mean fiber length ≤ about 9.5 mm. In another embodiment, the polyester fibers may have a mean fiber length of ≤ about 9 mm. In another embodiment, the polyester fibers may have a mean fiber length of ≤ about 8.5 mm. In another embodiment, the polyester fibers may have a mean fiber length of ≤ about 8 mm. In another embodiment, the polyester fibers may have a mean fiber length of ≤ about 7.5 mm. In another embodiment, the polyester fibers may have a mean fiber length of ≤ about 7 mm.

In one embodiment, the polyester fibers may have a mean fiber length of about 6-7 mm.

Any suitable wt% ratio of glass fibers : polyester fibers may be used provided the final bonded non-woven fibrous mat retains its stiffness, and crack resistance, when the mat is repeatedly folded or pleated. The ratio of glass fibers : polyester fibers may be in the range of about 50 : about 50 wt% to about 90 : 10 wt%. In one embodiment, the ratio of glass fibers : polyester fibers may be about 55 : about 45 wt%. In another embodiment, the ratio of glass fibers : polyester fibers may be about 60 : about 40 wt%. In one embodiment, the ratio of glass fibers : polyester fibers may be about 65 : about 35 wt%. In one embodiment, the ratio of glass fibers : polyester fibers may be about 70 : about 30 wt%. In one embodiment, the ratio of glass fibers : polyester fibers may be about 80 : about 20 wt%. In one

embodiment, the ratio of glass fibers : polyester fibers may be about 85 : about 15 wt%. In one embodiment, the ratio of glass fibers : polyester fibers may be about 90 : about 10 wt%.

The ratio of glass fibers : polyester fibers may be about 75 : about 25 wt%.

The weight of the glass and polyester fibers may be in the range of about 40 to about 170 gsm (grams per square meter). In one embodiment, the weight of the glass and polyester fibers may be in the range of about 60 to about 150 gsm. In one embodiment, the weight of the glass and polyester fibers may be ≥ about 60 gsm. In another embodiment, the weight of the glass and polyester fibers may be ≥ about 65 gsm. In another embodiment, the weight of the glass and polyester fibers may be ≥ about 70 gsm. In another embodiment, the weight of the glass and polyester fibers may be ≥ about 75 gsm. In another embodiment, the weight of the glass and polyester fibers may be ≥ about 80 gsm.

In one embodiment, the weight of the glass and polyester fibers may be ≤ about 170 gsm. In another embodiment, the weight of the glass and polyester fibers may be ≤ about 165 gsm. In one embodiment, the weight of the glass and polyester fibers may be ≤ about 160 gsm. In one embodiment, the weight of the glass and polyester fibers may be ≤ about 155 gsm. In one embodiment, the weight of the glass and polyester fibers may be ≤ about 150 gsm. In one embodiment, the weight of the glass and polyester fibers may be ≤ about 140 gsm. In one embodiment, the weight of the glass and polyester fibers may be ≤ about 135 gsm. In one embodiment, the weight of the glass and polyester fibers may be ≤ about 130 gsm.

In one embodiment, the weight of the glass and polyester fibers may be in the range of about 80 to about 130 gsm.

In one embodiment, the weight of the glass and polyester fibers may be about 85 gsm.

In another embodiment, the weight of the glass and polyester fibers may be about 127-128 gsm.

The first binder and impregnation composition are applied in two separate stages during the manufacture of the bonded non-woven fibrous mat. The first binder, or combination thereof, is applied first in the formation of the precursor mat, and the impregnation composition (comprising the second binder, or combination thereof, and filler) is applied secondly in the formation of the final bonded non-woven fibrous mat.

The precursor mat is dried before the impregnation composition is applied. The first binder therefore is dry in the precursor mat.

After the impregnation composition has been applied to the precursor mat, the impregnated precursor mat is dried to form the bonded non-woven fibrous mat of the present invention. Both the first and second binders therefore are dry in the bonded non-woven fibrous mat.

The first binder is selected from one or more (e.g. 1, 2, 3, 4, 5, or more) polycarboxylic acid binders, polyvinyl alcohol binders, or combination thereof. Polycarboxylic acid and polyvinyl alcohol binders are formaldehyde-free (or no-added formaldehyde ("NAF")) binders. Binders which are free of added formaldehyde are environmentally friendly i.e. "green".

The first binder may be a water-soluble or water-dispersible binder. In certain embodiments, the binder is a water-soluble binder. In certain embodiments, the binder is a water-dispersible binder. In certain embodiments, the binder composition comprises one or more of any water-based emulsion or solution.

The polycarboxylic acid binder may be a homopolymer or copolymer prepared from one or more (e.g. 1, 2, 3, 4, 5 or more) unsaturated carboxylic acid compounds including but not necessarily limited to, acrylic acid, methacrylic acid, crotonic acid, isocrotonic acid, maleic acid, cinnamic acid, 2-methylmaleic acid, itaconic acid, 2-methylitaeonic acid, α,β-methyleneglutaric acid, and the like. Methods for polymerising these acids are known to the skilled person. In this instance, the polycarboxylic acid binder is a homopolymer or copolymer comprising at least one or more (e.g. 1, 2, 3, 4, or 5) repeat units, and the or each repeat unit comprises a -COOH group.

Alternatively, the polycarboxylic acid binder may be prepared from unsaturated anhydrides including, but not necessarily limited to, maleic anhydride, methacrylic anhydride, and the like, as well as mixtures thereof. Methods for polymerising these anhydrides are known to the skilled person. In this instance, the polycarboxylic acid binder is a homopolymer or copolymer comprising at least one or more (e.g. 1, 2, 3, 4, or 5) repeat units, and the or each repeat unit comprises a -CO-O-CO- group.

The polycarboxylic acid binder may further comprise a homopolymer or copolymer prepared from one or more (e.g. 1, 2, 3, 4, 5 or more) unsaturated carboxylic acid ester compounds including, but not necessarily limited to, methyl acrylate, ethyl acrylate, n-butyl acrylate, isobutyl acrylate, methyl methacrylate, n-butyl methacrylate, isobutyl methacrylate, glycidyl methacrylate, vinyl acetate, and the like. Methods for preparing these polymers are known to the skilled person. In this instance, the polycarboxylic acid binder is a homopolymer or copolymer comprising at least one or more (e.g. 1, 2, 3, 4, or 5) repeat units, and the or each repeat unit comprises a -COOR group, and R is selected from the group consisting of methyl, ethyl, butyl (n-, i-, or t-), and 2,3-epoxypropyl as appropriate.

When the polycarboxylic acid binder comprises a mixture of a polymer (e.g. a homo- or co-polymer) of an unsaturated carboxylic acid (e.g. polyacrylic acid binder) and a polymer (e.g. a homo- or co-polymer) of an unsaturated carboxylic acid ester (e.g. polymethyl methacrylate), the wt% ratio of the polymer of the unsaturated carboxylic acid to the polymer of the unsaturated carboxylic acid ester may be in the

range of about 1 : about 0.01 wt% to about 1 : about 1 wt% of the total solids in the binder composition. In one embodiment, the wt% ratio of the polymer of the unsaturated carboxylic acid to the polymer of the unsaturated carboxylic acid ester may be in the range of about 1 : about 0.1 wt% to about 1 : about 0.8 wt% of the total solids in the binder composition. In another embodiment, the wt% ratio of the polymer of the unsaturated carboxylic acid to the polymer of the unsaturated carboxylic acid ester may be in the range of about 1 : about 0.2 wt% to about 1 : about 0.5 wt% of the total solids in the binder composition. In another embodiment, the wt% ratio of the polymer of the unsaturated carboxylic acid (e.g. polyacrylic acid binder) to the polymer of the unsaturated carboxylic acid ester (e.g. polymethyl methacrylate) may be about 1 : about 0.4 wt% of the total solids in the binder composition.

In one embodiment, the polycarboxylic acid binder may be a homopolymer or copolymer of polyacrylic acid. In one embodiment, the polycarboxylic acid binder is a homopolymer of polyacrylic acid i.e. the polymer is synthesised from acrylic acid. The weight average molecular weight (M_W) of the polycarboxylic acid binder, such as polyacrylic acid binder or polymethyl methacrylate binder, may be less than 10000 g/mole, such as less than 5000 g/mole, and for example about 3000 g/mole or less, e.g. about 2000 g/mole.

In one embodiment, the polycarboxylic acid binder may comprise polymethyl methacrylate.

In one embodiment, the polycarboxylic acid binder may comprise polyacrylic acid and polymethyl methacrylate.

The pH of the first binder may be low, for example, about 3 or less, such as about 2.5 or less, e.g. about 2 or less. The pH of the binder can be adjusted by adding a suitable acid, such as sulfuric acid. The low pH of the binder can provide processing advantages, while also providing a product which exhibits excellent recovery and rigidity properties. An example of the processing advantages include a reduction in cure temperature or time. In one embodiment, the pH of the first binder may be about pH 2 to about pH 3.

The first binder, or combination thereof, may additionally contain a polyol containing at least two hydroxyl groups. Any suitable polyol may be used provided the polyol is sufficiently non-volatile such that it will substantially remain available for reaction with the polyacid in the composition during heating and curing operations. The polyol may be a compound with a molecular weight less than about 1000 and bearing at least two hydroxyl groups such as ethylene glycol, glycerol, pentaerythritol, trimethylol propane, sorbitol, sucrose, glucose, resorcinol, catechol, pyrogallol, glycollated ureas, 1,4-cyclohexane diol, diethanolamine, or triethanolamine.

In one embodiment, the polyol may be glycerol.

When the polycarboxylic acid binder comprises a mixture of a polymer (e.g. a homo- or co-polymer) of an unsaturated carboxylic acid and a polyol, the wt% ratio of the unsaturated carboxylic acid polymer to polyol may be in the range of about 1 : about 0.01 wt% to about 1 : about 1 wt% of the total solids in the binder composition. In one embodiment, the wt% ratio of the unsaturated carboxylic acid polymer to polyol may be in the range of about 1 : about 0.1 wt% to about 1 : about 0.8 wt% of the total solids in the binder composition. In another embodiment, the wt% ratio of the unsaturated carboxylic acid polymer to polyol may be in the range of about 1 : about 0.2 wt% to about 1 : about 0.5 wt% of the total solids in the binder composition. In another embodiment, the wt% ratio of the unsaturated carboxylic acid polymer (e.g. polyacrylic acid binder) to polyol (e.g. glycerol) may be about 1 : about 0.3 wt% of the total solids in the binder composition, such as about 1 : about 0.25 wt% of the total solids in the binder composition.

In one embodiment, the first binder may be a combination of polyacrylic acid, polymethyl methacylate, and glycerol. In one embodiment, the first binder may be a combination of (a) polyacrylic acid and glycerol, and (b) polymethyl methacrylate latex. The wt% ratio of polyacrylic acid : glycerol may be about 75% to about 25% of the total solids in the binder composition. The ratio of (a) : (b) may be about 75% to about 25% of the total solids in the binder composition. The final wt% ratio of polyacrylic acid : glycerol : polymethyl methacrylate overall may be about 56% : about 19% : about 25% of the total solids in the binder composition.

In certain embodiments, the polyol is not comprise a -hydroxyalkylamide group. Examples of such polyols, include but are not limited to, bis[N,N-di(hydroxyethyl)]adipamide.

The first binder may be a polyvinyl alcohol binder. Polyvinyl alcohols are water-soluble polymers which may be manufactured by the hydrolysis (saponification) of polyvinyl acetate. Polyvinyl alcohols are typically described in terms of their degree of hydrolysis (% hydrolysis) and/or their weight average molecular weight (Mw).

The weight average molecular weight (M_W) of the polyvinyl alcohol binder, may be less than 10000 g/mole, such as less than 5000 g/mole, and for example about 3000 g/mole or less, e.g. about 2000 g/mole.

In some embodiments, the polyvinyl alcohol binder has a % hydrolysis which is about ≥ 80%. In some embodiments, the % hydrolysis is ≥ about 85%. In some embodiments, the % hydrolysis is ≥ about 90%. In some embodiments, the % hydrolysis is ≥ about 91%. In some embodiments, the % hydrolysis is ≥ about 92%. In some embodiments, the % hydrolysis is ≥ about 93%. In some embodiments, the % hydrolysis is ≥ about 94%. In some embodiments, the % hydrolysis is ≥ about 95%. In some embodiments, the % hydrolysis is ≥ about 96%. In some embodiments, the % hydrolysis is ≥ about 97%. In some embodiments, the % hydrolysis is ≥ about 98%. In some embodiments, the % hydrolysis is ≥ about 99%.

In one embodiment, the % hydrolysis is ≥ about 98-99%. In this instance, the polyvinyl alcohol binder has a high purity, and is particularly suitable for use in bonded non-woven fibrous mats in ceiling tiles. The polyvinyl alcohol binder may be liquid or a solid. In certain embodiments, the polyvinyl alcohol binder is a powder, such that it may be co-cast with the blend of glass and polyester fibers in the aqueous solution.

The polycarboxylic acid binder may be a copolymer prepared from one or more (e.g. 1, 2, 3, 4, 5 or more) unsaturated carboxylic acid compounds and one or more (e.g. 1, 2, 3, 4, 5 or more) aryl vinyl compounds. The unsaturated carboxylic acid include but not necessarily limited to, acrylic acid, methacrylic acid, crotonic acid, isocrotonic acid, maleic acid, cinnamic acid, 2-methylmaleic acid, itaconic acid, 2-methylitaeonic acid, α,β-methyleneglutaric acid, and the like. The aryl vinyl compounds include but are not limited to, styrene, methylstyrene (2-, 3-, or 4-), ethylstyrene (2-, 3-, or 4-), n-butylstyrene (2-, 3-, or 4-), iso-butylstyrene (2-, 3-, or 4-), tert-butylstyrene (2-, 3-, or 4-), α-methylstyrene (also known as isopropenylbenzene), β-methylstyrene (also known as propenylbenzene). Methods for preparing these copolymers are known to the skilled person. In this instance, the polycarboxylic acid binder is a copolymer comprising (a) a repeat unit comprising a -COOH group, and (b) a repeat unit comprising a substituted or unsubstituted styrenyl group.

In one embodiment, the first binder is styrene acrylic latex. In this instance, the copolymer is prepared from an unsaturated carboxylic acid which is acrylic acid, and an aryl vinyl compound which is styrene.

The wt% of the first binder, or combination thereof, may be in the range of about 5 wt% to about 50 wt% of the total solids in the precursor mat. In one embodiment, the wt% of the first binder, or combination thereof, may be in the range of about 10 wt% to about 40 wt% of the total solids in the precursor mat. In one embodiment, the wt% of the first binder, or combination thereof, may be ≥ about 10 wt% of the total solids in the precursor mat. In another embodiment, the wt% of the first binder, or combination thereof, may be ≥ about 11 wt% of the total solids in the precursor mat. In another embodiment, the wt% of the first binder, or combination thereof, may be ≥ about 12 wt% of the total solids in the precursor mat. In another embodiment, the wt% of the first binder, or combination thereof, may be ≥ about 13 wt% of the total solids in the precursor mat. In another embodiment, the wt% of the first binder, or combination thereof, may be ≥ about 14 wt% of the total solids in the precursor mat.

In one embodiment, the wt% of the first binder, or combination thereof, may be ≤ about 35 wt% of the total solids in the precursor mat. In another embodiment, the wt% of the first binder, or combination thereof, may be ≤ about 30 wt% of the total solids in the precursor mat. In another embodiment, the wt% of the first binder, or combination thereof, may be ≤ about 25 wt% of the total solids in the precursor mat. In another embodiment, the wt% of the first binder, or combination thereof, may be ≤ about 20 wt% of the total solids in the precursor mat.

In one embodiment, the wt% of the first binder, or combination thereof, may be about 14 wt% of the total solids in the precursor mat.

In one embodiment, the wt% of the first binder, or combination thereof, may be about 15 wt% of the total solids in the precursor mat.

The first binder, or combination thereof, may be different to the second binder, or combination thereof.

The precursor mat is substantially or completely impregnated with a composition to form the bonded non-woven fibrous mat of the present invention. The composition comprises (a) a second binder, or combination thereof, and (b) a filler. The composition is also described in the present specification as an "impregnation composition". In this respect, the final bonded non-woven fibrous mat is not asymmetric. This means that the composition does not coat or sit solely on one side of the precursor mat. Instead, the composition soaks or saturates the precursor mat such that the composition is detectable on both sides of the bonded non-woven fibrous mat.

In one embodiment, the composition substantially impregnates the precursor mat. In certain embodiments, the composition impregnates at least about 90% of the precursor mat, such as at least about 95% of the precursor mat, for example, at least about 97% of the precursor mat. In certain embodiments, the composition impregnates at least about 98% of the precursor mat, such as at least about 99% of the precursor mat.

In another embodiment, the composition completely impregnates the precursor mat.

The second binder is a polycarboxylic acid binder which is prepared from an unsaturated carboxylic acid compound and an aryl vinyl compound. Such polycarboxylic acid binders are formaldehyde-free (or no-added formaldehyde ("NAF")) binders. Binders which are free of added formaldehyde are environmentally friendly i.e. "green".

The second binder may be a water-soluble or water-dispersible binder. In certain embodiments, the binder is a water-soluble binder. In certain embodiments, the binder is a water-dispersible binder. In certain embodiments, the binder composition comprises one or more of any water-based emulsion or solution.

The polycarboxylic acid binder may be a copolymer prepared from one or more (e.g. 1, 2, 3, 4, 5 or more) unsaturated carboxylic acid compounds and one or more (e.g. 1, 2, 3, 4, 5 or more) aryl vinyl compounds. The unsaturated carboxylic acid include but not necessarily limited to, acrylic acid, methacrylic acid, crotonic acid, isocrotonic acid, maleic acid, cinnamic acid, 2-methylmaleic acid, itaconic acid, 2-methylitaeonic acid, α,β-methyleneglutaric acid, and the like. The aryl vinyl compounds include but are not limited to, styrene, methylstyrene (2-, 3-, or 4-), ethylstyrene (2-, 3-, or 4-), n-

butylstyrene (2-, 3-, or 4-), iso-butylstyrene (2-, 3-, or 4-), tert-butylstyrene (2-, 3-, or 4-), α-methylstyrene (also known as isopropenylbenzene), β-methylstyrene (also known as propenylbenzene). Methods for preparing these copolymers are known to the skilled person. In this instance, the polycarboxylic acid binder is a copolymer comprising (a) a repeat unit comprising a -COOH group, and (b) a repeat unit comprising a styrenyl group.

In one embodiment, the second binder is styrene acrylic latex. In this instance, the copolymer is prepared from an unsaturated carboxylic acid which is acrylic acid, and an aryl vinyl compound which is styrene.

The wt% of the second binder, or combination thereof, may be in the range of about 5 wt% to about 50 wt% of the total solids in the impregnation composition. In one embodiment, the wt% of the second binder, or combination thereof, may be in the range of about 9 wt% to about 40 wt% of the total solids in the impregnation composition. In one embodiment, the wt% of the second binder, or combination thereof, may be ≥ about 9 wt% of the total solids in the impregnation composition. In another embodiment, the wt% of the second binder, or combination thereof, may be ≥ about 10 wt% of the total solids in the impregnation composition. In another embodiment, the wt% of the second binder, or combination thereof, may be ≥ about 11 wt% of the total solids in the impregnation composition. In another embodiment, the wt% of the second binder, or combination thereof, may be ≥ about 12 wt% of the total solids in the impregnation composition. In another embodiment, the wt% of the second binder, or combination thereof, may be ≥ about 13 wt% of the total solids in the impregnation composition.

In one embodiment, the wt% of the second binder, or combination thereof, may be ≤ about 35 wt% of the total solids in the impregnation composition. In another embodiment, the wt% of the second binder, or combination thereof, may be ≤ about 30 wt% of the total solids in the impregnation composition. In another embodiment, the wt% of the second binder, or combination thereof, may be ≤ about 25 wt% of the total solids in the impregnation composition. In another embodiment, the wt% of the second binder, or combination thereof, be ≤ about 20 wt% of the total solids in the impregnation composition. In another embodiment, the wt% of the second binder, or combination thereof, be ≤ about 15 wt% of the total solids in the impregnation composition.

In one embodiment, the wt% of the second binder, or combination thereof, may be about 14 wt% of the total solids in the impregnation composition.

The impregnation composition comprises a filler. A filler may also be referred to as a mineral pigment. Any suitable filler may be used. When the bonded non-woven fibrous mat is for use in a ceiling tile, it is usually desirable for the filler/mineral pigment to be white. Examples of fillers suitable for making coated mats include, but are not limited to talc, aluminum trihydrate (ATH), vermiculite, antimony oxide, titanium dioxide, aluminium oxide (Al_2O_3), or a combination of any two or more of these substances.

In one embodiment, the filler is aluminum trihydrate (ATH). A bonded non-woven fibrous mat comprising ATH as a filler is beneficial when the mat is used in ceiling tiles. ATH has fire retardant and smoke suppressing properties. It decomposes at about 180 °C, absorbing heat during the decomposition process while releasing water vapour.

When the filler is ATH, the fire retardant and smoke suppressing properties of the bonded non-woven fibrous mat is exhibited substantially or completely throughout the final mat as a result of the composition (comprising ATH) substantially or completely impregnating the precursor mat to form the final bonded non-woven fibrous mat.

The filler (such as ATH) may also be an opacity modifier i.e. the filler may make the bonded non-woven fibrous mat less transparent and more opaque. The bonded non-woven fibrous mat of the present invention may be substantially or completely opaque.

The opacity of the bonded non-woven fibrous mat may be measured in accordance with TAPPI T425. In one embodiment, the bonded non-woven fibrous mat may have an opacity in the range of about 85% to about 99%, as measured in accordance with TAPPI T425. In one embodiment, the bonded non-woven fibrous mat may have an opacity of ≥ about 85%. In another embodiment, the bonded non-woven fibrous mat may have an opacity of ≥ about 86%. In another embodiment, the bonded non-woven fibrous mat may have an opacity of ≥ about 87%. In another embodiment, the bonded non-woven fibrous mat may have an opacity of ≥ about 88%. In another embodiment, the bonded non-woven fibrous mat may have an opacity of ≥ about 89%.

In one embodiment, the bonded non-woven fibrous mat may have an opacity of ≤ about 99%, as measured in accordance with TAPPI T425. In another embodiment, the bonded non-woven fibrous mat may have an opacity of ≤ about 98%. In another embodiment, the bonded non-woven fibrous mat may have an opacity of ≤ about 97%. In another embodiment, the bonded non-woven fibrous mat may have an opacity of ≤ about 96%. In another embodiment, the bonded non-woven fibrous mat may have an opacity of ≤ about 95%. In another embodiment, the bonded non-woven fibrous mat may have an opacity of ≤ about 94%. In another embodiment, the bonded non-woven fibrous mat may have an opacity of ≤ about 93%.

In one embodiment, the bonded non-woven fibrous mat may have an opacity in the range of about 90% to about 92%, as measured in accordance with TAPPI T425.

In one embodiment, the amount of filler in the bonded fibrous non-woven mat may be described as a percent weight of filler based on the weight of the total solids in the impregnation composition. Without wishing to be found by theory, fillers (for example, ATH) can bring opacity and a white appearance to a bonded fibrous non-woven mat.

The bonded non-woven fibrous mat may comprise filler in a range of about 50 wt% to about 95 wt% total solids in the impregnation composition. In one embodiment, the bonded non-woven fibrous mat may comprise filler in an amount of ≥ about 50 wt% total solids in the impregnation composition. In another embodiment, the bonded non-woven fibrous mat may comprise filler in an amount of ≥ about 55 wt% total solids in the impregnation composition. In another embodiment, the bonded non-woven fibrous mat may comprise filler in an amount of ≥ about 60 wt% total solids in the impregnation composition. In another embodiment, the bonded non-woven fibrous mat may comprise filler in an amount of ≥ about 65 wt% total solids in the impregnation composition. In another embodiment, the bonded non-woven fibrous mat may comprise filler in an amount of ≥ about 70 wt% total solids in the impregnation composition. In another embodiment, the bonded non-woven fibrous mat may comprise filler in an amount of ≥ about 75 wt% total solids in the impregnation composition. In another embodiment, the bonded non-woven fibrous mat may comprise filler in an amount of ≥ about 80 wt% total solids in the impregnation composition.

In one embodiment, the bonded non-woven fibrous mat may comprise filler in an amount of ≤ about 95 wt% total solids in the impregnation composition. In another embodiment, the bonded non-woven fibrous mat may comprise filler in an amount of ≤ about 94 wt% total solids in the impregnation composition. In another embodiment, the bonded non-woven fibrous mat may comprise filler in an amount of ≤ about 93 wt% total solids in the impregnation composition. In another embodiment, the bonded non-woven fibrous mat may comprise filler in an amount of ≤ about 92 wt% total solids in the impregnation composition. In another embodiment, the bonded non-woven fibrous mat may comprise filler in an amount of ≤ about 91 wt% total solids in the impregnation composition. In another embodiment, the bonded non-woven fibrous mat may comprise filler in an amount of ≤ about 90 wt% total solids in the impregnation composition. In another embodiment, the bonded non-woven fibrous mat may comprise filler in an amount of ≤ about 89 wt% total solids in the impregnation composition. In another embodiment, the bonded non-woven fibrous mat may comprise filler in an amount of ≤ about 88 wt% total solids in the impregnation composition. In another embodiment, the bonded non-woven fibrous mat may comprise filler in an amount of ≤ about 87 wt% total solids in the impregnation composition. In another embodiment, the bonded non-woven fibrous mat may comprise filler in an amount of ≤ about 86 wt% total solids in the impregnation composition.

In one embodiment, the bonded non-woven fibrous mat may comprise filler in an amount of about 85 wt% total solids in the impregnation composition.

The bonded non-woven fibrous mat does not comprise the filler which is calcium carbonate. Calcium carbonate is also referred to as limestone. Bonded non-woven fibrous mats comprising calcium carbonate are typically used in gypsum boards. The bonded non-woven fibrous mat of the present invention is not suitable for use in gypsum boards as it does not have a suitable air permeability or air flow resistance. In this respect, the bonded non-woven fibrous mat of the present invention is typically less air permeable than bonded non-woven fibrous mats for gypsum boards. In addition, the bonded

non-woven fibrous mat of the present invention typically has a greater air flow resistance than bonded non-woven fibrous mats for gypsum boards.

In certain embodiments, the filler is not clay. As such, if the bonded non-woven fibrous mat contains a filler or mineral pigment, the filler/mineral pigment is not clay. Clay is also referred to as aluminum silicate.

In certain embodiments, the filler is not calcitic marble. As such, if the bonded non-woven fibrous mat contains a filler or mineral pigment, the filler/mineral pigment is not calcitic marble.

In certain embodiment, the bonded non-woven fibrous mat does not comprise an organic phosphonate. Organic phosphonates may be flame retardant materials. Without wishing to be bound by theory, organic phosphonates are liquid and do not produce bonded non-woven fibrous mats which are (a) opaque, and (b) colour stable. This is in contrast to the present invention, in which a flame retardant filler, such as ATH, produces a bonded non-woven fibrous mat which is both opaque and colour stable.

The bonded non-woven fibrous mat may further comprise an additive selected from the group consisting of a biocide, dispersant, defoamer, pigment, viscosity modifier, preservative, pH adjuster, emulsion stabilizer, wetting and levelling agent, cross-linker, and combinations thereof.

The bonded non-woven fibrous mat may optionally include a biocide. The fouling of non-woven mats and facers primarily occurs through accumulated charged particles, biological growth, and fungal growth. Biological or fungal attacks are more typically a problem in pools, showers, and other hot, humid environments, but can also occur in any surface covering or dry wall application. Examples of suitable biocides include but are not limited to diiodomethyl-p-tolylsulfone, glutarealdehyde, isothiazolin, isothiazolin derivatives, zinc oxide, zinc omadine, and silver, such as isothiazolin or derivatives thereof. To prevent discoloration or unwanted microbiological or fungal attack, biocides, such as antimicrobial and/or antifungal agents may be present in bonded non-woven fibrous mat. In these embodiments, the bonded non-woven fibrous mat may include about 0.00001% to about 0.15% biocide based on the weight of the total solids in the bonded fibrous non-woven mat i.e. the total weight of the dried first binder (or combination thereof), dried second binder (or combination thereof), non-woven web of fibers, filler, biocide, and one or more further additives (if present). In certain embodiments, the bonded non-woven fibrous mat may include about 0.0001% to about 0.015% biocide, such as about 0.0005% to about 0.001% biocide, based on the weight of the total solids in the bonded fibrous non-woven mat i.e. the total weight of the dried first binder (or combination thereof), dried second binder (or combination thereof), non-woven web of fibers, filler, biocide, and one or more further additives (if present). In certain embodiments, the bonded non-woven fibrous mat may include about 0.0015% biocide based on the weight of the total solids in the bonded fibrous non-woven mat i.e. the total weight of the dried first binder (or combination thereof), dried second binder (or combination thereof), non-woven web of fibers, filler, biocide, and one or more further additives (if present).

The bonded non-woven fibrous mat may optionally include a dispersant. In these embodiments, the bonded non-woven fibrous mat include about 0.01% to about 0.5%, in other embodiments from about 0.05% to about 0.4%, and in other embodiments from about 0.1% to about 0.3% dispersant based on the weight of the total solids in the bonded fibrous non-woven mat i.e. the total weight of the dried first binder (or combination thereof), dried second binder (or combination thereof), non-woven web of fibers, filler, dispersant, and one or more further additives (if present). Suitable examples of dispersants include but are not limited to olefinic dispersants, and fatty derivatives.

When the bonded non-woven fibrous mat comprises one or more (e.g. 1, 2, 3, 4, 5, or more) mineral fillers, the mat may also comprise one or more (e.g. 1, 2, 3, 4, 5, or more) dispersants. In this instance, the one or more dispersants assist in slurrying the mineral fillers.

The bonded non-woven fibrous mat may optionally include a defoaming agent. In these embodiments, the bonded non-woven fibrous mat may include about 0.01% to about 0.5%, in other embodiments from about 0.05% to about 0.4%, and in other embodiments from about 0.1% to about 0.3% defoaming agent based on the weight of the total solids in the bonded fibrous non-woven mat i.e. the total weight of the dried first binder (or combination thereof), dried second binder (or combination thereof), non-woven web of fibers, filler, defoaming agent, and one or more further additives (if present). Suitable examples of defoaming agents include but are not limited to siloxanes, mineral oil, and polyoxalkylene. The bonded non-woven fibrous mat may comprise about 0.5 wt% of defoaming agent, such as Tego Antifoam 50 (also known as TAF50).

The bonded non-woven fibrous mat may optionally include a pigment. In these embodiments, the bonded non-woven fibrous mat may include about 0.01% to about 3%, in other embodiments from about 0.1% to about 2%, and in other embodiments from about 0.5% to about 1.5% pigment based on the weight of the total solids in the bonded fibrous non-woven mat i.e. the total weight of the dried first binder (or combination thereof), dried second binder (or combination thereof), non-woven web of fibers, filler, pigment, and one or more further additives (if present). Suitable examples of pigments include but are not limited to white, and black pigments.

The bonded non-woven fibrous mat may include a viscosity modifier. In these embodiments, the bonded non-woven fibrous mat may include about 0.01% to about 0.5%, in other embodiments from about 0.05% to about 0.4%, and in other embodiments from about 0.1% to about 0.3% viscosity modifier based on the weight of the total solids in the bonded fibrous non-woven mat i.e. the total weight of the dried first binder (or combination thereof), dried second binder (or combination thereof), non-woven web of fibers, filler, viscosity modifier, and one or more further additives (if present). Suitable examples of viscosity modifiers include but are not limited to polyacrylamide, alkali swellable emulsion (HASE/ASE type), and hydrophobically modified ethoxylated urethane (HEUR). The bonded non-woven fibrous mat may comprise about 0.5 wt% of viscosity modifier, such as BASF Rheovis 1152.

The bonded non-woven fibrous mat may include a pH adjuster. In these embodiments, the bonded non-woven fibrous mat may include about 0.01% to about 0.5%, in other embodiments from about 0.05% to about 0.4%, and in other embodiments from about 0.1% to about 0.3% pH adjuster based on the weight of the total solids in the bonded fibrous non-woven mat i.e. the total weight the dried first binder (or combination thereof), dried second binder (or combination thereof), non-woven web of fibers, filler, pH adjuster, and one or more further additives (if present). The pH adjuster may be selected from one or more (e.g. 1, 2, 3, 4, 5, or more) inorganic bases. Alternatively or in addition, the pH adjuster may be selected from one or more (e.g. 1, 2, 3, 4, 5, or more) organic bases. Suitable examples of pH adjusters include but are not limited to calcium hydroxide, sodium hydroxide, potassium hydroxide, 30% aqua ammonia, 2-amino-2-methyl-1-propanol, citric acid, acetic acid, oxalic acid, and lactic acid.

The bonded non-woven fibrous mat may include an emulsion stabilizer. In these embodiments, the bonded non-woven fibrous mat may include about 0.01% to about 0.5%, in other embodiments from about 0.05% to about 0.4%, and in other embodiments from about 0.1% to about 0.3% emulsion stabilizer based on the weight of the total solids in the bonded fibrous non-woven mat i.e. the total weight of the dried first binder (or combination thereof), dried second binder (or combination thereof), non-woven web of fibers, filler, emulsion stabilizer, and one or more further additives (if present). Suitable examples of emulsion stabilizers include but are not limited to bentonite clay, nonionic octylphenol ethoxylate surfactant, tall oil resin and natural resin extract.

The bonded non-woven fibrous mat may include a wetting and levelling agent. In these embodiments, the bonded non-woven fibrous mat may include about 0.01% to about 0.5%, in other embodiments from about 0.05% to about 0.4%, and in other embodiments from about 0.1% to about 0.3% wetting and levelling agent based on the weight of the total solids in the bonded fibrous non-woven mat i.e. the total weight of the dried first binder (or combination thereof), dried second binder (or combination thereof), non-woven web of fibers, filler, wetting and levelling agent, and one or more further additives (if present). Suitable examples of wetting and levelling agents include but are not limited to sulfosuccinate, polyether modified siloxane, urea modified polyurethane, modified urea ammonium salt of an acrylate copolymer.

The bonded non-woven fibrous mat may include a cross-linker. In these embodiments, the bonded non-woven fibrous mat may include about 0.01% to about 0.5%, in other embodiments from about 0.05% to about 0.4%, and in other embodiments from about 0.1% to about 0.3% cross-linker based on the weight of the total solids in the bonded fibrous non-woven mat i.e. the total weight the dried first binder (or combination thereof), dried second binder (or combination thereof), non-woven web of fibers, filler, cross-linker, and one or more further additives (if present). Suitable examples of cross-linkers include but are not limited to zinc oxide, zinc metal ions, stabilized ammonium zirconium carbonate containing anionic hydroxylated zirconium polymers and epoxy functional silane.

The weight of the dried precursor mat i.e. the dried weight of the glass fibers, the polyester fibers, the first binder, and further additives (if any), may be in the range of about 50 to about 200 gsm (grams per square meter). In one embodiment, the weight of the dried precursor mat may be in the range of about 75 to about 175 gsm. In one embodiment, the weight of the dried precursor mat may be ≥ about 75 gsm. In another embodiment, the weight of the dried precursor mat may be ≥ about 80 gsm. In another embodiment, the weight of the dried precursor mat may be ≥ about 85 gsm. In another embodiment, the weight of the dried precursor mat may be ≥ about 90 gsm. In another embodiment, the weight of the dried precursor mat may be ≥ about 95 gsm.

In one embodiment, the weight of the dried precursor mat may be ≤ about 175 gsm. In another embodiment, the weight of the dried precursor mat may be ≤ about 170 gsm. In another embodiment, the weight of the dried precursor mat may be ≤ about 165 gsm. In another embodiment, the weight of the dried precursor mat may be ≤ about 160 gsm. In another embodiment, the weight of the dried precursor mat may be ≤ about 155 gsm.

In one embodiment, the weight of the dried precursor mat may be in the range of about 100 to about 150 gsm.

The weight of the dried impregnation composition may be in the range of about 50 to about 300 gsm (grams per square meter). In one embodiment, the dried impregnation composition may be in the range of about 100 to about 230 gsm. In one embodiment, the dried impregnation composition may be ≥ about 100 gsm. In another embodiment, the weight of the dried impregnation composition may be ≥ about 110 gsm. In another embodiment, the dried impregnation composition may be ≥ about 120 gsm. In another embodiment, the dried impregnation composition may be ≥ about 130 gsm. In another embodiment, the dried impregnation composition may be ≥ about 140 gsm.

In one embodiment, the weight of the dried impregnation composition may be ≤ about 230 gsm. In another embodiment, the weight of the dried impregnation composition may be ≤ about 220 gsm. In one embodiment, the weight of the dried impregnation composition may be ≤ about 210 gsm. In one embodiment, the weight of the dried impregnation composition may be ≤ about 200 gsm. In one embodiment, the weight of the dried impregnation composition may be ≤ about 190 gsm.

In one embodiment, the weight of the dried impregnation composition may be in the range of about 150 to about 180 gsm. In one embodiment, the weight of the dried impregnation composition may be about 150 gsm. In another embodiment, the weight of the dried impregnation composition may be about 180 gsm.

The total weight of the (dried) bonded non-woven fibrous mat may be in the range of about 150 to about 430 gsm (grams per square meter). In one embodiment, the total weight of the bonded non-woven fibrous mat may be in the range of about 200 to about 380 gsm. In one embodiment, the total weight

of the bonded non-woven fibrous mat may be ≥ about 200 gsm. In another embodiment, the total weight of the bonded non-woven fibrous mat may be ≥ about 210 gsm. In another embodiment, the total weight of the bonded non-woven fibrous mat may be ≥ about 220 gsm. In another embodiment, the total weight of the bonded non-woven fibrous mat may be ≥ about 230 gsm. In another embodiment, the total weight of the bonded non-woven fibrous mat may be ≥ about 240 gsm.

In one embodiment, the total weight of the bonded non-woven fibrous mat may be ≤ about 380 gsm. In another embodiment, the total weight of the bonded non-woven fibrous mat may be ≤ about 370 gsm. In one embodiment, the total weight of the bonded non-woven fibrous mat may be ≤ about 360 gsm. In one embodiment, the total weight of the bonded non-woven fibrous mat may be ≤ about 350 gsm. In one embodiment, the total weight of the bonded non-woven fibrous mat may be ≤ about 340 gsm.

In one embodiment, the total weight of the bonded non-woven fibrous mat may be in the range of about 250 to about 330 gsm. In one embodiment, the total weight of the bonded non-woven fibrous mat may be about 250 gsm. In another embodiment, the total weight of the bonded non-woven fibrous mat may be about 330 gsm.

The thickness (or caliper) of the bonded non-woven fibrous mat may be measured in accordance with ASTM D1777. The thickness of the bonded non-woven fibrous mat may be in the range of about 0.5 mm to about 2 mm, as measured in accordance with ASTM D1777. In one embodiment, the thickness of the bonded non-woven fibrous mat may be ≥ 0.5 mm. In another embodiment, the thickness of the bonded non-woven fibrous mat may be ≥ 0.55 mm. In another embodiment, the thickness of the bonded non-woven fibrous mat may be ≥ 0.6 mm. In another embodiment, the thickness of the bonded non-woven fibrous mat may be ≥ 0.65 mm. In another embodiment, the thickness of the bonded non-woven fibrous mat may be ≥ 0.7 mm. In another embodiment, the thickness of the bonded non-woven fibrous mat may be ≥ 0.75 mm. In another embodiment, the thickness of the bonded non-woven fibrous mat may be ≥ 0.8 mm.

In one embodiment, the thickness of the bonded non-woven fibrous mat may be ≤ 2 mm, measured in accordance with ASTM D1777. In another embodiment, the thickness of the bonded non-woven fibrous mat may be ≤ 1.9 mm. In another embodiment, the thickness of the bonded non-woven fibrous mat may be ≤ 1.8 mm. In another embodiment, the thickness of the bonded non-woven fibrous mat may be ≤ 1.7 mm. In another embodiment, the thickness of the bonded non-woven fibrous mat may be ≤ 1.6 mm. In another embodiment, the thickness of the bonded non-woven fibrous mat may be ≤ 1.5 mm. In another embodiment, the thickness of the bonded non-woven fibrous mat may be ≤ 1.4 mm. In another embodiment, the thickness of the bonded non-woven fibrous mat may be ≤ 1.3 mm. In another embodiment, the thickness of the bonded non-woven fibrous mat may be ≤ 1.2 mm. In another embodiment, the thickness of the bonded non-woven fibrous mat may be ≤ 1.1 mm. In another embodiment, the thickness of the bonded non-woven fibrous mat may be ≤ 1 mm.

In one embodiment, the thickness of the bonded non-woven fibrous mat may be in the range of about 0.85 mm to about 0.9 mm, measured in accordance with ASTM D1777. In another embodiment, thickness of the bonded non-woven fibrous mat may be about 0.85 mm, measured in accordance with ASTM D1777.

The bonded non-woven fibrous mat may have a stiffness as measured in accordance with TAPPI T543. The stiffness may be measured for multiple samples, for example in a Machine Direction, and an average stiffness calculated. The bonded non-woven fibrous mat may have a stiffness in the range of about 7000 mgf to about 30000 mgf (milligram-force), measured in accordance with TAPPI T543. In one embodiment, the bonded non-woven fibrous mat may have a stiffness which is ≥ about 7000 mgf. In another embodiment, the bonded non-woven fibrous mat may have a stiffness which is ≥ about 8000 mgf. In another embodiment, the bonded non-woven fibrous mat may have a stiffness which is ≥ about 9000 mgf. In another embodiment, the bonded non-woven fibrous mat may have a stiffness which is ≥ about 10000 mgf. In another embodiment, the bonded non-woven fibrous mat may have a stiffness which is ≥ about 11000 mgf. In another embodiment, the bonded non-woven fibrous mat may have a stiffness which is ≥ about 12000 mgf. In another embodiment, the bonded non-woven fibrous mat may have a stiffness which is ≥ about 13000 mgf. In another embodiment, the bonded non-woven fibrous mat may have a stiffness which is ≥ about 14000 mgf. In another embodiment, the bonded non-woven fibrous mat may have a stiffness which is ≥ about 15000 mgf. In another embodiment, the bonded non-woven fibrous mat may have a stiffness which is ≥ about 16000 mgf.

In one embodiment, the bonded non-woven fibrous mat may have a stiffness which is ≤ about 30000 mgf, measured in accordance with TAPPI T543. In another embodiment, the bonded non-woven fibrous mat may have a stiffness which is ≤ about 29500 mgf. In another embodiment, the bonded non-woven fibrous mat may have a stiffness which is ≤ about 29000 mgf. In another embodiment, the bonded non-woven fibrous mat may have a stiffness which is ≤ about 28500 mgf. In another embodiment, the bonded non-woven fibrous mat may have a stiffness which is ≤ about 28400 mgf. In another embodiment, the bonded non-woven fibrous mat may have a stiffness which is ≤ about 28300 mgf. In another embodiment, the bonded non-woven fibrous mat may have a stiffness which is ≤ about 28200 mgf. In another embodiment, the bonded non-woven fibrous mat may have a stiffness which is ≤ about 28100 mgf. In another embodiment, the bonded non-woven fibrous mat may have a stiffness which is ≤ about 28000 mgf. In another embodiment, the bonded non-woven fibrous mat may have a stiffness which is ≤ about 27900 mgf.

In one embodiment, the bonded non-woven fibrous mat may have a stiffness in the range of about 7000 mgf to about 17000 mgf, such as about about 8000 mgf to about 12000 mgf, as measured in accordance with TAPPI T543.

In one embodiment, the bonded non-woven fibrous mat may have a stiffness in the range of about 17000 mgf to about 27800 mgf, measured in accordance with TAPPI T543.

The bonded non-woven fibrous mat may have an air permeability as measured in accordance with ASTM D737. The bonded non-woven fibrous mat may have an air permeability in the range of about 50 cfm to about 325 cfm (cubic feet per minute), measured in accordance with ASTM D737. In one embodiment, the bonded non-woven fibrous mat may have an air permeability ≥ about 50 cfm. In another embodiment, the bonded non-woven fibrous mat may have an air permeability ≥ about 55 cfm. In another embodiment, the bonded non-woven fibrous mat may have an air permeability ≥ about 60 cfm. In another embodiment, the bonded non-woven fibrous mat may have an air permeability ≥ about 65 cfm. In another embodiment, the bonded non-woven fibrous mat may have an air permeability ≥ about 70 cfm. In another embodiment, the bonded non-woven fibrous mat may have an air permeability ≥ about 75 cfm.

In one embodiment, the bonded non-woven fibrous mat may have an air permeability ≤ about 325 cfm, measured in accordance with ASTM D737. In another embodiment, the bonded non-woven fibrous mat may have an air permeability ≤ about 315 cfm. In another embodiment, the bonded non-woven fibrous mat may have an air permeability ≤ about 305 cfm. In another embodiment, the bonded non-woven fibrous mat may have an air permeability ≤ about 295 cfm. In another embodiment, the bonded non-woven fibrous mat may have an air permeability ≤ about 285 cfm. In another embodiment, the bonded non-woven fibrous mat may have an air permeability ≤ about 275 cfm.

In one embodiment, the bonded non-woven fibrous mat may have an air permeability in the range of about 75 cfm to about 275 cfm, measured in accordance with ASTM D737. In another embodiment, the bonded non-woven fibrous mat may have an air permeability in the range of about 100 cfm to about 250 cfm, measured in accordance with ASTM D737. In another embodiment, the bonded non-woven fibrous mat may have an air permeability in the range of about 110 cfm to about 200 cfm, measured in accordance with ASTM D737.

Methods for Manufacturing the Bonded Non-Woven Fibrous Mat

Preparing the Precursor Mat by Co-Casting the Fibers and First Binder Before Impregnating the Precursor Mat

In another aspect, the present invention provides a method for manufacturing a bonded non-woven fibrous mat comprising the steps of:

(i) providing an aqueous mixture comprising glass fibers, polyester fibers, and a first binder;
(ii) forming a dispersion of the aqueous mixture;
(iii) depositing the aqueous dispersion to form a wetlaid web of glass fibers, polyester fibers, and first binder;
(iv) drying the wetlaid web of glass fibers, polyester fibers, and first binder to form the precursor mat;

(v) substantially or completely impregnating the precursor mat with a composition comprising a second binder, and a filler; and

(v) drying the impregnated precursor mat to form the bonded non-woven fibrous mat;

wherein:

the first binder is selected from the group consisting of a polycarboxylic acid binder, a polyvinyl alcohol binder, or a combination thereof;

the second binder is a polycarboxylic acid binder which is prepared from an unsaturated carboxylic acid compound and an aryl vinyl compound; and

the first binder, and second binder are water-soluble or water-dispersible binders;

provided the bonded non-woven fibrous mat does not comprise the filler which is calcium carbonate.

The steps for forming the precursor mat may also be referred to as a “co-casting” method. This is because an aqueous mixture of glass fibers and polyester fibers is formed together with the first binder.

The glass fibers, the polyester fibers, the first binder (or combination thereof), the second binder (or combination), the filler, the precursor mat, the impregnation composition, the extent to which the precursor may is impregnated, and the bonded non-woven fibrous mat are as described above.

The flexible precursor mat may be formed by a wet-laid process. In certain exemplary embodiments, the non-woven mat is formed by a wet-laid process, which involves forming an aqueous dispersion, slurry, or mixture of discrete fibers in a mix tank filled with various optional components (sometimes referred to as white water). The aqueous mixture therefore comprises the glass fibers, the polyester fibers, the first binder (or combination thereof) and water, and optionally other components such as surfactants, viscosity modifiers, defoaming agents, lubricants, biocides, and/or other chemical agents.

The dispersion of the aqueous mixture may be obtained by any suitable means provided a uniform or substantially uniform distribution of the two groups of fibers in the aqueous medium is produced. In one embodiment, a uniform distribution of the two groups of fibers is produced. In another embodiment, a substantially uniform distribution of the two groups of fibers is produced. The dispersion may be obtained by a high shear mixing apparatus, such as a rotor/stator mixer.

In certain embodiments, aqueous mixtures of the glass and polyester fibers are individually prepared, and are then combined with agitation (e.g. high intensity mixing) to provide a uniform or nearly uniform dispersion of fibers.

In other embodiments, the glass and polyester fibers are combined to form a mixture of fibers. The mixture is then formed into an aqueous mixture with agitation (e.g. high intensity mixing) to provide a uniform or substantially uniform dispersion of fibers.

The first binder (or combination thereof) may optionally contain conventional additives as described above for the improvement of process and product performance such as dyes, oils, biocides, fillers, colorants, UV stabilizers, coupling agents (e.g., aminosilanes), lubricants, wetting agents, surfactants, and/or antistatic agents.

The water-soluble or water-dispersible first binder (or combination thereof) may be added at any suitable point in the preparation of the aqueous mixture. For example, the binder (or combination thereof) may be added before, after, or at the same time as the glass and/or polyester fibers.

The first binder (e.g. the polyvinyl alcohol binder) may be a liquid or solid. In certain embodiments, the polyvinyl alcohol binder is a powder, such that it may facilitate co-casting with the blend of glass and polyester fibers in the aqueous solution.

The aqueous fiber dispersion or slurry may then be processed into a wet-laid mat according to any number of conventional methods known in the art. For example, the aqueous fiber dispersion or slurry is deposited onto a moving screen or conveyor, on which the majority of the water drains through, leaving a randomly oriented fiber web. The water may be removed from the web by a conventional vacuum or air suction system.

Once the binder has been applied to the wetlaid web of glass fibers, polyester fibers, and first binder, the wetlaid web is passed through at least one drying oven to remove remaining water and cure the binder composition. The fiber web may be further dried by a vacuum slot or other drying means to provide a fiber web.

The formed precursor mat that emerges from the oven is an assembly of randomly oriented, dispersed, individual glass and polyester fibers. The fiber mat may be rolled onto a take-up roll for storage or later use.

The precursor mat is substantially or completely impregnated with a composition comprising a second binder, and a filler.

The impregnation composition is prepared by any suitable method, such as mixing the filler with the second binder, or vice versa.

The second binder (or combination thereof) may optionally contain conventional additives as described above for the improvement of process and product performance such as dyes, oils, biocides, fillers, colorants, UV stabilizers, coupling agents (e.g., aminosilanes), lubricants, wetting agents, surfactants, and/or antistatic agents.

If desired, the composition may comprise additional water. Additional water may be required, for example, to reduce the viscosity of the composition to aid the impregnation of the precursor mat.

The precursor mat is substantially or completely impregnated with the composition by any suitable method, such as press rolls, dip bath, or curtain coating.

The impregnated precursor mat is then dried to form the bonded non-woven fibrous mat. Typically the impregnated precursor mat may be passed through at least one drying oven to remove any remaining water and to cure the binder. The mat may be further dried by a vacuum slot or other drying means to provide the bonded non-woven fibrous mat as described above.

Preparing the Precursor Mat by a Wetlaid Method Before Impregnating the Precursor Mat

In another aspect, the present invention provides a method for manufacturing a bonded non-woven fibrous mat comprising the steps of:

(i) providing an aqueous mixture comprising glass fibers, and polyester fibers;

(ii) depositing the aqueous mixture to form a wetlaid web of glass fibers, and polyester fibers;

(iii) applying an aqueous solution or dispersion of a first binder to the wetlaid web of glass fibers, and polyester fibers to form a wetlaid web of glass fibers, polyester fibers, and first binder;

(iv) drying the wetlaid web of glass fibers, polyester fibers, and first binder to form the precursor mat;

(v) substantially or completely impregnating the precursor mat with a composition comprising a second binder, and a filler; and

(v) drying the impregnated precursor mat to form the bonded non-woven fibrous mat;

wherein:

the first binder is selected from the group consisting of a polycarboxylic acid binder, a polyvinyl alcohol binder, or a combination thereof;

the second binder is a polycarboxylic acid binder which is prepared from an unsaturated carboxylic acid compound and an aryl vinyl compound; and

the first binder, and second binder are water-soluble or water-dispersible binders;

provided the bonded non-woven fibrous mat does not comprise the filler which is calcium carbonate.

The glass fibers, the polyester fibers, the first binder (or combination thereof), the second binder (or combination), the filler, the precursor mat, the impregnation composition, the extent to which the precursor may is impregnated, and the bonded non-woven fibrous mat are as described above.

The flexible precursor mat may be formed by a wet-laid process. In certain exemplary embodiments, the non-woven mat is formed by a wet-laid process, which involves forming an aqueous dispersion, slurry, or mixture of discrete fibers in a mix tank filled with various optional components (sometimes referred to as white water). The aqueous mixture therefore comprises the glass fibers, the polyester

fibers, and water, and optionally other components such as surfactants, viscosity modifiers, defoaming agents, lubricants, biocides, and/or other chemical agents.

The dispersion of the aqueous mixture may be obtained by any suitable means provided a uniform or substantially uniform distribution of the two groups of fibers in the aqueous medium is produced. In one embodiment, a uniform distribution of the two groups of fibers is produced. In another embodiment, a substantially uniform distribution of the two groups of fibers is produced. The dispersion may be obtained by a high shear mixing apparatus, such as a rotor/stator mixer.

In certain embodiments, aqueous mixtures of the glass and polyester fibers are individually prepared, and are then combined with agitation (e.g. high intensity mixing) to provide a uniform or nearly uniform dispersion of fibers.

In other embodiments, the glass and polyester fibers are combined to form a mixture of fibers. The mixture is then formed into an aqueous mixture with agitation (e.g. high intensity mixing) to provide a uniform or substantially uniform dispersion of fibers.

The aqueous fiber dispersion or slurry may then be processed into a wet-laid mat according to any number of conventional methods known in the art. For example, the aqueous fiber dispersion or slurry is deposited onto a moving screen or conveyor, on which the majority of the water drains through, leaving a randomly oriented fiber web. The water may be removed from the web by a conventional vacuum or air suction system.

The first binder is then applied to the web of glass fibers and polyester fibers by a suitable binder applicator, such as a spray applicator or a curtain coater.

The first binder (or combination thereof) may optionally contain conventional additives as described above for the improvement of process and product performance such as dyes, oils, biocides, fillers, colorants, UV stabilizers, coupling agents (e.g., aminosilanes), lubricants, wetting agents, surfactants, and/or antistatic agents.

The first binder may be in any suitable form, such as a liquid or a solid (such as a powder), provided it is capable of being dissolved or suitably dispersed in water.

Once the binder has been applied to the wetlaid web of glass fibers, polyester fibers, and first binder, the wetlaid web is passed through at least one drying oven to remove remaining water and cure the binder composition. The fiber web may be further dried by a vacuum slot or other drying means to form the precursor mat.

The formed precursor mat that emerges from the oven is an assembly of randomly oriented, dispersed, individual glass and polyester fibers. The fiber mat may be rolled onto a take-up roll for storage or later use.

The precursor mat is substantially or completely impregnated with a composition comprising a second binder, and a filler.

The impregnation composition is prepared by any suitable method, such as mixing the filler with the second binder, or vice versa.

The second binder (or combination thereof) may optionally contain conventional additives as described above for the improvement of process and product performance such as dyes, oils, biocides, fillers, colorants, UV stabilizers, coupling agents (e.g., aminosilanes), lubricants, wetting agents, surfactants, and/or antistatic agents.

If desired, the composition may comprise additional water. Additional water may be required, for example, to reduce the viscosity of the composition to aid the impregnation of the precursor mat.

The precursor mat is substantially or completely impregnated with the composition by any suitable method, such as press rolls, dip bath, or curtain coating.

The impregnated precursor mat is then dried to form the bonded non-woven fibrous mat. Typically the impregnated precursor mat may be passed through at least one drying oven to remove any remaining water and to cure the binder. The mat may be further dried by a vacuum slot or other drying means to provide the bonded non-woven fibrous mat as described above.

Painting the Bonded Non-Woven Fibrous Mat

The bonded non-woven mat of the present invention is opaque and colour stable. As such, it does not need to be painted. If desired, however, the method for manufacturing the bonded non-woven fibrous mat may further comprise applying a liquid paint formulation to a first surface, a second surface, or both the first and second surfaces of the bonded non-woven fibrous mat to coat or impregnate the first surface, the second surface, or both the first and second surfaces of the bonded non-woven fibrous mat; and

drying the wet coated or impregnated non-woven fibrous mat to form a bonded non-woven fibrous mat comprising a dried layer of paint.

In one embodiment, a liquid paint formulation may be applied to the first surface of the bonded non-woven fibrous mat to coat or impregnate the first surface of the bonded non-woven fibrous mat. In another embodiment, a liquid paint formulation may be applied to the second surface of the bonded non-woven fibrous mat to coat or impregnate the second surface of the bonded non-woven fibrous mat.

In another embodiment, a liquid paint formulation may be applied to both the first and second surfaces of the bonded non-woven fibrous mat to coat or impregnate both the first and second surfaces of the bonded non-woven fibrous mat.

Methods for drying the wet coated or impregnated non-woven fibrous mat to form a bonded non-woven fibrous mat comprising a dried layer of paint are known to the skilled person. Methods include but are not limited to drying under ambient temperature and pressure, drying under hot air, and drying using infra-red technology.

In another aspect, the present invention provides coated bonded non-woven fibrous mat comprising:
a bonded non-woven fibrous mat as described above, and
the first surface, the second surface, or both the first and second surfaces comprise a coat of paint.

The glass fibers, the polyester fibers, the first binder (or combination thereof), the second binder (or combination), the filler, the precursor mat, the impregnation composition, the extent to which the precursor may is impregnated, and the bonded non-woven fibrous mat are as described above.

In one embodiment, the first surface may comprise a coat of paint. In another embodiment, the second surface may comprise a coat of paint. In another embodiment, both the first and second surfaces may comprise a coat of paint.

Uses for the Bonded Non-Woven Fibrous Mat

When bonded non-woven fibrous mats are produced using wet-laid procedures and the aqueous fiber dispersion or slurry is deposited onto a moving screen or conveyor, the resulting bonded non-woven fibrous mats typically have a smooth surface (the surface in contact with the moving screen or conveyor) and a non-smooth surface (the surface not in contact with the moving screen or conveyor). The smooth surface is typically the presentation surface. For example, when the bonded non-woven fibrous mat is attached to a construction board, the smooth surface is faces into the room and the non-smooth surface attaches to the board.

In another aspect, the present invention provides a construction board comprising:
a first surface and a second surface opposite the first surface,
a bonded non-woven fibrous mat adhered to the first surface, the second surface or both the first and second surfaces, and
wherein the bonded non-woven fibrous mat is as described above;
provided the construction board is not a gypsum board.

The glass fibers, the polyester fibers, the first binder (or combination thereof), the second binder (or combination), the filler, the precursor mat, the impregnation composition, the extent to which the precursor may is impregnated, and the bonded non-woven fibrous mat are as described above.

The bonded non-woven fibrous mat may be a facer in the construction board i.e. the facer is adhered to a first surface, a second surface or both first and second surfaces to form a construction board.

The construction board may further comprise a layer of paint as the outermost layer of the first surface, the second surface or both the first and second surfaces of the construction board. In one embodiment, the construction board may comprise a layer of paint as the outermost layer of the first surface of the construction board. In another embodiment, the construction board may comprise a layer of paint as the outermost layer of the second surface of the construction board. In another embodiment, the construction board may comprise a layer of paint as the outermost layers of both the first and second surfaces of the construction board. In these instances, the paint may be coated over the bonded non-woven fibrous mat, or impregnates the bonded non-woven fibrous mat.

The construction board is selected from the group consisting of a ceiling tile, building panel, isolation panel, and floorboard.

In one embodiment, the construction board is a ceiling tile. In this respect, the bonded non-woven fibrous mat provides a ceiling tile which is strong (due to the stiffness of the mat), flexible (due to the ability of the mat to be folded or pleated), and which has good acoustic absorption properties (due to the reduced air permeability and increased air flow resistance of the mat). In addition, when the filler is ATH, the ceiling tile is also has flame retardant and smoke suppressant properties.

The bonded non-woven fibrous mat of the present invention may be used as a fluid filter because the bonded non-woven fibrous mat has the characteristics as described above i.e. the mat is stiff but is capable of being repeatedly folded or pleated without cracking. Without wishing to be bound by theory, a fluid filter may need to be corrugated before use and, as such, folding resistance can play an important role in the performance properties of the filter.

In another aspect, therefore, the present invention provides a fluid filter comprising the bonded non-woven fibrous mat as described herein.

In another aspect, the present invention provides the use of the fluid filter as described above in air or liquid filtration. When the fluid filter is used in air filtration, dry air, humid air and/or compressed air may be filtered.

When the fluid filter is used in liquid filtration, any suitable liquid may be filtered provided the liquid does not adversely affect the filter itself. The liquid may include water and/or oil.

In another aspect, the present invention provides a filtration process comprising the step of passing a fluid through a fluid filter, wherein the fluid filter comprises the bonded non-woven fibrous mat as

described herein. The fluid may comprise air, such as dry air, humid air, and/or compressed air. The fluid may comprise a liquid, such as water and/or oil.

Embodiments and/or optional features of the invention have been described above. Any aspect of the invention may be combined with any other aspect of the invention, unless the context demands otherwise. Any of the embodiments or optional features of any aspect may be combined, singly or in combination, with any aspect of the invention, unless the context demands otherwise.

The invention will now be described further by reference to the following examples, which are intended to illustrate but not limit, the scope of the invention.

Examples

Example 1 (according to the invention)

A non-woven fibrous mat of the present invention is prepared in the following manner.

A dispersion of an aqueous mixture comprising a blend of wet use chopped glass fibers, polyester fibers, and polyvinyl alcohol (PVOH) powder binder is formed. The dispersion is deposited to form a wetlaid web of fibers and binder. The wetlaid web of fibers and binder is dried using an oven to form a precursor mat.

The dried precursor mat is then impregnated with a composition comprising styrene acrylic latex and aluminum trihydrate. The composition impregnates or substantially impregnates the entire mat. The mat is dried using an oven to form the Non-Woven Fibrous Mat 1 of the present invention. The mat was dried to remove sufficient water such that the mat exhibited the desired stiffness (measured using TAPPI T543) and crack under bend performance.

The composition of the non-woven fibrous mat is:

	Non-Woven Fibrous Mat 1
Precursor mat composition	
Fiber Weight	85 gsm*
Fiber Type	75% glass, 25% polyester**
Dimensions of the glass fibers	Mean Diameter = approx. 10 μm; Mean Length = approx. 10 mm
Dimensions of the polyester fibers	Mean Diameter = approx. 6 μm; Mean Length = approx. 6-7 mm
Amount of precursor binder in the precursor mat	15 wt% (15 gsm)
Precursor binder	PVOH (M_W = 2000 g/mole; ≥ 98-99% hydrolysed)

Impregnation composition

Added Weight	150 gsm
Amount of impregnation binder in impregnation composition	14 wt %
Impregnation binder	Styrene Acrylic Latex
Filler Amount	85 wt%
Filler Type	Aluminum Trihydrate
Tego Antifoam 50 (also known as TAF50) and BASF Rheovis 1152 viscosity modifier	1 wt% in total of both additives
Total Product Weight of Mat 1	250 gsm
Thickness of Mat 1 (mm) measured using ASTM D1777	0.85-0.9
Opacity of Mat 1 (%) measured using TAPPI T425	91-92

* gsm = grams per square meter

** The polyester fibers do not contain recycled material.

The glass fibers are Advantex™ glass fibers. Advantex™ glass fibers are commercially available from Owens Corning. Advantex™ is a boron-free ECR glass, which has the following composition:

Oxide	Wt%
SiO_2	54-62
Al_2O_3	9-15
B_2O_3	0
CaO	17-25
MgO	0-4
ZnO	2-5
BaO	0
Li_2O	0
Na_2O+K_2O	0-2
TiO_2	0-4
ZrO_2	0
Fe_2O_3	0-0.8
F_2	0

While various components in the glass may be expressed as a range, the total wt% of the components in the glass composition adds up to 100 wt%.

The polyester fibers are commercially available short cut fibers from Barnet.

The crack under bend performance of the Non-Woven Fibrous Mat 1 is evaluated by repetitively folding two samples of Mat 1 twenty times each. Figure 1 shows a photograph of each sample after being repetitively folded. No cracking is observed in either sample.

The stiffness of the Non-Woven Fibrous Mat 1 is measured in accordance with TAPPI T543 with 6 samples per manufacturing roll to produce a Machine Direction average stiffness of 9550 mgf, 10383 mgf, and 10917 mgf for three different rolls. All 18 samples produce a Machine Direction average stiffness of 10283 mgf.

Example 2 (according to the invention)

A non-woven fibrous mat of the present invention is prepared in the following manner.

An aqueous mixture comprising chopped glass fibers, and polyester fibers is formed. The aqueous mixture is deposited to form a wetlaid web of glass, fibers, and polyester fibers. The polycarboxylic acid binder set out in the table below was applied to the wetlaid web. The wetlaid web of fibers and binder is dried using an oven to form a precursor mat.

The dried precursor mat is then impregnated with a composition comprising styrene acrylic latex and aluminum trihydrate. The composition impregnates or substantially impregnates the entire mat. The mat is dried using an oven to form the Non-Woven Fibrous Mat 2 of the present invention. The mat was dried to remove sufficient water such that the mat exhibited the desired stiffness (measured using TAPPI T543) and crack under bend performance.

The composition of the non-woven fibrous mat is:

	Non-Woven Fibrous Mat 2
Precursor mat composition	
Fiber Weight	127.5 gsm*
Fiber Type	75% glass, 25% polymer**
Dimensions of the glass fibers	Mean Diameter = approx. 10 µm; Mean Length = approx. 10 mm
Dimensions of the polyester fibers	Mean Diameter = approx. 6 µm; Mean Length = approx. 6-7 mm
Amount of precursor binder in the precursor mat	15 wt% (22.5 gsm)
Precursor binder	Polycarboxylic acid binder‡

Impregnation composition	
Added Weight	180 gsm
Amount of impregnation binder in impregnation composition	14 wt %

Impregnation binder	Styrene Acrylic Latex
Filler Amount	85 wt%
Filler Type	Aluminum Trihydrate
Tego Antifoam 50 (also known as TAF50) and BASF Rheovis 1152 viscosity modifier	1 wt% in total of both additives
Total Product Weight of Mat 2	330 gsm
Thickness of Mat 2 (mm) measured using ASTM D1777	0.85
Opacity of Mat 2 (%) measured using TAPPI T425	90-91

* gsm = grams per square meter

** The polyester fibers do not contain recycled material.

‡ The polycarboxylic acid is a mixture of (a) polyacrylic acid and glycerol, and (b) polymethyl methacrylate latex. The wt% ratio of polyacrylic acid : glycerol is about 75% to about 25% dry weight. The ratio of (a) : (b) is about 75% to about 25% dry weight. The final ratio of polyacrylic acid : glycerol : polymethyl methacrylate overall is about 56% : about 19% : about 25% dry weight (i.e. about 1 : about 0.3 : about 0.4 wt%)

The glass fibers are Advantex™ glass fibers. Advantex™ glass fibers are commercially available from Owens Corning. Advantex™ is a boron-free ECR glass, the composition of which is as set out in Example 1.

The polyester fibers are commercially available short cut fibers from Barnet.

The crack under bend performance of the Non-Woven Fibrous Mat 2 is evaluated by repetitively folding a sample of Mat 2 twenty times. No cracking is observed in the sample.

The stiffness of the Non-Woven Fibrous Mat 2 is measured in accordance with TAPPI T543 with 10 samples to produce a Machine Direction average stiffness of 10560 mgf.

Example 3 (comparative)

A non-woven fibrous mat is prepared generally as set out in Example 2, except that the non-woven fibrous mat comprises 100 wt% glass fibers. The glass fibers are Advantex™ fibers as described above in Example 2 with respect to both composition and dimensions.

The crack under bend performance of the mat is evaluated by repetitively folding a sample of the mat. The sample is brittle and cracked after 1-2 folds.

The inventor envisages that a sample of a non-woven mat comprising 100 wt% polymer fibers does not have sufficient stiffness for use in a ceiling tile application.

Claims

1. A bonded non-woven fibrous mat, the bonded non-woven fibrous mat comprising:

(a) a precursor mat comprising:

- a non-woven web of fibers comprising a blend of glass fibers and polyester fibers, and
- a first binder;

and

(b) a composition which substantially or completely impregnates the precursor mat, the composition comprising:

- a second binder, and
- a filler;

wherein:

the first binder is selected from the group consisting of a polycarboxylic acid binder, a polyvinyl alcohol binder, or a combination thereof; and

the second binder is a polycarboxylic acid binder which is prepared from an unsaturated carboxylic acid compound and an aryl vinyl compound;

provided the bonded non-woven fibrous mat does not comprise a filler which is calcium carbonate.

2. A bonded non-woven fibrous mat according to claim 1, wherein the glass fibers have a mean fiber diameter in the range of ≥ about 6.5 μm and ≤ about 15 μm, optionally about 10 μm; and/or a mean fiber length in the range of ≥ about 5 mm and ≤ about 15 mm, optionally about 10 mm.

3. A bonded non-woven fibrous mat according to claim 1 or claim 2, wherein the polyester fibers are aliphatic-aryl polyester fibers, optionally poly(ethylene terephthalate) fibers, poly(butylene terephthalate) fibers, poly(hexamethylene terephthalate) fibers, poly(propylene terephthalate) fibers, or a combination thereof.

4. A bonded non-woven fibrous mat according to any one of the preceding claims, wherein the polyester fibers have a mean fiber diameter in the range of ≥ about 1 μm and ≤ about 15 μm, optionally about 6-7 μm; and/or a mean fiber length in the range of ≥ about 1 mm and ≤ about 15 mm, optionally about 6 mm.

5. A bonded non-woven fibrous mat according to any one of the preceding claims, wherein the ratio of glass fibers : polyester fibers may be in the range of about 50 : about 50 wt% to about 90 : 10 wt%, optionally about 75 : about 25 wt%.

6. A bonded non-woven fibrous mat according to any one of the preceding claims, wherein the first binder is:

(a) a combination of polyacrylic acid, polymethyl methacylate, and glycerol; or

(b) a polyvinyl alcohol binder.

7. A bonded non-woven fibrous mat according to any one of the preceding claims, wherein the second binder is styrene acrylic latex.

8. A bonded non-woven fibrous mat according to any one of the preceding claims, wherein the filler is selected from the group consisting of talc, aluminum trihydrate, vermiculite, antimony oxide, titanium dioxide, aluminium oxide, or a combination thereof, optionally aluminum trihydrate.

9. A bonded non-woven fibrous mat according to any one of the preceding claims, wherein the bonded non-woven fibrous has an opacity in the range of about 85% to about 99% as measured in accordance with TAPPI T425.

10. A bonded non-woven fibrous mat according to any one of the preceding claims, wherein the thickness of the bonded non-woven fibrous is in the range of about 0.5 mm to about 2 mm as measured in accordance with ASTM D1777, optionally in the range of about 0.85 mm to about 0.9 mm, optionally about 0.85 mm.

11. A bonded non-woven fibrous mat according to any one of the preceding claims, wherein the bonded non-woven fibrous mat has a stiffness in the range of about 7000 mgf to about 30000 mgf as measured in accordance with TAPPI T543, optionally in the range of about 17000 mgf to about 27800 mgf.

12. A bonded non-woven fibrous mat according to any one of the preceding claims, wherein the bonded non-woven fibrous mat has an air permeability in the range of about 50 cfm to about 325 cfm as measured in accordance with ASTM D737, optionally in the range of about 75 cfm to about 275 cfm, optionally in the range of about 100 cfm to about 250 cfm, optionally in the range of about 110 cfm to about 200 cfm.

13. A method for manufacturing a bonded non-woven fibrous mat comprising the steps of:

(i) providing an aqueous mixture comprising glass fibers, polyester fibers, and a first binder;

(ii) forming a dispersion of the aqueous mixture;

(iii) depositing the aqueous dispersion to form a wetlaid web of glass fibers, polyester fibers, and first binder;

(iv) drying the wetlaid web of glass fibers, polyester fibers, and first binder to form the precursor mat;

(v) substantially or completely impregnating the precursor mat with a composition comprising a second binder, and a filler; and

(v) drying the impregnated precursor mat to form the bonded non-woven fibrous mat;

wherein:

the first binder is selected from the group consisting of a polycarboxylic acid binder, a polyvinylalcohol binder, or a combination thereof;

the second binder is a polycarboxylic acid binder which is prepared from an unsaturated carboxylic acid compound and an aryl vinyl compound; and

the first binder, and second binder are water-soluble or water-dispersible binders;

provided the bonded non-woven fibrous mat does not comprise a filler which is calcium carbonate.

14. A method for manufacturing a bonded non-woven fibrous mat comprising the steps of:

(i) providing an aqueous mixture comprising glass fibers, and polyester fibers;

(ii) depositing the aqueous mixture to form a wetlaid web of glass fibers, and polyester fibers;

(iii) applying an aqueous solution or dispersion of a first binder to the wetlaid web of glass fibers, and polyester fibers to form a wetlaid web of glass fibers, polyester fibers, and first binder;

(iv) drying the wetlaid web of glass fibers, polyester fibers, and first binder to form the precursor mat;

(v) substantially or completely impregnating the precursor mat with a composition comprising a second binder, and a filler; and

(v) drying the impregnated precursor mat to form the bonded non-woven fibrous mat;

wherein:

the first binder is selected from the group consisting of a polycarboxylic acid binder, a polyvinyl alcohol binder, or a combination thereof;

the second binder is a polycarboxylic acid binder which is prepared from an unsaturated carboxylic acid compound and an aryl vinyl compound; and

the first binder, and second binder are water-soluble or water-dispersible binders;

provided the bonded non-woven fibrous mat does not comprise the filler which is calcium carbonate.

15. A construction board comprising:

a first surface and a second surface opposite the first surface,

a bonded non-woven fibrous mat adhered to the first surface, the second surface or both the first and second surfaces, and

wherein the bonded non-woven fibrous mat is according to any one of claims 1 to 12;

provided the construction board is not a gypsum board;

optionally, wherein the construction board is selected from the group consisting of a ceiling tile, building panel, isolation panel, and floorboard, optionally a ceiling tile.

16. A fluid filter comprising a bonded non-woven fibrous mat, wherein the bonded non-woven fibrous mat is according to any one of claims 1 to 12.

17. A use of a fluid filter in air filtration, wherein the fluid filter is according to claim 16.

18. A use of a fluid filter according to claim 17, wherein dry air, humid air and/or compressed air is filtered.

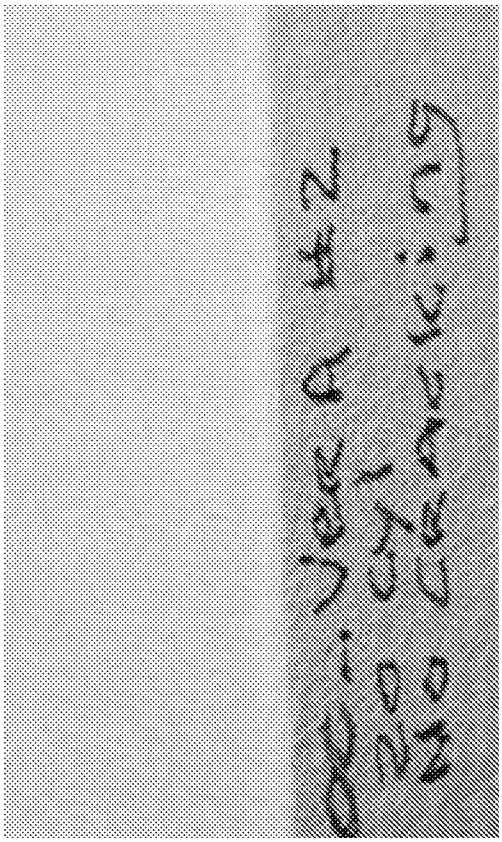
19. A use of a fluid filter in liquid filtration, wherein the fluid filter is according to claim 16.

20. A use of a fluid filter according to claim 19, wherein water and/or oil is filtered.

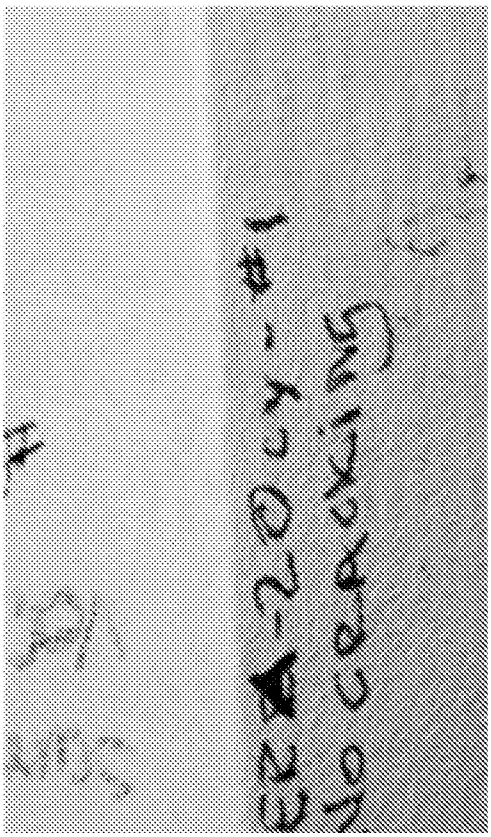
21. A filtration process comprising the step of passing a fluid through a fluid filter, wherein the fluid filter comprises the bonded non-woven fibrous mat according to any one of claims 1 to 12.

22. A filtration process according to claim 21, wherein the fluid comprises air, such as dry air, humid air, and/or compressed air.

23. A filtration process according to claim 21, wherein the fluid comprises a liquid, such as water and/or oil.



Mat 1 – Sample 2



Mat 1 - Sample 1

FIGURE 1

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2024/037503

A. CLASSIFICATION OF SUBJECT MATTER

INV. D04H1/4218 D04H1/435 D04H1/587 D04H1/64 D04H1/732
B01D39/16 E04B9/04 E04C2/26
ADD.

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)
D04H E04C E04B B01D

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 practicable, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 8 758 563 B2 (JAFFEE ALAN MICHAEL [US]; KAJANDER RICHARD EMIL [US] ET AL.) 24 June 2014 (2014-06-24) cited in the application examples	1-15
A	WO 2020/252220 A1 (OCV INTELLECTUAL CAPITAL LLC [US]) 17 December 2020 (2020-12-17) example 3	1-15
A	WO 2019/221863 A1 (OCV INTELLECTUAL CAPITAL LLC [US]) 21 November 2019 (2019-11-21) example 1	1-15

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[x] Further documents are listed in the continuation of Box C.

[x] 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 application or patent 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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 September 2024	17/10/2024

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Saunders, Thomas

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Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2024/037503

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2016/055128 A1 (SINIAT INTERNAT [FR]; AHLSTROEM OY [FI]) 14 April 2016 (2016-04-14) examples B3, B4; table 3	1-15
A	EP 1 319 746 A1 (OWENS CORNING VEIL NETHERLANDS [NL]) 18 June 2003 (2003-06-18) examples	1-15
A	US 2022/193589 A1 (CHENG XINQUAN [US] ET AL) 23 June 2022 (2022-06-23) example 1	1-14, 16-23

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2024/037503

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 8758563 B2	24-06-2014	EP 1541763 A2	15-06-2005
		PL 1541763 T3	30-09-2015
		US 2005112978 A1	26-05-2005
		US 2012321807 A1	20-12-2012
WO 2020252220 A1	17-12-2020	CA 3143263 A1	17-12-2020
		CN 114096498 A	25-02-2022
		EP 3983591 A1	20-04-2022
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