Title: FIRE RESISTANT COMPOSITE MAT

Abstract: Disclosed herein are flame resistant composite mats. The composite mat contains a fiber, fire resistant additive, and a binder. The mats are useful in the production of flame resistant sandwich constructions.
FIRE RESISTANT COMPOSITE MAT

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims benefit of U.S. Provisional Application No. 62/255,003, filed November 13, 2015, incorporated herein by reference in its entirety.

FIELD OF THE DISCLOSURE

This disclosure relates to fire resistant composite mats, and more particularly to composite mats that include a binder and fire resistant additive, and to methods of making and using the composite mat.

BACKGROUND OF THE DISCLOSURE

Prefabricated sandwich constructions are employed in a variety of different settings, including walls and panels for mobile homes, vehicles and various freestanding structures. These sandwich constructions often contain fiberglass reinforced plastics and/or plywood for rigidity. These walls are heavy, prone to water damage, and can emit formaldehyde. There remains a need for lightweight, strong and VOC (volatile organic compound) free wall and panel construction to replace existing prefabricated walls and panels. WO 2014/153053 discloses a sandwich wall construction for mobile homes that have a cellular core containing a foam made of polyurethane, polyisocyanate, or a mixture of the two. The wall further contains a fiber mat adjacent to the core, a thermoplastic polymer film adjacent to the fiber mat, and a clear cured coat covering the thermoplastic film.

There is a need for lightweight sandwich constructions with high strength and good flame resistance.

SUMMARY OF THE DISCLOSURE

This disclosure relates to a composite mat which contains at least one fiber, a binder, and a fire resistant additive. The fibers can be woven, non-woven, or a mixture of both woven and non-woven fibers. The fibers can be natural fibers, synthetic fibers, and mixtures thereof. The fibers can be cellulosic materials. Suitable natural fibers can include bast fibers, cotton fibers, wood fibers, leaf fibers, fruit fibers, animal fibers and mixtures thereof. Exemplary fibers
include, but are not limited to, kenaf, flax, hemp, jute, rayon, sisal, caroa, banana, coconut, wool, rye, wheat, rice, sugar cane, bamboo, and mixtures thereof.

The fibers can be a synthetic fiber, such as carbon fibers, polyethylenes, polyesters, polyamides, phenol-formaldehydes, polyvinyl chlorides, polyurethanes, and mixtures thereof. An exemplary synthetic fiber is polyethylene terephthalate. For embodiments in which the fiber is blend of natural and synthetic fibers, the synthetic fibers can be present in an amount that is 0.1-5%, 1-5%, 10-50%, 15-40%, 20-40%, 20-35%, 25-35%, or 30% by weight relative to the total weight of the fibers.

The fire resistant additive can be an organophosphorus compound, a borate salt, a melamine compound, an aluminum compound, and antimony compound, a halogen, or a mixture thereof. Suitable organophosphorus compounds include, but are not limited to, tetrakis hydroxymethyl phosphonium salt/urea condensate, a cyclic phosphonate, and mixtures thereof. Suitable borate salts include, but are not limited to, sodium borate, zinc borate, ammonium borate, boric oxide, and mixtures thereof. Suitable melamine compounds include, but are not limited to, melamine phosphate, melamine polyphosphate, melamine pyrophosphate, melamine, melamine cyanurate, melamine borate, and mixtures thereof. Suitable aluminum compounds include alumina trihydroxide. In certain cases, the fire resistant additive can be a mixture of a borate salt and an organophosphorus compound. Generally, the fire resistant additive can be present in an amount from 0.1-75%, 1-50%, 1-40%, 1-30%, 5-30%, 5-25%, 5-20%, 5-15%, 5-10%, 7-5-15%, 7.5-20% or 10-20% by weight relative to the total weight of the composite mat.

The binder can be a pure acrylic copolymer, a styrene acrylic copolymer, or a vinyl acrylic copolymer. The binder can be present in an amount from 0.1-75%, 5-75%, 5-50%, 10-50%, or 15-50% by weight dry binder relative to the total weight of the composite mat.

The composite mat can be prepared by obtaining a blend of binder and fire resistant additive, and then applying the blend to fiber. The blend can be applied either as a laminate layer on the fiber, or can be dispersed partially or completely throughout the fibers. Suitable methods for applying the blend include spraying, curtain coating, dip and squeeze, foulard (i.e., the use of foam without pressure), and foaming under pressure.

The composite mat can be used as a component in a sandwich construction. A sandwich construction can be formed by covering a planar core with a fire resistant composite mat, either on one or both sides of the planar core. When the composite mat is present on both planar sides, the mat can be the same or different. The sandwich construction can further contain a thermoplastic polymer film, a clear coat, or both. Both, or only one, of the planar sides may be
covered by either the thermoplastic film, clear coat or both. When both planar sides care covered by a thermoplastic polymer film, the thermoplastic polymer film can be the same or different on each side. When both planar sides care covered by a clear coat, the clear coat can be the same or different on each side.

The planar core of the sandwich construction can be made any suitable material, such as a cellulosic material. The cellulosic material can include, but is not limited to, bast fibers, wood fibers, seed fibers, leaf fibers, fruit fibers, animal fibers and mixtures thereof. Suitable cellulosic materials include, but are not limited to, kenaf, flax, hemp, jute, cotton, rayon, sisal, caroa, banana, coconut, wool and mixtures thereof.

The sandwich construction can be characterized, in some embodiments, by the absence of formaldehyde, styrene, or both. The sandwich construction can be characterized, in some embodiments, by the absence an adhesive layer between any of the components of the sandwich constructions, for instance, between the planar core and the composite mats, between the composite mat and thermoplastic polymer film, between the thermoplastic polymer film and cured clear coat, between the planar core and the thermoplastic polymer film, between the composite mat and cured clear coat, or between the planar core and cured clear coat.

**BRIEF DESCRIPTION OF THE DRAWINGS**

The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate several embodiments of the disclosure and together with the description, serve to explain the principles of the disclosure.

**Figure 1** depicts the flame spread index for composite mats determined by Steiner Tunnel Flame Testing. Flame travel distance (ft) is depicted on the y-axis and time (min) is depicted on the x-axis.

**Figure 2** depicts the smoke developed index for composite mats determined by Steiner Tunnel Flame Testing. Light absorption (%) is depicted on the y-axis and time (min) is depicted on the x-axis.

**DESCRIPTION OF THE DISCLOSURE**

Disclosed herein are flame resistant composite mats that can be employed as components of a sandwich wall or panel construction. The mat can be overlaid the core material of the sandwich construction. Because the mat is flame resistant, the mat reduces or prevents combustion of the core material, and thereby permits the use of cellulosic materials.
The composite mats contain at least one fiber, a binder, and a fire resistant additive. The fiber can include one or more natural fibers, one or more synthetic fibers, or mixtures thereof. Suitable natural fibers include, but are not limited to, bast fibers such as kenaf, flax, hemp, and jute; wood fibers, including rayon; cotton fibers; lead fibers such as sisal, caroa, and banana; fruit fibers such as a coconut; and animal fibers such as wool. The fibers can also include rye, wheat, rice, sugar cane, or bamboo. In some embodiments, the fibers include cellulosic fibers. The fibers can be woven or non-woven.

The fiber can also include synthetic fibers, such as carbon fibers, polyethylene fibers, polyester fibers, polyamide fibers, phenol-formaldehyde fibers, polyvinyl chloride fibers, and polyurethane fibers. In certain embodiments in which the fiber is a blend of natural and synthetic fibers, the synthetic fibers can be present in an amount that is 0.1-75%, 5-50%, 10-40%, 15-40%, 20-40%, 20-35%, 25-35%, or about 30% by weight relative to the total weight of the fibers.

In certain embodiments, the fiber includes bast fiber or a mixture of a bast fiber and polyester. In such mixtures, the bast fiber can be kenaf and the polyester can be polyethylene terephthalate (PET). In some embodiments, the mat includes non-woven bast fibers.

The composite fiber contains at least one fire resistant additive. Suitable additives include organophosphorus compounds, boric acids and borate salts, melamine compounds, and metal hydroxides, such as aluminum trihydroxide and magnesium trihydroxide. Exemplary organophosphorous compounds include tetrakis hydroxymethyl phosphonium salt/urea condensate, and cyclic phosphonate. Exemplary boric acid and borate salts include sodium borate, zinc borate, ammonium borate and boric oxide. Exemplary melamine compounds include melamine phosphate, melamine polyphosphate, melamine pyrophosphate, melamine, melamine cyanurate, and melamine borate. Mixtures of two or more fire resistant additives, either from the same or different chemical class, can also be present in the composite mat. The fire resistant additive can be present in an amount that is from 0.1-75%, 1-50%, 1-40%, 1-30%, 5-30%, 5-25%, 5-20%, 5-15%, 5-10%, 7.5-15%, 7.5-20% or 10-20% by weight relative to the total weight of the composite mat.

The composite mat also may contain a binder. The binder can include a pure acrylic polymer, a styrene acrylic copolymer, a styrene butadiene copolymer, a vinyl acrylic copolymer, a vinyl acetate polymer, or a vinyl acetate ethylene copolymer. Suitable unsaturated monomers for use in forming the binder are generally ethylenically unsaturated monomers and include vinylaromatic compounds (e.g. styrene, α-methyl styrene, o-chlorostyrene, and vinyltoluenes);
dienes (e.g., butadiene); α,β-monoethylenically unsaturated mono- and dicarboxylic acids or anhydrides thereof (e.g. acrylic acid, methacrylic acid, crotonic acid, dimethacrylic acid, ethylacrylic acid, allylacetic acid, vinylacetic acid maleic acid, fumaric acid, itaconic acid, mesaconic acid, methylenemalonic acid, citraconic acid, maleic anhydride, itaconic anhydride, and methylmalonic anhydride); esters of α,β-monoethylenically unsaturated mono- and dicarboxylic acids having 3 to 6 carbon atoms with alkanols having 1 to 12 carbon atoms (e.g. esters of acrylic acid, methacrylic acid, maleic acid, fumaric acid, or itaconic acid, with C1-C2, C1-C8, or C1-C4 alkanols such as ethyl, n-butyl, isobutyl and 2-ethylhexyl acrylates and methacrylates, dimethyl maleate and n-butyl maleate); acrylamides and alkyl-substituted acrylamides (e.g. (meth)acrylamide, N-tert-butyl acrylamide, and N-methyl(meth)acrylamide); (meth)acrylonitrile; vinyl and vinylidene halides (e.g. vinyl chloride and vinylidene chloride); vinyl esters of C1-C18 mono- or dicarboxylic acids (e.g. vinyl acetate, vinyl propionate, vinyl n-butyrate, vinyl laurate and vinyl stearate); C1-C4 hydroxyalkyl esters of C3-C6 mono- or dicarboxylic acids, especially of acrylic acid, methacrylic acid or maleic acid, or their derivatives alkoxylated with from 2 to 50 moles of ethylene oxide, propylene oxide, butylene oxide or mixtures thereof, or esters of these acids with C1-C18 alcohols alkoxylated with from 2 to 50 mol of ethylene oxide, propylene oxide, butylene oxide or mixtures thereof (e.g. hydroxyethyl (meth)acrylate, hydroxypropyl (meth)acrylate, and methylpolyglycol acrylate); and monomers containing glycidyl groups (e.g. glycidyl methacrylate).

Exemplary α,β-monoethylenically unsaturated mono- and dicarboxylic acids and esters thereof include, but are not limited to, (meth)acrylic acid, 2-hydroxyethyl(meth)acrylate, 2-hydroxypropyl(meth)acrylate, 2-hydroxybutyl(meth)acrylate, methyl(meth)acrylate, ethyl(meth)acrylate, propyl(meth)acrylate, isopropyl(meth)acrylate, butyl(meth)acrylate, amyl(meth)acrylate, isobutyl(meth)acrylate, t-butyl(meth)acrylate, pentyl(meth)acrylate, isooctyl(meth)acrylate, hexyl(meth)acrylate, heptyl(meth)acrylate, octyl(meth)acrylate, 2-ethylhexyl(meth)acrylate, nonyl(meth)acrylate, decyl(meth)acrylate, isodecyl(meth)acrylate, undecyl(meth)acrylate, dodecyl(meth)acrylate, laueryl(meth)acrylate, octadecyl(meth)acrylate, stearyl(meth)acrylate, tetrahydrofurfuryl(meth)acrylate, butoxyethyl(meth)acrylate, ethoxydiethylene glycol (meth)acrylate, benzyl(meth)acrylate, cyclohexyl(meth)acrylate, phenoxyethyl(meth)acrylate, polyethylene glycol mono(meth)acrylate, polypropylene glycol mono(meth)acrylate, methoxyethylene glycol (meth)acrylate, ethoxypolyethylene glycol (meth)acrylate, methoxypolyethylene glycol (meth)acrylate, methoxypolypropylene glycol (meth)acrylate, dicyclopentadiene(meth)acrylate,
dicyclopentanyl(meth)acrylate, tricyclodecanyl(meth)acrylate, isobornyl(meth)acrylate, bornyl(meth)acrylate. Similar esters may be derived using fumaric acid and itaconic acid as well.

Additional monomers that can be used include linear 1-olefins (e.g., ethylene or propylene), branched-chain 1-olefins or cyclic olefins (e.g., ethene, propene, butene, isobutene, pentene, cyclopentene, hexene, and cyclohexene); vinyl and allyl alkyl ethers having 1 to 40 carbon atoms in the alkyl radical, wherein the alkyl radical can possibly carry further substituents such as a hydroxyl group, an amino or dialkylamino group, or one or more alkoxylated groups (e.g. methyl vinyl ether, ethyl vinyl ether, propyl vinyl ether, isobutyl vinyl ether, 2-ethylhexyl vinyl ether, vinyl cyclohexyl ether, vinyl 4-hydroxybutyl ether, decyl vinyl ether, dodecyl vinyl ether, octadecyl vinyl ether, 2-(diethylamino)ethyl vinyl ether, 2-(di-n-butylamino)ethyl vinyl ether, methyldiglycol vinyl ether, and the corresponding allyl ethers); sulfo-functional monomers (e.g. allylsulfonic acid, methallylsulfonic acid, styrenesulfonate, vinylsulfonic acid, allyloxybenzenesulfonic acid, 2-acrylamido-2-methylpropanesulfonic acid, and their corresponding alkali metal or ammonium salts, sulfopropyl acrylate and sulfopropyl methacrylate); vinylphosphonic acid, dimethyl vinylphosphonate, and other phosphorus monomers; alkylaminoalkyl (meth)acrylates or alkylaminoalkyl(meth)acrylamides or quaternization products thereof (e.g. 2-(N,N-dimethylamino)ethyl (meth)acrylate, 3-(N,N-dimethylamino)propyl (meth)acrylate, 2-(N,N,N-trimethylammonium)ethyl (meth)acrylate chloride, 2-dimethylaminoethyl(meth)acrylamide, 3-dimethylaminopropyl(meth)acrylamide, and 3-trimethylammoniumpropyl(meth)acrylamide chloride); allyl esters of C1-C30 monocarboxylic acids; N-Vinyl compounds (e.g. N-vinylformamide, N-vinyl-N-methylformamide, N-vinylpyrrolidone, N-vinylimidazole, 1-vinyl-2-methylimidazole, 1-vinyl-2-methylimidazoline, N-vinylcaprolactam, vinylcarbazole, 2-vinylpyridine, and 4-vinylpyridine); monomers containing 1,3-diketo groups (e.g. acetoacetoxethyl(meth)acrylate or diacetonacrylamide; monomers containing urea groups (e.g. ureidoethyl (meth)acrylate, acrylamidoglycolic acid, and methacrylamidoglycolate methyl ether); and monomers containing silyl groups (e.g. trimethoxysilylpropyl methacrylate).

The monomers can also include one or more crosslinkers such as N-alkylolamides of α,β-monoethylenically unsaturated carboxylic acids having 3 to 10 carbon atoms and esters thereof with alcohols having 1 to 4 carbon atoms (e.g. N-methylol aery lamide and N-methylolmethacrylamide); glyoxal based crosslinkers; monomers containing two vinyl radicals; monomers containing two vinylidene radicals; and monomers containing two alkenyl radicals.
Exemplary crosslinking monomers include diesters of dihydric alcohols with α,β-
monoethylenically unsaturated monocarboxylic acids, of which in turn acrylic acid and
methacrylic acid can be employed. Examples of such monomers containing two non-conjugated
ethylenically unsaturated double bonds are alkylene glycol diacrylates and dimethacrylates, such
as ethylene glycol diacrylate, 1,3-butylene glycol diacrylate, 1,4-butylene glycol diacrylate and
propylene glycol diacrylate, divinylbenzene, vinyl methacrylate, vinyl acrylate, allyl
methacrylate, allyl acrylate, diallyl maleate, diallyl fumarate and methylenebisacrylamide. In
some embodiments, the crosslinking monomers include alkylene glycol diacrylates and
dimethacrylates, and/or divinylbenzene. The crosslinking monomers when used in the binder
can be present in an amount of from 0.2% to 5% by weight based on the weight of the total
monomer and are considered part of the total amount of monomers used in the binder.

In addition to the crosslinking monomers, small amounts (e.g. from 0.01 to 4% by weight
based on the total monomer weight) of molecular weight regulators, such as tert-dodecyl
mercaptan, can be present in the binder.

In some embodiments, the unsaturated monomers can include styrene, α-methyl styrene,
(meth)acrylic acid, itaconic acid, maleic acid, fumaric acid, crotonic acid, methyl (meth)acrylate,
ethyl (meth)acrylate, n-butyl (meth)acrylate, isobutyl (meth)acrylate, tert-butyl (meth)acrylate,
2-ethylhexyl (meth)acrylate, vinyl acetate, butadiene, ethylene, (meth)acryl amide,
(meth)acrylonitrile, hydroxyethyl (meth)acrylate and glycidyl (meth)acrylate.

In some embodiments, the binder can be formed by the reaction product of a
polyacrylic acid (e.g., a polyacrylic acid or polycarboxylic acid modified pure acrylic or
styrene acrylic copolymer) and a crosslinker such as a polyl (e.g., glycerol or triethanolamine).
The binder can include, for example, a styrene-acrylic polymer modified with a polycarboxylic
acid and reacted with a polyl crosslinking agent. Suitable binders include ACRODUR DS 3515,
ACRODUR 950L, ACRODUR DS 3558, or combinations thereof. ACRODUR products
are commercially available from BASF Corporation. In some embodiments, the polycarboxylic
acid and crosslinker can be blended with another latex such as a pure acrylic polymer, a styrene
acrylic copolymer, a styrene butadiene copolymer, a vinyl acrylic copolymer, a vinyl acetate
polymer, or a vinyl acetate ethylene copolymer.

The binder can be present in an amount that is from 0.1-75%, 5-75%, 5-50%, 10-50%, or
15-50% by weight dry binder relative to the total weight of the composite mat.

The composite mat can have a thickness that is from 0.1 mm to 50 mm, 0.5 mm to 30
mm, 0.25 mm to 5 mm, 0.5 mm to 4 mm, 1 mm to 3 mm, or 1.5 mm to 2 mm thick.
The composite mat can be used as a component of a sandwich construction. A sandwich construction can be characterized by a planar core having a first face and an opposed second face. Each face can be covered by an adjacent composite mat, which can be the same or different on each face of the core. In other embodiments, only one face of the planar core is covered by a composite mat.

In some embodiments, the composite mats can be covered on one or both of the faces opposite the planar core by a thermoplastic polymer film. The thermoplastic polymer film on each face can be the same or may be different. The thermoplastic polymer films can then be covered by a cured clear coat. The clear coat on each face can be the same or may be different.

Although any suitable material can serve as the planar core, in certain embodiments the core contains one or more cellulosic materials. Suitable cellulosic materials include, but are not limited to, bast fibers, wood fibers, including rayon, seed fibers, leaf fibers, fruit fibers and animal fibers. Exemplary bast fibers include kenaf, flax, hemp, and jute. Exemplary seed fibers include cotton. Exemplary leaf fibers include sisal, caroa, and banana. Exemplary fruit fibers include coconut, and exemplary animal fibers include wool.

Suitable thermoplastic films include polyurethanes. The clear coating can be a 100% solids coating, including those having units of oligomeric polyunsaturated compounds such as aliphatic urethane acrylates. The thermoplastic film, the clear coating, or both, can contain one or more additives such as pigments, dyes, flame retardants, hindered amine light stabilizers, ultraviolet light absorbers, and anti-static agents. The thermoplastic film can have a thickness that is from 1-30 mm, 1-20 mm, 2-18 mm, 4-16 mm or 6-12 mm. The clear coat can have a thickness that is from 0.01-0.25 mm, 0.025-0.2 mm or 0.05-0.15 mm.

The sandwich construction can have a total thickness that is between 0.5-300 mm, 10-125 mm, 20-100 mm or 20-75 mm. In certain embodiments, the sandwich construction can be characterized in that it contains no free formaldehyde or free styrene. Sandwich constructions that do not contain formaldehyde and/or styrene can include those that do not release formaldehyde and/or styrene, those that do not contain any formaldehyde and/or styrene, and both. In some embodiments, the dispersion can contain a small amount of formaldehyde as a preservative, but the curing mechanism does not involve formaldehyde crosslinking. In some embodiments, styrene can be included in the polymer backbone of the binder, but is not released as free styrene. The sandwich construction can also be characterized by the absence of an adhesive layer between the any of the planar core, composite mats, thermoplastic polymer films, and cured clear coats.
The composite mat can be prepared by blending the acrylic binder with the flame retardant, and applying the mixture to the fiber. Suitable methods for applying the blend include spraying, curtain coating, dip and squeeze, foulard (i.e., the use of foam without pressure), and foaming under pressure. Preferably, the blend is applied to the fibers (e.g., impregnated into the mat) as a foam under pressure, e.g., 0.5 to 5 bar. In contrast to conventional lamination processes, the use of pressurized foam results in the penetration of the binder/additive blend into the fibers. As used herein, the fibers are said to be penetrated when the blend does not exist as a separate layer that is distinct from the fibers. In some cases, the binder/additive blend is impregnated into the fibers. As used herein, the term "impregnated" means that the concentration of the blend and fiber is generally the same throughout the mat so that there is substantially no concentration gradient from one side of the mat to the other.

The blend of the binder and fire resistant additive can also be used for various applications including building materials, furniture, apparel, and a variety of automotive, recreational and household goods.

By way of non-limiting illustration, examples of certain embodiments of the present disclosure are given below. Unless indicated otherwise, parts are parts by weight, temperature is in °C or is at ambient temperature, and pressure is at or near atmospheric.

Example 1:

Preparation of Composite Mat

The following composites were prepared by blending resin formulations, foaming the resin, driving the foamed resin into a nonwoven, drying and consolidating to desired thickness. Blending the resin formulations was performed by weighing and combining water, flame retardant(s), foaming agent (Lutensol TDA 10) and pigment to form an intermediate blend, and finally adding Acrodur resin (at 50 wt% solid / 50 wt% water) to create a homogeneous solution/ dispersion. The resin blends were then mixed with air under high shear rates to generate a foam using a Hansa foam generator. The foams were then applied to their respective nonwovens using a Hansa foam linear. In this process, the nonwovens were pulled through the foam linear at a constant rate as the foams were applied to the upper and lower sides of the nonwovens in order to promote equal distributions of the resin formulations. The nonwovens were at this stage considered to be impregnated. These impregnated nonwovens were subsequently dried using a radio frequency drier to a moisture content of -15 wt%. Once dried the previously impregnated materials were cut to 24" x 32" sections to allow for consolidation.
Consolidation was performed using a static hydraulic Dieffenbacher press with flat platens heated to 400T with a 5 mm gap. The consolidation durations were set using a thermocouple inserted at the core; the platen gap was maintained for 35 seconds after the core reached 350°F (i.e. R38 core temp was reached 350°F at 110 s, therefore total close time was 145 s). The aforementioned processing conditions resulted in high-loft, high-stiffness composites that were formed to 5 mm thickness.

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flame Spread Index</td>
<td>40</td>
<td>35</td>
<td>25</td>
</tr>
<tr>
<td>Smoke Developed Index</td>
<td>120</td>
<td>350</td>
<td>250</td>
</tr>
<tr>
<td>Fiber weight (g/sm)</td>
<td>759</td>
<td>759</td>
<td>656</td>
</tr>
<tr>
<td>Resin weight (g/sm)</td>
<td>303</td>
<td>303</td>
<td>230</td>
</tr>
<tr>
<td>Total FR weight (gsm)</td>
<td>106</td>
<td>102</td>
<td>177</td>
</tr>
<tr>
<td>Composite weight (gsm)</td>
<td>1168</td>
<td>1164</td>
<td>1063</td>
</tr>
<tr>
<td>Fiber type</td>
<td>100% kenaf</td>
<td>100% kenaf</td>
<td>70% kenaf, 30% PET</td>
</tr>
<tr>
<td>Resin type (amount of dry resin as a percentage of starting dry mat)</td>
<td>40% 950L</td>
<td>40% 3515L</td>
<td>17.5% 950L, 17.5% 3515</td>
</tr>
<tr>
<td>FR type</td>
<td>35% Aflammit¹</td>
<td>34% Aflammit¹</td>
<td>35% Aflammit/40% Polybor²</td>
</tr>
</tbody>
</table>

¹ Aflammit is a trademark of Thor Specialties (UK) Limited
² Polybor is a trademark of Rio Tinto Group.
The combustion resistance of the above composite mats was evaluated using the Steiner Tunnel Flame Test (ATSM E84). The results are depicted in the table below.

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self Supported</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Steady Ignition Time (s)</td>
<td>9</td>
<td>6</td>
<td>21</td>
</tr>
<tr>
<td>Max Distance (ft)</td>
<td>8.20</td>
<td>7.94</td>
<td>5.06</td>
</tr>
<tr>
<td>Time to Max Distance (s)</td>
<td>139</td>
<td>133</td>
<td>109</td>
</tr>
<tr>
<td>Rate of Flame Increase (ft/s)</td>
<td>0.063</td>
<td>0.063</td>
<td>0.058</td>
</tr>
<tr>
<td>Receded Distance (ft)</td>
<td>0.00</td>
<td>0.00</td>
<td>0.54</td>
</tr>
<tr>
<td>Time to Receded Distance (s)</td>
<td>239</td>
<td>272</td>
<td>267</td>
</tr>
<tr>
<td>Rate of Flame Decrease (ft/s)</td>
<td>-0.082</td>
<td>-0.057</td>
<td>-0.029</td>
</tr>
<tr>
<td>Flame Spread</td>
<td>38.95</td>
<td>37.36</td>
<td>24.05</td>
</tr>
<tr>
<td>Area Under Flame Curve (ft/min)</td>
<td>75.62</td>
<td>72.54</td>
<td>46.70</td>
</tr>
<tr>
<td>Peak Smoke (%Abs.)</td>
<td>54</td>
<td>87</td>
<td>48</td>
</tr>
<tr>
<td>Time to Peak Smoke</td>
<td>90</td>
<td>90</td>
<td>84</td>
</tr>
<tr>
<td>Smoke Developed</td>
<td>121.80</td>
<td>345.81</td>
<td>233.96</td>
</tr>
<tr>
<td>Area Under Smoke Curve (%Abs/min)</td>
<td>62.12</td>
<td>176.36</td>
<td>119.32</td>
</tr>
<tr>
<td>Self Extinguishing?</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

The compositions and methods of the appended claims are not limited in scope by the specific compositions and methods described herein, which are intended as illustrations of a few aspects of the claims and any compositions and methods that are functionally equivalent are intended to fall within the scope of the claims. Various modifications of the compositions and methods in addition to those shown and described herein are intended to fall within the scope of the appended claims. Further, while only certain representative materials and method steps disclosed herein are specifically described, other combinations of the materials and method steps also are intended to fall within the scope of the appended claims, even if not specifically recited. Thus, a combination of steps, elements, components, or constituents may be explicitly mentioned herein; however, other combinations of steps, elements, components, and constituents are included, even though not explicitly stated. The term "comprising" and variations thereof as used herein is used synonymously with the term "including" and variations thereof and are open, non-limiting terms. Although the terms "comprising" and "including" have been used herein to
describe various embodiments, the terms "consisting essentially of" and "consisting of" can be used in place of "comprising" and "including" to provide for more specific embodiments and are also disclosed. As used in this disclosure and in the appended claims, the singular forms "a", "an", "the", include plural referents unless the context clearly dictates otherwise.
CLAIMS

1. A composite mat, comprising:
   a) a fiber,
   b) a binder, and
   c) a fire resistant additive.

2. The composite mat of claim 1, wherein the fiber comprises natural fibers, synthetic fibers, or mixtures thereof.

3. The composite mat of claim 1 or 2, wherein the fiber comprises cellulosic fibers.

4. The composite mat of any of claims 1-3, wherein the fiber comprises bast fibers, cotton fibers, wood fibers, leaf fibers, fruit fibers, animal fibers or mixtures thereof.

5. The composite mat of any of claims 1-4, wherein the fiber comprises kenaf, flax, hemp, jute, rayon, sisal, caroa, banana, coconut, wool, rye, wheat, rice, sugar cane, bamboo, or mixtures thereof.

6. The composite mat of any of claims 1-5, wherein the fiber comprises kenaf.

7. The composite mat of any of claims 1-6, wherein the fiber is non-woven.

8. The composite mat of any of claims 1-6, wherein the fiber is woven.

9. The composite mat of any one of claims 1-8, wherein the fiber includes synthetic fibers, and the synthetic fibers are selected from carbon fibers, polyethylenes, polyesters, polyamides, phenol-formaldehydes, polyvinyl chlorides, polyurethanes, and mixtures thereof.

10. The composite mat of any of claims 1-9, wherein the fiber comprises polyester.

11. The composite mat of any of claims 1-10, wherein the fiber comprises polyethylene terephthalate.
12. The composite mat of any of claims 1-11, wherein the fiber is blend of natural and synthetic fibers, and the synthetic fibers are present in an amount that is 0.1-75%, 5-50%, 10-40%, 15-40%, 20-40%, 20-35%, 25-35%, or 30% by weight relative to the total weight of the fibers.

13. The composite mat of any of claims 1-12, wherein the fire resistant additive comprises an organophosphorus compound, a borate salt, a melamine compound, or a mixture thereof.

14. The composite mat of any of claims 1-13, wherein the fire resistant additive comprises a borate salt, and the borate salt comprises sodium borate, zinc borate, ammonium borate, boric oxide, or a mixture thereof.

15. The composite mat of any of claims 1-14, wherein the fire resistant additive comprises a tetrakis hydroxymethyl phosphonium salt/urea condensate, a cyclic phosphonate, or a mixture thereof.

16. The composite mat of any of claims 1-15, wherein the fire resistant additive comprises melamine phosphate, melamine polyphosphate, melamine pyrophosphate, melamine, melamine cyanurate, melamine borate, or a mixture thereof.

17. The composite mat of any of claims 1-16, wherein the fire resistant additive comprises a mixture of a borate salt and an organophosphorus compound.

18. The composite mat of any of claims 1-17, wherein the composite mat comprises the fire resistant additive in an amount from 0.1-75%, 1-50%, 1-40%, 1-30%, 5-30%, 5-25%, 5-20%, 5-15%, 5-10%, 7.5-15%, 7.5-20% or 10-20% by weight relative to the total weight of the composite mat.

19. The composite mat of any of claims 1-18, wherein the binder includes an acrylic polymer.

20. The composite mat of any of claims 1-19, wherein the binder comprises a polymer polymerized from monomers selected from styrene, a-methylstyrene, (meth)acrylic acid, itaconic
acid, maleic acid, fumaric acid, crotonic acid, methyl (meth)acrylate, ethyl (meth)acrylate, n-butyl (meth)acrylate, isobutyl (meth)acrylate, tert-butyl (meth)acrylate, 2-ethylhexyl (meth)acrylate, vinyl acetate, butadiene, ethylene, (meth)acrylamide, (meth)acrylonitrile, hydroxyethyl (meth)acrylate, glycidyl (meth)acrylate, and mixtures thereof.

21. The composite mat of any one of claims 1-20, wherein the composite mat comprises the acrylic binder in an amount from 0.1-75%, 5-75%, 5-50%, 10-50%, or 15-50% by weight dry binder relative to the total weight of the composite mat.

22. The composite mat of any of claims 1-21, wherein the acrylic binder and fire resistant additive penetrates the fiber.

23. The composite mat of any of claims 1-22, wherein the acrylic binder and fire resistant additive impregnates the fiber.

24. The composite mat of claim 1, where the fiber comprises non-woven cellulosic bast fibers and the acrylic binder is present in the composite mat in an amount from 15% to 50% by weight dry binder, based on the weight of the composite mat.

25. A sandwich construction comprising:
   a) a planar core having a first face and an opposed second face, and
   b) a first composite mat adjacent to and covering the first face of the planar core and
   a second composite mat adjacent to and covering the second face of the planar core, the first composite mat and the second composite mat each comprising a composite mat of any one of claims 1-23.

26. The sandwich construction of claim 25, further comprising a first thermoplastic polymer film adjacent to and covering the first composite mat and a second thermoplastic polymer film adjacent to and covering the second composite mat.

27. The sandwich construction of either of claims 25 or 26, further comprising at least one cured clear coat.
28. The sandwich construction of any of claims 25-27, wherein the planar core comprises a cellulosic material.

29. The sandwich construction of any of claims 25-28, wherein the planar core comprises bast fibers, wood fibers, seed fibers, leaf fibers, fruit fibers, animal fibers or mixtures thereof.

30. The sandwich construction of any of claims 25-29, wherein the planar core comprises kenaf, flax, hemp, jute, cotton, rayon, sisal, caroa, banana, coconut, wool or mixtures thereof.

31. The sandwich construction of any of claims 26-30, wherein at least one of the first thermoplastic polymer film and the second thermoplastic polymer film is a thermoplastic polyurethane film.

32. The sandwich construction of any of claims 27-31, wherein the cured clear coat is a cured 100% solids coatings formulation.

33. The sandwich construction of any of claims 27-32, wherein at least one of the first cured clear coat and the second cured clear coat is a cured coatings formulation comprising units of oligomeric polyunsaturated compounds selected from aliphatic urethane acrylates.

34. The sandwich construction of any one of claims 26-33, wherein at least one of the first thermoplastic polymer film and the second thermoplastic polymer film comprises one or more additives selected from pigments, dyes, flame retardants, hindered amine light stabilizers, ultraviolet light absorbers, and anti-static agents.

35. The sandwich construction of any one of claims 27-34, wherein at least one of the first cured clear coat and the second cured clear coat comprises one or more additives selected from hindered amine light stabilizers and ultraviolet light absorbers.

36. The sandwich construction of any one of claims 25-35, which contains no formaldehyde, no styrene, or no adhesive layers between the planar core, the first and second composite mats, the first and second thermoplastic polymer films, and the first and second cured clear coats.
37. The sandwich construction of any one of claims 25-36, wherein the composite mat is from 0.1 mm to 50 mm thick.

38. The sandwich construction of any one of claims 26-37, wherein at least one of the first thermoplastic polymer film and the second polymer film is from 1 mils to 30 mils thick.

39. The sandwich construction of any one of claims 27-38, wherein the cured clear coat is from 0.5 mils to 15 mils thick.

40. The sandwich construction of any one of claims 25-39, having a thickness from 0.5 mm to 300 mm thick.

41. The sandwich construction of any one of claims 25-40, wherein the first composite mat and the second composite mat are identical.

42. The sandwich construction of any one of claims 25-40, wherein the first composite mat and the second composite mat are different.
# INTERNATIONAL SEARCH REPORT

**International application No**
PCT/IB2016/056845

### A. CLASSIFICATION OF SUBJECT MATTER


**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)

- E04B
- E04C

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, WPI Data

### C. DOCUMENTS CONSIDERED TO BE RELEVANT

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[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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Date of the actual completion of the international search: 16 January 2017

Date of mailing of the international search report: 25/01/2017

Name and mailing address of the ISA:
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Lanni el , Genevi eve

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