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(54) **Microfiber-containing fiber reinforced facer mats and the method of making**

(57) Fiber-reinforced composite mats are described that include a non-woven web of fibers. The web of fibers may include a first group of fibers having an average fiber diameter from about 8 μm to about 25 μm, and a second group of fibers having an average fiber diameter from about 0.5 μm to about 6.5 μm. A binder bonds together the non-woven web of fibers into the fiber reinforced composite having an air permeability of 250 cfm/ft^2 or less. Also described are gypsum boards that include one or more facers affixed to at least one surface of the gypsum board. The facers may be made from the above, described fiber-reinforced composite mats.

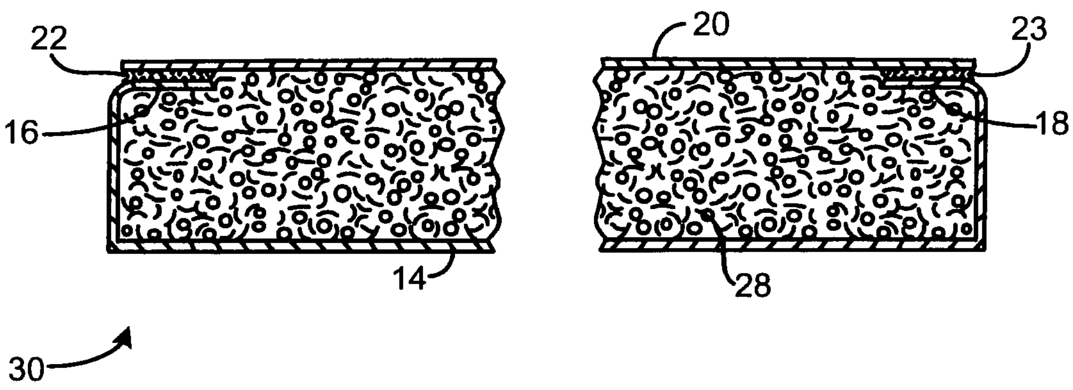

Fig. 1

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Description

FIELD OF THE INVENTION

[0001] Embodiments of the invention relate to construction materials used in building construction, including fiber-reinforced composite faced construction board, such as gypsum board. The fiber-reinforced composite facers on exposed surfaces of the construction board may include a glass fiber mat made from a blend of large and small diameter glass fibers bonded together with a binder, such as an organic or inorganic binder.

BACKGROUND OF THE INVENTION

[0002] Wallboard formed of a gypsum core sandwiched between facing layers is used in the construction of virtually every modern building. In its various forms, the material is employed as a surface for walls and ceilings and the like, both interior and exterior. It is relatively easy and inexpensive to install, finish, and maintain, and in suitable forms, is relatively fire resistant.

[0003] Paper-faced wallboard (e.g., gypsum wallboard) is commonly used for finishing interior walls and ceilings. Gypsum wallboard and gypsum panels are traditionally manufactured by a continuous process. In this process, a gypsum slurry is generated and deposited on a continuously advancing, lower facing sheet, such as kraft paper. A continuously advancing upper facing sheet is laid over the gypsum and the edges of the upper and lower facing sheets are pasted to each other with a suitable adhesive. The facing sheets and gypsum slurry are passed between parallel upper and lower forming plates or rolls in order to generate an integrated and continuous flat strip of unset gypsum sandwiched between the sheets. Such a flat strip of unset gypsum is known as a facing or liner. The strip is conveyed over a series of continuous moving belts and rollers for a period of several minutes, during which time the core begins to hydrate. The process is conventionally termed "setting," since the rehydrated gypsum is relatively hard. During each transfer between belts and/or rolls, the strip is stressed in a way that can cause the facing to delaminate from the gypsum core if its adhesion is not sufficient.

[0004] While paper is widely used as a facing material for gypsum board products because of its low cost, many applications demand water resistance that paper facing cannot provide. Upon exposure to water either directly in liquid form or indirectly through exposure to high humidity, paper is highly prone to degradation, such as by delamination, that substantially compromises its mechanical strength. Gypsum products typically rely on the integrity of the facing as a major contributor to their structural strength. Consequently, paper-faced products are generally not suited for exterior or other building uses in which exposure to moisture conditions is presumed.

[0005] In addition, there is growing attention being given to the issue of mold and mildew growth in building interiors and the potential adverse health impact such activity might have on building occupants. The paper facing of conventional gypsum board contains wood pulp and other organic materials that may act in the presence of moisture or high humidity as nutrients for such microbial growth. A satisfactory alternative facing material less susceptible to growth is highly sought.

[0006] A further drawback of paper-faced gypsum board is flame resistance. In a building fire, the exposed paper facing quickly burns away. Although the gypsum itself is not flammable, once the facing is gone the board's mechanical strength is greatly impaired. At some stage thereafter the board is highly likely to collapse, permitting fire to spread to the underlying framing members and adjacent areas of a building, with obvious and serious consequences. A board having a facing less susceptible to burning would at least survive longer in a fire and thus be highly desirable in protecting both people and property.

[0007] To overcome these and other problems, alternatives to paper facing have been proposed. For example, exterior insulation systems have been developed that include a fibrous mat-faced gypsum board. However, gypsum board products incorporating the fibrous mats have proven to have certain drawbacks: Some persons are found to be quite sensitive to the fiberglass mat, and develop skin irritations and abrasions when exposed to the mat at various stages, including the initial production of the mat, the manufacture of composite gypsum board with the mat facing, and during the cutting, handling, and fastening operations (e.g., with nails or screws) that attend installation of the end product during building construction. Handling of the mat, and especially cutting, is believed to release glass fibers responsible for the irritation. The fibers may either become airborne or be transferred by direct contact. As a result, workers are generally forced to wear long-sleeved shirts and long pants and to use protective equipment such as dust masks. Such measures are especially unpleasant in the sweaty, hot and humid conditions often encountered either in manufacturing facilities or on a construction jobsite.

[0008] In addition, many commercial fiber-faced construction boards have a surface roughness that makes them difficult to finish satisfactorily by normal painting, because the texture of the mat remains perceptible through the paint. The fibers in the mat themselves give rise to various asperities, and to additional, larger sized irregularities often termed in the industry with descriptives such as "orange peel", "cockle", or similarly evocative terms describing surface non-planarity. The perceived smoothness of a board surface is the result of a complex interplay between various topographic features of the board, including the size, depth, spacing, and regularity of the features. Although some of these attributes may be quantified somewhat using image analysis techniques, visual comparison, especially under obliquely incident light, is more than sufficient for comparing the relative smoothness of different surfaces.

[0009] Moreover, making the construction board may involve the deposition of a relatively wet slurry onto the fiber-reinforced mat, which is generally found to result in considerable intrusion of the slurry through the mat and onto the faced surface. Prevention of this excess intrusion typically requires very careful control of the slurry viscosity, which, in turn, frequently leads to other production problems. Alternative mats, which inherently limit intrusion, yet still have sufficient permeability to permit water to escape during the formation and heat drying of the construction board are thus eagerly sought as a simpler alternative. These and other problems are address in the present application.

BRIEF SUMMARY OF THE INVENTION

[0010] Fiber-reinforced composite mats for use in construction board and other building materials are described, as well as processes of making the mats, boards, and materials. The mat-faced construction boards may have one or more of a smoother surface, a stronger internal bond to prevent delamination of the facer when subjected to prolonged wetness after installation, a surface requiring less paint to produce an aesthetically acceptable finished wall, etc., and better flame and mold resistance.

[0011] Exemplary fiber-reinforced composite mats may include a blend of large and small fibers to give the mats lower air permeability than conventional mats for construction board facer applications. The fiber-reinforced composite mats may be used as facers for construction board, such a gypsum board having a layer of set gypsum with a first face and a second face and the fiber-reinforced composite mat affixed as a facer to at least one of the faces. The gypsum board may be used for a number of purposes in building construction, such as a surface material for walls and ceilings and as an underlayment for floors, roofs, and the like. The present construction board may find application in both interior and exterior environments. As a result of the selection of fibers in the facing, the board has a smooth, uniform surface that readily accepts paint or other surface treatments to provide a pleasing aesthetic appearance.

[0012] The low air permeability of the mats (typically 250 cfm/ft^2 at 0.5" w.c. or less) reduces bleedthrough from aqueous slurries of construction materials applied to the mat. These slurries may include calcium sulfate, calcium sulfate hemi-hydrate, and/or hydraulic setting cement that are often used to make gypsum board, among other construction board materials. The low air permeability of the mats permits slurry compositions with lower viscosity to be applied without increasing the rate at which the slurry bleeds through the mat to create a rough, uneven surface on the exposed faces of the construction board.

[0013] Embodiments of the invention include fiber-reinforced composite mats that include a non-woven web of fibers. The web of fibers may include a first group of fibers having an average fiber diameter from about 8 μm to about 25 μm, and a second group of fibers having an average fiber diameter from about 0.5 μm to about 6.5 μm. A binder bonds together the non-woven web of fibers into the fiber reinforced composite having an air permeability of 250 cfm/ft^2 or less.

[0014] Embodiments of the invention further include gypsum board having at least one fiber-reinforced composite facers affixed to at least one surface of the gypsum board. The fiber-reinforced facer may include a non-woven web of fibers, wherein the fibers may be a blend of a first group of fibers having an average fiber diameter from about 8 μm to about 25 μm, and a second group of fibers having an average fiber diameter from about 0.5 μm to about 6.5 μm. The fiber-reinforced facers may also include a binder that bonds together the non-woven web of fibers into the fiber reinforced composite. The composite may have an air permeability of 250 cfm/ft^2 or less.

[0015] Embodiments of the invention still further include processes for manufacturing a fiber-reinforced composite. The processes may include blending a first group of fibers having an average fiber diameter from about 8 μm to about 25 μm with a second group of fibers having an average fiber diameter from about 0.5 μm to about 6.5 μm to form a non-woven web of fibers. The non-woven web of fibers may be contacted with a binder solution to form a wet mat, which may be cured to form a fiber-reinforced composite mat. The fiber-reinforced composite mat may have an air permeability of 250 cfm/ft^2 or less.

[0016] In further embodiments, an aqueous slurry may be applied to a surface of the fiber-reinforced composite mat. The slurry may include one or more materials such as calcium sulfate, calcium sulfate hemi-hydrate, and hydraulic setting cement.

[0017] In still further embodiments, a first facer made of the above-described fiber-reinforced composite mat may be provided, and the aqueous slurry may be distributed on the first facer to form a layer. A second facer (which may be made of the same fiber-reinforced composite mat as the first facer or a different material) may be applied on top of the layer to form a laminate. The laminate may be cut into specified lengths, which may be dried to form dried pieces that have a smoothness sufficient to be directly painted. Exemplary dried pieces include interior gypsum board for building construction.

[0018] Additional embodiments and features are set forth in part in the description that follows, and in part will become apparent to those skilled in the art upon examination of the specification or may be learned by the practice of the invention.

The features and advantages of the invention may be realized and attained by means of the instrumentalities, combinations, and methods described in the specification.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] A further understanding of the nature and advantages of the present invention may be realized by reference to the remaining portions of the specification and the drawings wherein like reference numerals are used throughout the several drawings to refer to similar components. In some instances, a sublabel is associated with a reference numeral and follows a hyphen to denote one of multiple similar components. When reference is made to a reference numeral without specification to an existing sublabel, it is intended to refer to all such multiple similar components.

[0020] Fig. 1 shows a simplified cross-sectional view of a mat-faced construction board according to embodiments of the invention;

[0021] Fig. 2 shows selected steps in a process for manufacturing a fiber-reinforced composite according to embodiments of the invention; and

[0022] Fig. 3 shows selected steps in a process for manufacturing a faced construction board according to embodiments of the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0023] Construction boards (such as hydraulic set and cementitious board) are described having front and back large surfaces, at least one of which is faced with a fiber-reinforced composite mat. By hydraulic set is meant a material capable of hardening to form a cementitious compound in the presence of water. Typical hydraulic set materials include gypsum, Portland cement, pozzolanic materials, and the like.

<u>Exemplary Fiber-Reinforced Composite Mat-Faced Construction Board</u>

[0024] Referring now to FIG. 1, there is shown generally at 30 a sectional view across the width direction of one embodiment of a fiber-reinforced composite mat-faced construction board. In the embodiment shown, the board has a layer of set gypsum 28 which is sandwiched between first and second fibrous mats 14, 20, and bonded thereto. Two right-angled folds are formed in each lateral edge of first mat 14, a first upward fold and a second inward fold. The two folds are separated by a small distance, whereby the thickness of board is generally determined. The second folds define longitudinally extending strips 16 and 18 that are substantially parallel to the main part of the mat. A second fibrous mat 20 covers the other side of the set gypsum core 28. The respective lateral edges of second mat 20 are affixed to strips 16 and 18, preferably with adhesive 22, 23. Ordinarily board 30 is installed with the side bearing mat 14 facing a finished space. The board is advantageously ready for painting, but other finishing forms such as plaster, wallpaper or other known wall coverings may also be applied with a minimum of surface preparation.

[0025] The mats for one or both of the large faces of the gypsum board may include a non-woven web bonded together with a resinous binder. The web comprises chopped continuous glass fibers, that may be a blend of larger diameter fibers (e.g., chopped strand fibers, staple fibers) and smaller diameter fibers (e.g., microfibers). The larger diameter fibers may have an average fiber diameter of 7 μm or more. Exemplary size ranges for the larger diameter fibers may include about 8 μm to about 25 μm, about 10 μm to about 20 μm, about 12 μm to about 14 μm, about 13 μm, etc. The smaller diameter fibers may have an average size range of less than 7 μm. Exemplary size ranges for the smaller diameter fibers from about 0.5 μm to about 6.5 μm, about 2 μm to about 5 μm, about 2.5 μm, etc.

[0026] Embodiments include blending a larger quantity of the larger diameter fibers with a smaller quantity of the smaller diameter fibers to make the non-woven fiber web. For example, the larger diameter fibers may make up more than half the total weight of the fiber blend in the web. Exemplary quantities of the larger diameter fibers may include about 70 wt.% to about 90 wt.% of the total weight of the fibers (e.g., about 80 wt.%). Exemplary quantities of the smaller diameter fibers may include about 10 wt.% to about 30 wt.% of the total weight of the fibers (e.g., about 20 wt.%).

[0027] The fiber length of the larger diameter fibers and the smaller diameter fibers used in the blend may be the same or different. Exemplary fiber lengths may include about 6 mm to about 18 mm. The web of fibers may also include fibers that are broken into two or more pieces and small glass fibers (e.g., less than 1 mm), chips, and flakes.

[0028] The web of fibers may include chopped strand fibers, staple fibers, or both. Staple fibers are usually made by processes such as rotary fiberization or flame attenuation of molten glass. They typically have a wider range of lengths and fiber diameters than chopped strand fibers.

[0029] Surfaces of the present construction boards may have an improved "hand," i.e., an improved subjective feel, and better accepts surface treatments because of its greater smoothness. In contrast to conventional construction boards where even substantial amounts of paint applied in multiple coats can still leave the facing mat visible and aesthetically unpleasing, the present boards may be finished to provide an aesthetic and functional surface with less paint and the associated labor to prepare the surface and apply the paint or other desired finish, wallpaper or other coating, or the like.

[0030] The glass used in the fibers of the present webs may include one or more types of glass selected from the group consisting of E, C, and T type and sodium borosilicate glasses, and mixtures thereof. C glass typically has a soda-lime-borosilicate composition that provides it with enhanced chemical stability in corrosive environments, and T glass usually has a magnesium aluminosilicate composition and especially high tensile strength in filament form. E glass, which is sometimes called electrical glass, generally has a calcium aluminoborosilicate composition and a maximum alkali content of about 2.0%. The chopped fibers of larger average diameter can have varying lengths, but more commonly are substantially of similar length. E glass fiber has sufficiently high strength and other mechanical properties to produce acceptable mats and is relatively low in cost and widely available. Exemplary sizes of E glass fibers may include an average fiber diameter of about 9 μm to about 13 μm, and a length ranging from about 6 to 12 mm.

[0031] The aforementioned glass fibers may be bound together with an organic or inorganic binder. This may include flame and water resistant resinous binders such as urea formaldehyde, modified urea formaldehyde, acrylic resins, melamine resins, homopolymers or copolymers of polyacrylic acid; crosslinking acrylic copolymers (e.g., acrylic copolymers having a glass transition temperature (GTT) of at least about 25°C); crosslinked vinyl chloride acrylate copolymers (e.g., copolymers having a GTT of about 113°C or less), among other types of binders. A lower GTT may promote better softness and smoothness of the mat surface, but tensile strength may be improved with a higher GTT. Exemplary GTT may range from about 15°C to 45°C. Exemplary binder systems may further include aqueous modified and plasticized urea formaldehyde resin binders.

[0032] The binder may include an effective amount of a water repellant to limit the intrusion of aqueous slurry during board production. For example, vinyl acrylate latex copolymers may further incorporate stearylated melamine for improvement in water repellency. Exemplary concentrations of the stearylated melamine may include about 3 wt. % to 10 wt. %, (e.g., about 6 wt. %). Aqueous stearylated melamine emulsions are available commercially from Omnova Solutions Inc., under the tradename SEQUAPEL™ 409. The stearylated melamine is in liquid form having a solids content of about 40 wt. percent and is mixed with a suitable copolymer latex and water to prepare binders for the mats. This material mixture has a pH of about 9, a viscosity of about 45 centipoises and is anionic. In some instances, construction board faced with fiber-reinforced composite mat that incorporates a water repellant in the binder may also be more resistant to abrasion than similar mats that don't use a water repellant.

[0033] Exemplary binders for the fiber-reinforced composite mats may include an acrylate copolymer binder latex with a GTT of about 25°C. These binders are commercially available from Noveon, Inc. of Cleveland, Ohio, under the tradename Hycar™ 26138. As delivered, this acrylate copolymer latex has a solids content of about 50 weight percent solids, and in some instances may be diluted with water to a concentration about 25 wt. percent solids before being applied to the web of fibers. A crosslinker may be added to the acrylate binder system, such as a melamine formaldehyde crosslinker in a concentration of up to about 10 wt.% (e.g., about 2 wt.% to about 5 wt.% of the binder solution weight). In some embodiments, the webs of fibers bound with the acrylate copolymer latex is smoother and the mat thinner for equivalent weight and properties than with other known binders. The binder systems do not require fluorochemical emulsions, which can be expensive.

[0034] The amount of acrylate copolymer latex binder (and any optional crosslinker) left in the wet mat during manufacture can be determined by a loss on ignition (LOI) test, the result thereof being specified as a percentage of the dry weight of the finished mat. Exemplary amounts of binder in the final mat, based on its dry weight, may range from about 15 wt.% to 35 wt.% (e.g., about 20 wt.% to about 30 wt.%; about 25 $\pm$ 2.5 wt.%, etc.). The upper limit may be dictated by process constraints and cost, while the minimum is required for adequate tensile strength.

[0035] Optionally the fiber-reinforced mats may further contain fillers, pigments, or other inert or active ingredients either throughout the mat or concentrated on a surface. For example, the mat may contain effective amounts of fine particles of limestone, glass, clay, coloring pigments, biocide, fungicide, intumescent material, or mixtures thereof. Such additives may be added for known structural, functional, or aesthetic qualities imparted thereby. These qualities include coloration, modification of the structure or texture of the surface, resistance to mold or fungus formation, and fire resistance. Flame retardants sufficient to provide flame resistance may be added (e.g., ASTM Standard E84, Class 1, by the American Society for the Testing of Materials). A biocide may added to the mat and/or aqueous slurry to resist fungal growth, its effectiveness being measurable in accordance with ASTM Standard D3273. The facer mat and gypsum layer may have a very low cellulosic fiber content from which microbes could derive nutrition. In some embodiments, any cellulosic fiber present in the mats or gypsum is only an impurity of other ingredients.

[0036] The present construction board may be faced with a fiber-reinforced composite mat having a basis weight ranging from about 0.6 to 2.2 pounds per 100 square feet (e.g., ranging from about 0.9 to 2.2 lbs./100 ft^2; about 1.7 $\pm$ 0.2 lbs./100 ft^2, etc.). Exemplary binder content of the dried and cured mats may range from about 10 wt.% to about 35 wt.%, (e.g., about 15 to about 30 wt.%; about 25 $\pm$ 3 wt.%, etc., based on the weight of the finished mat). The basis weight should be large enough to provide the mat with sufficient tensile strength for producing quality construction board. At the same time, the binder content should be limited for the mat to remain sufficiently flexible to permit it to be bent to form the corners of the board, as shown in Fig. 1. Too thick a mat may also render the board difficult to cut during installation. Such cuts are needed both for overall size and to fit the board around protrusions such as plumbing and electrical hardware.

[0037] It is conventional in the wallboard industry to characterize mat using mechanical testing machines with samples about 7.5 cm (3 inches) wide. Tests are conducted with tension applied either in the machine direction (i.e., along the mat's elongated dimension) or in the cross-machine direction (i.e., along its width). Mats having adequate strength in both the machine and cross-machine directions are required for producing gypsum board that will withstand the stresses invariably encountered in manufacturing, handling, shipping, and installing the board. It is also preferred that the combined strengths in the two directions be high for the same reason.

[0038] The present fiber-reinforced composite mats are further enhanced by their relatively low air permeability. During the construction board formation process, an aqueous slurry of cementitious material (e.g., one or more of calcium sulfate, calcium sulfate hemihydrate, and/or hydraulic setting cement) applied to the mats and susceptible to migrating though the mats and onto its outer surface. In severe cases, the slurry may seep through the mat and drip onto the underlying mat support that will then require more frequent and involved cleaning. Decreasing the air permeability of the mat also decreases the rate of migration of the slurry through the mat, which in-turn reduces the instances of slurry bleed through that can cause irregularities on the outer surface of the facer and, in severe cases, migration of the slurry unto the underlying processing equipment.

[0039] The air permeability of the mat may be measured by the air flow between reservoirs separated by the mat. One such test is called the Frazier test and is further described by ASTM Standard Method D737, with the results ordinarily being given in units of cubic feet per minute per square foot (cfm/ft^2). The test is carried out at a differential pressure of about 0.5 inches of water.

[0040] The air permeability of the present fiber-reinforced composite mats may preferably be about 250 cfm/ft^2 or less. Exemplary air permeability levels for the present mats may include a range of about 250 cfm/ft^2 to about 150 cfm/ft^2; about 250 cfm/ft^2 to about 200 cfm/ft^2; about 240 cfm/ft^2 to about 220 cfm/ft^2; about 235 cfm/ft^2 to about 225 cfm/ft^2; and about 235 cfm/ft^2 to about 230 cfm/ft^2, among other exemplary ranges. These air permeabilities produce mats for construction board that have a reduced level of bleed through for slurries set to conventional viscosities, which results in an outer facer surface with reduced roughness. In addition to the lower air permeability, the selection of the fiber blends may produce a mat with sufficient smoothness to permit direct painting without the application of tapes and/or surfacing materials (e.g., plaster) to the facer. Thus, these mats are well suited as components of construction board such as interior gypsum board.

Exemplary Processes

[0041] Fig. 2 shows selected steps in an exemplary process 200 of manufacturing a fiber-reinforced composite according to embodiments of the invention. The process 200 may include the step 202 of blending a first and second group of fibers to form a non-woven web of fibers. The first group of fibers may have an average fiber diameter of about 8 μm to about 25 μm, while the second group of fibers may have an average fiber diameter of about 0.5 μm to about 6.5 μm. An exemplary technique for the blending may include the forming of a slurry (e.g., an aqueous slurry) with the fibers. The fiber slurry may then be mechanically agitated to dispense the fibers more homogeneously through the slurry. Following the agitation, the slurry may be dispensed on a moving screen. A vacuum may be applied to remove a substantial part of the aqueous solution, which may be recycled into more solution for the slurry. With a substantial portion of the aqueous solution removed, the non-woven web of fibers is formed on the moving screen.

[0042] The non-woven web of fibers may then be contacted with a binder solution 204 to form a wet mat. The binder solution may be an aqueous binder solution applied to the web using, for example, a curtain coater or a dip-and-squeeze applicator. Excess binder solution may pass through the screen supporting the binder-coated wet mat.

[0043] The wet mat may then be cured 206 to form the fiber-reinforced composite mat. Exemplary curing techniques may include heating, among other techniques. Continuing with the moving screen technique described above, heat may be applied following the remove of excess binder though the web of fibers to evaporate any remaining water and cure the polymer precursors in the binder solution into a polymerized binder that bonds together the fibers. The heat source may be an oven though which the wet mat is conveyed on the moving screen.

[0044] In some embodiments, the process of manufacturing the fiber-reinforced mat may be a continuous process, with the moving screen providing a continuous, conveyor-like loop that may be on a slight upward incline while the fiber slurry is deposited thereon. Subsequently, the excess slurry solution is removed and the non-woven web of fibers is conveyed an area where binder solution is applied. Following the spraying, curtain coating, etc., of the binder solution, the wet mat is conveyed on the moving screen though an oven for the drying of the mat and polymerization of the binder. Exemplary heating conditions may include subjecting the wet mat to temperatures of about 120°C to about 330°C for periods of, for example, 1 to 2 minutes, less than 40 seconds, etc. The final mat may have a thickness of, for example, about 10 mils to about 30 mils.

[0045] Referring now to Fig. 3, selected steps in a process 300 for manufacturing a faced construction board according to embodiments of the invention is shown. The process 300 includes the step 302 of forming a fiber-reinforced composite mat that will act as a first facer for the construction board. The fiber-reinforced composite mat may be formed according to the processes described above.

[0046] The process 300 may further include the step 304 of distributing a slurry of construction material on the first facer to form a layer. The slurry may be an aqueous slurry that includes one or more materials selected from the group of calcium sulfate ($CaSO_4$), calcium sulfate hemihydrate ($CaSO_4.\%H_2O$), and hydraulic setting cement. The slurry may also optionally include reinforcing fibers, process control agents, biocides, flame retardants, and water repellants, among other slurry additives.

[0047] The process 300 may also include the step 306 of applying a second facer onto the top of the layer formed by the aqueous slurry to form a laminate of the slurry material sandwiched between the first facer and the second facer. The laminate may be separated 308 into individual pieces. Separation techniques may include cutting the laminate into sheets having standard dimensions for commercially sold construction board (e.g., widths of at least 2 feet, 4 feet, etc.; and lengths of at least 2 feet (e.g., about 8 ft to about 12 ft, etc.)). The individual pieces of laminate may then be dried 310 for form the final construction board that is faced to provide a smoothness sufficient to permit the dried article to be directly painted.

[0048] The present construction boards exhibit a number of desirable qualities: The fibrous mat used results in a surface that is smoother and more amenable to painting or other surface finishing processes, making them excellent candidates for interior construction board. The mat is also more flexible, facilitating the bending operations needed to fold the facer around the core during production, as illustrated for mat 14 in Fig. 1. Moreover, board incorporating the fibrous mat of the invention has a reduced tendency to generate irritating dust during cutting and handling.

EXPERIMENTAL

[0049] The following examples are presented to provide a more complete understanding of the invention. The specific techniques, conditions, materials, proportions and reported data set forth to illustrate the principles and practice of the invention are exemplary and should not be construed as limiting the scope of the invention.

Preparation and Testing of a Conventional Non-Woven Glass Fiber Mat

[0050] A non-woven glass fiber mat of types typically used as a facer for conventional gypsum board is prepared using a wet laid mat machine in the manner disclosed in U.S. Pat. No. 4,129,674, which is herein incorporated in the entirety by reference for all purposes. The mat, designated as comparative example 1, contains chopped glass fibers and is bonded together with a polymer binder. The specific materials used are set forth in Table I. The M137 and K137 glass fibers are commercially available from the Johns Manville Corporation of Denver, Colo. A conventional modified urea formaldehyde binder is applied with a curtain coating/saturation technique.

TABLE I

Constituents of Conventional Non-Woven Glass Fiber Mats		
Property		Comparative Example 1
Fiber	type	K137
	avg. length (mm)	19
	avg. fiber diam. (μm)	13
	amount (wt.%. of mat)	79
Binder	type	modified urea formaldehyde
	amount (wt.%. of mat)	21

[0051] Standard tests for characterizing the physical and mechanical properties are carried out on the comparative example mat, including basis weight per unit area, loss of weight on ignition, and thickness. The test results are summarized in Table II.

TABLE II

Physical and Mechanical Properties of Conventional Non-Woven Glass Fiber Mats	
Physical/Mechanical Property	**Comparative Example 1**
	1
Basis weight (lbs./100 sq. ft.)	2.1
LOI (%)	21
Thickness (mils)	36.5
Machine Direction (Tensile Strength lbs./3 in. width)	124
Cross Machine (" " " " ")	84
Tabor Stiffness	45
Frazier Permeability (cfm/ft^2)	625

[0052] Strengths are measured both along the web direction and across the web, using a conventional mechanical testing machine to determine the peak tensile strength of a sample about 7.5 cm wide. The stiffness is determined using the standard Taber stiffness test, wherein a 38 mm wide strip is deflected by applying force at a point 50 mm from a clamping point. The torque (in g-cm) required to achieve a 15° deflection is conventionally termed the Taber stiffness. Air permeability is measured using the Frazier test at a differential pressure of 0.5 inches of water in accordance with ASTM Method D737.

Preparation and Testing of Exemplary Fiber-Reinforced Composite Mats

[0053] Fiber blends using fibers with a diameter of 8-14 μm are combined with microfibers to increase the smoothness and density of the fiberglass facer mat produced in examples 2A-B. The present microfibers have diameters ranging from 0.5- 6.50 μm, and are produced using a flame attenuated or rotary process. The microfibers may make up 5-30 wt.% of the total mat weight.

[0054] The fiber blends produce a dense, closed, uniform, and smooth facer sheet which helps minimize gypsum bleed through, and provides protection to the gypsum core. The fiberglass mats are produced with lower air permeability and smaller pore size than the mats made in comparative example 1. Table III below shows the impact of different fiber combinations on the air permeability.

TABLE III

Constituents of Exemplary Fiber-Reinforced Composite Mats			
Property		**Example 2A**	**Example 2B**
Larger Fibers	avg. length (mm)	10	10
	avg. fiber diam. (μm)	13	13
	amount (wt.%. of mat)	80	80
Smaller Fibers	avg. length (mm)	10	10
	avg. fiber diam. (μm)	2.5	2.5
	amount (wt.%. of mat)	20	20
Binder	Type	Styrene Acrylic Copolymer	Styrene Acrylic Copolymer + Water Repellant
	amount (wt.%. of mat)	21	21

[0055] The fiber-reinforced composite mats of examples 2A-B were tested for air permeability using the Frazier test at a differential pressure of 0.5 inches of water in accordance with ASTM Method D737. Table IV lists the air permeability measurement data and the rate of penetration for an aqueous gypsum slurry.

TABLE IV

Physical Properties of Exemplary Fiber-Reinforced Composite Mats					
Example	**Basis Weight ($lbs/100ft^2$)**	**Thickness (mm)**	**Air Perm (cfm/ft^2)**	**Avg. Pore Size (μm)**	**Slurry Penetration Time (sec)**
2A	1.7	20.3	231	13.0	87
2B	1.7	19.9	233	12.9	485

[0056] The low air permeability of examples 2A&B correlate with longer slurry penetration times. The addition of the a water repellant to the binder composition in example 2B was also helpful to increase the slurry penetration time (i.e., lower the slurry penetration rate) by making the mat more hydrophobic and hence more difficult for an aqueous slurry to migrate through the mat.

[0057] Having described several embodiments, it will be recognized by those of skill in the art that various modifications, alternative constructions, and equivalents may be used without departing from the spirit of the invention. Additionally, a number of well-known processes and elements have not been described in order to avoid unnecessarily obscuring the present invention. Accordingly, the above description should not be taken as limiting the scope of the invention.

[0058] Where a range of values is provided, it is understood that each intervening value, to the tenth of the unit of the lower limit unless the context clearly dictates otherwise, between the upper and lower limits of that range is also specifically disclosed. Each smaller range between any stated value or intervening value in a stated range and any other stated or intervening value in that stated range is encompassed. The upper and lower limits of these smaller ranges may independently be included or excluded in the range, and each range where either, neither or both limits are included in the smaller ranges is also encompassed within the invention, subject to any specifically excluded limit in the stated range. Where the stated range includes one or both of the limits, ranges excluding either or both of those included limits are also included.

[0059] As used herein and in the appended claims, the singular forms "a", "an", and "the" include plural referents unless the context clearly dictates otherwise. Thus, for example, reference to "a process" includes a plurality of such processes and reference to "the facer" includes reference to one or more facers and equivalents thereof known to those skilled in the art, and so forth.

[0060] Also, the words "comprise," "comprising," "include," "including," and "includes" when used in this specification and in the following claims are intended to specify the presence of stated features, integers, components, or steps, but they do not preclude the presence or addition of one or more other features, integers, components, steps, acts, or groups.

Claims

1. A fiber-reinforced composite mat comprising:

a non-woven web of fibers, wherein the fibers comprise:

a first group of fibers having an average fiber diameter from about 8 μm to about 25 μm; and
a second group of fibers having an average fiber diameter from about 0.5 μm to about 6.5 μm; and
a binder to bond together the non-woven web of fibers into the fiber reinforced composite, wherein the composite has an air permeability of 250 cfm/ft^2 or less.

2. The fiber-reinforced composite of claim 1, wherein the air permeability of the composite is 250 cfm/ft^2 to about 150 cfm/ft^2, preferably 250 cfm/ft^2 to about 200 cfm/ft^2, most preferably about 230 cfm/ft^2 to about 235 cfm/ft^2.

3. The fiber-reinforced composite of claim 1, wherein the first group of fibers have an average fiber diameter of about 13 μm.

4. The fiber-reinforced composite of claim 1, wherein the second group of fibers have an average fiber diameter of about 2.5 μm.

5. The fiber-reinforced composite of claim 1 wherein:

the first group of fibers comprise about 70 wt.% to about 90 wt.% of a total weight of fibers; and
the second group of fibers comprise about 10 wt.% to about 30 wt.% of the total weight of fibers, preferably about 20 wt.% of the total weight of the fibers.

6. The fiber-reinforced composite of claim 1, wherein the thickness of the fiber-reinforced composite comprises about 10 mils to about 30 mils.

7. The fiber-reinforced composite of claim 1, wherein the binder comprises a styrene-acrylic copolymer.

8. The fiber-reinforced composite of claim 1, wherein the binder comprises a water repellant additive.

9. The fiber-reinforced composite of claim 1, wherein the composite is a facer for a building material.

10. The fiber-reinforced composite of claim 1, wherein the building material comprises gypsum board.

11. The fiber reinforced composite of claim 1, wherein the fibers are selected from the group consisting of glass, mineral, wool, ceramic, carbon, metal, refractory materials, and mixtures thereof.

12. The fiber reinforced composite of claim 1, wherein fibers are glass fibers selected from the group consisting of E glass, C glass, T glass, sodium borosilicate glass, and mixtures thereof.

13. A gypsum board comprising:

a fiber-reinforced composite facer affixed to at least one surface of the gypsum board, wherein the facer comprises:

a non-woven web of fibers, wherein the fibers comprise:

a first group of fibers having an average fiber diameter from about 8 μm to about 25 μm; and
a second group of fibers having an average fiber diameter from about 0.5 μm to about 6.5 μm; and
a binder to bond together the non-woven web of fibers into the fiber reinforced composite,
wherein the fiber-reinforced composite facer has an air permeability of 250 cfm/ft^2 or less.

14. The gypsum board of claim 13, wherein the gypsum board comprises two or more of the fiber-reinforced composite facers.

15. A process for manufacturing a fiber-reinforced composite, the process comprising:

blending a first group of fibers having an average fiber diameter from about 8 μm to about 25 μm with a second group of fibers having an average fiber diameter from about 0.5 μm to about 6.5 μm to form a non-woven web of fibers;
contacting the non-woven web of fibers with a binder solution to form a wet mat; and
curing the wet mat to form a fiber-reinforced composite mat, wherein the fiber-reinforced composite mat has an air permeability of 250 cfm/ft^2 or less.

16. The process of claim 15, wherein the process further comprises applying an aqueous slurry to a surface of the fiber-reinforced composite mat, wherein the slurry comprises at least one material selected from the group consisting of calcium sulfate, calcium sulfate hemi-hydrate, and hydraulic setting cement.

17. The process of claim 15, wherein the process further comprises:

providing a first facer comprising the fiber-reinforced composite mat;
distributing an aqueous slurry to form a layer on the first facer, wherein the aqueous slurry comprises at least one material selected from the group consisting of calcium sulfate, calcium sulfate hemi-hydrate, and hydraulic setting cement;
applying a second facer onto the top of the layer formed from the aqueous slurry to form a laminate;

separating the laminate into individual pieces; and
drying the pieces,
wherein the first facer provides a first face of the dried piece with a smoothness sufficient to permit the dried article to be directly painted.

18. The method of claim 17, where the dried piece comprises a piece of gypsum board.

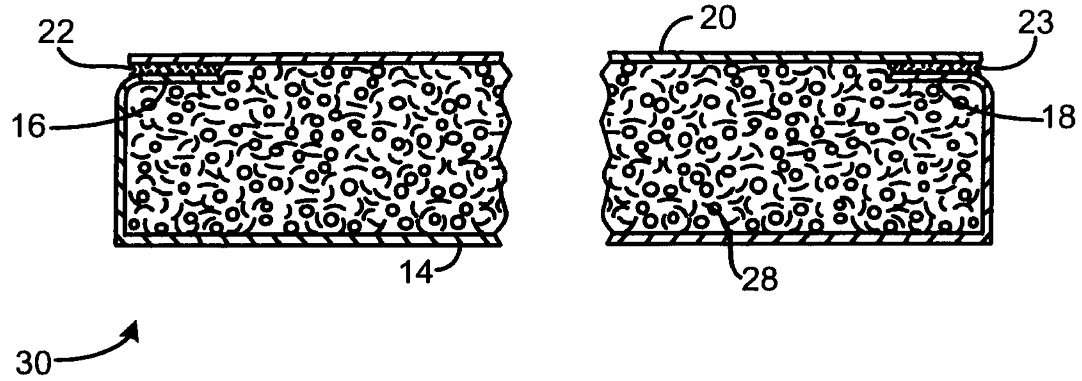
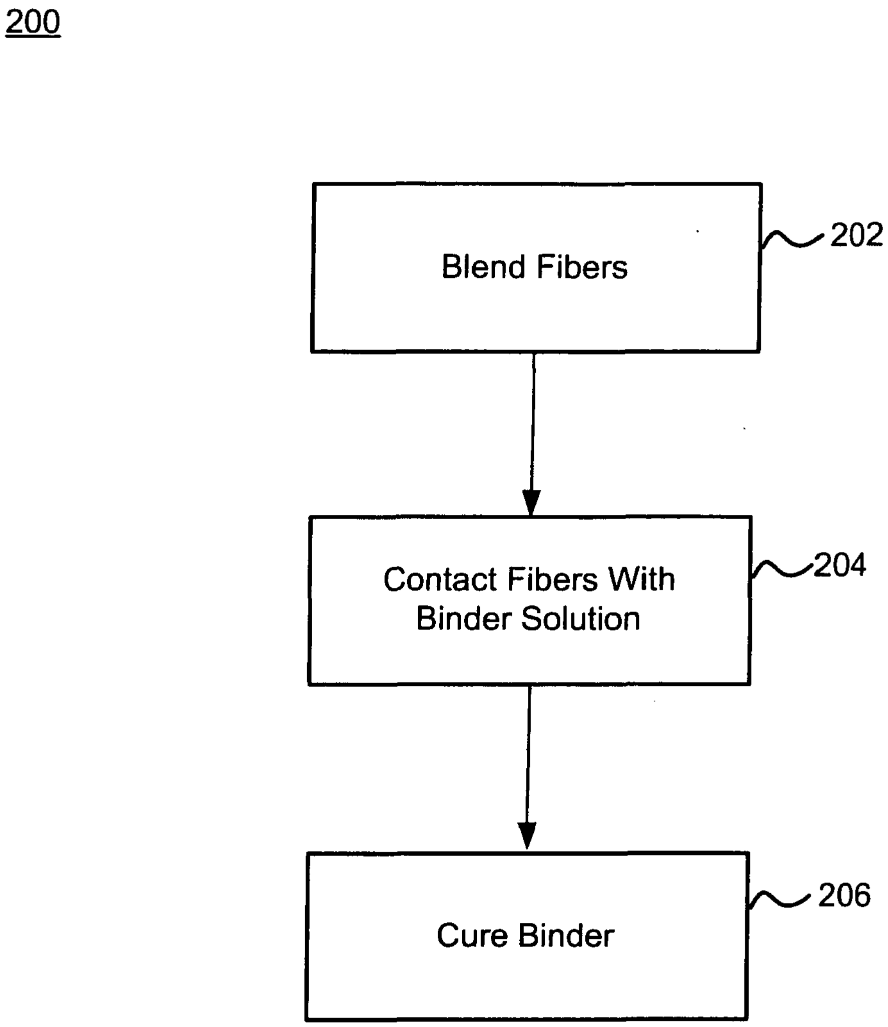


Fig. 1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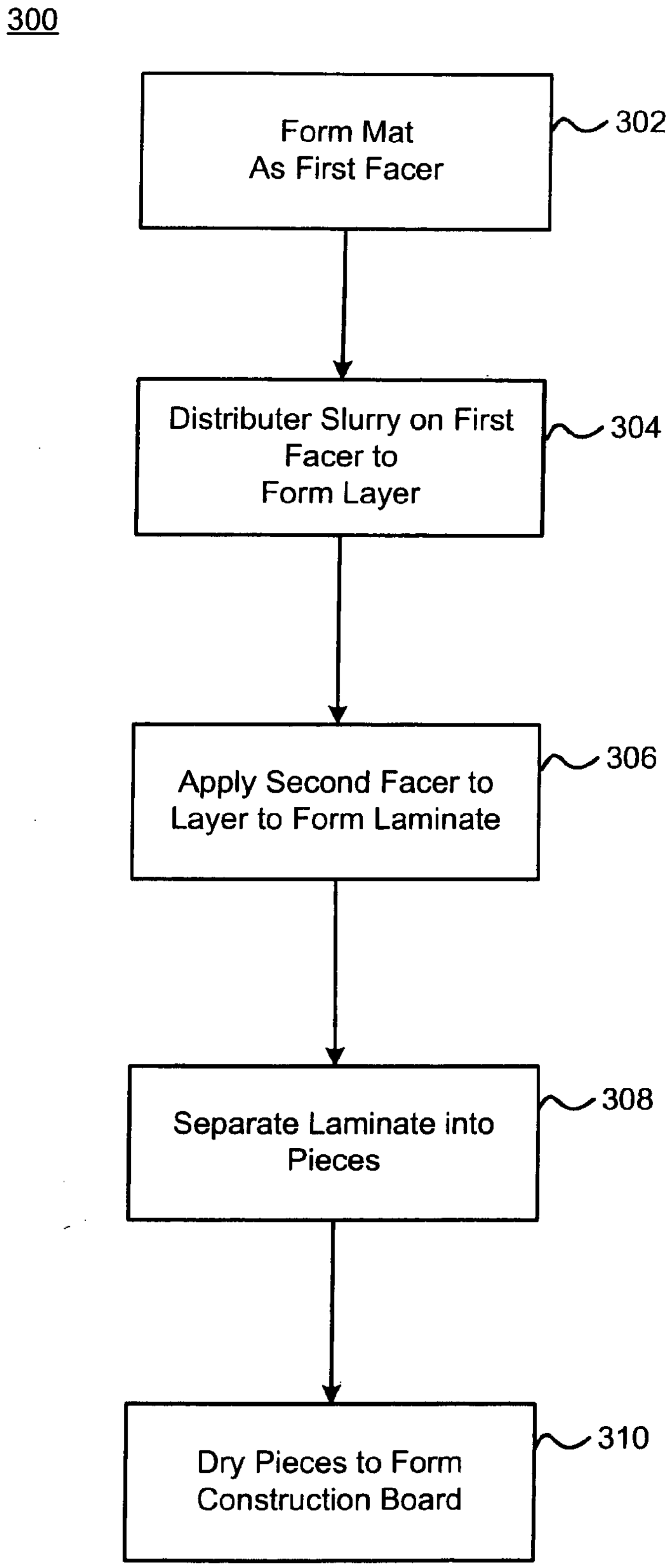
Blend Fibers
202
Contact Fibers With Binder Solution
204
Cure Binder
206

Fig. 2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As First Facer
302
Distributer Slurry on First
Facer to
Form Layer
304
Apply Second Facer to
Layer to Form Laminate
306
Separate Laminate into
Pieces
308
Dry Pieces to Form
Construction Board
310

Fig. 3

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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