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(54) Title: MEMBRANE-READY FIBROUS FACED GYPSUM PANELS, APPARATUS, AND METHODS

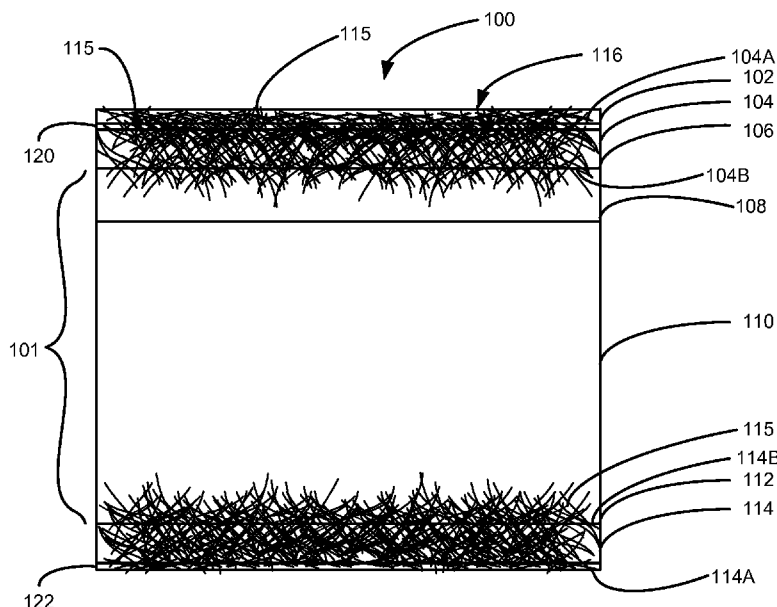


FIG. 1

(57) Abstract: Membrane-ready fibrous
faced gypsum panels, methods, and appar-
atus are provided. The panels include a first
fibrous mat having a first surface and a
second surface, a second fibrous mat hav-
ing a first surface and a second surface, a
gypsum core in contact with the second sur-
faces of the first and second fibrous mats,
and a material coating that covers the first
surface of the first fibrous mat and forms a
substantially smooth outer surface.



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MEMBRANE-READY FIBROUS FACED GYPSUM PANELS, APPARATUS, AND METHODS

Related Applications

[0001] This application claims the benefit of U.S. Provisional Application No. 61/870,341, filed on August 27, 2013, which is incorporated by reference herein in its entirety.

[0002] Reference is further made to U.S. Provisional Application No. 61/870,602, filed on August 27, 2013, entitled COATING AND BINDER COMPOSITIONS FOR GYPSUM BOARDS, which is incorporated by reference herein in its entirety.

BACKGROUND

[0003] The present disclosure relates generally to the field of panels for use in building construction, and more particularly to membrane-ready fibrous faced gypsum panels for use with air barrier membranes.

[0004] Many modern building codes require the use of vapor barriers in construction to protect the building from air and water penetration. For example, building codes in eastern Canada and the northeastern United States now require air barriers to be used in all construction. Moreover, the 2006 International Building Code/International Residential Code (IBC/IRC) requires the use of a weather restrictive air barrier for all new construction. Air barriers may be formed from a variety of materials and structures and applied to the surface of construction sheathing materials (e.g., fibrous faced gypsum panels).

[0005] A popular air barrier system is self-adhered (i.e., “peel and stick”) membranes. Current peel and stick membranes require the surface of the sheathing material to be coated with adhesive in the field before the membrane may be applied, which significantly slows down the construction process. Additionally, the adhesive application step is estimated to cost the contractor \$0.20/ft² (\$2.15/m²) in labor and materials.

[0006] Accordingly, it would be desirable to provide a sheathing panel that can be used with peel and stick membranes and requires minimal or no field applied adhesive.

SUMMARY

[0007] In one aspect, the present disclosure is directed to a method of making an unattached, membrane-ready, exterior gypsum panel, including:

depositing a gypsum slurry onto a surface of a first fibrous mat;

depositing a second fibrous mat onto a surface of the gypsum slurry opposite the first fibrous mat, such that a surface of the second fibrous mat contacts the gypsum slurry, to form a gypsum sandwich structure;

drying the gypsum sandwich structure;

applying an adhesive coating composition to a surface of the first fibrous mat opposite the gypsum slurry, such that the adhesive coating covers at least a portion of the surface of the first fibrous mat; and

drying the adhesive coating composition to form a material coating on the first fibrous mat and form a membrane-ready gypsum panel, wherein the material coating includes a substantially smooth outer surface.

[0008] In another aspect, the present disclosure is directed to an apparatus for fabricating membrane-ready gypsum panels, including:

a board line for transporting a first fibrous mat;

a depositing mechanism configured to deposit a gypsum slurry onto a surface of the first fibrous mat;

a conveyor configured to deposit a second fibrous mat onto a surface of the gypsum slurry opposite the first fibrous mat, such that a surface of the second fibrous mat contacts the gypsum slurry, to form a gypsum sandwich structure on the board line;

a dryer for drying the gypsum sandwich structure;

an applicator configured to apply an adhesive coating composition to a surface of the first fibrous mat opposite the gypsum slurry, such that the adhesive coating composition covers the surface of the first fibrous mat; and

a dryer for drying the adhesive coating composition to provide a material coating and form a membrane-ready gypsum panel, wherein the material coating includes a substantially smooth outer surface.

[0009] In yet another aspect, the present disclosure is directed to a membrane-ready gypsum panel, including:

a first fibrous mat having a first surface and a second surface;

a second fibrous mat having a first surface and a second surface;

a gypsum core in contact with the second surfaces of the first and second fibrous mats;

and

a material coating that covers at least a portion of the first surface of the first fibrous mat and forms a substantially smooth outer surface thereon, wherein the material coating is derived from an adhesive coating composition including a polymeric adhesive. In one embodiment, the polymeric adhesive includes an aqueous emulsion selected from acrylics, styrene acrylics, vinyl acrylics, styrene acetate acrylics, and combinations thereof.

[0010] In yet another embodiment, the present disclosure is directed to a method for coating an unattached, exterior gypsum wallboard to make the wallboard membrane-ready, including the steps of:

applying an adhesive coating composition to an exposed surface of a fibrous mat of an exterior gypsum panel, wherein the adhesive coating composition includes water and an acrylic latex; and

drying the adhesive coating composition to form a material coating, wherein the coating provides a non-tacky, substantially smooth outer surface capable of adhering to an adhesive-backed membrane, and the coating composition penetrates the fibrous mat to enhance the cohesive strength thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] Referring now to the drawings, which are meant to be exemplary and not limiting, and wherein like elements are numbered alike:

[0012] FIG. 1 is a cross-sectional view of an embodiment of a membrane-ready gypsum panel.

[0013] FIG. 2 is a schematic of an embodiment of an in-process coating application apparatus.

[0014] FIG. 3 is a schematic of an embodiment of a post-process coating application apparatus.

DETAILED DESCRIPTION

[0015] Disclosed herein are membrane-ready gypsum panels and methods and apparatus for manufacturing membrane-ready gypsum panels. The membrane-ready panels have a substantially smooth outer surface that can be used with peel and stick membranes using minimal or no field-applied adhesive.

[0016] As used herein, the term “membrane-ready” refers to panels that are configured with a material coating layer during the panel manufacturing process and have a substantially smooth outer surface that can be used with peel and stick membranes using minimal or no field-applied adhesive.

[0017] As used herein, the terms “peel and stick,” “self-adhering,” or “self-sealing,” membranes refer to adhesive-backed air and moisture impermeable membranes, or moisture permeable membranes, commonly used in the building construction industry,. For example, in some embodiments the self-adhering membranes may be asphalt backed membranes. Exemplary self-adhering membranes include PERM-A-BARRIER wall membranes or wall flashings, commercially available from Grace Construction (Cambridge, MA); BLUESKIN SA or LT, commercially available from Henry Company (El Segundo, CA); MIRADRI 860 or 861, commercially available from Carlisle Coatings and Waterproofing (Wylie, Texas); and WIP 300 HT or 200, commercially available from Carlisle Residential (Carlisle, PA). In other embodiments, the membranes may include nonwoven moisture permeable membranes such as those available from E.I DuPont, Wilmington, DE, under the trade designation TYVEK.

PANELS

[0018] As shown in FIG. 1, in one embodiment, a membrane-ready gypsum panel **100** includes a first fibrous mat **104** having a first surface **104A** and a second surface **104B**, and a second fibrous mat **114** having a first surface **114A** and a second surface **114B**. A gypsum core **101** is in contact with the second surfaces **104B**, **114B** of the first and second fibrous mats **104**, **114**. A material coating **102** covers the first surface **104A** of the first fibrous mat **104** and forms a substantially smooth outer surface **116**. As used herein, the term “substantially smooth” refers to the outer surface being completely or mostly free of texturing and voids. For example, the substantially smooth outer surface may have a board finish from about a level 1 finish to about a level 5 finish, according to ASTM C11, ASTM C840, and GA-216 standards for gypsum boards. In one embodiment, the outer surface has a level 5 finish.

[0019] In certain embodiments, the panels **100** have a thickness from about ¼ inch (0.64 cm) to about 1 inch (2.54 cm). For example, the panels **100** may have a thickness of about ½ inch (1.27 cm), about ¾ inch (1.91 cm), or about 7/8 inch (2.22 cm).

[0020] The gypsum core **101** may be similar to those used in other gypsum products, such as, for example, gypsum wallboard, dry wall, gypsum board, gypsum lath, and gypsum sheathing. For example, the gypsum core **101** may be formed by mixing water with powdered anhydrous calcium sulfate or calcium sulfate hemi-hydrate, also known as calcined gypsum, to form an aqueous gypsum slurry, and thereafter allowing the slurry mixture to hydrate or set into calcium sulfate dihydrate, a relatively hard material. The gypsum core may include about 80 weight percent or above of set gypsum (i.e., fully hydrated calcium sulfate). For example, the gypsum core may include about 85 weight percent set gypsum. The gypsum core may also include a variety of additives, such as accelerators, set retarders, foaming agents, and dispersing agents.

[0021] In certain embodiments, the gypsum core **101** also includes reinforcing fibers, such as chopped glass fibers. For example, the gypsum core **101** may include up to about 0.6 pounds of reinforcing fibers per 100 square feet (29.3 g/m^2) of panel. For example, the gypsum core **101** may include about 0.3 pounds of reinforcing fibers per 100 square feet (14.6 g/m^2) of panel. The reinforcing fibers may have a diameter between about 10 and about 17 microns and have a length between about 1/4 to 1/2 inch (0.64 to 0.12 cm).

[0022] The gypsum core **101** may also include an additive that improves the water-resistant properties of the core. Such additives may include, for example, poly(vinyl alcohol), optionally including a minor amount of poly(vinyl acetate); metallic resins; wax, asphalt, or mixtures thereof, for example as an emulsion; a mixture of wax and/or asphalt and cornflower and potassium permanganate; water insoluble thermoplastic organic materials such as petroleum and natural asphalt, coal tar, and thermoplastic synthetic resins such as poly(vinyl acetate), poly(vinyl chloride), and a copolymer of vinyl acetate and vinyl chloride, and acrylic resins; a mixture of metal rosin soap, a water soluble alkaline earth metal salt, and residual fuel oil; a mixture of petroleum wax in the form of an emulsion and either residual fuel oil, pine tar, or coal tar; a mixture of residual fuel oil and rosin; aromatic isocyanates and diisocyanates; organopolysiloxanes; siliconates; a wax emulsion and a wax-asphalt emulsion, each optionally with potassium sulfate, alkali, or alkaline earth aluminates, and Portland cement; a wax-asphalt emulsion prepared by adding to a blend of molten wax and asphalt, an oil-soluble, water-dispersing emulsifying agent, and admixing the aforementioned with a solution of case including, as a dispersing agent, an alkali sulfonate of a polyarylmethylene condensation

product. Mixtures of these water-resistance additives may also be employed. For example, a mixture of two or more of: poly(vinyl alcohol), siliconates, wax emulsion, and wax-asphalt emulsion of the aforementioned types, may be used to improve the water resistance of the gypsum core **101**.

[0023] In certain embodiments, the gypsum core **101** has a density from about 130 pounds per 100 square feet to about 145 pounds per 100 square feet ($6347.1 - 7079.5 \text{ g/m}^2$). For example, the gypsum core **101** may have a density of about 135 pounds per 100 square feet (6591.3 g/m^2). In certain embodiments, the gypsum core **101** includes a first gypsum layer **108** in contact with the second surface **104B** of the first fibrous mat **104** and a second gypsum layer **110** having a lower density than the first gypsum layer **108** and in contact with the first gypsum layer **108** and the second surface **114B** of the second fibrous mat **114**. For example, the first gypsum layer **108** may be a densified gypsum layer having a density about 15 to about 25 percent greater than the density of the second gypsum layer **110**.

[0024] As shown in FIG. 1, in certain embodiments, both surfaces of the **101** gypsum core are faced with coated fibrous mats **104**, **114**. The mats **104**, **114** include a plurality of fibers **115** that are typically enmeshed or entangled with the gypsum core **101** at the surface interfaces **106**, **112**.

[0025] In certain embodiments, the fibrous mats **104**, **114** include a non-woven mat of fiber material that is capable of forming a strong bond with the set gypsum of the gypsum core **101** through a mechanical-like interlocking between the interstices between the fibers **115** of the fibrous mats **104**, **114** and portions of the gypsum core **101**. Examples of fiber materials for use as the fibers **115** in the non-woven mats **104**, **114** include mineral-type materials such as glass fibers, cellulosic fibers (e.g., paper), synthetic resin fibers, and mixtures or blends thereof. Both chopped strands and continuous strands may be used.

[0026] In certain embodiments, the mats **104**, **114** are non-woven fiberglass mats. For example, the glass fibers **115** in the mats **104**, **114** may an average diameter from about 10 to about 17 microns and an average length from about $\frac{1}{4}$ inch to about $\frac{3}{4}$ inch (0.64 to 1.91 cm). For example, the glass fibers **115** may have an average diameter of 13 microns (i.e., K fibers) and an average length of $\frac{3}{4}$ inch. In certain embodiments, the non-woven fiberglass mats **104**, **114** have a basis weight from about 1.5 pounds to about 2.5 pounds per 100 square feet ($73.2 -$

122.1 g/m²) of the mat. The mats **104**, **114** may each have a thickness from about 20 mils to about 26 mils.

[0027] The strands of the fibers **115** may be bonded together to form a unitary mat structure by a suitable adhesive. For example, the adhesive may be an amine-aldehyde resin (e.g., urea-formaldehyde resin) adhesive, optionally modified with a thermoplastic extender or cross-linker, such as an acrylic cross-linker, or an acrylate adhesive resin.

[0028] The fibrous mats **104**, **114** may each also include a mat coating **120**, **122** on one or both surfaces of the non-woven fibrous mat. For example, as shown in FIG. 1, the first and second fibrous mats **104**, **114** may each be coated on the surface of the mat opposite the gypsum slurry **101**. The mat coating **120**, **122** may include a filler and an adhesive binder. In certain embodiments, the binder makes up from about 1% to about 17% of the mat coating **120**, **122**, on a dry weight basis, with the balance being the filler. Thus, the weight ratio of the filler to the binder may be from about 5:1 to about 20:1. In one embodiment, the mat coating **120**, **122** has a basis weight from about 3 to about 6 pounds of solids per 100 square feet (146.5 – 292.9 g/m²) of the non-woven fibrous mat **104**, **114**.

[0029] In certain embodiments, the filler of the mat coating **120**, **122** is an inorganic, mineral filler. For example, the filler may be ground limestone (calcium carbonate), clay, sand, mica, talc, gypsum (calcium sulfate dihydrate), aluminum trihydrate (ATH), antimony oxide, or any combination thereof. The filler may be in a particulate form. For example, the filler may have a particle size such that at least 95% of the particles pass through a 100 mesh wire screen.

[0030] In certain embodiments, the filler may inherently contain a naturally occurring inorganic adhesive binder. For example, the filler may be limestone containing quicklime (CaO), clay containing calcium silicate, sand containing calcium silicate, aluminum trihydrate containing aluminum hydroxide, cementitious fly ash, or magnesium oxide containing either the sulfate or chloride of magnesium, or both. In certain embodiments, the filler may include an inorganic adhesive binder as a constituent, cure by hydration, and act as a flame suppressant. For example, the filler may be aluminum trihydrate (ATH), calcium sulfate (gypsum), and the oxychloride and oxysulfate of magnesium.

[0031] In certain embodiments, the binder of the mat coating **120**, **122** is a polymer latex adhesive. For example, the binder may be styrene-butadiene-rubber (SBR), styrene-butadiene-styrene (SBS), ethylene-vinyl-chloride (EVC), poly-vinylidene-chloride (PVdCl) and

poly(vinylidene) copolymers, modified poly-vinyl-chloride (PVC), poly-vinyl-alcohol (PVOH), ethylene-vinyl-acetate (EVA), poly-vinyl-acetate (PVA) and polymers and copolymers containing units of acrylic acid, methacrylic acid, their esters and derivatives thereof (acrylic-type polymers), such as styrene-acrylate copolymers.

[0032] In one embodiment, the binder is a hydrophobic, UV resistant polymer latex adhesive. For example, the hydrophobic, UV resistant polymer latex binder adhesive may be based on a (meth)acrylate polymer latex, wherein the (meth)acrylate polymer is a lower alkyl ester, such as a methyl, ethyl or butyl ester, of acrylic and/or methacrylic acids, and copolymers of such esters with minor amounts of other ethylenically unsaturated copolymerizable monomers (such as styrene) which are known to the art to be suitable in the preparation of UV resistant (meth)acrylic polymer latexes.

[0033] In certain embodiments, the mat coating composition that forms the mat coatings **120**, **122** also includes water and/or other optional ingredients such as colorants (e.g., dyes or pigments), thickeners or rheological control agents, defoamers, dispersants, and preservatives.

[0034] A material coating **102** covers the first surface **104A** of the first fibrous mat **104** and forms a substantially smooth outer surface **116**. The material coating **102** is derived from an adhesive composition that can include a wide variety of polymeric adhesives. A variety of polymers may be employed in the adhesive composition, including latex polymers, water-dispersible polymers, water-reducible polymers, and oil-modified polymers.

[0035] Suitable latex polymers include (meth)acrylics, vinyls, polyesters, polyurethanes, polyamides, chlorinated polyolefins, ethylene vinyl acetate, polybutadiene, polyvinylidene, styrene acrylics, vinyl acrylics, vinyl versatic acid esters, styrene/butadiene, epoxy esters, polyureas, polysiloxanes, silicones, fluorinated copolymers, and mixtures or copolymers thereof. Such latex polymers normally contain at least polymeric particles, water, and one or more emulsifiers. The waterborne latex polymer particles may include one or more functional groups capable of reacting with an external crosslinker, and such external crosslinker may also be a part of the disclosed compositions.

[0036] Suitable latex polymers are typically stabilized using one or more nonionic or anionic emulsifiers (viz., surfactants), used either alone or together. If desired, the latex polymers may be stabilized with an alkali-soluble polymer. A water-soluble free radical initiator is typically used in the polymerization of a latex polymer. The latex polymer may optionally also

be functionalized with olefinic groups or other crosslinkable groups where it is desired to enable the latex polymer to participate in radiation curing.

[0037] Exemplary commercially available latex polymers include ALBERDINGK AC 2514, ALBERDINGK AC 25142, ALBERDINGK AC 2518, ALBERDINGK AC 2523, ALBERDINGK AC 2524, ALBERDINGK AC 2537, ALBERDINGK AC 25381, ALBERDINGK AC 2544, ALBERDINGK AC 2546, ALBERDINGK MAC 24, and ALBERDINGK MAC 34 polymer dispersions from Alberdingk Boley, Inc.; AQUAMAC 720 from Hexion Specialty Chemicals; EPS 2538 acrylic latex, EPS 2540 styrene acrylic latex and EPS 2725 acrylic latex emulsions from Engineered Polymer Solutions, Inc. ("EPS"); RESYN™ 7305 vinyl acrylic emulsion from Celanese Emulsion Polymers; RHOPLEX™ 3131-LO, RHOPLEX E-693, RHOPLEX E-940, RHOPLEX E-1011, RHOPLEX E-2780, RHOPLEX HG-95P, RHOPLEX HG-700, RHOPLEX HG-706, RHOPLEX PR-33, RHOPLEX TR-934HS, RHOPLEX TR-3349 and RHOPLEX VSR- 1050 acrylic emulsions from Rohm and Haas Co.; RHO SHIELD™ 636 and RHOSHIELD 3188 polymer dispersions from Rohm and Haas Co.; JONCRYL™ 538, JONCRYL 1552, JONCRYL 1972, JONCRYL 1980, JONCRYL 1982, JONCRYL 1984 and JONCRYL 8383 acrylic emulsions from BASF Resins; NEOCRYL™ A-1127, NEOCRYL A-6115, NEOCRYL XK-12, NEOCRYL XK-90, NEOCRYL XK-98 and NEOCRYL XK-220 acrylic latex polymers from DSM NeoResins, Inc., and mixtures thereof.

[0038] The adhesive composition may alternatively or optionally contain a water-dispersible or water-reducible polymer. Exemplary water-dispersible polymers include polyurethanes, polyamides, chlorinated polyolefins, (meth)acrylics, vinyls, polyesters, and mixtures or copolymers thereof. The water-dispersible polymer typically will include as a part of the polymer a group or groups which render the polymer dispersible by itself in water. The water-dispersible polymer may optionally also be functionalized with olefinic groups or other crosslinkable groups where it is desired to enable the water-dispersible polymer to participate in radiation curing.

[0039] Exemplary commercially available water-dispersible or water-reducible polymers include acrylic copolymers available from BASF Corporation under the trade designation JONCRYL; PARALOID™ WR-97 water-reducible acrylic resin from Dow Coating Materials; AROLON™ 562-G2-70 water-reducible acrylic resin from Reichhold Inc.; MAINCOTE™ HG-54D and RHOPLEX™ WL-96 waterborne acrylic resins from Rohm and Haas Co.;

AQUAMAC™ thermoplastic styrene acrylic latex resin from Momentive Specialty Chemicals Inc.; CARBOSET™ CR-760 and CARBOSET CR-765 thermoplastic styrene-acrylic copolymer emulsions from Lubrizol Advanced Materials, Inc.; TEXICRYL™ acrylic and styrene acrylate dispersions from Scott Bader Inc.; TEXIGEL™ dispersions from Scott Bader Inc.; EPS 6208 water-reducible alkyd resin from EPS; ANCAREZ™ AR555 water-reducible epoxy resin from Air Products and Chemicals, Inc.; BECKOPOX™ EP386W/56WA water-reducible epoxy resin from Cytec Industries; EPS 3216 water-reducible polyester resin from EPS; EPS 4213 polyurethane dispersion from EPS; BAYHYDROL™ PR 240 polyurethane dispersion from Bayer Material Science; and POLIDENE™ vinylidene chloride copolymer emulsions from Scott Bader Inc.

[0040] Oil-modified polymers may also be used as latex polymers or if appropriately stabilized as water-dispersible polymers. As used herein, oil-modified polymers include polymers that contain oils or oil based derivatives such as glyceride oils (monoglycerides, diglycerides, and the like), fatty acids, fatty amines, and mixtures thereof. Examples of such oil-modified polymers include alkyds, oil-modified polyurethanes, oil-modified polyamides, oil-modified acrylics, and mixtures or copolymers thereof.

[0041] In various embodiments, the adhesive compositions that give rise to the material coating **102** contain about 90 to about 30% by weight latex or water-dispersible polymer based on the total weight of the non-volatile components in the coating system, about 80 to about 35% by weight, or about 70 to about 40% by weight. If a water-dispersible polymer is also employed, it may be present in an amount less than the amount of latex polymer.

[0042] In some embodiments, aqueous emulsions such as acrylics, styrene acrylics, and vinyl acrylics have been found to work well in the adhesive composition. In some embodiments, the polymers and copolymers in these emulsions have a glass transition temperature (T_g) of about -45 °C to about 115 °C, and in other embodiments the polymers and copolymers can have glass transition temperatures (T_g) of about 0 °C to about 30 °C. In some embodiments, (meth)acryl monomers can be copolymerized with styrene or vinyl monomers, and may be incorporated into the gypsum slurry in water-borne or 100% solids form. In some embodiments, the resins range in pH from about 1.5 to about 11, or from about 1.78 to about 10.0, have particle sizes that range from about 30 to about 400 nanometers, and NVM ranges from about 21% to about 65%.

[0043] Suitable polymers for use in the adhesive composition include, but are not limited to, acrylic aqueous emulsions available from EPS, under the trade designations EPS 2103, EPS 2111, EPS 2113, EPS 2117, EPS 2257, EPS 2293, EPS 2705, EPS 2708, EPS 2757 and EPS 2772, as well as styrene acrylic aqueous emulsions EPS 2272, EPS 2507, EPS 2510, EPS 2512, EPS 2514, EPS 2526, EPS 2533, EPS 2535, EPS 2537, EPS 2548, EPS 2550, EPS 2561, EPS 2568, EPS 2572, and EPS 2851. Other examples include vinyl acetate acrylic copolymer emulsions available from Dow Chemical Co., Midland, MI, under the trade designation Rovace, particularly Rovace 9100.

[0044] In various embodiments, the adhesive composition may also include a wide range of additives including, but not limited to, water, glass, paper or wood fibers, mineral fillers, strength additives, accelerators, retarders, crystallized gypsum particles, surfactants, dispersants, fire retarders, water absorbers, water repellants, mold inhibitors, ultraviolet (UV) light resistant compounds, pH adjusters, rheology modifiers, flow control agents, defoamers, and the like.

[0045] Suitable thickeners may include hydroxyethyl cellulose; hydrophobically modified ethylene oxide urethane; processed attapulgite, a hydrated magnesium aluminosilicate; and other thickeners known to those of ordinary skill in the art. For example, thickeners may include CELLOSIZ QP-09-L and ACRY SOL RM-2020NPR, commercially available from Dow Chemical Company (Philadelphia, PA); and ATTAGEL 50, commercially available from BASF Corporation (Florham Park, NJ). In other embodiments, nonionic surfactants may be incorporated into the adhesive composition. Examples include, but are not limited to, compounds of block copolymers based on ethylene oxide and propylene oxide available under the trade designation Pluronic from BASF SE, such as Pluronic L31 (difunctional block copolymer terminating in primary hydroxyl groups), Pluronic 17R2 (difunctional block copolymer terminating in secondary hydroxyl groups), and Pluronic 25R2 (difunctional block copolymer terminating in secondary hydroxyl groups). These compounds have an HLB value of about 1 to about 7. Other suitable surfactants include nonionic octylphenol ethoxylates and nonionic nonylphenol ethoxylate available from Dow Chemical Co. under the trade designation Triton X-405 (HLB = 17-18) and Tergitol NP-10 (HLB = 13-14), as well as other nonionic surfactants like those available from Air Products and Chemicals, Allentown PA, under the trade designation Dynol, particularly Dynol 607 (HLB = 8). Other suitable surfactants may include HYDROPALAT 44, commercially available from BASF Corporation.

[0046] Defoamers may include multi-hydrophobe blend defoamers and other defoamers known to those of ordinary skill in the art. For example, defoamers may include FOAMASTER SA-3, commercially available from BASF Corporation.

[0047] Fillers may include inorganic, mineral fillers, such as sodium-potassium alumina silicates, microcrystalline silica, talc (magnesium silicate), and the like. For example, fillers may include MINEX 7, commercially available from the Cary Company (Addison, IL); IMSIL A-10, commercially available from the Cary Company; and TALCRON MP 44-26, commercially available from Specialty Minerals Inc. (Dillon, MT).

[0048] Biocides may include broad-spectrum microbiocides that prohibit bacteria and fungi growth, antimicrobials such as those based on the active diiodomethyl-ptolylsulfone, and other compounds known to those of ordinary skill in the art. For example, biocides may include KATHON LX 1.5 %, commercially available from Dow Chemical Company, POLYPHASE 663, commercially available from Troy Corporation (Newark, NJ), and AMICAL Flowable, commercially available from Dow Chemical Company. Biocides may also act as preservatives.

[0049] Ultraviolet (UV) absorbers may include encapsulated hydroxyphenyl-triazine compositions and other compounds known to those of ordinary skill in the art, for example, TINUVIN 477DW, commercially available from BASF Corporation.

[0050] Transfer agents such as polyvinyl alcohol (PVA) and other compounds may also be included in the material coating composition.

[0051] In some embodiments, the adhesive composition may optionally include an ammonia composition including ammonium hydroxide, for example, AQUA AMMONIA 26 BE, commercially available from Tanner Industries, Inc. (Southampton, PA).

[0052] These additives are optionally present in the adhesive composition at up to about 5 wt%, or at about 0.01 wt% to about 2 wt%, or about 0.1 wt% to about 1 wt%, based on the total weight of the composition.

[0053] The adhesive composition from which the material coating **102** is derived may be varied based on the type of applicator used to apply the adhesive composition to the first fibrous mat **104**. For example, for curtain coat applicators, the adhesive composition may be formulated as given in Table 1. In some embodiments, the curtain coat compositions may include a self-crosslinking latex that allows the gypsum panel **100** to be completely covered by the primer and not block when stacking.

Table 1			
Material Coating Composition for Curtain Coat Applicators			
Ingredients	Description	Composition 1 (Parts By Wt)	Composition 2 (Parts By Wt)
	Water	10.59	16.28
	Thickener	1.34	1.10
	Surfactant	0.71	1.22
	Defoamer	0.11	0.20
	Base	0.05	0.10
Minex 7	Filler	7.52	12.70
Imsil A-10	Filler	6.98	11.80
Talcron MP 44-26	Filler	7.52	12.70
	Biocide	0.47	0.40
Joncyl 1987	Self Crosslinking Latex	63.91	43.00
	UV Absorber	0.8	0.20

[0054] In another embodiment, for direct roll coat applicators, the adhesive composition may be formulated as given in Table 2. The direct roll coating composition may include a PVOH transfer agent that allows for higher application rates with the increased smoothness needed for improved interfacial adhesion.

Table 2		
Material Coating Composition for Direct Roll Coat Applicators		
Ingredients	Description	Composition (Parts By Wt)
Water	Water	29.36
	Thickener	1.19
	Surfactant	1.43
	Defoamer	0.2
	Base	0.15
Minex 4	Filler	18.88
Imsil A-10	Filler	12.92
Talcron MP 44-26	Filler	11.92
	Biocide	0.55

Acrylic emulsion	Latex	22.66
PVA Solution	Transfer Agent	0.74

[0055] In another embodiment, for airless applicators, the adhesive composition may be formulated as given in Table 3. The airless coating composition may have a reduced viscosity to allow a more uniform deposition due to finer atomization of the coating.

Table 3		
Material Coating Composition for Airless Applicators		
Ingredients	Description	Composition (Parts By Wt)
	Water	29.23
	Thickener	0.90
	Surfactant	1.40
	Defoamer	0.20
	Base	0.15
Minex 4	Filler	19.00
Imsil A-10	Filler	13.00
Talcron MP 44-26	Filler	12.00
	Biocide	0.55
Acrylic emulsion	Latex	22.84
PVA Solution	Transfer Agent	0.73

[0056] In certain embodiments, the adhesive composition giving rise to the material coating **102** has an applied weight from about 5 pounds per 1000 sq ft (24.41g per 1000 sq m) to about 100 pounds per 1000 sq ft (4882.43 g per 1000 sq m). For example, the material coating **102** may have an applied weight from about 6 pounds per 1000 sq ft (29.29 g per 1000 sq m) to about 10 pounds per 1000 sq ft (48.82 g per 1000 sq m). In certain embodiments, the adhesive composition from which the material coating **102** is derived contains solids in an amount from about 35 to about 100 weight percent, or from about 50 to about 60 weight percent.

[0057] The adhesive composition giving rise to the material coating **102** may be applied in an amount and composition such that a self-adhering membrane (not shown in FIG. 1) applied directly to the outer surface **116** of the membrane-ready gypsum panel **100** has a peel strength similar to a traditional self-adhering membrane applied with an adhesive primer, for example a peel strength above 3 pounds per linear inch (535.7 g/cm) at 22.2 °C. In one embodiment, the

adhesive composition giving rise to the material coating **102** is applied on the surface **104A** of the fibrous mat **104** such that a self-adhering membrane applied directly to the outer surface **116** of the membrane-ready gypsum panel **101** has a peel strength above from about 3.3 pounds per linear inch (589.3 g/cm) to above about 5.1 pounds per linear inch (910.8 g/cm). In some embodiments the fibers **115** from the fibrous mat **104** extend through the mat coating **120** (if present) and into the material coating **102**, and the adhesive composition enters the interstices between the fibers **115** such that the material coating **102** bonds to the fibrous mat **104**.

[0058] The membrane-ready gypsum panels **100** may be configured to have certain material properties to keep water or air or both from permeating the panels. For example, the membrane-ready gypsum panel **100** may have a Cobb value below about 5 grams, more preferably below 2 grams, even more preferably below 0.84 grams. In one embodiment, the membrane-ready gypsum panel **100** has a Cobb value of 0.5 grams or below. The membrane-ready gypsum panel **100** may also have a vapor permeance equal to or greater than 1.5, more preferably equal to or greater than 5, most preferably equal to or greater than 10 perms. The membrane-ready gypsum panels **100** may also have additional properties desirable for building materials. For example, the membrane-ready gypsum panel **100** may have a class 1 fire rating according to the ASTM E84 standard. The membrane-ready gypsum panel **100** may also have a mold growth resistance rating of 10 according to the ASTM D3273 standard.

METHODS & APPARATUS

[0059] Methods and apparatus for making membrane-ready gypsum panels **100** as described herein are also provided. The method of making a membrane-ready gypsum panel may include depositing a gypsum slurry onto a surface of a first fibrous mat, depositing a second fibrous mat onto a surface of the gypsum slurry opposite the first fibrous mat, such that a surface of the second fibrous mat contacts the gypsum slurry, to form a gypsum sandwich structure, drying the gypsum sandwich structure, and applying a material coating to a surface of the first fibrous mat, such that the material coating covers the surface of the first fibrous mat opposite the gypsum slurry to form a membrane-ready gypsum panel having a substantially smooth outer surface.

[0060] The first and second fibrous mats may be coated or uncoated upon contacting the gypsum slurry. In certain embodiments, both the first and second fibrous mats are coated on the

surfaces opposite the gypsum slurry. For example, coated fibrous mats may be obtained in a pre-fabricated form. For example, the fibrous may be wet-formed into a continuous non-woven web of any workable width, coated with a binder, and dried to remove excess water and cure the binder to form a fibrous mat. Any suitable method may be used to apply a mat coating (i.e., the filler and binder composition described above) to the fibrous mat, such as roller coating, curtain coating, knife coating, spray coating and the like, including combinations thereof. For example, the mat coating may be applied in an amount from about 4 to pounds to about 12 pounds of aqueous coating per 100 square feet ($195.3 - 585.9 \text{ g/m}^2$) of mat. Following application of the aqueous coating to the mat, the composition may be dried to cure the mat coating, usually by heat to form the pre-coated mat. For example, the coated fibrous mats may be prepared in accordance U.S. Patent Application Publication No. 2009/0208714, which discloses using pre-coated non-woven fibrous mats for improved adherence of gypsum board to membranes in roofing applications. Thus, coated fibrous mats may be provided having a dried, adherent coating applied to one of their surfaces. These mats may be substantially liquid impermeable, but allow water vapor to pass through during manufacturing of the gypsum panel.

[0061] In certain embodiments, a gypsum slurry may be deposited onto a non-coated surface of a fibrous mat, i.e., the slurry is deposited on a surface of the fibrous mat opposite the surface to which the mat coating composition was applied. In certain embodiments, the gypsum slurry contains excess water (i.e., water in excess of that needed to hydrate the calcined gypsum from which the slurry is made). Reinforcing fibers may also be included in the gypsum slurry.

[0062] The slurry may be deposited on the non-coated side of a horizontally oriented moving web of pre-coated fibrous mat. A second coated fibrous mat may be deposited onto the surface of the gypsum slurry opposite the first coated fibrous mat, i.e., the non-coated surface of the second coated fibrous mat contacts the gypsum slurry. For example, another moving web of a pre-coated non-woven fibrous mat may be placed on the upper free surface of the aqueous gypsum slurry. The gypsum slurry is sandwiched between the coated fibrous mats. Using the coated fibrous mats may allow the use of less coating and allow the fibrous mat to be saturated with a gypsum slurry without excessive bleed through. This saturating helps to insure a maximum bond of the fibrous mat to the gypsum core.

[0063] In other embodiments, the fibrous mats are both uncoated, only one mat is coated, the mats are coated on both surfaces, or the mats are coated on the surfaces contacting the gypsum slurry.

[0064] In certain embodiments, the step of depositing the gypsum slurry includes depositing a first gypsum slurry onto the surface of the first fibrous mat, and depositing a second gypsum slurry onto the first gypsum slurry, the second gypsum slurry having a lower density than the first gypsum slurry.

[0065] The gypsum sandwich structure is subsequently dried to evaporate the excess water from the gypsum slurry and set the gypsum core. An adhesive coating composition as described above is applied to an exposed surface of the first fibrous mat, i.e., the outward-facing surface of the fibrous mat onto which the gypsum slurry was deposited, and then may be at least partially cured or dried to form a material coating layer. The adhesive coating composition is applied to cover the surface of the first fibrous mat opposite the gypsum and, when cured or dried, forms a membrane-ready gypsum panel having a substantially smooth outer surface suitable to accept a membrane. For example, the adhesive coating composition may be applied to a coated surface of the first fibrous mat opposite the gypsum. In certain embodiments, the step of applying the adhesive coating composition occurs after drying the gypsum sandwich structure. In alternative embodiments, the step of applying the adhesive coating composition occurs before drying the gypsum sandwich structure.

[0066] In certain embodiments, the adhesive coating composition is applied by spray coating, ribbon coating, or direct roll coating the material coating on the surface of the first fibrous mat opposite the gypsum. For example, the adhesive coating composition may be applied such that the exposed outer surface of the membrane-ready gypsum panel (e.g. the surface 116 in FIG. 1) has a finish from about a level 1 finish to about a level 5 finish. In certain embodiments, the adhesive coating composition is applied such that a self-adhering membrane applied directly to the outer surface of the membrane-ready gypsum panel has a peel strength of above 3 pounds per linear inch (535.7 g per lineal cm) at 22.2°C. In certain embodiments, methods include applying a membrane, such as the self-adhering membranes described herein, to the substantially smooth outer surface of the membrane-ready gypsum panel. For example, Table 4 shows exemplary coating specifics, film thickness, and spread rate for the material coatings applied to the gypsum sandwich structure.

Table 4							
Material Coating Application Parameters							
Product	Coating Specifics		Film Thickness		Spread rate		
	Wt/gal (kg/L)	Weight solids	Liq. Film wt. g/ft ² (g/m ²)	Transfer efficiency (100% = max)	ft ² /gal (m ² /l)	gal/MSF (L/MSM)	lbs/MSF (g/MSM)
Curtain Coat 1	9.94 (1.19)	50.45%	8.7 (28.54)	100	261.42 (6.42)	1.56 (5.91)	38.97 (190.27)
Curtain Coat 2	11.13 (1.33)	57.21%	14.5 (47.57)	100	199.17 (4.89)	2.15 (8.14)	53.62 (261.79)
DRC	11.79 (1.41)	58.54%	3.5 (11.48)	100	894.37 (21.95)	0.45 (1.70)	11.17 (54.54)
Airless	11.8 (1.41)	58.61%	3 (9.84)	100	1045.56 (25.66)	0.38 (1.44)	9.57 (46.72)
Airless	11.8 (1.41)	58.61%	6.8 (22.31)	100	461.28 (11.32)	0.87 (3.29)	21.69 (105.90)
Airless	11.8 (1.41)	58.61%	15.4 (50.52)	100	203.68 (5.00)	1.96 (7.42)	49.11 (239.78)

[0067] As shown in FIGS. 2 and 3, apparatus for fabricating membrane-ready gypsum panels as described above are also provided. In one embodiment, shown in FIG. 2, the apparatus 200 includes a board line 202 for transporting a first fibrous mat 201A, a depositing mechanism 203 configured to deposit a gypsum slurry 211 onto a surface of the first fibrous mat 201A, a conveyor 205 configured to deposit a second fibrous mat 201B onto a surface of the gypsum slurry opposite the first fibrous mat, such that a surface of the second fibrous mat contacts the gypsum slurry. The resulting gypsum sandwich structure 206, i.e., the gypsum slurry between two fibrous mats, may be transported to a dryer 214 for drying the gypsum sandwich structure. For example, the dryer 214 may be an oven operated at a temperature to heat and set the gypsum slurry.

[0068] The apparatus also includes adhesive coating composition applicator 210, which is configured to apply an adhesive coating composition to the surface of the first fibrous mat opposite the gypsum slurry, i.e., the outward-facing surface of the first fibrous mat. The adhesive coating composition is applied to cover the surface of the first fibrous mat to form a membrane-ready gypsum panel 216 having a substantially smooth outer surface. In certain

embodiments, the first fibrous mat includes a mat coating on the surface opposite the gypsum, such that the adhesive coating composition is applied to the surface of the mat coating.

[0069] In certain embodiments, as shown in FIG. 2, the adhesive coating composition applicator is configured to apply the adhesive coating composition to the first fibrous mat before the gypsum sandwich structure **206** is dried in dryer **214**. In alternative embodiments, as shown in FIG. 3, the adhesive coating composition applicator **306** of apparatus **300** is configured to apply the adhesive coating composition to the first fibrous mat after the gypsum sandwich structure **302** is dried in dryer **314**.

[0070] In certain embodiments, the apparatus includes a transfer mechanism configured to overturn the gypsum sandwich structure **206** such that the outer surface of the first fibrous mat, i.e., the surface opposite the gypsum, is exposed prior to application of the adhesive coating composition. In certain embodiments, the apparatus includes a cutting mechanism **204** to cut the continuous gypsum sandwich structure into panels **206A** having the desired dimensions. In certain embodiments, a roller or a forming plate (not shown in FIG. 2) compresses the sandwich assembly to the desired thickness.

[0071] The dry ingredients from which the gypsum core is formed may be pre-mixed and fed to a mixer **220**, such as a pin mixer. Water and other liquid constituents, such as soap, used in making the core may be metered into the mixer **220** and combined with the desired dry ingredients to form the aqueous gypsum slurry. The reinforcing fiber may be added to the slurry in the mixer **220**. Foam (e.g., soap) may be added to the slurry in the mixer **220** to control the density of the resulting core and/or gypsum layers.

[0072] The gypsum slurry may be dispersed in the depositing mechanism **203** through one or more outlets from the mixer **220** onto a moving sheet (i.e., non-woven fibrous mat **201A**), which is indefinite in length and is fed from a roll thereof onto a board line and advanced by the conveyor **205**. In certain embodiments, the fibrous mats have a basis weight, in the absence of the coating, of about 2 pounds per 100 square feet (97.65 g/m^2). The fibrous mat may have a mat coating on what constitutes the bottom surface of the mat as the mat is fed to the board line. As described above, the mat coating may include a dried aqueous mixture of a filler and a polymer latex adhesive. The basis weight of the mat coating may be between about 3 and 6 pounds per 100 square feet ($146.5 - 293.0 \text{ g/m}^2$) of mat.

[0073] One stream of gypsum slurry may be discharged through an outlet to provide a relatively thin layer of aqueous calcined gypsum slurry **211** on the surface of the first fibrous mat **201A**. When used, the thin layer of gypsum slurry is somewhat denser than the aqueous slurry of gypsum that is used to form the main portion of the core of the gypsum board, which is dispensed from another outlet. As shown schematically in FIG. 1, this higher density region of the core may penetrate into the interstices of the fibrous mat and help to form a strong bond between the lower density portion of the core and the fibrous mat face. For example, the first gypsum layer may be a densified gypsum layer having a density about 15 to about 25 percent greater than the density of the second gypsum layer. Another fibrous mat may be fed onto the top of the gypsum slurry to form a gypsum sandwich structure.

[0074] The membrane ready gypsum panels may be used in conjunction with a variety of different suitable membranes. In general, suitable membranes provide air barrier and/or weather resistive barrier properties. Examples of such suitable membranes include the commercial membranes listed in Table 5, as well as any other suitable membranes known in the art.

EXAMPLES

[0075] Embodiments of the membrane-ready gypsum panels disclosed herein were constructed and tested for adhesive properties. The results were compared to traditional self-adhering membranes requiring on-site adhesive primer application.

[0076] Examples of comparative membrane/primer systems are listed in Table 5 below. These systems require the outer surface of the fibrous mats on the gypsum panel to be prepped with a solvent-based or water-based adhesive primer before the membrane is overlaid and applied directly to one of the exterior faces (e.g., walls, roof) of the building. Traditional adhesive primers must be spray or roller applied in the field after raw substrate installation and before the air and moisture impermeable membrane is manually applied to the surface of the fibrous mats and/or pressed with a roller until the membrane is adhered.

[0077] The interfacial adhesion between the membrane and the raw fibrous mat substrate is low, such that the primer is necessary and the membrane cannot be adhered directly to the substrate. A raw substrate of the fibrous mat can be very irregular at the membrane interface, locally minimizing the actual contact of the membrane with the board and leading to less than 1.0 lb/linear in (178.6 g/cm) adhesive strength that will not allow the membrane to stick without

a supplemental adhesive primer. Adhesive strength is measured by the accepted peel strength test outlined in ASTM D903 at room temperature (RT), approximately 72°F (22.2°C), and 35°F (1.7°C). Adhesion force data was attained from AMETEK Test System 500 with 50LBF Module after the asphalt membrane, 2 inches wide (5.08 cm), was roller applied onto the coated board after 24 hours of conditioning at RT, approximately 72 °F (22.2°C), with an approximately 3.5 pound (1588 g) roller.

[0078] The application coverage for the standard adhesive primers is also high because the bare substrates soak up the adhesive, thereby requiring significant amounts to reduce the Cobb value and obtain the desired weathering properties. Application coverage rates of traditional adhesive primers are given in table 6 below. Field applied adhesive primer is not normally required with the panels of the present invention. However, if one were to apply such primers to the panels of the present invention, one would be expected to use much lower amounts than listed in Table 6.

Table 5		
Comparative Self Sealing Membrane/Adhesive Primer Systems		
Company	Adhesive	Membrane
Carlisle	CCW-702	WIP 300 HT
Carlisle	CAV-GRIP	WIP 200
Carlisle	CCW AWP	MiraDRI 860
Carlisle	CCW AWP	MiraDRI 861
Henry	Blueskin® Spray Adhesive	BlueSkin SA
Henry	Aquatac™ Primer	BlueSkin LT
Grace	Perm-A-Barrier®WB	PermaBarrier Wall Membrane
Grace	Perm-A-Barrier®WB	PermaBarrier Wall Flashing

Table 6		
Comparative Adhesive Primer Application Rates		
Company	Adhesive	Application Rate
Carlisle	CCW AWP	400 ft ² /gal (9.82 m ² /l)
Henry	Blueskin® Spray Adhesive	125 to 250 ft ² /gal (3.07 - 6.14 m ² /l)
Henry	Aquatac™ Primer	250 – 500 ft ² /gal (6.14 - 12.27 m ² /l)

Grace	Perm-A-Barrier®	250- 350 ft ² /gal (6.14 - 8.59 m ² /l)
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[0079] Adhesive coating compositions as described in Tables 1, 2, and 3 were prepared and applied to a DENS sheathing product, commercially available from Georgia Pacific (Atlanta, GA), which is a gypsum sandwich structure produced in accordance with the methods described herein. For each of the adhesive coatings, the following tests were performed, unless otherwise indicated: (1) Block - two gypsum boards 6 in by 6 in (15.24 cm by 15.24 cm) were placed face to back at 120°F (48.9°C) / 20 PSI (0.137 N/mm²) / 2hrs. The boards were tested while still hot after applying and curing two coats at 2-4 mils wet and baked at 210 °F (98.89 °C) BST for 23 seconds per coat. The test was considered passed when the boards freely release; and (2) Adhesion - measured by the accepted peel strength test outlined in ASTM D903 at room temperature (RT), approximately 72 °F (22.2 °C), and 35 °F (1.7 °C). Adhesive force data was attained from AMETEK Test System 500 with 50LBF Module after the asphalt membrane, 2 inches wide (5.08 cm), was roller applied onto the coated board after 24 hours of conditioning at RT, approximately 72 °F (22.2 °C), with an approximately 3.5 pound (1588 g) roller. The comparative sample was a raw gypsum based substrate with no coatings applied to the face.

[0080] The curtain coat applicator material coating compositions (shown in Table 1) were prepared and had the properties shown in Table 7.

Table 7			
Curtain Coat Applicator Material Coating Properties			
Coating Property	Composition 1	Composition 2	Units
Solids	50.45	57.21	% NVM
PVC	25.08	44.98	%
VOC	0	0	g/l (-H ₂ O and Exempts)
VHAP	0	0	g/l (-H ₂ O and Exempts)
Application Rate	653.85 (16.05)	685.23 (16.82)	ft ² /gal (m ² /l)

[0081] Coated boards, 4 in x 11 in (10.2 cm by 27.9 cm) were produced with two coats (8 mils wet each), air flashed for 5 min and dried at 220°F (104.4 °C) for 10 min. An asphalt membrane, 2 in by 18 in (5.1 cm by 45.7 cm), was roller applied onto the coated board after 24 hours of conditioning at RT. A control panel with no adhesion had membrane applied directly to

the raw substrate. A second control panel included a solventborne adhesive (Henry BLUESKIN Adhesive) applied at 8 mils each for two coats and dried at RT for 30 min. For the Block test, two gypsum boards, 6 in by 6 in (15.2 cm by 15.2 cm), were placed face to back at 120 °F (48.9 °C) under 20 psi (0.137 N/mm²) for 1 hour and 30 minutes after applying two coats at 8 mils (~200 micron) each. The test results of the curtain coated samples are given in Table 8.

Table 8													
Curtain Coat Material Coatings Performance for Adhesion (g/cm)													
Time	15 min				1 hour				48 hour				Block
Temperature	35F		RT		35F		RT		35F		RT		
Coating	Avg.	σ	Avg.	σ	Avg.	σ	Avg.	σ	Avg.	σ	Avg.	σ	
Control with No Adhesive	0.0	0.0	44.6	26.8	0.0	0.0	53.6	17.9	0.0	0.0	44.6	8.9	Pass
Control with Blueskin Adhesive	455.4	294.7	544.7	232.2	750.0	535.7	571.5	241.1	1125.1	455.4	678.6	276.8	NA
Curtain Coat Composition 1 No Adhesive	375.0	285.7	535.7	214.3	705.4	535.7	562.5	232.2	1134.0	482.2	660.7	267.9	Pass
Curtain Coat Composition 2 No Adhesive	285.7	241.1	473.2	232.2	589.3	455.4	482.2	223.2	937.5	437.5	571.5	276.8	Pass

[0082] The direct roll coat (DRC) applicator material coating compositions (shown in Table 2) were prepared and had the properties shown in Table 9.

Table 9		
DRC Applicator Material Coating Properties		
Coating Property	Composition 1	Units
Solids	58.54	% NVM
PVC	59.92	%
VOC	2.40	g/l (-H ₂ O and Exempts)
VHAP	1.20	g/l (-H ₂ O and Exempts)
Application Rate	15.72	m ² /L

[0083] A control was coated with a solventborne adhesive (Henry BLUESKIN adhesive) at 6 - 8mils each and dried at RT for 30 min. A second control was prepared without a coating. For the Block test, two coats at 2 - 4 mils wet were applied and baked at 210 °F (98.9 °C) BST for 23 seconds per coat. The test results of the direct roll coated samples are given in Table 10.

Table 10													
DRC Material Coatings Performance for Adhesion (g/cm)													
Time	15 min				1 hour				48 hour				Block
Temperature	35F		RT		35F		RT		35F		RT		
Coating	Avg.	σ	Avg.	σ	Avg.	σ	Avg.	σ	Avg.	σ	Avg.	σ	
Control with Blueskin Spray Adhesive	89.3	35.7	526.8	44.6	89.3	44.6	508.9	71.4	80.4	44.6	875.0	142.9	NA
Control No Adhesive	0.0	0.0	44.6	26.8	0.0	0.0	53.6	17.9	0.0	0.0	44.6	8.9	Pass
DRC Variable No Adhesive	348.2	71.4	660.7	44.6	330.4	80.4	678.6	53.6	696.5	125.0	821.5	267.9	Pass

[0084] The airless applicator material coating compositions (shown in Table 3) were prepared and had the properties shown in Table 11.

Table 11		
Airless Applicator Material Coating Properties		
Coating Property	Composition 1	Units
Solids	58.61	% NVM
PVC	59.75	%
VOC	2.40	g VOC/l (- H ₂ O and Exempt Solvents)
VHAP	1.20	g VHaps/l (- H ₂ O and Exempt Solvents)
Application Rate	15.84	m ² /L

[0085] A control was coated with a solventborne adhesive (Henry BLUESKIN adhesive) at 6 - 8mils each and dried at RT for 30 min. Comparative samples were prepared using the DRC composition applied with a Dubois direct roll coater run in DRC mode with a 40 durometer blue rubber roll at 85 KU (1 Pa-s) viscosity at 66 °F (18.9 °C), double passed wet-on-wet application of 0.9 to 1.1 g/ft² (9.7 to 11.8 g/m²) and cured with IR heat to a 190 °F (87.8 °C) BST after the first coat and 205°F (96.1 °C) BST after the second coat with burners at 70% intensity on 16" (40.64 cm) centers. The airless composition samples were prepared by applying the airless composition with a 1226 tip and a 33 restrictor using a single spray gun approximately 12" (30.48 cm) above the board surface and centered over the board as the material was sprayed in a single pass application of 6 to 8 g/ft² (64.6 to 81.6 g/m²), and curing the samples with IR heat to

205 °F (96.1 °C) BST after two passes with burners at 70% intensity on 16" (40.64 cm) centers. The test results of the airless coated samples are given in Table 12.

Table 12							
Airless Material Coatings Performance for Adhesion (g/cm)							
Time	15 min		1 hour		48 hour		Block
Temperature	RT		RT		RT		
Coating	Avg.	σ	Avg.	σ	Avg.	σ	
Control with Blueskin Spray Adhesive	1046.5	107.1	1107.2	125.0	1075.0	133.9	NA
DRC Composition with Blueskin Spray Adhesive	1044.7	142.9	1091.1	116.1	1139.3	116.1	Pass
Airless Composition with Blueskin Spray Adhesive	1432.2	35.7	2091.2	133.9	2953.7	160.7	Pass
Airless Composition with Blueskin Spray Adhesive	1355.4	80.4	2112.6	133.9	2846.5	366.1	Pass
Control No Adhesive	94.6	53.6	100.0	26.8	78.6	17.9	NA
DRC Composition No Adhesive	671.5	267.9	626.8	80.4	809.0	98.2	Pass
Airless Composition with No Adhesive	921.5	89.3	1030.4	44.6	1087.5	17.9	Pass
Airless Composition with No Adhesive	948.3	62.5	1037.5	66.1	1057.2	26.8	Pass

[0086] As can be seen from the above test results, the membrane-ready gypsum panels displayed membrane adhesion properties comparable, and often stronger, than the primed control samples. The membrane-ready gypsum panels also display improved application rates and simplify the panel/membrane installation process, thereby increasing productivity and lowering installed system cost. The membrane-ready gypsum panels also advantageously reduce or eliminate high VOC primers on site. The membrane-ready gypsum panels also display the necessary block resistant properties needed for the panels to be stacked in preparation for shipping and transportation.

[0087] Without intending to be bound by a particular theory, it is believed that the material coating fills voids in the fibrous mesh, thereby smoothing the surface, which facilitates increased adhesion surface area between the gypsum panel face/back and the membrane barrier. Additionally, the application of a material coating to a fibrous faced gypsum panel can reduce adhesive/primer penetration into the glass fiber mat and gypsum board, which as a result can reduce or eliminate primer usage.

[0088] The membrane-ready gypsum panels disclosed herein may be suitable for use in any applications where fibrous mats or other glass mats are used, for example in roof boards, wall boards, soffits, etc. The membrane-ready panels may also be suitable for applications in which it is desirable to limit air infiltration into a building, for example in health care and educational/research and development settings.

[0089] Embodiments of the present disclosure further relate to any one or more of the following paragraphs:

[0090] 1. A method of making an unattached, membrane-ready, exterior gypsum panel, comprising:

depositing a gypsum slurry onto a surface of a first fibrous mat;

depositing a second fibrous mat onto a surface of the gypsum slurry opposite the first fibrous mat, such that a surface of the second fibrous mat contacts the gypsum slurry, to form a gypsum sandwich structure;

drying the gypsum sandwich structure;

applying an adhesive coating composition to a surface of the first fibrous mat opposite the gypsum slurry, such that the adhesive coating covers at least a portion of the surface of the first fibrous mat; and

drying the adhesive coating composition to form a material coating on the first fibrous mat and form a membrane-ready gypsum panel, wherein the material coating comprises a substantially smooth outer surface.

[0091] 2. The method of paragraph 1, wherein the first fibrous mat has a mat coating on the surface of the first fibrous mat opposite the gypsum slurry.

[0092] 3. The method of paragraph 1, wherein the second fibrous mat has a mat coating on the surface of the second fibrous mat opposite the gypsum slurry.

[0093] 4. The method of paragraph 1, wherein applying the adhesive coating composition occurs after drying the gypsum sandwich structure.

[0094] 5. The method of paragraph 1, wherein applying the adhesive coating composition occurs before drying the gypsum sandwich structure.

[0095] 6. The method of paragraph 1, wherein applying the adhesive coating composition comprises spray coating, ribbon coating, or direct roll coating the adhesive coating on the surface of the first fibrous mat opposite the gypsum slurry.

[0096] 7. The method of paragraph 1, wherein the adhesive coating composition is applied such that the outer surface has a finish from about a level 1 finish to about a level 5 finish.

[0097] 8. The method of paragraph 1, wherein the adhesive coating composition contains solids in an amount from about 35 to about 100 weight percent.

[0098] 9. The method of paragraph 1, wherein the adhesive coating composition comprises a polymeric adhesive comprising at least one of a latex polymer, a water-dispersible polymer, a water-reducible polymer, or an oil-modified polymer.

[0099] 10. The method of paragraph 9, wherein the polymeric adhesive comprises a polymer selected from acrylics, styrene acrylics, vinyl acrylics, styrene acetate acrylics, and combinations thereof.

[00100] 11. The method of paragraph 10, wherein the polymeric adhesive comprises a polymer or a copolymer with a glass transition temperature of 0 to 30 °C.

[00101] 12. The method of paragraph 1, wherein depositing a gypsum slurry comprises:
depositing a first gypsum slurry onto the surface of the first fibrous mat; and
depositing a second gypsum slurry onto the first gypsum slurry, the second gypsum slurry having a lower density than the first gypsum slurry.

[00102] 13. The method of paragraph 1, further comprising:
attaching the membrane-ready gypsum panel to a building; and
applying a membrane to the substantially smooth outer surface of the membrane-ready gypsum panel.

[00103] 14. The method of paragraph 13, wherein the membrane comprises WIP 300 HT, WIP 200, MiraDRI 860, MiraDRI 861, Blueskin SA, Blueskin LT, PermaBarrier Wall membrane, or PermaBarrier Wall flashing.

[00104] 15. The method of paragraph 1, wherein the adhesive coating composition is applied such that a self-adhering membrane applied directly to the outer surface of the membrane-ready gypsum panel has a peel strength of above 3 pounds per linear inch at 72 °F (535.7 g/cm at 22.2 °C).

[00105] 16. The method of paragraph 1, wherein the first fibrous mat is a fiberglass mat.

[00106] 17. The method of paragraph 1, wherein the first fibrous mat is paper.

[00107] 18. An apparatus for fabricating membrane-ready gypsum panels, comprising:

a board line for transporting a first fibrous mat;
a depositing mechanism configured to deposit a gypsum slurry onto a surface of the first fibrous mat;
a conveyor configured to deposit a second fibrous mat onto a surface of the gypsum slurry opposite the first fibrous mat, such that a surface of the second fibrous mat contacts the gypsum slurry, to form a gypsum sandwich structure on the board line;
a dryer for drying the gypsum sandwich structure;
an applicator configured to apply an adhesive coating composition to a surface of the first fibrous mat opposite the gypsum slurry, such that the adhesive coating composition covers the surface of the first fibrous mat; and
a dryer for drying the adhesive coating composition to provide a material coating and form a membrane-ready gypsum panel, wherein the material coating comprises a substantially smooth outer surface.

[00108] 19. The apparatus of paragraph 18, wherein the applicator is configured to apply the adhesive coating composition to the first fibrous mat before the gypsum sandwich structure is dried.

[00109] 20. The apparatus of paragraph 18, wherein the applicator is configured to apply the adhesive coating composition to the first fibrous mat after the gypsum sandwich structure is dried.

[00110] 21. The apparatus of paragraph 18, further comprising a transfer mechanism configured to overturn the gypsum sandwich structure such that the surface of the first coated fibrous mat opposite the gypsum slurry is exposed prior to application of the adhesive coating composition.

[00111] 22. A membrane-ready gypsum panel, comprising:

a first fibrous mat having a first surface and a second surface;
a second fibrous mat having a first surface and a second surface;
a gypsum core in contact with the second surfaces of the first and second fibrous mats;
and

a material coating that covers at least a portion of the first surface of the first fibrous mat and forms a substantially smooth outer surface thereon.

[00112] 23. The membrane-ready gypsum panel of paragraph 22, wherein the material coating is derived from an adhesive coating composition comprising a polymeric adhesive, wherein the polymeric adhesive comprises an aqueous emulsion selected from acrylics, styrene acrylics, vinyl acrylics, styrene acetate acrylics, and combinations thereof.

[00113] 24. The membrane-ready gypsum panel of paragraph 22, wherein the outer surface of the material coating has a finish from about a level 1 finish to about a level 5 finish.

[00114] 25. The membrane-ready gypsum panel of paragraph 22, wherein the gypsum core comprises:

a first gypsum layer in contact with the second surface of the first fibrous mat; and

a second gypsum layer having a lower density than the first gypsum layer and in contact with the first gypsum layer and the second surface of the second fibrous mat.

[00115] 26. The membrane-ready gypsum panel of paragraph 22, wherein the membrane-ready gypsum panel has a Cobb value below 5 grams.

[00116] 27. The membrane-ready gypsum panel of paragraph 22, wherein the membrane-ready gypsum panel has a vapor permeance equal to or greater than 1.5 perms.

[00117] 28. The membrane-ready gypsum panel of paragraph 22, wherein the material coating has a weight from about 5 lbs/MSF (24.41 g per 1000 sq m) to about 100 lbs/MSF (4882.43 g per 1000 sq m).

[00118] 29. The membrane-ready gypsum panel of paragraph 22, wherein the outer surface is substantially smooth such that a self-adhering membrane applied directly to the outer surface of the membrane-ready gypsum panel has a peel strength of above 3 pounds per linear inch at 72 °F (535.7 g/cm at 22.2 °C).

[00119] 30. The membrane-ready gypsum panel of paragraph 22, wherein the first and second fibrous mats each comprise a non-woven fibrous mat comprising glass fibers.

[00120] 31. The membrane-ready gypsum panel of paragraph 22, wherein the first and second fibrous mats each comprise paper.

[00121] 32. The membrane-ready gypsum panel of paragraph 30, wherein the glass fibers have an average diameter from about 10 to about 17 microns and an average length from about one-quarter (1/4) inch to about three-quarter (3/4) inch (0.64 to 1.91 cm).

[00122] 33. The membrane-ready gypsum panel of paragraph 22, wherein the mats further comprise a mat coating on a surface thereof, wherein the mat coating comprises a filler and an adhesive binder.

[00123] 34. A method for coating an unattached, exterior gypsum wallboard to make the wallboard membrane-ready, comprising the steps of:

applying an adhesive coating composition to an exposed surface of a fibrous mat of an exterior gypsum panel, wherein the adhesive coating composition comprises water and an acrylic latex; and

drying the adhesive coating composition to form a material coating, wherein the coating provides a non-tacky, substantially smooth outer surface capable of adhering to an adhesive-backed membrane, and the coating composition penetrates the fibrous mat to enhance the cohesive strength thereof.

[00124] 35. The method of paragraph 34, further comprising:

attaching the membrane-ready gypsum wallboard to a building; and

applying a membrane to the substantially smooth outer surface of the membrane-ready gypsum panel without a field-applied adhesive.

[00125] 36. The method of paragraph 35, wherein the membrane comprises WIP 300 HT, WIP 200, MiraDRI 860, MiraDRI 861, Blueskin SA, Blueskin LT, PermaBarrier Wall membrane, or PermaBarrier Wall flashing.

[00126] 37. The method of paragraph 35, wherein the membrane has a peel strength of above 3 pounds per linear inch at 72 °F (535.7 g/cm at 22.2 °C).

[00127] While the disclosure has been described with reference to a number of embodiments, it will be understood by those skilled in the art that the invention is not limited to such disclosed embodiments. Rather, the invention can be modified to incorporate any number of variations, alterations, substitutions, or equivalent arrangements not described herein, but which are commensurate with the spirit and scope of the invention. Additionally, while various embodiments of the invention have been described, it is to be understood that aspects of the invention may include only some of the described embodiments. Accordingly, the invention is not to be seen as limited by the foregoing description, but is only limited by the scope of the appended claims.

What is claimed is:

1. A method of making an unattached, membrane-ready, exterior gypsum panel, comprising:
 - depositing a gypsum slurry onto a surface of a first fibrous mat;
 - depositing a second fibrous mat onto a surface of the gypsum slurry opposite the first fibrous mat, such that a surface of the second fibrous mat contacts the gypsum slurry, to form a gypsum sandwich structure;
 - drying the gypsum sandwich structure;
 - applying an adhesive coating composition to a surface of the first fibrous mat opposite the gypsum slurry, such that the adhesive coating covers at least a portion of the surface of the first fibrous mat; and
 - drying the adhesive coating composition to form a material coating on the first fibrous mat and form a membrane-ready gypsum panel, wherein the material coating comprises a substantially smooth outer surface.
2. The method of claim 1, wherein the first fibrous mat has a mat coating on the surface of the first fibrous mat opposite the gypsum slurry.
3. The method of claim 1, wherein the second fibrous mat has a mat coating on the surface of the second fibrous mat opposite the gypsum slurry.
4. The method of claim 1, wherein applying the adhesive coating composition occurs after drying the gypsum sandwich structure.
5. The method of claim 1, wherein applying the adhesive coating composition occurs before drying the gypsum sandwich structure.
6. The method of claim 1, wherein the adhesive coating composition is applied such that the outer surface has a finish from about a level 1 finish to about a level 5 finish.

7. The method of claim 1, wherein the adhesive coating composition contains solids in an amount from about 35 to about 100 weight percent.
8. The method of claim 1, wherein the adhesive coating composition comprises a polymer or a copolymer with a glass transition temperature of 0 to 30 °C.
9. The method of claim 1, wherein depositing a gypsum slurry comprises:
depositing a first gypsum slurry onto the surface of the first fibrous mat; and
depositing a second gypsum slurry onto the first gypsum slurry, the second gypsum slurry having a lower density than the first gypsum slurry.
10. The method of claim 1, further comprising:
attaching the membrane-ready gypsum panel to a building; and
applying a membrane to the substantially smooth outer surface of the membrane-ready gypsum panel.
11. The method of claim 10, wherein the membrane comprises WIP 300 HT, WIP 200, MiraDRI 860, MiraDRI 861, Blueskin SA, Blueskin LT, PermaBarrier Wall membrane, or PermaBarrier Wall flashing.
12. The method of claim 1, wherein the first fibrous mat is a fiberglass mat.
13. The method of claim 1, wherein the first fibrous mat is paper.
14. An apparatus for fabricating membrane-ready gypsum panels, comprising:
a board line for transporting a first fibrous mat;
a depositing mechanism configured to deposit a gypsum slurry onto a surface of the first fibrous mat;
a conveyor configured to deposit a second fibrous mat onto a surface of the gypsum slurry opposite the first fibrous mat, such that a surface of the second fibrous mat contacts the gypsum slurry, to form a gypsum sandwich structure on the board line;

a dryer for drying the gypsum sandwich structure;

an applicator configured to apply an adhesive coating composition to a surface of the first fibrous mat opposite the gypsum slurry, such that the adhesive coating composition covers the surface of the first fibrous mat; and

a dryer for drying the adhesive coating composition to provide a material coating and form a membrane-ready gypsum panel, wherein the material coating comprises a substantially smooth outer surface.

15. The apparatus of claim 14, further comprising a transfer mechanism configured to overturn the gypsum sandwich structure such that the surface of the first coated fibrous mat opposite the gypsum slurry is exposed prior to application of the adhesive coating composition.

16. A membrane-ready gypsum panel, comprising:

a first fibrous mat having a first surface and a second surface;

a second fibrous mat having a first surface and a second surface;

a gypsum core in contact with the second surfaces of the first and second fibrous mats;

and

a material coating that covers at least a portion of the first surface of the first fibrous mat and forms a substantially smooth outer surface thereon.

17. The membrane-ready gypsum panel of claim 16, wherein the outer surface of the material coating has a finish from about a level 1 finish to about a level 5 finish.

18. The membrane-ready gypsum panel of claim 16, wherein the gypsum core comprises:

a first gypsum layer in contact with the second surface of the first fibrous mat; and

a second gypsum layer having a lower density than the first gypsum layer and in contact with the first gypsum layer and the second surface of the second fibrous mat.

19. The membrane-ready gypsum panel of claim 16, wherein the membrane-ready gypsum panel has a Cobb value below 5 grams.

20. The membrane-ready gypsum panel of claim 16, wherein the membrane-ready gypsum panel has a vapor permeance equal to or greater than 1.5 perms.

21. The membrane-ready gypsum panel of claim 16, wherein the material coating has a weight from about 5 lbs/MSF (24.41 g per 1000 sq m) to about 100 lbs/MSF (4882.43 g per 1000 sq m).

22. The membrane-ready gypsum panel of claim 16, wherein the outer surface is substantially smooth such that a self-adhering membrane applied directly to the outer surface of the membrane-ready gypsum panel has a peel strength of above 3 pounds per linear inch at 72 °F (535.7 g/cm at 22.2 °C).

23. The membrane-ready gypsum panel of claim 16, wherein the first and second fibrous mats each comprise a non-woven fibrous mat comprising glass fibers.

24. The membrane-ready gypsum panel of claim 16, wherein the first and second fibrous mats each comprise paper.

25. The membrane-ready gypsum panel of claim 23, wherein the glass fibers have an average diameter from about 10 to about 17 microns and an average length from about one-quarter (1/4) inch to about three-quarter (3/4) inch (0.64 to 1.91 cm).

26. A method for coating an unattached, exterior gypsum wallboard to make the wallboard membrane-ready, comprising the steps of:

applying an adhesive coating composition to an exposed surface of a fibrous mat of an exterior gypsum panel, wherein the adhesive coating composition comprises water and an acrylic latex; and

drying the adhesive coating composition to form a material coating, wherein the coating provides a non-tacky, substantially smooth outer surface capable of adhering to an adhesive-backed membrane, and the coating composition penetrates the fibrous mat to enhance the cohesive strength thereof.

27. The method of claim 26, further comprising:
attaching the membrane-ready gypsum wallboard to a building; and
applying a membrane to the substantially smooth outer surface of the membrane-ready gypsum panel without a field-applied adhesive.
28. The method of claim 27, wherein the membrane has a peel strength of above 3 pounds per linear inch at 72 °F (535.7 g/cm at 22.2 °C).

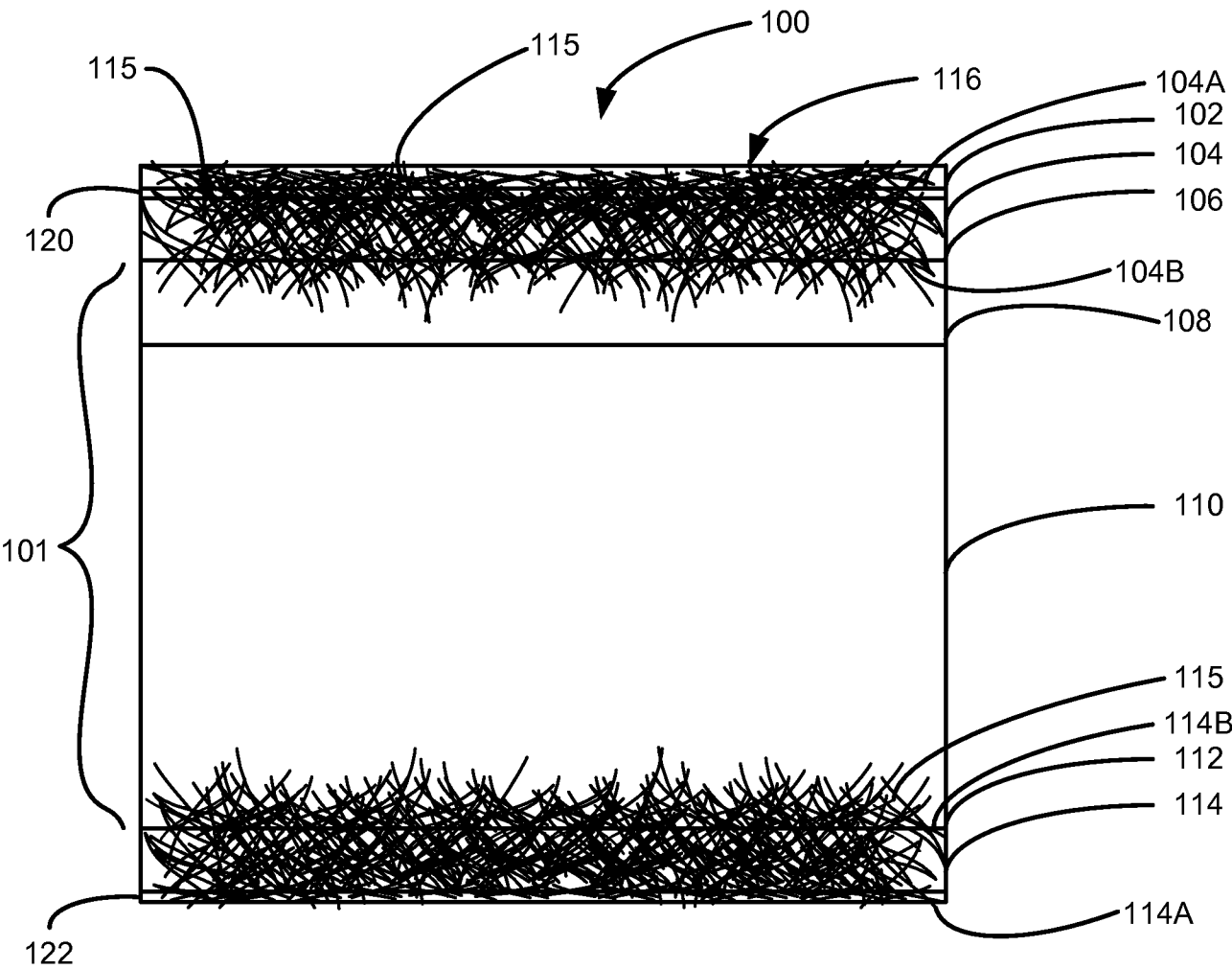


FIG. 1

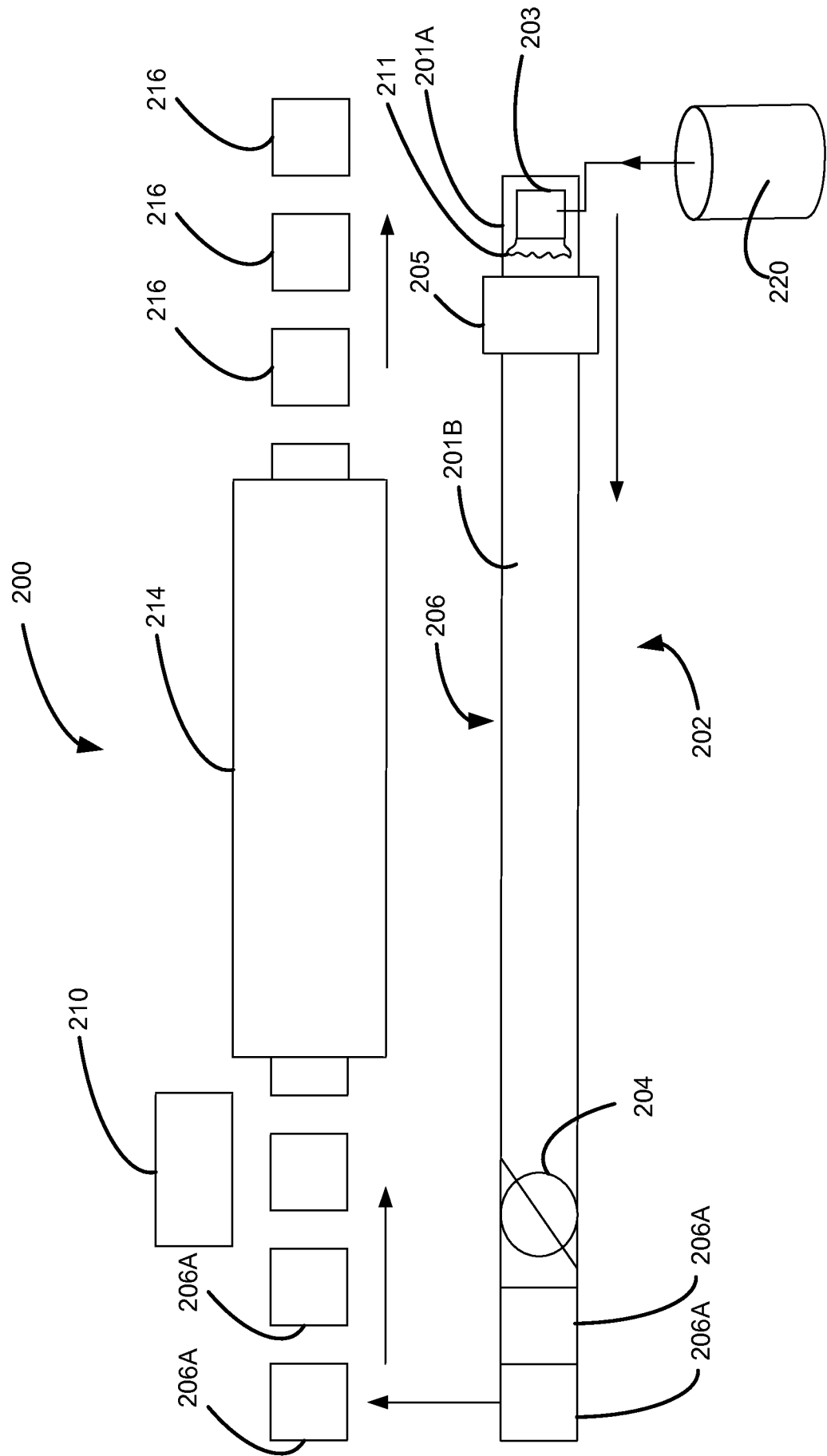


FIG. 2

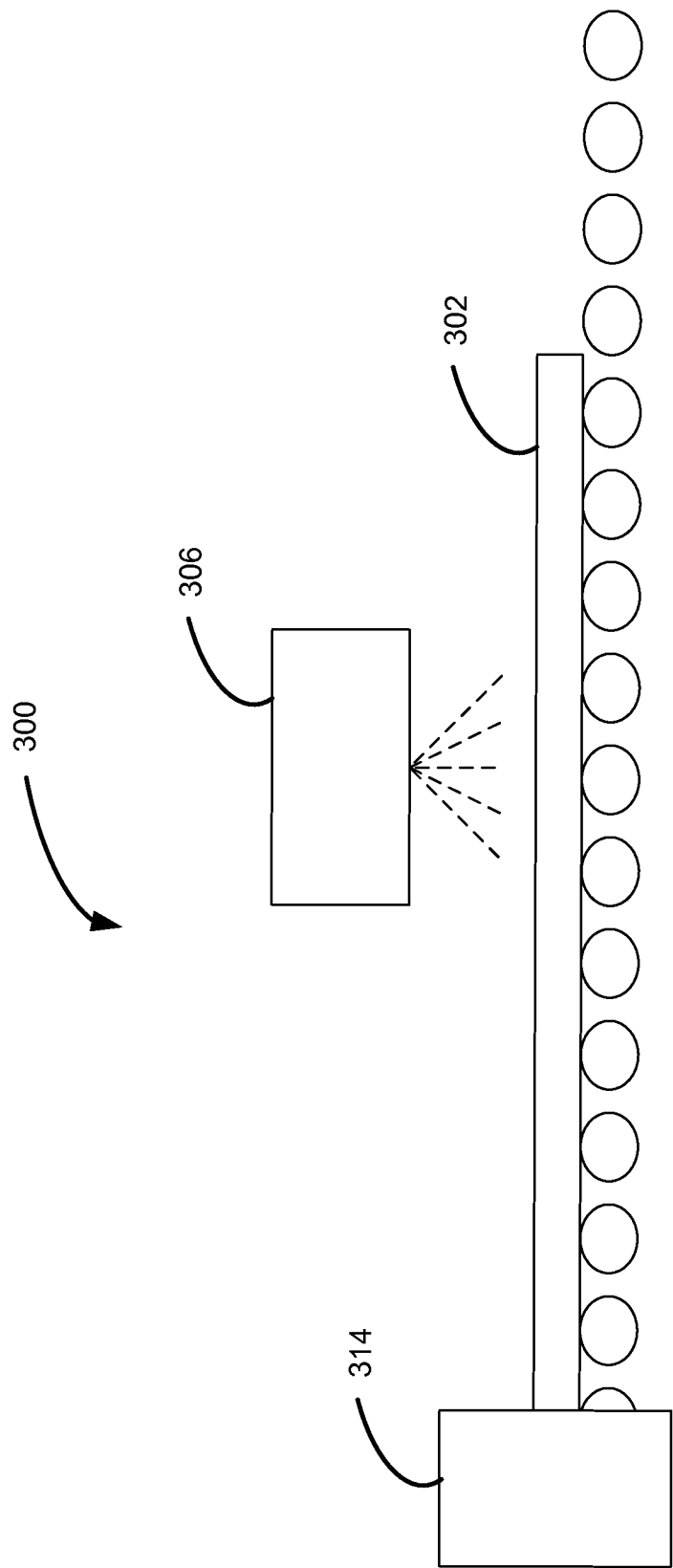


FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/052678**A. CLASSIFICATION OF SUBJECT MATTER****E04C 2/02(2006.01)i, E04C 2/26(2006.01)i**

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)

E04C 2/02; B32B 7/02; D04H 5/00; B32B 37/00; B32B 13/02; E04C 2/04; B28B 23/00; B32B 1/00; E04C 2/26

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords: gypsum , fibrous mat , coating, adhesive coating

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2009-0208714 A1 (CURRIER ALAN E. et al.) 20 August 2009	16-17, 19, 23-25
A	See paragraph [0035]-paragraph [0087]; figures 1-2.	1-15, 18, 20-22, 26-28
Y	US 2006-0240236 A1 (BRIAN W. BLAND et al.) 26 October 2006	16-17, 19, 23-25
A	See paragraph [0005]-paragraph [0016].	1-15, 18, 20-22, 26-28
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A	See paragraph [0023]-paragraph [0039]; figures 1-2.	
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A	See paragraph [0031]; figures 1-3.	
A	US 2009-0173423 A1 (JAFEE ALAN MICHAEL) 09 July 2009	1-28
A	See paragraph [0023]-paragraph [0026]; figure 1.	



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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

"E" earlier 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

08 December 2014 (08.12.2014)

Date of mailing of the international search report

09 December 2014 (09.12.2014)

Name and mailing address of the ISA/KR

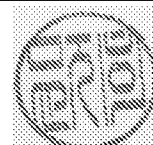
International Application Division
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INTERNATIONAL SEARCH REPORTInternational application No.
PCT/US2014/052678**Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)**

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

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

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

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

Group 1, claims 1-13 are directed to a method of making an exterior gypsum panel.

Group 2, claims 14-15 are directed to an apparatus for fabricating a gypsum panel.

Group 3, claims 16-25 are directed to a gypsum panel.

Group 4, claims 26-28 are directed to a method of coating an exterior gypsum wallboard.

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

Remark on Protest

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

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2014/052678

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INTERNATIONAL SEARCH REPORT

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