

Dec. 16, 1969

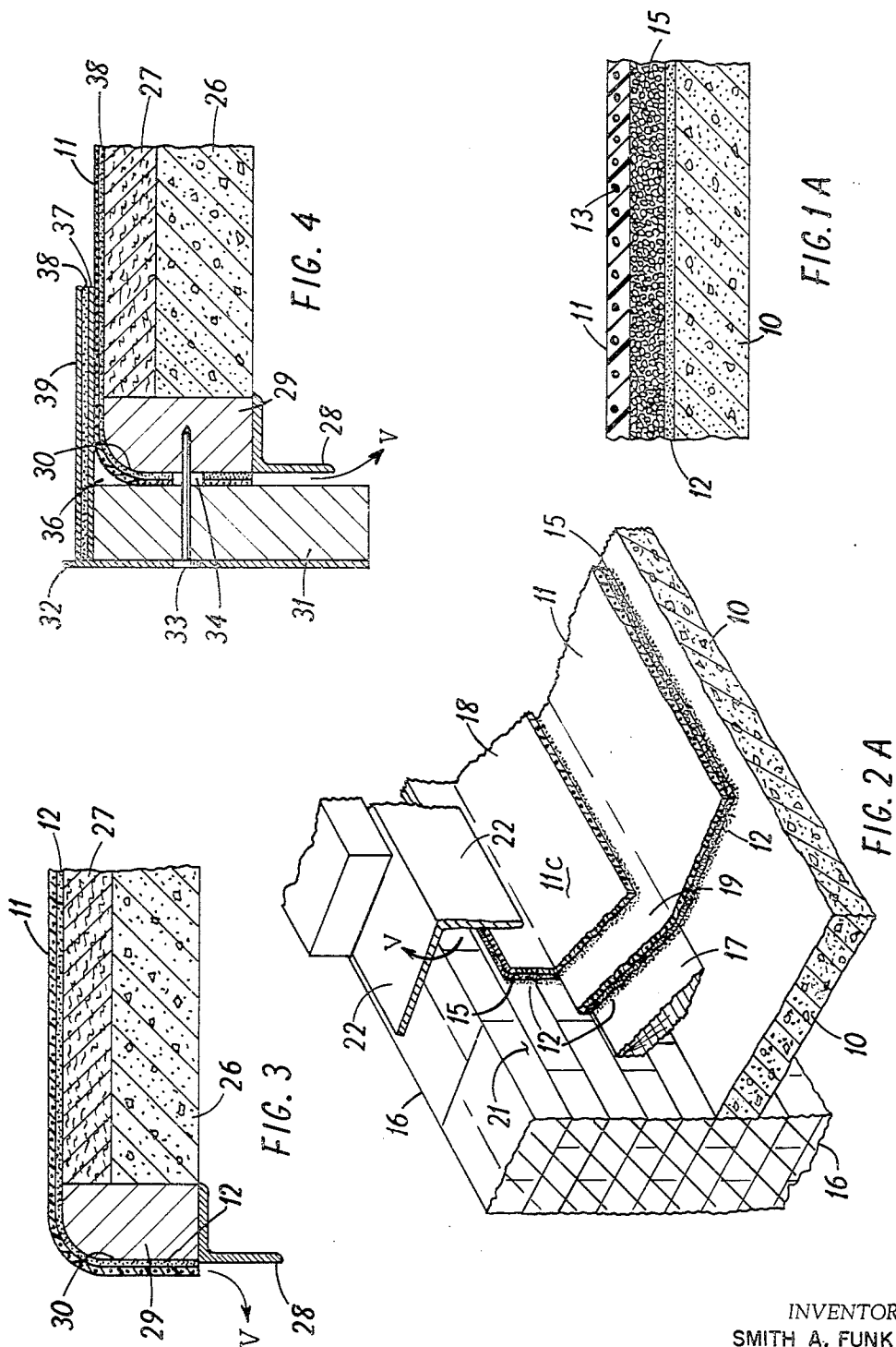
S. A. FUNK ET AL

3,483,664

ROOFING SYSTEM

Filed April 19, 1967

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

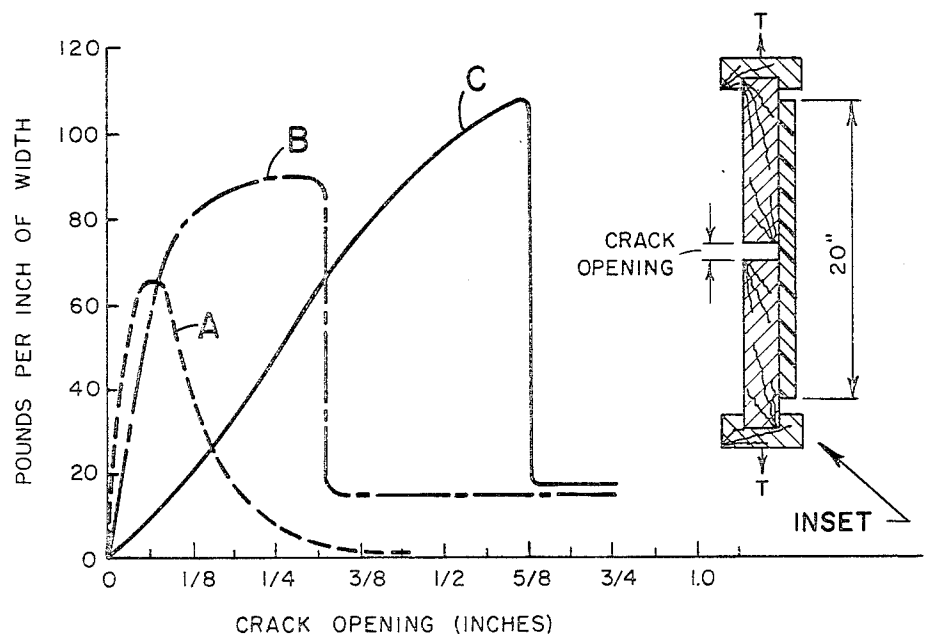


FIG. 5

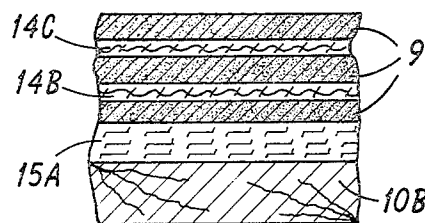


FIG. 1B

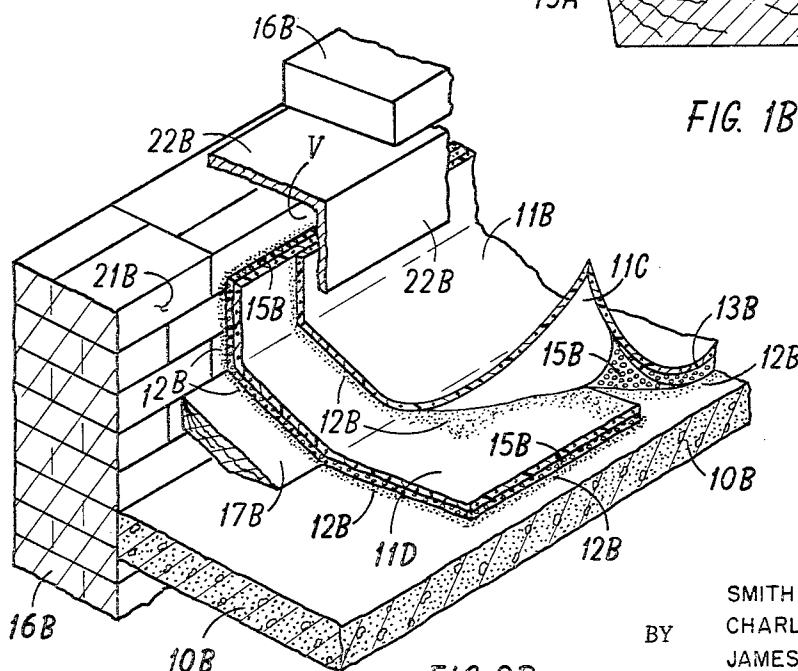


FIG. 2B

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3,483,664

ROOFING SYSTEM

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Continuation-in-part of application Ser. No. 547,205, May 3, 1966. This application Apr. 19, 1967, Ser. No. 632,080

Int. Cl. E04c 2/02; E04d 1/30, 3/40

U.S. Cl. 52—309

8 Claims

ABSTRACT OF THE DISCLOSURE

A novel roofing system is provided which consists essentially of (1) a roofing sheet which is exposed to moisture at its surface but is substantially impermeable to the passage of moisture through it, and (2) a porous underlay which has substantial resiliency, is non-matting and allows vapors forming below the roofing sheet to be vented. A preferred system comprises a reinforced plastic roofing sheet with an underlay of open cell plastic foam.

This application is a continuation-in-part of our application filed on May 3, 1966, Ser. No. 547,205, now abandoned.

This invention relates to a novel roofing system, and more particularly to a new and improved composite roof which essentially comprises (1) a moisture impermeable surface sheet and (2) a porous underlay which permits vapors formed underneath the impermeable surface sheet to be vented by passing through the underlay to the atmosphere. As a specific preferred embodiment, a single ply roofing which combines a plastic sheet material with an underlay of open cell plastic foam into a unitary structure, is provided. The invention also relates to roof construction incorporating such single ply roofing material and to methods of installing such roofs.

Built-up roof construction conventionally consists of the application to a suitable roof deck of bituminous cement, bituminous saturated felts, top pouring materials, and gravel or slag surfacing. The components of the built-up roof system are waterproofing agents, e.g. saturants, adhesives, or top pouring materials, reinforcing agents, e.g. rag, asbestos, or glass felts, and weather resistant protective surfacings such as slag, gravel, or crushed stone. Specifications for a roof over a wood deck typically require one ply sheathing paper, two nailed fifteen pound saturated felts, and three cemented fifteen pound saturated felts all bonded together and topped by pitch or asphalt and a surface covering of loose slag or gravel to protect against ultraviolet light and permit foot traffic. The many steps inherent in this multi-component built-up roofing system contribute to high labor costs, primarily because of manual material handling and lengthy application times.

Further, protective sheeting materials are commonly employed to form waterproof seals between different parts of the roofing structure. Such protective sheeting materials are commonly known as flashing and are applied by cutting and heat forming to the desired shape as may be required by the particular application. For example, the sheet may be cut and formed about the base of a chimney, vent stack, roof ventilator, etc., to prevent seepage through the roof. It is similarly used at the junction of the roof deck and main walls. Within the structure, flashing is commonly used as a base mat for flooring such as ceramic tiles, etc., and also in conjunction with piping to prevent water seepage through the floors and frame. Such sheet material may also be shaped to form expansion joints between various sections of a structure. With respect to flashing, a

number of materials have been proposed. Sheet metal such as copper, galvanized iron, aluminum, and lead have been used in the past in large quantities as flashing. It has also been proposed to use filled plastic sheet compositions as flashing to overcome difficulties encountered with the use of sheet metals. Such compositions generally are composed of a resin base combined with plasticizers and fillers and have been designed to be relatively easy to form to the more complex shapes required in certain applications. The formulation of these flashing compositions has not been a simple matter because of the properties which the compositions should have. Such properties include hardness, high tensile strength, low modulus, high elongation, low brittle temperature, low shrinkage, low volatility, the retention of properties on aging, and processability. The compositions must be compatible with commonly employed bonding agents such as pitch and asphalt, must be heat-formable at moderate temperatures, and capable of withstanding exposure to the elements for indefinitely long periods of time without cracking or deterioration. Cracking, of course, destroys the integrity of the roof and leaking results.

It has therefore been suggested that a one-ply roofing system be substituted for the multi-component built-up roofing system; however, because of the demanding requirements for a one-ply roof, which must have the same 15 to 25 year life as the built-up roof, it has been extremely difficult to find a one-ply system or membrane which will be comparable to or better than the multi-ply built-up roof. The difficulty can be traced largely to the tremendous forces set up by the volatilization of moisture trapped under the roofing sheet. As the vapor forms, there is great expansion often forming large blisters, and as it condenses the blisters contract. This repeated flexing of the roofing sheet as the vapor expands and contracts soon produces cracks.

Recently there have been various proposals relating to the use of polymeric materials in roofing applications in an effort to reduce the number of plies or layers required to meet standard specifications. Such polymeric sheet materials have been proposed for use as flashing while certain of these have been suggested as a useful roofing sheet per se or both as flashing material and roofing sheet, the latter combination being especially desirable to permit the finishing of a roof with only a single material. Because of the rigid specifications for roofing materials the polymeric materials have had varying degrees of success although such polymeric sheets have reduced the time and materials required in roof construction. Generally, the polymeric roofing sheets are of very reduced thickness compared to the conventional multi-component built-up roof. Such reduced thickness is the basis for a number of potential advantages in roofing applications but has also created certain disadvantages or limitations with respect to the use of polymeric materials as a truly single-sheet roofing. One such limitation has been with respect to vapor formation within the roof causing blistering or distortion of the roof surface. One approach to reducing the destructive vapor forces is the application of a vapor impervious roofing sheet between the roof base and polymeric roofing sheet. However, the requirement for such an impervious sheet material increases the number of sheet layers and adhesive applications in completing the roof and accordingly reduces the advantages and effect of the polymeric sheet as a truly one-ply or single sheet roofing. In short, such problems have left much room for desired improvement in single-sheet roofing despite many various attempts at solutions.

An object of the present invention is to provide a new and improved composite roofing system which consists essentially of a porous vapor venting underlay applied below the moisture impermeable roofing sheet.

Another object of the invention is to provide a roofing sheet which may be applied as a single entity and consisting essentially of a water impermeable sheet and a porous open cell underlay.

Another object of the invention is to provide a new and improved factory-made composite plastic sheet material adhered in combination with an open cell underlay having particularly advantageous utility as a single-ply roofing which meets the stringent technical and economical requirements of multi-ply built-up roof construction.

Another object is to provide a composite plastic sheet material with a layer of open cell foam adhered thereto which composite is useful as the sole roofing membrane over a roof deck.

A further object is to provide a composite plastic sheet material including an open cell porous substrate which is useful as a single-ply roofing and which affords self-venting properties for moisture vapors generated between the roof and said composite.

A still further object is to provide new and improved roof construction based on this composite single-ply plastic roofing sheet.

Other objects and advantages of the present invention will be evident from the following description and accompanying drawing in which:

FIG. 1A is a vertical section through a roof showing applied thereon the preferred composite of plastic roofing sheet in combination with an open cell plastic foam.

FIG. 1B depicts an alternate embodiment wherein a porous open cell underlay other than open cell plastic foam is utilized.

FIG. 2A and FIG. 2B are perspective views showing preferred roof constructions at the junction of a roof base and wall when employing the preferred composite plastic-foam sheet material of the invention.

FIG. 3 is a vertical section view showing a preliminary stage in roof end construction when employing the roofing system of the invention.

FIG. 4 is a vertical sectional view showing a preferred roof end or eave construction upon completion of the preliminary stage shown in FIG. 3.

FIG. 5 is a comparative diagram depicting the improved crack absorption tolerance of a roofing system employing a porous resilient underlay according to the invention.

In accordance with the present invention it has been found that substantially increased life to roofing is provided by a composite roofing which comprises an underlay below the moisture impermeable surface sheet which has an open cell structure and which has substantial resiliency, i.e. which resists cracking. The underlay permits vapors which are formed from moisture to permeate through and obviate heaving which normally occurs when moisture which is trapped is vaporized. A particularly preferred composite according to the present invention is a reinforced synthetic plastic membrane, preferably having an intermediate reinforcing scrim, i.e. a reinforcing fabric of glass fiber, nylon or wire embedded therein, and combined therewith a thin layer of synthetic open cell plastic foam or other open cell porous material joined to one surface of the reinforced plastic membrane. The composite sheeting of the invention may be no more than one-half inch in thickness and the flexible foam or other material which is adhered thereto and which permits the transmission of vapors is generally less than one-quarter inch in thickness, preferably as little as 0.03 to 0.15 inch in thickness.

The roofing composite according to the invention of impermeable surface sheet and vapor penetrable porous underlay is characterized by permitting the construction of roofing of markedly improved functionality and superior performance satisfying rigid roofing specifications. As a general proposition, the roofing of the invention has been found to offer the outstanding advantages of providing a less bulky yet far more effective roofing wherein only the moisture impermeable surface sheet and vapor

transmitting layer are the sole roofing material, thus eliminating the requirement for the use of various conventional layers and coatings such as a vapor impervious base sheet between the roof base and roofing.

The plastic sheet and open cell plastic foam underlay composite which comprises a preferred embodiment provides a single sheet roofing material which may be employed both as a single sheet roofing and a selvage portion thereof may be used as a flashing.

The present invention, as is apparent from the description taken as a whole, provides a novel roofing system, an essential feature of which resides in the vapor venting underlay which precludes heaving and other stresses resulting when trapped moisture vaporizes. While the underlay described in paramount detail in the present application comprises a flexible open cell plastic foam, it will be apparent that any material which is open cell and permits vapor pass-through and which has substantial resistance to rotting, generally, for example materials which do not absorb moisture, may also be used, e.g. polypropylene or nylon mats or rugs.

The plastic membrane which comprises the moisture impermeable roofing sheet may be compounded from any suitable synthetic plastic material suitable for use in sheet form in roof surfacing applications. Examples of such polymeric materials include chlorinated polyethylene, polyvinyl chloride, chloro sulfonated polyethylene, polychloroprene, polyisobutene, and polyvinyl fluoride. The especially preferred polymeric material is an elastomeric chlorinated or chlorosulfonated polyethylene having chlorine content between about 25-40% by weight as described in greater detail in the pending U.S. Patent Application filed on Apr. 6, 1965, Ser. No. 446,091 having been assigned to the present assignee of record, and now abandoned. The foam layer through which formed vapors are vented may also be prepared from any suitable synthetic plastic flexible foam-forming material including polyurethane, chlorinated polyethylene, and polyvinyl chloride, preferably a polyurethane. While some advantage is derived from the foam structure as such, it is important that the foam joined to membrane is an open intercommunicating cell foam. Such open cell foam has been found to provide a self-venting roof structure from a single layer roofing sheet. The roofing of the present invention, when manufactured as a prepared composite rather than applying the membrane and underlay separately on the roof, provides numerous additional features and advantages including: (1) complete factory prepared-ready-to-install roofing; (2) exceptional light weight; (3) rapid and one-step installation at substantial cost savings; (4) can be applied over a wide temperature range and thus cold adhesives may be used eliminating need for hot asphalt, and (5) excellent conformity with various roof designs and slopes.

The present invention is applicable generally to built-up roofing including non-insulated roof construction as illustrated in FIGURES 1A and 1B, as well as to insulated structures illustrated in FIGURE 4. As used herein and the appended claims, the terms "roof base" and "built-up roof base" shall be taken as including any portion of the total built-up roof including the roof deck and lying below the preformed plastic-foam sheet of the invention. The term "roof deck" as used herein and the appended claims shall mean for the supporting structure or foundation over which the total roof excluding the composite but including insulation is built-up. The roof deck may be any suitable structure such as the concrete deck shown in FIGURES 1-4, or may be of wood, e.g. plywood, concrete, steel or other material conventionally employed in the industry. In insulated structures, the roof base may also include a vapor impervious roofing sheet or barrier bonded between the insulation and roof deck as conventional in insulated structures.

Referring to FIGURE 1A of the drawing, a typical preferred roof in accordance with the invention is con-

structed over a conventional concrete roof deck or foundation 10. The composite plastic membrane-foam roofing sheet 11 is bonded by a suitable adhesive 12 to the roof deck 10. The adhesive 12 is preferably a solvent based synthetic plastic adhesive such as a polychloroprene resin. Other suitable adhesives may be employed including bitumen-based cements and adhesives which may be both hot and cold applied. The foam surface of the composed plastic membrane-foam preformed sheet, having the intermediate reinforcing scrim 13 which preferably is a woven commercial glass fabric, is laid down over the adhesive layer 12 to complete the roof in a simple two-step operation involving the application of adhesive and a single sheet of roofing.

While the system depicted in FIG. 1A, wherein a roofing sheet of open pore flexible plastic foam 15 adhered to a plastic membrane 11, which is manufactured as a preassembled composite, may be adhered at 12 to the roof and this offers a preferred embodiment, the invention also contemplates a built-up roof system. Illustrative of an alternate embodiment is the system shown in FIG. 1B wherein a polypropylene fiber mat 15A, through which moisture which may vaporize is vented, is suitably secured such as by nailing or by adhesive to a roof deck 10B. While a wooden deck 10B is shown, it will be apparent that decks of other materials may likewise be used. Built up over the vapor venting layer 15A are alternate layers 14B and 14C of a material such as felt or builders paper, i.e. rosin paper, and layers 9 of pitch or asphalt to provide the necessary waterproof system. In this structure, the venting layer 15A provides the necessary "outlet," i.e. the means to vent vapors which form from moisture present between the deck 10B and watertight layer placed over it, and thereby eliminates the heaving and flexing to this layer which would cause it to crack. Optionally, it may be desirable to add gravel on the uppermost layer of pitch or asphalt in conventional amounts.

FIGURES 2A and 2B of the drawing show typical applications when using the roofing sheet in its preferred embodiment in constructing roofs. In FIG. 2A, a junction of the roof deck 10 and a wall 16 is depicted. The showing illustrates the dual utility of the composite sheet 11 as both a roofing sheet and where desired, a part of which may be used as a flashing, in the manner described in greater detail hereinafter. The sheet 11 is provided in rolls of suitable widths, preferably 36 inch or 48 inch widths, and include a selvage or border portion 11C (see FIG. 2B) which has no foam 15 adhered thereto and which overlaps on the contiguous previously applied strip 11D. The underside of selvage portion 11C is coated with a suitable lap adhesive so that a plastic to plastic seal between membranes 14 directly, i.e. without foam intermediate, is provided. A cant strip 17 is positioned in the conventional manner between the roof deck and wall 16. In FIG. 2A, the composite roofing sheet 11 applied over the roof deck 10 is continued up the cant strip 17 and terminated at the wall 16, substantially as shown. A layer of the adhesive 12 bonds the sheet 11 to the upper surface of the cant strip 17. A strip of the composite roofing sheet 11, which includes the selvage portion 11C is cut to suitable dimensions to form the flashing 18. Flashing 18 has the selvage portion 11C of the flashing 18 bonded to the upper exposed surface 19 of plastic membrane of the composite sheeting 11 which lies on the canting strip 17 to produce a membrane to membrane bond free of foam intermediate. The selvage or foam-free portion 11C of the flashing 18 may be bonded to the exposed membrane 11 preferably using a suitable bonding agent such as, preferably, by an adhesive. Optionally, a bonding strip of a conventional bonding tape (not shown) of the kind useful in roof construction such as mastic tape, may be used in lieu of adhesive at the selvage seal to give a membrane to membrane seal. The portion of flashing 18 which has a foam surface is disposed vertically and suitably adhered onto the surface 21 of the wall 16. It is thus

seen that the foam portion of flashing 18 is that part only of the flashing 18 which is vertical and begins at about the intersection of the wall surface 21 and cant strip 17. This arrangement prevents "wicking" or seepage of moisture at the overlap or selvage seal at cant strip 17. The exposed foam surface of the flashing 18 is bonded directly in contact with the wall surface 21 by a suitable adhesive layer 12. Cap flashing 22 overlaps the top of wall 16 and extends over the upwardly exposed end of the composite flashing sheet 18 in the conventional manner. The upwardly extended portion of the flashing 18 may also be fixed to the wall 16 by suitably spaced fasteners.

In the embodiment shown in FIG. 2B, no separate flashing (corresponding to 18 in FIG. 2A) is employed; instead, the composite sheet 11B is carried up over the cant strip 17B terminating in a vertical portion which is secured as by adhesive 12B to the vertical face 21B of wall 16B. FIG. 2B also depicts the use of the preferred composite sheet which comprises a glass mesh fabric 13B embedded in plastic to form the waterproof membrane 11B. As shown, one edge of the sheet 11B is provided with a selvage portion 11C which omits the foam layer 15B. This selvage portion is adhered directly to the membrane surface of the preceding composite sheet 11D, there being no foam interposed in this joint. It is important in applying the composite sheet that there be a membrane to membrane seal because otherwise the interposition of a porous layer (e.g. the foam) at the joint would result in undesirable wicking or seepage of moisture (at the joint) to the roof deck through such porous layer. Also, it will be noted that it is essential in order to have adequate venting that the porous layer be substantially continuous, i.e. so that vapors generated can be vented through the porous layers 15 and escape such as at the places shown by the arrows and marked V.

In the especially preferred embodiments of the invention the foam of the composite roofing sheet 11 is an open-communicating cell foam found to permit vapors normally created within a roofing structure to be vented through sheet 15 (15B in FIG. 2B) to the atmosphere at the upwardly extending portion, i.e. the flashing 18 (FIG. 2A) and vertical terminal portion of composite sheet 11B in FIG. 2B. Thus, vapors generated within the roof can flow through the open cell foam structure of the main roofing sheet to the end thereof adjacent to the wall surface. Vapors discharged from the end of the sheet at the wall surface 21 (or 21B) rise upwardly into and through the open-communicating cells of the porous underlay and are vented, as shows by arrows V, to the atmosphere inside surface of the cap flashing 22 (FIG. 2A) and 22B (FIG. 2B).

FIGURES 3 and 4 show preliminary and final stages in construction of a non-walled roof end or eave when employed in the preformed plastic membrane-foam roof sheeting of the invention. For purposes of illustration, the insulated roof base is shown in FIGS. 3 and 4 to include a roof deck 26 and layer of fiberboard insulation 27. As shown in FIG. 3, the roof deck 26 supported on a beam 28 and the construction includes a conventional roof end piece beam 29 but having a curved outer portion 30 at the top thereof. The preformed roofing sheet 11 is bonded to the outer surface of the fiberboard 27 and roof end piece 29 by the application of an adhesive 12. The preformed roofing sheet 11, whose cross-sectional structure is not depicted in detail but comprises a structure having a porous underlay as described in connection with FIGS. 1A and 1B, extends downwardly over the vertical side portion of the end piece 29 and preferably terminates at about the horizontal level of the beam 28, substantially illustrated. In the construction stage, illustrated in FIG. 4, the eave assembly is completed employing a conventional wood nailer 31 and gravel stop 32 which are secured to the end piece 29 and roof deck by a suitable fastener 33. A spacer 34 is preferably inserted between the end piece 29 and nailer 31 to prevent nailer 31 from closing against

piece 29 and compressing the foam or other flexible porous material, and thereby inhibiting the venting ability of the roofing sheet, i.e. so that the continuous passageway formed by the intercommunicating cells of the foam or other porous layer is closed. Thus, the spacer 34 assures the movement around the spacers of vapors within the foam cells downwardly in the downwardly directed vertical portion of the roofing sheet and discharge of such vapors to the atmosphere between the opposing inside surfaces of the nailer 31 and beam 28, as illustrated in FIG. 4. Similarly, the rounded portion 30 of the end piece 29 creates a space 36 thereby avoiding a pinching or cell-closing compression of the foam or assembly of the nailer 31 and gravel stop 32. The roofing assembly may employ a strip 37, e.g. a bonding or mastic edge, bonded to the upper surface of the plastic membrane and abutting more or less against the end of horizontal leg of the gravel stop 32. A layer 38 of adhesive is applied over the upper surface of the horizontal leg of the gravel stop and bonding strip 37, and a layer of flashing 39 bonded thereto. The flashing 39 may be any suitable or conventional flashing adapted to form with the adhesive 38 and bonding strip 37 a waterproof construction resisting the passage of water between the upper surface of the roofing sheet 11 and lower surface of the horizontal leg of the gravel stop 32.

In the plastic-foam roofing of the invention, the plastic membrane may be produced from any suitable synthetic plastic which can be compounded and combined with a reinforcing scrim to provide a thin sheet meeting the requirements for roof surfacing application. Included among the synthetic thermoplastic materials which may be employed in producing the membrane are chlorinated polyethylene, chlorosulfonated polyethylene, polyvinyl chloride, polychloroprene, polyisobutylene and polyvinyl fluoride. The membrane is highly flexible and readily passes on bending on a 1/8 inch mandrel. The synthetic plastic membrane must have low temperature flexibility and desirably has a brittle point temperature less than 0° C., preferably less than minus 5° C. The more preferred synthetic plastic materials are those which can be compounded into a sheet having such low temperature flexibility with the addition of no more than 15 parts of plasticizer per 100 parts of resin, preferably between 0 to 10 parts. Elastomeric polymers are the most preferred resins for preparations of the membrane. Generally, the preferred membranes are further characterized by ultimate elongation of at least 100%, ultimate tensile strength of at least 800 p.s.i., tear resistance (ASTMD 1004) of at least 100 p.s.i., low water vapor transmission, and high solvent and chemical resistance. Thickness of the membrane can vary between about 4 to 75 mils, and is preferably 15 to 60 mils.

In preparation of the plastic membrane various additives such as fillers, pigments, stabilizers, etc. may be employed. Fillers are generally judiciously added depending upon the final desired properties of membrane such as elongation, stiffness, brittle temperature, etc. Amounts of total filler and pigments may range up to as much as 300 parts per 100 parts of resin. As little as 20 parts or less may be suitable depending largely on the particular synthetic resin employed and properties desired. Preferably, the total amount of filler and pigment ranges between about 50 to 200 parts per 100 parts of resin. Examples of suitable fillers which can be used in producing the membrane include silica or silica hydrates; silicates, e.g. calcium or alkaline earth silicates; materials containing silicates, e.g. infusorial earths, pumice, or rock or asbestos powder; silicon carbide; sulfates or alkaline earth metals; and other fillers such as coal, graphite, cryolite, asbestos fiber, sand, kaolin, calcium carbonate, ash, and textile fiber.

Organic and mineral pigments can be incorporated into the membrane. Examples are titanium dioxide, carbon black, antimony trioxide, iron oxides, phthaloxyanines

and others. They may be used alone or in blends. Amounts used can vary from about 2 parts to about 50 parts per 100 parts by weight of the resin mixture. For black colored membranes about 5 parts of carbon black is generally satisfactory, while opaque membranes may be obtained by use of preferably from about 28 to 38 parts by weight of titanium dioxide. Small amounts of other pigments may be combined with the titanium oxide to achieve pastel shades. In addition to their primary function as colorants, pigments such as titanium oxide and carbon black act as effective screening agents against the deteriorating influence of ultraviolet light and afford excellent protection for the resin. Carbon black is outstanding reinforcement agent for chlorinated polyethylene resins. Pigments such as carbon black and iron oxide, can be used both as filler and pigment where desired.

The membranes employed in the roofing sheet of the invention require a reinforcement or reinforcing layer which may be provided by several suitable materials and various methods. Desirably, the reinforcement is encapsulated within the membrane plastic, preferably centrally thereof, such that the plastic of the membrane is contiguous despite the presence of the reinforcement. Thus, thin separate plastic sheets are preferably used to form the membrane by sandwiching an intervening layer of glass or other suitable scrim, e.g. an open weave glass cloth supplied as "Victor S229," using only heat and pressure (laminating pressure about 80/p.s.i.; laminating temperature about 250° F.). Adhesives can be used as a sandwich if desired. Similarly, the membrane can be used as a sandwich with a great variety of substrates, such as asbestos felt impregnated with neoprene and Masonite. The aforementioned glass scrim sandwich is not considered a true laminate because the fibers in the open weave cloth are encapsulated by the chlorinated polyethylene when heat and pressure are applied. If desired, the scrim may be laminated to only one sheet of plastic membrane rather than incorporating the scrim in a sandwich. The use of scrim in this manner produces laminates in which the plastic membrane serves as the outer or upper surface of the laminate and the other material serving as the under surface or backing for the plastic membrane. However, in view of the encapsulation of the scrim, the demarcation of plastic membrane is not as distinct as, for example, when using an asbestos felt in such a lamination process.

The foam employed in the preformed roofing sheet of the invention may be produced from any suitable synthetic thermoplastic resin which can produce a flexible foam. Examples of suitable thermoplastic materials include polyurethane, polyethylene, chlorinated polyethylene, and polyvinyl chloride. The foam must be a highly flexible material readily passing on bending on a 1/8 inch mandrel. On combination with the plastic membrane, the outer exposed surface of the foam is free of skin commonly formed during preparation so that the foam cells at such surface are exposed. Thickness of the foam may range generally between about 0.02 to 0.5 inch, and is preferably between 0.03 to 0.15 inch. Foams of suitable thickness may be prepared directly, but are preferably cut or sliced from thicker section thereby assuring exposure of the surface cells. Especially excellent results are obtained when the foam is an open communicating cell foam found to provide a self-venting roof structure employing only a single sheet roofing. The more preferred foam material is polyurethane. The preparation of the polyurethane foams is well known as described, for example, by Saunders and Frisch, "Polyurethanes: Chemistry and Technology," part II, 1964, pages 1-192. The more preferred polyurethane foams are produced from the diisocyanates and a polyether to assure the provision of a polyurethane foam having optimum aging properties including prolonged resistance to decay in the presence of moisture. As noted hereinabove, a variety of other porous layers, in lieu of open cell plastic foam, may be

employed to impart crack absorption tolerance to the roof, i.e. to prevent a rupture of the waterproof integrity of the membrane or other water impermeable roofing sheets as the roof deck expands or otherwise moves, e.g. settles.

The preformed composite roofing sheet of the invention is preferably formed by adhesive bonding of the plastic membrane and a sheet of the flexible foam or other porous layer. A solvent-based curable polychloroprene resin is an example of a suitable adhesive which may be utilized although various other high strength adhesives, preferably elastomeric adhesive, may be also employed. The adhesive is preferably coated on the membrane surface and the porous sheet continuously pressed lightly into contact with the adhesive-coated membrane between a pair of rolls. In the case of plastic foam, the resulting composite sheet is then subjected to elevated temperatures, preferably between 120° F. to 250° F. for about ½ to 5 minutes to cure the adhesive. Alternately, the composite roof sheet may be produced by high temperature thermal bonding without an adhesive to directly join the foam sheet to the membrane. The roofing sheet may also be produced by direct expansion of a foam-forming composition on the plastic membrane, felt paper, etc., or by forming a sandwich of foamable material between two such sheets and slitting the resulting foam sandwich to simultaneously produce two sheets of the preformed roofing.

The thermoplastic resin which we especially prefer in forming the membrane is an elastomeric chlorinated linear polyethylene having chlorine content between about 25-40% by weight, a glass transition temperature of no higher than 10° C., and a crystallinity of no greater than 10% as determined by the substantial absence of an endothermal differential thermal analysis peak at about the melting point of the parent polyethylene. Such chlorinated polyethylene may be combined with fillers and stabilizers to produce particularly excellent roofing membranes which have an especially desired combination of roofing properties including weatherability, colorability, water and fire resistance, low temperature flexibility, heat, light, abrasion, pressure, chemical and grease resistance, and low plasticizer requirements. A particularly preferred membrane has been found to be provided by employing a combination of such chlorinated polyethylenes in accordance with the hereinabove identified abandoned application of C. J. Klasen, J. J. Malone, Jr., and W. F. Chapman, Ser. No. 446,091, filed Apr. 6, 1965. According to that application, the membrane is produced from a resin composed of a combination of a major portion, about 75% to 95% of a chlorinated linear polyethylene of 25-40% chlorine content, a glass transition temperature of no higher than 10° C., a crystallinity of not more than 10% as determined by differential thermal analysis, and an intrinsic viscosity between about 1.0 to 2.0 dl./gm. in o-dichlorobenzene at 100° C., and a minor portion, about 5% to 25%, of a chlorinated linear polyethylene of 30-40% by weight chlorine content, glass transition temperature no higher than 5° C., crystallinity of not more than 1%, and intrinsic viscosity between about 3.5 to about 4.8 dl./gm. in o-dichlorobenzene at 100° C.

A typical construction of a single-sheet roofing system using for illustration the membrane-foam composite of the invention, is as follows:

An adhesive is applied over a clean dry roof deck such as plywood, monolithic concrete, steel or other substrates with a roller or other applicator. The membrane-foam sheet is rolled out on the adhesive and then either broomed or rolled to secure proper contact, the joints can be lapped with adhesive and, if desired, sealed with tape. End portions of the preformed sheet may be prepared without foam for the overlapping joints. The set-time depends on the adhesive used. Flashing is then applied as required to finish the roof.

Obviously, the foam layer may be applied initially,

separately followed by adhesion thereon of the membrane. Like-wise, other suitable porous underlays, such as a non-matting fibrous rug, e.g. polypropylene, may be adhered to the roof deck followed by a layer of pitch, felt, etc. as described in conjunction with FIG. 1B.

The crack absorption tolerance of the sheeting material of the invention is demonstrated by the attached diagram of FIG. 5.

Referring to the diagram drawn to show tensile force versus crank opening at 75° F., the relative superiority of the sheet which contains a porous backing is demonstrated; whereas the material, i.e. conventional roofing felt without a resilient porous underlay (curve A) has a tensile failure when a crack occurs below it of about ¼". The plastic sheet of the kind described in Example 1 and employed in the invention but without the porous backing, has a tensile failure when a crack occurs below it of about ⅝". The open pore plastic foam backed sheet material, in accordance with the teaching of the invention, has a tensile failure only after a crack of greater than ⅞" has occurred.

The test used in the foregoing comprises laminated 20" length of test material to two separate piece of ⅝" plywood of about one foot length. The two pieces of plywood were butted together at their ends to form a continuous length 24" long. Overlapping the butt joint were the test strips of material 20" long by 2" wide laminated to the plywood thereby leaving a 2" length at each end of the butted pieces serving as gripping surface. (See the schematic inset illustration on the diagram.)

This assembly is pulled apart lengthwise so as to cause a separation at the place where the two pieces of plywood abut. The data at failure is recorded, i.e. the opening where the pieces abutted and the point of failure underload is recorded. Curve A uses two sheets of conventional asphalt impregnated and coated felt. Curve B uses a chlorinated polyethylene laminate in which a glass fabric is embedded and curve C comprises a chlorinated polyethylene laminate in which glass fabric is embedded and upon which a thin layer of polyurethane foam underlay is used.

It will be apparent that in addition to this foam backing or underlay any backing material which is porous and preferably which resists rotting and having a character which in itself does not absorb moisture, may be substituted for the open cell foam described hereinabove. Suitable materials, for example, may be felted, matted, woven or otherwise interlocking fibrous compositions. Specific examples include the so-called "in-door out-door" rugs now commercially available, some of which are comprised of polypropylene, as well as other fibers such as nylon, acrylic fibers and the like.

Desirably, adhesives employed in the roofing system should have a high initial tack, be quick-setting, resistant to heat and moisture, have good aging characteristics, high solid content and be easy to apply. Three major types of adhesives can be employed, namely, the hot-melt type as exemplified by steep roofing asphalt; the water emulsion latex type; and solvent-based elastomeric compositions. Examples of adhesives, by trade name and chemical composition are: flintkote No. 746 adhesive (rubberized asphaltic water-based adhesive); Flintkote No. 231 adhesive (white latex adhesive); Rubber-weld 3004 (rubber-based contact adhesive); and 3M Adhesive EC 1828 (a synthetic rubber-based contact adhesive in organic solvent). There are a vast number of various adhesives on the market and many of them are suitable and may be chosen to meet different requirements. Asphaltic hot melts can be used on all types of substrata, but for obvious reasons are suitably only for installation of black or very dark colored membranes. Water-based adhesives require absorbent substrata, such as wood and concrete. Contact adhesives are very satisfactory but quite difficult to handle because of the immediate strong bond which permits no sliding in place. The preferred adhesive is an elastomeric

solvent-based adhesive employing such as a neoprene or chlorinated polyethylene containing curing agent, such as magnesium oxide, zinc oxide, and the like, along with antioxidant, such curing agents and antioxidants being well-known materials.

The following example in which parts and percentages are by weight, is illustrative of the invention:

EXAMPLE 1

A plastic sheet was prepared in accordance with Example 1 of copending application Ser. No. 446,091 having been assigned to the present assignee of record, and now abandoned and had the following formulation:

	Parts	
Chlorinated polyethylene -----	90	15
Chlorine content=30%		
Intrinsic Viscosity=1.5		
Crystallinity=<1%		
Glass transition temperature=<-10° C.		
Chlorinated polyethylene -----	10	20
Chlorine content=40%		
Intrinsic Viscosity=4.0		
Crystallinity=<1%		
Glass transition temperature=<-10° C.		
Epoxide 201 ¹ (3,4-epoxy-6-methylcyclohexyl-3,4-epoxy-6-methylcyclohexane carboxylate) --	3	25
Ionol ¹ (2,6-Di-tertiary butyl-4-methylphenol) ----	1	
Pentaerythritol -----	1	
Carbon black -----	3	
Diocetyl phthalate -----	6.4	30
Atomite (calcium carbonate) -----	150	

¹ Registered Trademarks.

The above composition was formed into a sheet by first blending in a Henschel mixer, masticating in a Banbury at about 320° F. compound temperature, sheeting on a Farrell rubber mill at 330-335° F. roll temperature and finally calendaring on an inverted L four-roll unit (manufactured by the Farrell Corporation of Ansonia, Connecticut). Sheet thickness was 24 mils.

An open weave glass scrim (Victor S229) was sandwiched between 2 layers of the chlorinated polyethylene membrane of Example 1 using a temperature of 150° C. and a pressure of 80 pounds per square inch. The resulting sandwich was 24 mils thick and was a truly single-ply membrane with the scrim completely encapsulated within the chlorinated polyethylene such that the resin was contiguous within the weave openings.

A sheet of flexible open-communicating cell polyurethane foam was prepared by expansion of a foam-forming composition having the following formulation: 44.6 parts toluene diisocyanate; 100 parts of polyoxypropylene triol obtained under the trademark designation "Actol" 31-56 Triol; 10 parts of fluorotrichloromethane obtained under the trademark designation "Genetron" 11; 1.5 parts of a silicone oil-glycol copolymer as silicone emulsifier; 1.0 part of an amine catalyst contained under the trademark designation "Dabco" 33 LV; 0.3 part of stannous octoate as catalyst; and 3.5 parts of water. Sufficient foam-forming formulation was laid down to produce a foam of substantial thickness from which there was cut with spaced hot wires a sheet having a thickness of only about 0.10 inch. The thin foam sheet was then bonded to the scrim reinforced chlorinated polyethylene membrane by coating one surface of the membrane with an aromatic solvent-based curable butadiene-acrylonitrile adhesive obtained under the designation 566-1 Heat Seal Adhesive from Clifton Adhesive, Inc. and then pressing one surface of the thin flexible polyurethane sheet in contact therewith. The assembly and bond between the membrane and foam were completed by curing of the adhesive at a temperature of 180° F. for 1 minute.

The preformed membrane-foam sheet was supplied in a roof application being bonded directly to the fiber-

board of an insulated roof base employing a mopping of an adhesive composed of a 35% solids solution of 100 parts polychloroprene, 4 parts magnesium oxide, 5 parts zinc oxide, 20 parts fibrous filler, 50 parts tackifier resins, and 2 parts of an antioxidant obtained under the trademark "Salba Special." Observation of the installation over an extended term showed a substantial absence of moisture vapor blistering which would have been normally encountered in such an installation with a single sheet roofing not including the open cell foam.

Although certain preferred embodiments of the invention have been disclosed for purpose of illustration; it will be evident that various changes and modifications may be made therein.

We claim:

1. A composite assembly consisting essentially of a flexible web underlayer whose cross-section is characterized by interconnected porosity through which vapors present there are freely vented and selected from the group consisting of layers of synthetic plastic foam and pervious layers of fibrous fabrics whose fibers are substantially resistant to water absorption, in combination with

a covering layer which is characterized by its impermeability to moisture adhered continuously on the upper surface of said underlayer,

said composite being laminated unto a unitary structure which is handled as a single sheet and wherein the covering layer is a glass-reinforced chlorinated polyethylene membrane and wherein the underlayer is an open cell plastic foam comprising polyurethane adhered to said membrane and

wherein the unitary structure has a selvage edge portion on the membrane on which the underlayer is omitted, said composite being in combination with a roof deck to which said underlayer is secured with the selvage edge overlapping and sealed to a contiguous strip of membrane, said selvage edge extending only over portions of said contiguous strip having foam adhered thereto, to provide a substantially uninterrupted foam layer between said roof deck and said membrane through which vapors generated between said roof deck and said membrane are vented to the atmosphere at the peripheral ends of said foam layer.

2. A composite assembly in the form of sheets laminated into a unitary structure consisting essentially of: an underlayer comprising an open-communicating cell flexible strata of synthetic plastic foam whose cross-section is characterized by interconnected porosity through which vapors present therein are freely vented, in combination with a covering layer of a flexible, synthetic plastic, glass fiber-reinforced sheet membrane with a selvage edge portion on the membrane on which the underlayer is omitted, said membrane being characterized by its impermeability to moisture and being adhered continuously on the upper surface of said underlayer.

3. A composite in accordance with claim 2 in which the membrane is composed of an elastomeric thermoplastic material.

4. A composite in accordance with claim 2 in which the membrane is composed of chlorinated polyethylene.

5. A composite in accordance with claim 2 in which the plastic foam is polyurethane.

6. A composite assembly which is handled as a single sheet laminated into a unitary structure consisting essentially of a flexible web underlayer, said underlayer being an open cell plastic foam comprising polyurethane and being characterized by interconnected porosity through which vapors present therein are freely vented, in combination with

a covering layer which is a glass-reinforced chlorinated polyethylene membrane characterized by its impermeability to moisture

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said covering layer being adhered continuously on the upper surface of said underlayer.

7. The composite of claim 6 wherein the unitary structure has a selvage edge portion on the membrane on which the underlayer is omitted.

8. The composite of claim 2 in combination with a roof deck to which said underlayer is secured so that vapors generated between said roof deck and said composite are vented freely through the open cell foam to the atmosphere.

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