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Baker, M. C.

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M.C. Baker

Please note

Traditional sloping roofs are easily covered with discontinuous overlapping units of impervious materials to shed water. Even materials that are not waterproof may sometimes give reasonable service when used in this manner. Flat or nearly flat roofs of relatively recent use require a jointless waterproof covering to hold water while it drains slowly to outlets. Such a continuous waterproof covering for roofs has come to be called a roofing membrane. For something over one hundred years it has been the practice to make this membrane of bitumen and felts in alternate layers.

This has been easy to do, but the waterproof condition has sometimes been difficult to maintain. Moisture in building materials, humidity arising from the use of buildings, and changes of temperature all have effects that are more difficult to deal with when the covering must be absolutely watertight.

Architects, in the past, have not always been concerned with the design of roofing membranes, and it has been usual to accept the recommendations of manufacturers of roofing felts or of roofers. A successful roof was not always assured by this procedure, although when guarantee bonds were issued a reasonable standard existed for membrane specification and construction. Other considerations in the design of a roofing system were often ignored, however.

Previous Digests have dealt with bituminous materials and the fundamentals of roof design related to structural, thermal and moisture considerations. This Digest deals with the choice of bitumen and felts and the methods of laying felts.

Bitumens

Bitumens are used for roofing mainly because of their high resistance to moisture penetration, good adhesive and cohesive properties, and their ability to deform slowly and continuously when subjected to shearing forces. Other desirable properties are weather resistance, chemical and physical stability, low sensitivity to temperature, high flash-point, low vapour formation, and compatibility with other materials used in roofing.

Weather Resistance.

The properties of the bitumen and the slope of the roof are both involved. Lower softening point asphalts generally have better resistance to water absorption and penetration, but they

cannot be used on higher slopes because they soften and flow off. Water absorption and penetration, however, are a function of time, and it is desirable to slope roofs to carry water away. On steeper slopes air-oxidized, higher-softening-point bitumen must be used as a compromise.

Stability and Temperature Sensitivity.

It would appear that successful use of bitumen for roofing could be assured if the limits of temperature defined by the softening point and its brittle condition were not exceeded in service. A brittle condition for asphalt exists from about 0 to 20°F, and for coal tar pitch is as high as 50°F. Softening points for asphalt are from 140 to 200°F and for coal tar pitch about 140°F. This indicates that successful use of bitumen in most parts of Canada is difficult without modification or protection, or without placing it in a more suitable environment. Gravel protection has been a standard practice, and this accounts to some extent for its reasonably successful use.

Vapour Formation and Flash-Point.

When heated to working temperatures bitumen should have the least possible volatile content, be free of any tendency to coke or any tendency for oily components to separate during application or subsequent weathering. A high flash-point is necessary to diminish the risk of fire during application and on the completed roof.

Compatibility.

Felt saturants must be compatible with felt coatings, and both must be compatible with felt interply adhesives. Incompatibility can cause the breakdown of the desirable properties of one or both of the bitumens involved and result in loss of cohesion, adhesion and watertightness.

Bitumens Available.

Building designers do not generally have a choice regarding the saturant or coating used in the manufacture of felts, but they will normally have some choice as to the type of bitumen and felt used in the construction of built-up roofing. The Canadian Standards Association has set requirements on three types of asphalt and coal-tar pitch for use in construction of built-up roofing membranes. Some of the properties are shown in Table I.

Table I. Properties of Roofing Bitumens

Type of Bitumen	Use Related To Incline	Softening Point, °F	Penetration: 1/10 MM, 77°F, 100G, 5 Sec	Flash-Point, °F	Ductility, CM
Asphalt Type 1 (CSA)	Flat to 1 in. to 1 ft	140-150	25-40	450	10
Asphalt Type 2 (CSA)	1 to 3 in. to 1 ft	165-175	20-30	450	3
Asphalt Type 3	Over 3 in. to 1 ft	190-205	15-25	450	Not Specified

(CSA)					
Coal Tar Pitch (CSA)	Flat to 1 in. to 1 ft	140-155	15	248	50
Asphalt Emulsion	No Limit - roof coating	100-130	50-125	500	100
Asphalt Cutback	No limit - cold process cement	150-175	30-50	100	Not Specified

Clay-stabilized asphalt emulsion and cutback asphalt for cold application have been included in Table I for comparison. Because of the stability of asphalt emulsion, even on steep slopes, it is possible to use a very soft asphalt, which has considerable advantage in water resistance.

Felts

Types of felt available to the designer, as specified by the Canadian Standards Association, are shown in Table II.

Table II. Properties of Roofing Felts

Designation	CSA Specification	Type	Min. Weight Per 100 Sq Ft Finished Felt, lb	Min. Weight Per 100 Sq Ft Of Dry Felt, lb	Min. Weight Of Saturant % Of Dry Felt (or lb)	Weight of Coating And Surfacing lb/100 Sq Ft
Asphalt-Saturated (Organic)	A123.6	15-lb	12.2	5.1	140	-
Asphalt-Saturated (Asbestos)	A123.9	15-lb	13.0	9.0	40	-
Asphalt-Saturated (Glass Fibre)	A123.17	Ply Sheet	7.5	0.85	(4.5)	-
Coal-Tar Pitch Sat.	A123.8	15-lb	12.2	5.1	140	-

(Organic)						
Asphalt-Saturated And Coated (Organic)	A123.3	55-lb	46	9.1	150	16.7
		45-lb	37	5.6	140	16.7
Asphalt-Saturated And Coated (Asbestos)	A123.11	55-lb	50	17.5	50	18.0
		20-lb	16.9	8.5	40	6.5

Strength.

CSA does not specify the strength of felt, except for glass fibre felt. This will vary with temperature and all felts are stronger at lower temperatures. At room temperature the average tensional breaking strength of a 1-inch wide strip of 15-pound type, asphalt-saturated, dry organic fibre felt is about 30 pounds longitudinally and 15 pounds transversely. For asbestos fibre felt the strength is about 20 longitudinally and 10 transversely; and for glass fibre felt, about 25 longitudinally and 20 transversely.

Dimensional Stability.

The water absorption and dimensional stability of felts are of some importance. Asphalt-saturated organic felt will pick up 50 per cent by weight of water when immersed, and coal-tar saturated organic felt about 80 per cent. These changes in moisture content cause relatively large dimensional movements of about 0.2 per cent parallel to, and 1.5 per cent perpendicular to, the fibre or machine direction. As moisture can cause rotting of organic fibres as well, it is very necessary that roofing felts do not become wet during storage or application.

Asbestos felts consisting predominantly of asbestos fibres, but including a small percentage of organic fibres necessary to facilitate manufacture, are also not entirely free from moisture movement and decay. Glass fibre felts are only very slightly affected by moisture.

Coated Felts.

Some current thinking favours the use of coated organic roofing felts instead of saturated felts for the construction of built-up roofing membranes. In this case, the bitumen required for waterproofing has already been applied in a uniform coating at the manufacturing plant, and application is essentially the sticking together of sufficient layers to give the strength required. The heavier grades of coated felt have been used for many years in this and other countries as a single-layer roofing material on simply pitched roofs of barns and sheds. In more sophisticated roofing systems, several layers of coated felt are used with hot or cold adhesives and a surface protection of gravel or weathering coat of clay-stabilized asphalt emulsion.

The use of coated felts largely eliminates the hazards of storage and construction, but may introduce other problems. The weights of available coated felts make them difficult to lay in cold weather without wrinkles or fishmouths. A heated roller can be used to advantage with the cold system, but the heat of the bitumen has to be relied on for the hot application. There appears to be a need for more flexible felts such as those produced in some other countries.

Bitumen Thickness

The waterproofing function of the membrane is provided by the bitumen. For bitumen to perform as a water barrier there must be a continuous layer free of any voids, pinholes or cracks. Although a uniform thickness of less than 1/64 inch can achieve this, it is impractical to

try to obtain it because of surface roughness and the methods of application, and considerably greater thickness is used in practice.

The thickness is usually specified by the number of pounds of bitumen to be used per 100 square feet, and varies somewhat depending on whether it is the supporting structure adhering layer, the between-plies layer, or the top-surfacing layer. Figure 1 gives the thickness of bitumen layer that can be obtained with uniform coatings. Twenty pounds of asphalt as normally specified between plies, if uniformly spread, represents a thickness of a little over 1/32 inch, and 60 pounds as normally specified for a top pour gives a thickness slightly less than 1/8 inch. Part of the top pour thickness is utilized in holding the protective layer of mineral aggregate normally used over this application.

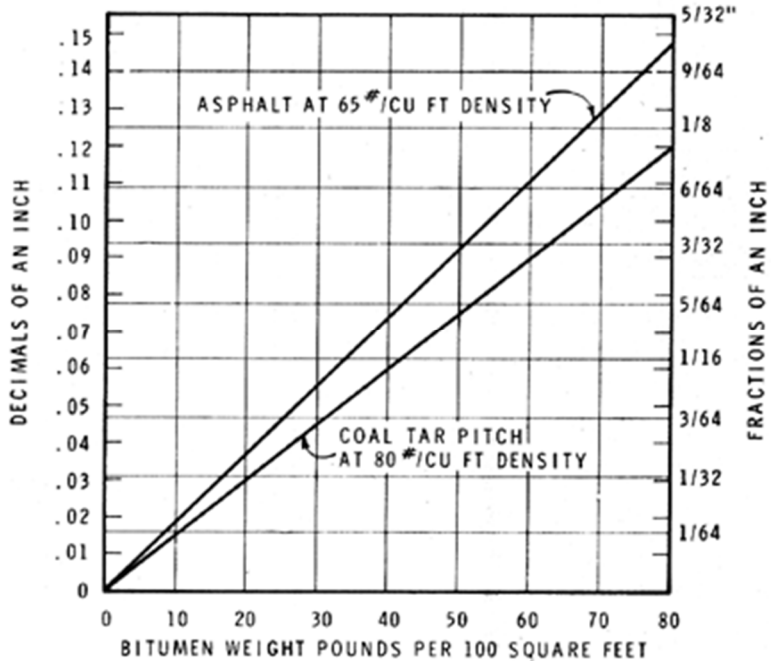

Figure 1. Uniform Coatings of Bitumen

Whether the thicknesses specified are achieved will depend on workmanship. The advantage of coated felts is that they already have a factory-applied layer of bitumen. This provides protection to the felt fibres against moisture pick-up no matter how poor the workmanship. Since moisture pick-up usually causes expansion and wrinkling of felts, it is of particular significance when felts are laid on a supporting deck or insulation with open joints. It is improbable, in such cases, that the adhesive bitumen will provide a complete coating for the felt.

Felts are used as a reinforcement to stabilize the bitumen layers, to provide the strength required to span irregularities in the supporting surface, and to distribute strains over a greater dimension. The relatively low cost of the materials makes it economical to use several layers to give greater strength, and in the hope that several layers of bitumen will increase the factor of safety. The top layers of felt must be coated with bitumen for protection against water from snow or rain. This top layer of bitumen is obviously of prime importance, for once it is breached and water gets into even the topmost layers the felts will rapidly deteriorate.

Methods of Laying

The performance of the membrane depends, to a very large measure, on the method of laying. There is only one in general use in Canada, and it may be referred to as the shingle method (Figure 2A). It is simple to understand, and fast and easy to carry out. Half-lapping gives a two-ply, two-thirds lapping a three-ply, and three-quarters lapping a four-ply roofing membrane. It has the very serious disadvantage that any wrinkling of felts or lifting at the laps

tends to provide a direct path to the supporting insulation or deck. This is why it is considered so essential with this method to achieve intimate contact between plies without wrinkles or fishmouths.

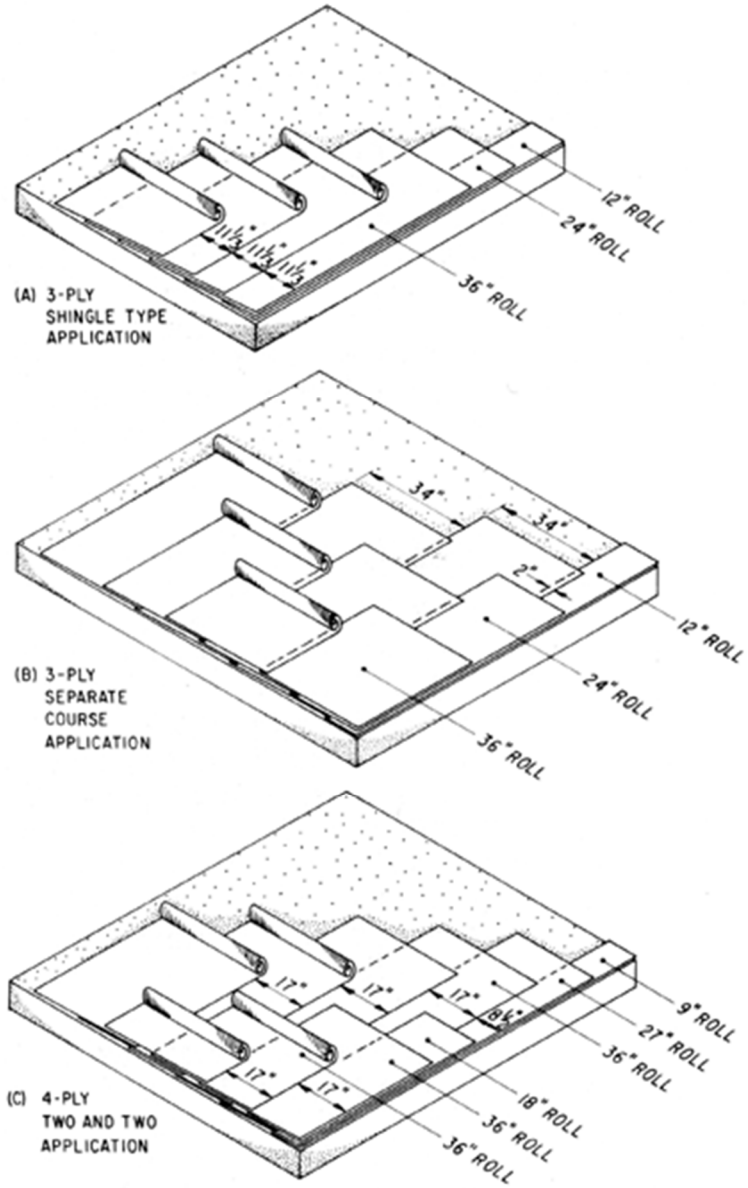

Figure 2. Felt Application

This disadvantage of the shingle method of laying can be overcome by separate layer application with a narrow lap at the edges and with subsequent layers laid so that the edge and end laps are staggered. This avoids unevenness in the membrane and imperfectly sealed edges corresponding to similar defects in the other layers. With this method (Figure 2B) fewer laps are exposed to the weather, and if there is any lifting at a lap the leakage path leads only to the next layer.

An alternative to separate layer construction is the use of two and one for a three-ply, and two and two for a four-ply roof membrane. It has some of the advantage of separate layers, and is illustrated in Figure 2C for a four-ply membrane.

For either of the two separate layer type applications the work must be planned for continuous coverage, with all layers laid at the same time. The practice of laying one or two plies, with

additional plies added at a later time, may be hazardous. There is danger of trapping construction dirt and moisture between the layers, resulting in poor adhesion and blistering later.

It may sometimes be an advantage, however, to put down one layer of felt to cover the deck or insulation quickly. Coated felt should be used in this case, since it is not so susceptible to damage from moisture as is saturated felt. Whether this protective layer of felt can be incorporated in the final roofing membrane depends on its condition, and can only be decided by the competent designer on the job site. For any of the application methods, a start should be made, if possible, at the lowest point so that lapped edges do not obstruct the flow of draining water.

Conclusion

This Digest has considered only the roof covering and some of the factors in its design and application. Analysis of all the factors indicates that in many instances the placement of the membrane below the insulation may be the only way in which a built-up bituminous membrane can survive in contemporary buildings. This will be the subject for a further Digest. Whether the built-up membrane forms the covering for the whole system or acts as the water drainage layer within the system, the principles of design and application for the membrane are the same and the factors explained above apply.