Bituminous roofing membranes: practical considerations

Turenne, R. G.

Publisher's version / Version de l'éditeur:
https://doi.org/10.4224/40000691
Canadian Building Digest, 1980-07-01

Canadian Building Digest
Division of Building Research, National Research Council Canada

CBD-211

Bituminous Roofing Membranes: Practical Considerations

Please note

Originally published July 1980.

R. G. Turenne

Bitumens and felts. combined to form an impervious membrane, have long been used to waterproof flat and moderately sloped roofs. If properly maintained, these membranes usually perform satisfactorily and, although durability is difficult to establish, their useful life is thought to be 20 years. Some of these roofs, however, fail within 5 to 10 years. Many reasons have been advanced for these failures, perceived by many to be a recent phenomenon. But all the major problems observed on roofs today, such as ridging, splitting, shrinkage and blistering have been problems for many years, indicating that perhaps design and workmanship may play an important role in the premature failure of bituminous roofing membranes.

Aspects of design and workmanship pertaining to adhesion and edge restraint were discussed in Digests **181** and **202**. The effect of moisture on bituminous membranes has been studied by Laaly[1] and the effect of cyclical heating and cooling is discussed by Handegord and Solvason.[2] This Digest examines the two materials, bitumens and felts, used in the installation of bituminous membranes.

Bitumen

Only two bitumens are used in the roofing industry: coal tar pitch and asphalt. Coal tar pitch is a byproduct of the production of coke from coal; roofing asphalt is the oxidized residue of the distillation of crude oil. Their sources, preparation and properties have been described in **CBD 38**.[3]

Bitumens perform two functions in a built-up membrane: they act as an adhesive (bonding the felts together) and they constitute, in the form of a pour coat, the main waterproofing component of the built-up membrane.

There are several temperature-related properties that can influence the performance of bitumens. These are softening point, finished blowing temperature, flash point, and application temperature (also called equiviscous temperature (EVT)).

Softening point. -- The softening point is the temperature at which a particular bitumen softens. The softening point of coal tar pitch generally falls between 60 and 68°C so it is suitable for use on flat or almost flat roofs. The softening point of residual or straight-run asphalt must usually be raised by oxidation in a blowstill before the material can be used for roofing. This process produces asphalts with a range of softening points as listed in the following Canadian Standards Association table.

Bitumens	Softening Point, °C	Recommended Slopes
Asphalt Type 1	60-65.5	0 to 1:16
Asphalt Type 2	74-79.5	1:16 to 1:8
Asphalt Type 3	88-96	Greater than 1:8
Coal Tar Pitch	60-68	0 to 1:25

Finished blowing temperature. -- Oxidation is achieved by blowing small air bubbles into a blowstill containing straight-run asphalt, preheated to about 160°C. The oxygen reacts with the asphalt to form asphaltenes (oxidized hydrocarbons). As the reaction continues, the asphaltene molecules increase in size and number, raising the viscosity of the asphalt and hence its softening point. This chemical activity produces heat which further raises the temperature of the asphalt in the container and which must be controlled, usually by evaporative cooling. The maximum temperature that can be withstood safely by the asphalt is called the finished blowing temperature (about 250°C for Type 1 asphalt; 260°C for Type 3).

Bitumens must be heated before application so they will flow and bond to the felts. Heating oxidized asphalt in a closed tanker or closed kettle above its finished blowing temperature can lower the softening point and cause slippage. Overheating asphalt in an open kettle hardens it through loss of volatiles which reduces its flexibility, its adhesive qualities and resistance to weathering. The extent of the damage resulting from overheating depends on the temperature and the length of time the asphalt is maintained at the high temperature.

Coal tar pitch should not be heated above 205°C as prolonged overheating will remove some volatiles resulting in a harder product.

Flash point. -- Asphalt will ignite when touched by a flame if heated to or above its flash point. Although for most asphalts there is usually a large temperature difference between the finished blowing temperature and the flash point (between 50 and 60 C deg) in some cases the difference can be as little as 10 to 15 C deg.

The flash point for coal tar pitch is only 120°C. Care must be taken on construction sites, therefore, as the material is always heated above this temperature.

Equiviscous temperature. -- At low temperature asphalt is brittle, at room temperature it behaves viscoelastically, at high temperatures it flows like a liquid. The optimum viscosity for mopping asphalt at the recommended application of 1 kg/m² 125 x 10^{-6}m²/s. As the temperature at which asphalt achieves this viscosity varies with source and type, no single temperature applies to all. The temperature at which an asphalt achieves its optimum viscosity for mopping is called the equiviscous temperature (EVT).

As it is more practical to work within a range of temperature, the concept of the equiviscous temperature range has been developed setting temperature limits of EVT ± 15°C. These limits allow an application of asphalt ranging between 0.8 and 1.2 kg/m² proper techniques are used. A typical EVT range at the point of application for a Type 1 asphalt might be between 180 and 210°C; for a Type 3 it could be between 210 and 240°C. In obtaining these temperatures, however, the asphalt must not be overheated. Particularly in cold weather, insulated lines, luggers and buckets along with auxiliary heating equipment close to the point of application might have to be used to meet the temperature limits set by the finished blowing temperature.

For coal tar pitch an application temperature of 190°C is generally recommended with a minimum of 165°C acceptable, depending on site conditions. As coal tar pitch is 23% heavier than asphalt, its application should be 1.25 kg/m².

Felts

Two types of felt, saturated felts and coated sheets, are generally used in built-up membranes. Saturated felts consist primarily of organic or inorganic fibres (asbestos) which are interlocked to form a continuous sheet, then saturated with asphalt or coal tar pitch (organic felts only) and perforated for use in roofing. Coated sheets are saturated felts to which has been applied, usually to both surfaces, a coating composed of an asphalt that has a high softening point and contains a mineral stabilizer. Coated sheets are often used as the first or bottom sheet in a built-up membrane since the coating provides some protection to the felt above the joints in the rigid insulation. Such protection is often lacking when saturated felts are used exclusively as the space between insulation boards allows the hot asphalt to run down, exposing the fibres to moisture absorption if any moisture is already in the system or if it infiltrates after completion of the roofing.

Saturated felts have an open texture and the hot bitumen can penetrate into the spaces between the fibres to ensure good adhesion between the two. As these felts absorb moisture (and moisture interferes with adhesion) they must be appropriately protected at the site from the weather.

Adhesion between coated sheets and hot asphalt occurs at the interface. To achieve satisfactory adhesion the asphalt must be applied at the correct temperature and the coated surface must be free of moisture, etc.

Felts are used in built-up membranes to provide a uniform substrate for the asphalt pour coat and to give the membrane the necessary strength to withstand thermal stresses, small structural movements and light traffic. Organic felts can lose much strength when they become saturated with moisture. water, therefore, should be prevented from ponding on the membrane by sloping it to a drain; proper flashing details should be provided to protect all edges of the roofing system. The installation should be carried out according to recognized standards, and the roofing should not be abused by other trades once completed.

Membranes

A built-up membrane has a different construction depending on whether it is examined in the longitudinal or in the transverse direction of the felts (Figure 1). A section taken in the longitudinal direction usually shows 3 or 4 superimposed and continuous felts separated by a thin layer of bitumen. A section taken in the transverse direction, however, shows a number of narrow felts overlapping one another by 2/3 or 3/4 of their width and adhering to one another by a layer of asphalt. Tensile stresses in a membrane in the longitudinal direction are thus resisted in tension by the reinforcement provided by the continuous felts; stresses in the transverse direction are transferred from felt to felt by the asphalt adhesive. Thus the type, quality of adhesion, and quantity of asphalt are critical factors in the transverse direction and help to explain why failures such as ridging and splitting generally occur in the longitudinal direction.

Figure 1. Sections through 4-ply membrane.

Adhesion. -- When asphalt mopping is applied in the quantity of 1 kg/m^2 at the proper temperature, it wets and penetrates the surface of a #15 felt, forming a thin continuous glue line between the felts. If not enough asphalt is used the glue may be discontinuous. This will weaken adhesion and facilitate the growth of blisters. Too much asphalt makes the glue line unnecessarily thick and this may modify the behaviour of the membrane.

Ridging. -- If the interply layers of asphalt, especially one with a low softening point, are too thick, slippage can occur between plies in warm weather and this may contribute to ridge formation. As ridges form parallel to the longitudinal direction of the felts and require from 6 to 10 mm of membrane, anything that causes widening and movement of a membrane (resulting in a fold) must be considered as a source of ridging. Quantity of asphalt is but one factor, others are: cyclical heating and cooling of the membrane, joints in the rigid insulation supporting the membrane, and poor adhesion.

During warm weather the maximum temperature of a roofing membrane can exceed the softening point of the asphalt used in its construction. When heated, a membrane expands. If it is restrained in the horizontal plane, most of the expansion will occur in the vertical plane (thickening of the membrane). If there is poor adhesion between the membrane and its substrate (or too much bitumen) expansion may also occur in the horizontal plane with the membrane buckling opposite discontinuities in the substrate, e.g., at insulation joints.

When a cooling cycle begins, the stresses induced in the membrane change from compressive to tensile and, due to the overlapping construction in the transverse direction, stresses in adjacent felts may act in opposite directions. If the tensile stresses in the felts are less than the bond strength between plies, the member will return to its original size and the buckle will disappear. If, however, the felts are adhered together by a heavy coating of low softening point asphalt, laminar flow may occur between the plies and the buckle may not disappear. Growth of the ridge will continue as the daily heating-cooling cycle induces expansion of the membrane followed by tensile stresses in the felts.

Roofing membranes installed in cold weather are susceptible to this type of problem as the rapid drop in temperature of the asphalt often results in thick interply moppings and relatively poor adhesion of the membrane to its substrate. Ridges will start to form in the spring as the membrane temperatures reach or exceed the softening point of the asphalt. Laboratory tests on a membrane that had ridged extensively showed that the average weight of application was in the neighbourhood of 1.75 kg/m^2.

Increasing the weight of interply asphalt may have other deleterious effects on the membrane, e.g., tests revealed that such an increase may aggravate the stresses in cold weather.[4] This increase may also make the composite more brittle and thus more susceptible to splitting in cold periods.

Slippage. -- Slippage of roofing membranes on sloped roofs and interply blistering on flat roofs is a potential problem when a built-up membrane includes a coated sheet. Even at the recommended application of 1 kg/m^2 glue line between a coated sheet and a #15 felt is usually thicker than normal because the asphalt does not penetrate the coated sheet. The phase construction required to install a coated sheet followed by 3 plies of #15 felt results in an unbroken layer of asphalt between the coated sheet and the #15 felts and slippage can occur along this plane if too much asphalt or one having too low a softening point is used on sloping roofs.

Coated sheets. -- Coated sheets are often left for several days as temporary roofing over insulation pending completion of the membrane. This is an unwise practice as water may infiltrate if the laps are not well sealed and moisture, dirt and other foreign matter may collect and settle on the sheets. When installation of the remaining plies resumes, adhesion may be jeopardized resulting in a permanent separation between the base sheet and the #15 felts.

Glaze coat. -- Glaze coating of felts should not be used in phase construction as double mopping results in excess asphalt between plies. Designers should not require that felts be laid in opposite directions in a two on two construction unless all felts can be laid the same day. As glaze coats are used mainly to provide overnight or short-term protection for the insulation and the building, dust and moisture, which often collect on the coating, can only add to the problem created by an excess of asphalt between plies.

Moisture. -- Foaming often occurs when hot asphalt is applied on a felt that contains moisture. This can interfere with penetration and adhesion and can trap air bubbles within the asphalt coating when water vapour is replaced by air especially in cold weather. Interply blisters occur when the temperature rises. Moisture that is sometimes present only in the outer edges of a roll of felt can produce a scalloped effect along the exposed edge of the felt when it is being laid. This edge will invariably protrude through the pour coat and the felts will absorb moisture every time it rains leading to membrane deterioration.

Points to remember

A roofing contractor should:

- know the equiviscous temperature, the finished blowing temperature, the flash point and softening point for the asphalt purchased
- verify that the type supplied is the one specified especially if it is to be used on a sloping roof
- not heat the asphalt above its finished blowing temperature (its temperature at the time of application should be within the EVT range)
- reorganize the operation or stop temporarily if required temperatures cannot be maintained
- apply the proper weight of asphalt (the EVT concept will not guarantee the amount of bitumen to be applied per square metre)
- complete the entire membrane the same day (including pour coat and gravel)
- not use a coated sheet, glaze-coated or not, to provide overnight or short-term protection from rain (ideally, coated sheets used as the bottom ply in the a built-up membrane should be coated on the underside only so the topside can adhere well to the other felts)
- use only dry materials and install proper water cutoffs at the end of every day and remove them before continuing the next day
- apply the final pour coat as uniformly as possible and without any omissions so as to completely waterproof all felts.

References

1. Laaly, H. O. Effect of moisture on the strength characteristics of built-up roofing felts. Am Soc. Test Mater., ASTM STP 603, 1976, p. 104-113.
2. Solvason, K. R. and Handegord, G. 0. Ridging, shrinkage and splitting of built-up roofing membranes. Nat. Res. Council Canada, Div. Bldg. Res., Bldg. Res. Note 112, June 1976.
3. Jones, P. M. Bituminous materials, Nat. Res. Council Canada, Div. Bldg. Res. **CBD 38**, 1963.
4. Lee, J. W., Dupuis, R. M., and Johnson, J. E. Experimental determination of temperature induced loads in BUR systems. Proc., Symposium on Roofing Technology, Washington, Sept. 21-23, 1977, p. 38-48.