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Bituminous Materials

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Please note

Bituminous materials have had wide application in the building industry for a great many years. As early as 3800 B.C. they were used in construction because of their adhesive and waterproofing properties. Obtained from naturally occurring deposits these bitumens were used by the rulers of the Assyrian, Sumerian and Chaldean empires to waterproof their palace walls.

In spite of the passage of many centuries, bituminous materials are still used extensively in construction; they retain their excellent adhesive and waterproofing properties although it is recognized that they can be adversely affected if the materials are improperly used. For example, under the influence of water, excessive temperature and solar radiation, bitumens can be slowly broken down to carbon dioxide and water. Their service life, however, can be greatly extended if they are given a measure of protection. It is the purpose of this Digest to discuss the properties of bituminous materials and the manner in which they should be handled to derive the maximum benefit from their use.

What are Bitumens?

Many terms and definitions of terms are used to describe bitumens. "Bitumen" itself is a generic name applied to mixtures of hydrocarbons, which can be gaseous, liquid, semi-solid or solid and are completely soluble in carbon disulphide. Within this class of materials there are many substances, the most common of which are tars, pitches and asphalts.

Tars are dark brown condensates produced by the destructive distillation of materials such as wood, peat, shale, bone and coal. Fractional distillation or partial evaporation of tar results in a solid or semi-solid residue known as pitch. Coal-tar pitch is the most common material of this type that is used in construction.

Asphalts are dark brown to black solids or semi-solids that gradually liquefy when heated. They are found in the natural state but may also be obtained from petroleum. Essentially, the origin of natural asphalt is the same as that of asphalt produced by the refining of petroleum, except that the latter process is accomplished at higher temperatures in a much shorter time.

The largest commercially exploited natural asphalt is a lake over 300 feet deep and covering an area of 100 acres on the island of Trinidad. Other natural asphalts occur as rock asphalt in Kentucky and as very hard asphalts such as Gilsonite in Utah and Colorado.

The removal of gasolines, oils and other volatile products from crude oil results in a residual asphalt often called a straight-run asphalt. The properties of this product depend upon the nature of the crude source and the conditions of refining. Residual material is often used directly, but on occasion further refining is necessary to produce a harder material. This can be achieved by an air-blowing or oxidation process in which air is blown through heated residual asphalt, control of the process producing various degrees of hardness. The actual chemical and physical process is not fully understood, owing to, the complex nature of the bituminous materials; they are thought to be colloidal and to consist of a dispersion of high molecular weight material in a fluid having a lower molecular weight. The bitumen is changed physically if this colloid system is disturbed, as may be seen when a bitumen is overheated. Some of the lower molecular weight material is distilled off so that some of the flexibility and adhesive qualities are lost. Consistency can also be increased by using a pulverized mineral filler whose chief function is to increase viscosity. This achieves the same result as oxidation without sacrificing the serviceability expected from soft asphalts.

Properties

Adhesiveness of bitumen to a surface depends upon both the nature of the surface and the state of the bitumen. For an adhesive to act it must be able to wet a surface. In a fluid state bitumens can wet a dry solid surface and good adhesion will result, but the presence of water will prevent adhesion. The temperatures of the solid and the bitumen also influence the bond, as will any dust on the surface of the solid and the nature of the solid itself. Even after a bitumen bas been successfully applied, the bond can be decreased or even destroyed by the entrance of water into the bitumen-solid interface.

A number of additives to improve adhesion of bitumens to solid surfaces have been proposed. These compounds have a powerful wetting and adhesive action, and when present in small amounts in bitumens they displace water from the solid surface and permit a good bond. They also prevent any deterioration of the bond should water ever reach the interface. The creation and maintenance of a good adhesive bond between bitumen and a solid is an essential requirement for satisfactory performance.

The water resistance properties of bitumens depend upon the degree of impermeability and water absorption inherent in them. Even a very thin layer (1/64 inch) in a continuous film provides an excellent water barrier. In practical applications the degree of impermeability will be affected by the nature of the filling materials and the continuity of the bituminous coating. For waterproofing and roofing applications, fabrics or felts are used to build up a membrane to provide and maintain continuous waterproofing films.

Under certain conditions water may be absorbed by the bitumen itself or by minute quantities of inorganic salts or fillers in it. The normal solubility of water in bitumen is in the order of 0.001 to 0.01 per cent by weight and is so small as to be negligible. The presence of water soluble salts in any quantity will result in a large capacity for water absorption by osmosis. For this reason oil refineries de-salt the crude oil before refining it. Fillers also can absorb certain quantities of water, the amount varying with the composition and granular size of the material. As a result it bas been found that bitumens in permanent contact with water absorb it in varying amounts, and various claims as to the relative water absorption properties of coal-tar pitch and asphalt have been made.

Results of recent tests on asphalt and coal-tar pitch have reported water absorptions of 0.5 to 2.4 grams/sq ft for commercial coal-tar pitches and 2.0 to 3.9 grams/sq ft for commercial asphalts after one year. This rate of absorption is very low and there is very little difference between the two. It is more significant that the rate of water penetration into the bitumen is also very low.

The viscous or flow properties of bitumens are of importance, both at the high temperatures encountered in processing and application and at the low temperatures to which bitumens are subjected in service. Flow properties are complex and are further confused by changes in the colloidal nature of the bitumens that occur with heating. When the temperature is high enough for the bitumen to be liquid, the rate of shear is directly proportional to the shearing stress. As the temperature drops, how ever, these flow properties are complicated by elasticity and other effects. This has necessitated empirical tests, which. are used by the producer and consumer to measure the consistency of the bituminous materials at temperatures comparable to those encountered in the service life of the bitumen. Among the most common of these tests are the penetration and softening point tests and various indices using them.

The penetration test measures the depth of penetration in tenths of millimetres that a weighted needle achieves in a bitumen after a known time at a known temperature. The most common combination of factors is a weight of 100 grams applied for 5 seconds at a temperature of 77°F. The penetration is a measure of hardness, and typical values obtained are approximately 10 for hard coating grade asphalts, 15 to 40 for roofing asphalts, and up to 100 or more for certain waterproofing materials.

The softening point test measures the temperature in degrees Fahrenheit at which a steel ball falls a known distance through the bitumen when the test assembly is heated at a known rate. The usual combination of factors is a ¾-inch diameter steel ball weighing 3.5 grams sinking 1 inch through a 5/8-inch diameter ¼-inch thick disc of bitumen held in a brass ring, with the whole assembly heated at a rate of 9F degrees per minute. The resulting measured temperature is not the melting point, but merely gives a measure of flow under controlled conditions. The softening point value is used to grade bitumens into groups. Typical values would be up to 240°F for coating grade asphalts, from 140°F to 220°F for roofing asphalts, and down to approximately 115°F for certain waterproofing materials.

When chilled sufficiently all bitumens lose their viscous properties and behave as brittle elastic solids. The interval between the softening point temperature and the temperature at which a brittle condition is reached gives a measure of the temperature susceptibility of the material. This can vary a great deal, depending on the crude oil source and the bitumen processing. Successful use of bitumen usually results if a material has been chosen that will be subjected in service to temperatures well within the limits defined by its brittle condition and softening point.

Lack of compatibility between different bitumens is also of importance, and exhibits itself by staining and the appearance of oil spots or large cracks. If a coal-tar pitch and an asphalt are incompatible, one will be softened and the other hardened, the nature and extent of incompatibility depending upon the chemical composition and internal physical structure of the bitumens. The reaction of asphalt towards pitch can be manifested in two ways:

1. If asphalt is applied over pitch it can soften and flow off, leaving exposed pitch that will weather rapidly.

2. If pitch is applied over asphalt, the pitch may harden and crack.

These reactions do not always occur and sometimes asphalt can be applied over pitch, or vice versa, with no ill effects. It is considered advisable, however, to avoid contact of the two bitumens if possible, and for this reason asphalt should not be used with tar-saturated felt, nor should tar be used with asphalt-saturated felt. If any doubt exists on the compatibility of bituminous materials, a test bas been devised to establish it (ASTM D1370-58).

To enable bitumens to wet the surface that is to be protected, they are often applied in the hot liquid state. The temperature to which they should be heated depends upon both the consistency of the bitumen and the temperature of the surface to, which it is applied. As a maximum temperature exists, however, above which chemical degradation of the bitumen occurs, it is not advisable to, heat asphalts above 450°F and coal-tar pitches above 400°F. Coal-tar pitches and one grade of asphalt for built-up roofing have a softening point of about 140°F; it is thus possible, by heating these materials even to 350°F or lower, to obtain a liquid that will wet a dry solid surface and enable the bitumen to be applied so that it can act as a waterproofing agent.

It is occasionally desirable to avoid the use of a hot material. At such times bituminous products are used in so-called cold applications, with the bitumen in liquid form as a cutback or an emulsion. (A cutback material is a solution of the bitumen in a suitable solvent.) After application of the bituminous solution to the solid surface, the solvent evaporates leaving the bituminous film to act as a coating. Numerous solvents are sufficiently volatile and are good solvents for bitumens, but many are either too expensive or too hazardous. To control the drying times of the solution, care must be taken in the selection of the bitumen and solvent.

Emulsions are dispersions of very small drops of bitumen in water. A satisfactory emulsion is smooth in appearance, usually brown In colour, and can be made from bitumens having a wide range of consistencies. Emulsions usually contain a mineral material and are often called clay emulsions, although the mineral can also be coal, shale, metallic oxides, portland cement or asbestos. The most widely used is a special clay known as bentonite. An obvious advantage of emulsions over other bituminous products is that they are easy to handle, addition of water being all that is necessary to decrease their viscosity. Curing involves, primarily, a loss of water by evaporation; its stability, however, depends upon many factors such as asphalt concentration, size and distribution of asphalt droplets, freezing of the water and the nature of the stabilizing agent.

Durability

Mention bas been made of the changes that bitumens undergo when they are overheated; this is but one of the peculiarities encountered in their handling and service. Among the other factors to be considered are water absorption and photo-oxidation. Bitumens are readily oxidized when subjected to ultra-violet radiation, a process that forms water soluble products and results in a material that is harder and less flexible than it was originally. If it continues until the bitumen can no longer withstand the strains imposed by thermal and structural movement, the material cracks. The loss of volatile materials also causes contractions that frequently cause shrinkage cracks. In the absence of light and heat, however, the rate of oxidation is low and the useful life of the materials can be extended. Light-coloured gravel in built-up roofing construction provides the protection required for satisfactory durability.

Uses of Bitumens

The desirable qualities of bitumens control the uses to which they may be put; the limitations of the materials control the methods of application and their performance in service. Adhesiveness and waterproofing qualities, combined with low cost, make them useful as a protective agent in both built-up and prepared roofing and in prepared siding. They have wide use also as sealants and adhesives. Combined with other materials, bitumens may be used as vapour barriers and as agents to waterproof and damp-proof structures.

Bitumen is used in many forms depending upon the characteristics and properties desired. Saturated felts, used in built-up roofing as a base for prepared roofing and siding, as underlays for floors, and as a membrane for waterproofing, require a particular grade of bitumen that bas a low viscosity at the saturation temperature. The flash-point should be above the saturating temperature, however, and a reasonably low temperature susceptibility is desirable. In the preparation of asphalt-saturated felt an asphalt having a softening point of approximately 140°F and penetration value of 50 is used.

Prepared roofing products such as shingles and roll roofing consist of saturated felts coated with asphalt. The coating grade asphalts used for this application are high softening point (200 to 240°F) air-blown products with high penetration values of 18 to 30 at 77°F; they have low temperatures susceptibility. Care is taken during manufacture to ensure that the coating asphalt is compatible with the saturant.

Bitumens are widely used to provide a waterproof coating to walls and to construct waterproof membranes in buildings and engineering structures. Hot applied bitumens used below grade, where they are not subjected to high temperatures, are of a type having a low softening point (115 to 145°F) and a high penetration value (up to 85). Where the bitumen is to be used above grade and may be applied to vertical surfaces exposed to direct solar radiation, a type having a higher softening point (200 to 220°F) and a lower penetration value (15 to 25) should be selected. Emulsions and cutbacks that are applied cold are being used to an ever-increasing extent for damp-proofing and waterproofing. They may be used alone or with felts to build up a membrane.

Asphaltic cutbacks and emulsions have their greatest use in road construction and maintenance. With roofing it accounts for about 95 per cent of the asphalt produced in North America. There are still, however, large quantities of asphalt modified by the addition of mineral matter used in the building industry as sealants, acoustical coatings and paints.

Summary

Some of the more important properties of bitumens have been examined in this Digest. Particular mention has been made of the adhesive, waterproofing and flow characteristics that control the use to which bitumens are placed in construction. An outline has also been given of the various bitumens and the manner in which they are used. Recent studies have produced much information to justify even more research into the properties of bituminous materials. As more becomes available on composition, internal structure, mechanisms of flow, degradation and adhesiveness, a more widespread and even more successful use of this material in construction can be anticipated.