7. BITUMIN-BOUND MATERIALS

7.1 Introduction

Binders used in pavement construction are mainly of two types: cement and bitumen. Cement is the most commonly used cementing agent in the concrete building industry. In road construction, it is used as a binder for rigid pavement structures and a stabilizing agent. Bituminous material (or bitumen), also known as asphalt cement in the US, is a viscous liquid or solid material, black or dark brown in colour, having adhesive properties, consisting essentially of hydrocarbons which are soluble in carbon disulphate. They are usually fairly hard at normal temperatures. When heated, they soften and flow. When mixed with aggregates in their fluid state, and then allowed to cool, they solidify and bind the aggregates together, forming a pavement surface. They are used on all types of roadway – from multiple layers of asphalt concrete on the highest class of highways to thin, dust-control layers on seldom-used roads. Because enough coverage on properties, mix design, and quality control of cement concrete is normally provided in other civil engineering courses, this chapter focuses on bituminous binders.

7.2 Types of Bituminous Materials

Bituminous materials are derived from petroleum or occur in natural deposits in different parts of the world. Based on their sources there are two main categories of bitumens, namely, those which occur naturally and those which are by-products of the fractional distillation of petroleum at refinery. Refinery bitumens are by far the greater proportion of road bitumen used all over the world. Of the possible types falling into these categories, the ones that are used for highway paving purposes are illustrated in Figure 7.1.

![Figure 7-1: Commonly used types of road bitumen](image-url)

Bituminous Materials

- Natural Bitumen
  - Lake asphalt
  - Rock asphalt
- Refinery Bitumen
  - Penetration grade bitumen
  - Liquid bitumen
  - Cutbacks
    - Slow curing cutback
    - Medium curing cutback
    - Rapid curing cutback
  - Emulsions
    - Anionic emulsion
    - Cationic emulsion
7.2.1 Natural Bitumen

Native or natural Bitumens relate to a wide variety of materials and refer to those bitumens that are found in nature as native asphalts or rock asphalts associated with appreciable quantities of mineral matter. Native asphalts are obtained from asphalt lakes in Trinidad and other Caribbean areas, and were used in some of the earliest pavements in North America after softening with petroleum fluxes. The properties depend on the insoluble materials (organic and inorganic) the asphalt contains. Some natural asphalts are soft and adhesive; others are very hard and brittle. Some exist on the surface of the earth in lakes or pools, while others occur at depth and must be mined. Rock asphalts are natural rock deposits containing bituminous materials that have been used for road surfaces in localities where they occur.

7.2.2 Refinery Bitumen

Bitumens artificially produced by the industrial refining of crude petroleum oils are known under a number of names depending on the refining method used such as residual bitumens, straight-run bitumens, steam-refined bitumens and — as is now most commonly accepted — refinery bitumens. Petroleum crudes are complex mixtures of hydrocarbons differing in molecular weight and consequently in boiling range. Before they can be used, crudes have to be separated, purified, blended, and sometimes chemically or physically changed. Not all petroleum crudes contain a sufficient quantity of bitumen to enable straight reduction to specification road bitumen. Those which do are known as asphalitic-base crudes. Crudes which contain high proportions of simpler paraffinic compounds, with little or no bituminous bodies present, are known as paraffinic-base crudes. Some petroleum crudes exhibit characteristics of both the previous categories, and these are known as mixed-base crudes.

The primary processing involved in the production of bitumen from petroleum is fractional distillation. This is carried out in tall steel towers known as fractionating or distillation columns as schematically shown in Figure 7.2. The inside of the column is divided at intervals by horizontal steel trays with holes to allow vapour to rise up the column. In this process, part of the hydrocarbon materials in the crude oil are vaporized by heating them above their boiling points under pressure. The lightest fractions of the crude remain as a vapour and are taken from the top of the distillation column, heavier fractions are taken off the column as side-streams with the heaviest fractions remaining as a liquid and therefore left at the base of the column. The lightest fractions produced by the crude distillation process include propane and butane which are gases under
atmospheric conditions. Moving down the column a slightly heavier product, naphtha, is produced which is a feedstock for gasoline production and the chemical industry. Then there is kerosine, which is used primarily for aviation fuel and to a lesser extent for domestic fuel. Heavier again is gas oil, which is used as a fuel for diesel engines and central heating. The heaviest fraction taken from the crude oil distillation process is long residue which is a complex mixture of high molecular weight hydrocarbons. Such refining process is known as straight-run distillation, and the residue is straight-run bitumen.

**Figure 7-2:** Flow chart of the manufacture of refinery bitumen

To remove high boiling temperature constituents such as those contained in the non-volatile oils, refining is carried out, without changing them chemically by the use of reduced pressures and steam injection in the fractionating column. This type of distillation is known as vacuum or steam distillation, and bitumen produced by such means are said to be vacuum reduced or steam refined.

On the other hand, when the objective is primarily to increase the yield of fuels, the petroleum oil undergoes cracking distillation. In general, cracking process consists in exposing the petroleum crude to a temperature of 475-600°C at pressure varying from 3 to 75 atmospheres. This process
produces heavier residues as a consequence of forming the lighter materials. These residues are known as "cracked oil" or "cracked asphalt". They are characterized by relatively high specific gravity, low viscosity, and poor temperature susceptibility. They are generally regarded as less durable or weather resistant than straight run materials.

In a few cases, a selective solvent, such as propane, is used to treat the topped crude to separate paraffinic crude oils of high viscosity index for use in the manufacture of lubricating oils and special products. This separation method is based on chemical type and molecular weight rather than by boiling point as in the usual distillation. In the process, the paraffinic oils are dissolved by the solvent and come afloat in the fractioner vessel. The residual asphalt, which is relatively insoluble, is drawn off at the bottom.

These residual asphalts produced by the different methods of refining described above are of various grades asphalt cement, depending upon the degree to which distillates are removed as determined by the conditions of distillations. They are further processed by air-blowing, blending, compounding, and admixing with other ingredients to make variety of asphalt products used in paving, roofing, waterproofing, coating and sealing materials, and materials for industrial applications.

7.2.3 Penetration Grade Bitumen

In the preparation of paving binders, it is common to blend two or more different asphaltic residues to produce a material possessing desirable physical properties. Additive materials may also be used to improve properties such as adhesion to solid surfaces and flowing characteristics. By varying the ingredients and the amounts used, it is possible to exercise considerable control over the properties of the finished asphalt. The major paving products are penetration grade bitumens (also known as asphalt cements), cutback asphalts, and asphalt emulsions.

Penetration grade bitumen or asphalt cements are in consistency from semi-solid to semi-liquid at room temperature. Such bitumen are graded according their viscosity (mainly used in the US) and penetration. Penetration is the depth in 0.1 mm that a specified needle is able to penetrate the samples when standard penetration tests are carried out. They are produced in various viscosity grades, the most common being AC 2.5, AC 5, AC 10, AC 20, and AC 40. These roughly correspond to penetration grades 200-300, 120-150, 85-100, 60-70, and 40-50, respectively. The viscosity grades indicate the viscosity in hundreds of poises ± 20% measured at 60°C (140°F). For example, AC 2.5 has a viscosity of 250 poises ± 50. AC 40 has a viscosity of 4000 poises ± 800.
The majority of penetration grade bitumens is used in road construction, the harder grades, 35 pen to 100 pen, being used in asphalt where bitumen stiffness is of primary importance and the softer grades, 100 pen to 450 pen, in macadams where the lubricating properties during application and bonding of the aggregate in service are more important. During construction asphalt cements require to be heated to varying degrees before mixing with hot or warm aggregates and the mixed material must be laid while hot within a few hours of mixing.

7.2.4 Liquid Bitumen

Sometimes it is uneconomical or inconvenient to use hot asphalt in road construction. In such situations, liquid binders are preferable to handle at relatively low temperatures and mixed with aggregates either when cold or only warmed sufficiently to make them surface-dry. For the suitability of such construction methods, asphalt cements are frequently modified by preparation as liquid products. The two forms of liquid bitumen generally, are those which are prepared by dissolving the asphalt cement in a suitable volatile solvent and known as cutback bitumen, and those which are prepared by emulsifying the asphalt cement in an aqueous medium and called bitumen emulsions.

Cutback Bitumen

Cutback bitumen are prepared by dissolving penetration grade bitumen in suitable volatile solvents to reduce their viscosity to make them easier to use at ordinary temperatures. They are commonly heated and then sprayed on aggregates. Upon curing by evaporation of the solvent, the cured-out asphalt cement will be in approximately the same condition as before being taken into solution and bind the aggregate particles together. The curing period depends on the volatility of solvents.

Cutback bitumen are grouped into three types based on the type of solvent, which governs the rates of evaporation and curing, namely, slow-curing (SC), medium-curing (MC), and rapid-curing (RC). Each type of cutback bitumen is subdivided into several grades characterized by their viscosity limits. The viscosity is controlled by the quantity of cutback solvent to make the various grades from very fluid to almost semi-solid at ambient temperatures.

**Slow-Curing (SC) Cutbacks:** Slow-curing asphalts can be obtained directly as slow-curing straight-run asphalts through the distillation of crude petroleum or as slow-curing cutback asphalts by "cutting back" asphalt cement with a heavy distillate such as diesel oil. They have lower viscosities than asphalt cement and are very slow to harden. Slow-curing asphalts are usually
designated as SC-70, SC-250, SC-800, or SC-3000, where the numbers are related to the approximate kinematic viscosity in centistokes at 60°C (140°F). They are used with dense-graded aggregates and on soil-aggregate roads in warm climates to avoid dust.

Medium-Curing (MC) Cutbacks: Medium-curing asphalts are produced by fluxing, or cutting back, the residual asphalt (usually 120-150 penetration) with light fuel oil or kerosene. The term medium refers to the medium volatility of the kerosene-type diluent used. Medium-curing cutback asphalts harden faster than slow-curing liquid asphalts, although the consistencies of the different grades are similar to those of the slow-curing asphalts. However, the MC-30 is a unique grade in this series as it is very fluid and has no counterpart in the SC and RC series.

The fluidity of medium-curing asphalts depends on the amount of solvent in the material. MC-3000, for example, may have only 20 percent of the solvent by volume, whereas MC-70 may have up to 45 percent. These medium-curing asphalts can be used for the construction of pavement bases, surfaces, and surface treatments.

Rapid-Curing (RC) Cutbacks: Rapid-curing cutback asphalts are produced by blending asphalt cement with a petroleum distillate that will easily evaporate, thereby facilitating a quick change from the liquid form at time of application to the consistency of the original asphalt cement. Gasoline or naphtha generally is used as the solvent for this series of asphalts.

The grade of rapid-curing asphalt required dictates the amount of solvent to be added to the residual asphalt cement. For example, RC-3000 requires about 15 percent of distillate, whereas RC-70 requires about 40 percent. These grades of asphalt can be used for jobs similar to those for which the MC series is used, but where there is a need for immediate cementing action or colder climates.

Asphalt emulsions

Emulsified asphalts are produced by breaking asphalt cement, usually of 100-250 penetration range, into minute particles and dispersing them in water with an emulsifier. These minute particles have like electrical charges and therefore do not coalesce. They remain in suspension in the liquid phase as long as the water does not evaporate or the emulsifier does not break. Asphalt emulsions therefore consist of asphalt, which makes up about 55 percent to 70 percent by weight, up to 3% emulsifying agent, water and in some cases may contain a stabilizer.
Two general types of emulsified asphalts are produced, depending on the type of emulsifier used: cationic emulsions, in which the asphalt particles have a positive charge; and anionic, in which they have a negative charge. Each of the above categories is further divided into three subgroups, based on how rapidly the asphalt emulsion will return to the state of the original asphalt cement. These subgroups are rapid setting (RS), medium-setting (MS), and slow setting (SS). A cationic emulsion is identified by placing the letter "C" in front of the emulsion type; no letter is placed in front of anionic and nonionic emulsions. For example, CRS-2 denotes a cationic emulsion, and RS-2 denotes either anionic or nonionic emulsion.

The anionic and cationic asphalts generally are used in highway maintenance and construction. Note, however, that since anionic emulsions contain negative charges, they are more effective in adhering aggregates containing electropositive charges such as limestone, whereas cationic emulsions are more effective with electronegative aggregates such as those containing a high percentage of siliceous material. Cationic emulsions also work better with wet aggregates and in colder weather. Bitumen emulsions break when sprayed or mixed with mineral aggregates in a field construction process; the water is removed, and the asphalt remains as a film on the surface of the aggregates. In contrast to cutback bitumens, bitumen emulsions can be applied to a damp surface.

7.2.5 The Air-Blown Bitumen

The physical properties of the short residue are further modified by air-blowing. Air-blowing is a process in which a soft asphaltic residue is heated to a high temperature in an oxidation tower where air is forced through the residue either on a batch or a continuous basis. The process results in a dehydrogenation and polymerization of the residue. The hard asphaltic material produced by this process is known as oxidized or air-blown asphalt and is usually specified and designated by both softening point and penetration tests. If proper precautions are not taken, the temperature can rise to the point where the physical characteristics of the product are seriously affected. However, by controlling the conditions in the process a large variety of blown asphalts can be produced. Oxidised bitumens are used almost entirely for industrial applications, such as roofing, flooring, mastics, pipe coatings, paints, etc, but their use in road construction is limited.

7.2.6 Road Tars

Tars are obtained from the destructive distillation of such organic materials as coal. Their properties are significantly different from petroleum asphalts. In general, they are more susceptible
to weather conditions than are similar grades of asphalts, and they set more quickly when exposed to the atmosphere. Tars are rarely used now for highway pavements.

7.3 Tests on Bituminous Materials

Several tests are conducted on bituminous materials to determine both their consistency and their quality to ascertain whether materials used in highway construction meet the prescribed specifications. Some of these specifications are provided in standards of AASHTO, ASTM, and Asphalt Institute. Procedures for testing and selecting representative samples of asphalt have also been standardized.

7.3.1 Consistency Tests

The consistency of bituminous materials is important in pavement construction because the consistency at a specified temperature will indicate the grade of the material. It is important that the temperature at which the consistency is determined be specified, since temperature significantly affects the consistency of bituminous materials. As stated earlier, asphaltic materials can exist in either liquid, semisolid, or solid states. This necessitates for more than one method for determining consistency of asphaltic materials. The property generally used to describe the consistency of asphaltic materials in the liquid state is the viscosity, which can be determined by conducting either the Saybolt Furol viscosity test or the kinematic viscosity test. Tests used for asphaltic materials in the semisolid and solid states include the penetration test and the float test. The ring-and-ball softening point test may also be used for blown asphalt.

7.3.1.1 Saybolt Furol Viscosity Test

Saybolt Furol viscosity test is a test carried out by the Saybolt Furol Viscometer which has a standard viscometer tube, 12.7 cm (5 in) long and about 2.54 cm (1 in) in diameter with an orifice of specified shape and dimensions provided at the bottom of the tube. When testing, the orifice is closed with a stopper, and the tube is filled with a quantity of the material to be tested. The material in the tube is brought to the specified temperature by heating in a water bath and when the prescribed temperature is reached the stopper is removed, and the time in seconds for exactly 60 milliliters of the asphaltic material to flow through the orifice is recorded. This time is the Saybolt Furol viscosity in units of seconds at the specified temperature. Temperatures at which asphaltic materials for highway construction are tested include 25°C (77°F), 50°C (122°F), and 60°C
(140°F). It is apparent that the higher the viscosity of the material, the longer it takes for a given quantity to flow through the orifice.

7.3.1.2 Kinematic Viscosity Test

The test uses a capillary viscometer tube to measure the time it takes the asphalt sample to flow at a specified temperature between timing marks on the tube. Three types of viscometer tubes, namely Zeitfuch's cross-arm viscometer, Asphalt Institute vacuum viscometer, and Cannon-Manning vacuum viscometer are used.

When the cross-arm viscometer is used, the test is started by placing the viscometer tube in a thermostatically controlled constant temperature bath, and a sample of the material to be tested is then preheated and poured into the large side of the viscometer tube until the filling line level is reached. The temperature of the bath is then brought to 135°C (275°F), and some time is allowed for the viscometer and the asphalt to reach a temperature of 135°C (275°F). Flow is then induced by applying a slight pressure to the large opening or a partial vacuum to the efflux (small) opening of the viscometer tube. This causes an initial flow of the asphalt over the siphon section just above the filling line. Continuous flow is induced by the action of gravitational forces. The time it takes for the material to flow between two timing marks is recorded. The kinematic viscosity of the material in units of centistokes is obtained by multiplying the time in seconds by a calibration factor for the viscometer used. The calibration of each viscometer is carried out by using standard calibrating oils with known viscosity characteristics. The factor for each viscometer is usually furnished by the manufacturer.

The test may also be conducted at a temperature of 60°C (140°F) using either the Asphalt Institute vacuum viscometer or the Cannon-Manning vacuum viscometer. In this case, flow is induced by applying a prescribed vacuum through a vacuum control device attached to a vacuum pump. The product of the time interval and the calibration factor in this test gives the absolute viscosity of the material in poises.

7.3.1.3 Penetration Test

The penetration test gives an empirical measurement of the consistency of a semi-solid asphaltic material in terms of the depth a standard needle penetrates into that material under a prescribed loading and time. It is the bases for classifying semi-solid bituminous materials into standard grades.
Figure 7-3: Standard penetration test

Figure 7-3 shows a schematic of the standard penetration test. A sample of the asphalt cement to be tested is placed in a container, which in turn is placed in a temperature-controlled water bath. The sample is then brought to the prescribed temperature of 25°C (77°F), and the standard needle, loaded to a total weight of 100 gm, is left to penetrate the sample of asphalt for the prescribed time of exactly 5 sec. The penetration is given as the depth in units of 0.1 mm that the needle penetrates the sample. For example, if the needle penetrates a depth of exactly 20 mm, the penetration is of the material is said to be 200. When carried out at different temperature penetration test can indicate temperature susceptibility of the binder.

7.3.1.4 Float Test

The float test is used to determine the consistency of semisolid asphalt materials that are more viscous than grade 3000 or have penetration higher than 300, since these materials cannot be tested conveniently using either the Saybolt Furol viscosity test or the penetration test.

Figure 7-4: Float test

The float test is conducted with the apparatus schematically shown in Figure 7-4. It consists of an aluminum saucer (float), a brass collar that is open at both ends, and a water bath. The brass collar is filled with a sample of the material to be tested and then is attached to the bottom of the float and chilled to a temperature of 5°C (41°F) by immersing it in ice water. The temperature of the
water bath is brought to 50°C (122°F), and the collar (still attached to the float) is placed in the water bath, which is kept at 50°C (122°F). The head gradually softens the sample of asphaltic material in the collar until the water eventually forces its way through the plug into the aluminium float. The time in seconds that expires between the instant the collar is placed in the water bath and that at which the water forces its way through the bituminous plug is the float test value, and it is a measure of consistency. It is apparent that the higher the float-test value, the stiffer the material.

7.3.1.5 Ring-and-Ball Softening Point Test

The ring-and-ball softening point test is used to measure the susceptibility of asphaltic maertails to temperature changes by determining the temperature at which the material will be adequately softened to allow a standard ball to sink through it. Figure 7-5 shows the apparatus commonly used for this test. It consists principally of a small brass ring of 15.875 mm (5/8 in) inside diameter and 6.35 mm (1/4 in) high, a steel ball 9.525 mm (3/8 in) in diameter, and a water or glycerin bath. The test is conducted by first placing a sample of the material to be tested in the brass ring, which is cooled and immersed in the water or glycerin bath that is maintained at a temperature of 50°C (41°F). The ring is immersed to a depth such that its bottom is exactly 2.54 mm (1 in) above the bottom of the bath. The temperature of the bath is then gradually increased, causing the asphalt to soften and permitting the ball to sink eventually to the bottom of the bath. The temperature in at which the asphaltic material touches the bottom of the bath is recorded as the softening point.

![Figure 7-4: Ring-and-ball softening point test](image-url)
7.3.2 Durability Tests

When asphaltic materials are used in the construction of roadway pavements, they are subjected to changes in temperature and other weather conditions over a period of time. These changes cause natural weathering of the material, which may lead to loss of plasticity, cracking, abnormal surface abrasion, and eventual failure of the pavement. This change, known as weathering, is caused by chemical and physical reactions that take place in the material. One test used to evaluate the susceptibility characteristics of asphaltic materials to changes in temperature and other atmospheric factors is the thin-film oven test.

7.3.2.1 Thin-Film Oven Test (TFO)

This is a procedure that measures the changes that take place in an asphalt during the hot-mix process by subjecting the asphaltic material to hardening conditions similar to those in a normal hot-mix plant operation. The consistency of the material is determined before and after the TFO procedure, using either the penetration test or a viscosity test, to estimate the amount of hardening that will take place in the material when used to produce plant hot-mix.

The procedure is performed by pouring 50 cc of the material into a cylindrical flat-bottom pan, 14 cm (5.5 in) inside diameter and 1 cm (3/8 in) high. The pan containing the sample is then placed on a rotating shelf in an oven and rotated for five hours at a temperature of 163°C (325°F). The amount of penetration after the TFO test is then expressed as a percentage of that before the test to determine percent of penetration retained. The minimum allowable percent of penetration retained is usually specified for different grades of asphalt cement.

7.3.3 Rate of Curing

Tests for curing rates of cutbacks and emulsions are based on inherent factors, which can be controlled. The test is conducted to determine the time required for a liquid asphaltic material to increase in its consistency on the assumption that the external factors are held constant. Volatility and quantity of solvent for cutbacks are commonly used to indicate the rate of curing. The curing rates for both cutbacks and emulsions may be determined from the distillation test.

7.3.3.1 Distillation Test for Cutbacks

In the distillation test for cutbacks, the apparatus used consists principally of a flask in which the material is heated, a condenser, and a graduated cylinder for collecting the condensed material. A
sample of 200 cc of the material to be tested is measured and poured into the flask. The material is then brought to boiling point by heating it with the burner. The evaporated solvent is condensed and collected in the graduated cylinder. The temperature in the flask is continuously monitored and the amount of solvent collected in the graduated cylinder recorded when the temperature in the flask reaches 190°C (374°F), 225°C (437°F), 260°C (500°F), and 316°C (600°F). The amount of condensate collected at the different specified temperatures gives an indication of the volatility characteristics of the solvent. The residual in the flask is the base asphaltic material used in preparing the cutback.

7.3.3.2 Distillation Test for Emulsions

The distillation test for emulsions is similar to that described for cutbacks. A major difference, however, is that the glass flask and Bunsen burner are replaced with an aluminum alloy still and a ring burner. This equipment prevents potential problems that may arise from the foaming of the emulsified asphalt as it is being heated to a maximum of 260°C (500°F). The results obtained from the use of this method to recover the asphaltic residue and to determine the properties of the asphalt base stock used in the emulsion may not always be accurate because of significant changes in the properties of the asphalt due to concentration of inorganic salts, emulsifying agent, and stabilizer. These changes, which are due mainly to the increase in temperature, do not occur in field application of the emulsion since the temperature in the field is usually much less than that used in the distillation test. The emulsion in the field, therefore, breaks either electrochemically or by evaporation of the water. An alternative method to determine the properties of the asphalt after it is cured on the pavement surface is to evaporate the water at subatmospheric pressure and lower temperatures.

7.3.4 General Tests

Several other tests are routinely conducted on asphaltic materials used for pavement construction either to obtain specific characteristics for design purposes (for example, specific gravity) or to obtain additional information that aids in determining the quality of the material. Some of the more common routine tests are described briefly hereunder.

7.3.4.1 Specific Gravity Test

The specific gravity of asphaltic materials is used mainly to determine the weight of a given volume of material, or vice versa, to determine the amount of voids in compacted mixes and to
correct volumes measured at high temperatures. Specific gravity is defined as the ratio of the weight of a given volume of the material to the weight of the same volume of water. The specific gravity of bituminous materials, however, changes with temperature, which dictates that the temperature at which the test is conducted should be indicated. For example, if the test is conducted at 25°C (77°F) which is usually the case and the specific gravity is determined to be 1.41, this should be recorded as 1.41/25°C. Note that both the asphaltic material and the water should be at the same temperature.

The test is normally conducted with the dry weight (W1) of the pycnometer and stopper is obtained, and then the pycnometer is filled with distilled water at the prescribed temperature. The weight (W2) of the water and pycnometer together is determined. If the material to be tested can flow easily into the pycnometer, then the pycnometer must be completely filled with the material at the specified temperature after pouring out the water. The weight W3 is then obtained. The specific gravity of the asphaltic material is then given as

$$G_b = \frac{W_3 - W_1}{W_2 - W_1}$$  \hspace{1cm} (7.1)

Where GB is the specific gravity of the asphaltic material and W1, W2, and W3 are in grams. If the asphaltic material cannot easily flow, a small sample of the material is heated gradually to facilitate flow and then poured into the pycnometer and left to cool to the specified temperature. The weight W4 of pycnometer and material is then obtained. Water is then poured into the pycnometer to completely fill the remaining space not occupied by the material. The weight W5 of the filled pycnometer is obtained. The specific gravity is then given as

$$G_b = \frac{W_4 - W_1}{(W_2 - W_1) - (W_2 - W_4)}$$  \hspace{1cm} (7.2)

7.3.4.2 Ductility Test

Ductility is the distance in centimeters a standard sample of asphaltic material will stretch before breaking when tested on standard ductility test equipment at 25°C (77°F). The result of this test indicates the extent to which the material can be deformed without breaking. It also indicates the temperature susceptibility of binders. Bitumens possessing high ductility are usually highly susceptible to temperature while low ones are not.
The test is used mainly for semisolid or solid materials, which first are gently heated to facilitate flow and then are poured into a standard mold to form a briquette of at least 1 cm\(^2\) in cross section. The material is then allowed to cool to 25°C (77°F) in a water bath. The prepared sample is then placed in the ductility machine and extended at a specified rate of speed until the thread of material joining the two ends breaks. The distance (in centimeters) moved by the machine is the ductility of the material.

7.3.4.3 Solubility Test

The solubility test is used to measure the amount of impurities in the asphalitic material. Since asphalt is nearly 100 percent soluble in certain solvents, the portion of any asphalitic material that will be effective in cementing aggregates together can be determined from the solubility test. Insoluble materials include free carbon, salts, and other inorganic impurities. The test is conducted by dissolving a known quantity of the material in a solvent, such as trichloroethylene, and then filtering it through a Gooch Crucible. The material retained in the filter is dried and weighed. The test results are given in terms of the percent of the asphalritic material that dissolved in the solvent.

7.3.4.4 Flash-Point Test

The flash point of an asphalitic material is the temperature at which its vapors will ignite instantaneously in the presence of an open flame. Note that the flash point is normally lower than the temperature at which the material will burn. The test can be conducted by using either the Tagliabue open-cup apparatus or the Cleveland open-cup apparatus. The Cleveland open-cup test is more suitable for materials with higher flash points, whereas the Tagliabue open-cup is more suitable for materials with relatively low flash points, such as cutback asphalts. The test is conducted by partly filling the cup with the asphalitic material and gradually increasing its temperature at a specified rate. A small open flame is passed over the surface of the sample at regular intervals as the temperature increases. The increase in temperature will cause evaporation of volatile materials from the material being tested, until a sufficient quantity of volatile materials is present to cause an instantaneous flash when the open flame is passed over the surface. The minimum temperature at which this occurs is the flash point. It can be seen that this temperature gives an indication of the temperature limit at which extreme care should be taken, particularly when heating is done over open flames in open containers.
7.3.4.5 Loss-on-Heating Test

The loss-on-heating test is used to determine the amount of material that evaporates from a sample of asphalt under a specified temperature and time. The result indicates whether an asphaltic material has been contaminated with lighter materials. The test is conducted by pouring 50 g of the material to be tested into a standard cylindrical tin and leaving it in an oven for 5 hr at a temperature of 163°C (325°F). The weight of the material remaining in the tin is determined, and the loss in weight is expressed as a percentage of the original weight. The penetration of the sample may also be determined before and after the test to determine the loss of penetration due to the evaporation of the volatile material. This loss in penetration may be used as an indication of the weathering characteristics of the asphalt.