CHAPTER 4

BITUMEN BOUND PAVEMENT MATERIALS
4. Bitumen Bound Pavement Materials

- Binders used in pavement construction are mainly of two types:
  - **Cement**: most commonly used cementing agent in the concrete building industry, and in road construction, it is used as a binder for rigid pavement structures and a stabilizing agent.
  - **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 - bind aggregates together and form asphalt concrete from the highest class of highways to thin, dust-control layers on seldom-used roads.
4. Bitumen Bound Pavement Materials

Types of Bituminous Materials

- **Bituminous Materials**
  - Natural Bitumen
    - Lake
    - Rock asphalt
  - Refinery Bitumen
    - Penetration grade bitumen
    - Liquid bitumen
  - Cutbacks
    - Slow curing cutback
    - Medium curing cutback
    - Rapid curing cutback
  - Emulsions
    - Anionic emulsion
    - Cationic emulsion
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- Natural Bitumens are:
  - 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.
  - Rock asphalts are natural rock deposits containing bituminous materials that have been used for road surfaces in localities where they occur.

- Refinery Bitumens are:
  - 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.
  - Petroleum crudes are complex mixtures of hydrocarbons differing in molecular weight and consequently with varying bitumen contents.
    - asphaltic-base crudes are crudes which contain high proportions of road bitumen.
    - paraffinic-base crudes are with little or no bituminous bodies present.
    - mixed-base crudes are crudes which exhibit characteristics of both the previous categories.
4. Bitumen Bound Pavement Materials

Manufacture of refinery bitumens
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- **Types of petroleum refinery processes:**
  - **Fractional distillation** -- the crude oil is vaporized by heating it above its boiling point 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.
  - **Vacuum or steam distillation** -- refining is carried out, without changing them chemically by the use of reduced pressures and steam injection in the fractionating column to remove high boiling temperature constituents such as those contained in the non-volatile oils.
  - **Cracking distillation** -- consists of 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".
  - Asphalts produced by these different methods 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.
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Penetration grade bitumens

- Penetration grade bitumens or asphalt cements are in consistency from semi-solid to semi-liquid at room temperature.
  - Such bitumens are graded according to their
    - viscosity (mainly used in the US): the most common grading are AC 2.5, AC 5, AC 10, AC 20, and AC 40
    - 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.
    - The penetration grades which roughly correspond to the above viscosity grades are 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.
  - 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.
4. Bitumen Bound Pavement Materials

Liquid Bitumens

- Liquid binders are modified penetration grade bitumens prepared as liquid products for handling at relatively low temperatures and mixed with aggregates either when cold or only warmed sufficiently to make them surface-dry.

- The two forms of liquid bitumens are:
  - Cutback bitumens -- prepared by dissolving the asphalt cement in a suitable volatile solvent to reduce their viscosity to make them easier to use at ordinary temperatures,
  - Bitumen emulsions --- prepared by emulsifying the asphalt cement in an aqueous medium
4. Bitumen Bound Pavement Materials

Cutback Bitumens

- During construction, 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 bitumens are grouped into three types based on the type of solvent, which governs the rates of evaporation and curing:
  - 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.
4. Bitumen Bound Pavement Materials

- **Cutback Bitumens**
  - **Slow-curing (SC):**
    - 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.
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- **Cutback Bitumens**
  - *Medium-Curing (MC) Cutbacks:*
    - 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 dilutent 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.
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**Cutback Bitumens**

- **Rapid-Curing (RC) Cutbacks**:
  - 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.
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Asphalt emulsions

- 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 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;
  - Anionic emulsions, in which they have a negative charge.
- Each of the categories is further divided into three subgroups, based on how rapidly the asphalt emulsion will return to the state of the original asphalt cement as: rapid setting (RS), medium-setting (MS), and slow setting (SS).
4. Bitumen Bound Pavement Materials

- **Asphalt emulsions**
  - 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.
  - 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 sillicous 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.
4. Bitumen Bound Pavement Materials

**The Air-Blown Bitumens**

- The physical properties of the short residue are further modified by air-blowing: 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 used almost entirely for industrial applications, such as roofing, flooring, mastics, pipe coatings, paints, etc, but their use in road construction is limited.

**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.
4. Bitumen Bound Pavement Materials

Tests for Bituminous Materials

- Several tests are conducted on bituminous materials to ascertain whether materials used in highway construction meet the prescribed specification. These include:
  - Consistency Tests:
    - Viscosity Test
    - Penetration Test
    - Float Test
    - Ring-and-Ball Softening Point Test
  - Durability Tests: Thin-Film Oven Test (TFO)
  - Rate of Curing:
    - Distillation Test for Emulsions
    - Distillation Test for Cutbacks
  - Other general Tests:
    - Specific Gravity Test
    - Ductility Test
    - Solubility Test
    - Flash-Point Test
    - Loss-on-Heating Test
4. Bitumen Bound Pavement Materials

Tests for Bituminous Materials

- 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.
  - Because asphaltic materials exist in either liquid, semisolid, or solid states, more than one method is 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.
4. Bitumen Bound Pavement Materials

- Tests for Bituminous Materials
  - Consistency Tests:
    - 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.
4. Bitumen Bound Pavement Materials

Tests for Bituminous Materials

- **Consistency Tests:**

  - **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.
4. Bitumen Bound Pavement Materials

Tests for Bituminous Materials

- Consistency Tests:
  - **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.
4. Bitumen Bound Pavement Materials

Tests for Bituminous Materials

- **Consistency Tests:**
  - 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.
  - 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 heat 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.
4. Bitumen Bound Pavement Materials

- Tests for Bituminous Materials
  - Consistency Tests:
    - The float test

![Diagram of float test](image)

(a) Start of test
(b) End of test
4. Bitumen Bound Pavement Materials

Tests for Bituminous Materials

- **Consistency Tests:**
  - **Ring-and-Ball Softening Point Test**: Used to measure the susceptibility of asphaltic materials to temperature changes by determining the temperature at which the material will be adequately softened to allow a standard ball to sink through it.
  - 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 of 15.875 mm (5/8 in) inside diameter, which is cooled and immersed in the water or glycerin bath that is maintained at a temperature of 5°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 a steel ball 9.525 mm (3/8 in) in diameter 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.
4. Bitumen Bound Pavement Materials

- Tests for Bituminous Materials
  - Consistency Tests:
    - *Ring-and-Ball Softening Point Test*
4. Bitumen Bound Pavement Materials

Tests for Bituminous Materials

- **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.

  - **Thin-Film Oven Test (TFO):** 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.
4. Bitumen Bound Pavement Materials

Tests for Bituminous Materials

- **Rate of Curing**
  - Tests for curing 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.

- **Distillation Test for Cutbacks**
  - In the distillation test, a sample of 200 cc of the material to be tested is measured and poured into the graduated 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.

- **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).
4. Bitumen Bound Pavement Materials

Tests for Bituminous Materials: Other Tests

Specific Gravity Test

- The specific gravity of asphaltic materials varies with temperature – it is therefore recorded as 1.41/25°C.
- The test is normally conducted with the dry weight \(W_1\) of the pycnometer and stopper is obtained, and then the pycnometer is filled with distilled water at the prescribed temperature. The weight \(W_2\) 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 \(W_3\) is then obtained. The specific gravity of the asphaltic material is then given as

\[
G_b = \frac{W_3 - W_1}{W_2 - W_1}
\]

- Where \(G_b\) is the specific gravity of the asphaltic material and \(W_1, W_2,\) and \(W_3\) are in grams.
4. Bitumen Bound Pavement Materials

Tests for Bituminous Materials: Other Tests

- Specific Gravity Test

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 \( W_4 \) 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 \( W_5 \) of the filled pycnometer is obtained. The specific gravity is then given as

\[
G_b = \frac{W_4 - W_1}{(W_2 - W)_1 - (W_5 - W_4)}
\]
4. Bitumen Bound Pavement Materials

Tests for Bituminous Materials: Other Tests

- 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 cm² 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.
4. Bitumen Bound Pavement Materials

Tests for Bituminous Materials: Other Tests

- Solubility Test
  - The solubility test is used to measure the amount of impurities in the asphaltic material.
  - Since asphalt is nearly 100 percent soluble in certain solvents, the portion of any asphaltic 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 asphaltic material that dissolved in the solvent.
4. Bitumen Bound Pavement Materials

Tests for Bituminous Materials: Other Tests

Flash-Point Test

- The flash point of an asphaltic 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 is conducted by partly filling the cup (either the Tagliabue open-cup apparatus or the Cleveland open-cup) with the asphaltic 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.
- 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.
4. Bitumen Bound Pavement Materials

- Tests for Bituminous Materials: Other Tests
  - **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.
4. Bitumen Bound Pavement Materials

Bitumen Bound Pavement Materials

- Depending on the gradation of aggregates used, the mixture is known as:
  - Asphalt concrete,
  - Rolled asphalt,
  - Bitumen macadam, or
  - Sand asphalt.

- Depending on the temperature during mixing and construction, it is also designated as:
  - Hot-mix hot-laid,
  - Hot-mix cold-laid, or
  - Cold-mix cold-laid
Pavement Materials

- **Bitumen-bound Pavement Materials (Cont’d):**
  - The most common type of premixed asphalt is asphalt concrete
    - made from a continuous graded aggregate and it relies for its strength on the interlock between the aggregate particles and on the properties of the mortar of bitumen, fine aggregate, and fillers.
    - Asphalt concrete of different qualities may be used for the construction of wearing course, binder course, and base course.
  - Premixed asphalts are either designed using special mix design methods or made according to recipe specification
    - Asphalt concrete and sand asphalt are designed using mix design methods such as the Marshall method,
    - Rolled asphalt and asphalt macadam are made to recipe specification
Pavement Materials

- Bitumen-bound Pavement Materials (Cont’d):
  - Two fundamental characteristics of bitumen-bound materials are stability and durability --- intimately related to density of the mixture
  - The most desirable bitumen content for bituminous mixtures is that which would just fill the voids
  - This, however, has two pit falls in practice:
    - Any increase in temperature would cause expansion of bitumen binder which results in the subsequent of bleeding and loss of stability; and
    - Extra compaction of the mixture under the action of traffic loading causes excess of binder which again results in bleeding and loss of stability
  - These lead to a practical consideration to fix the voids in the mixture in the range of the minimum to avoid bleeding and loss of stability and the maximum voids content based on durability consideration
Pavement Materials

- Bitumen-bound Pavement Materials (Cont’d):
  - **Required characteristics bitumen-bound layer**
    - High stiffness in order to reduce the stresses transmitted to the underlying layer;
    - High resistance to deformation;
    - High resistance to fatigue;
    - High resistance to environmental degradation i.e. good durability;
    - Low permeability to prevent the ingress of water and air; and
    - Good workability to allow adequate compaction to be obtained during construction.
Pavement Materials

- Bitumen-bound Pavement Materials (Cont’d):
  - Aggregates used in asphalt concrete:
    - coarse aggregates: retained on 2.36 mm sieve,
    - fine aggregates: passing 2.36 mm sieve, and
    - fillers: passing 0.075 mm sieve.
  - Bitumen: penetration 40/50, 60/70, or 80/100.
    - the selection of bitumen is a compromise between workability, deformation resistance and potential hardening in service.
Pavement Materials

Bitumen-bound Pavement Materials (Cont’d):
*Recommended quality of coarse and fine aggregates for use in premixed*

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<th>Coarse aggregate</th>
<th>Fine aggregate</th>
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Pavement Materials

Bitumen-bound Pavement Materials (Cont’d):

- **Job-Mix Formula**: an established proportion of aggregate fractions and amount of binder designed to satisfy all specification requirements for a given road project.

- Two general steps of establishing **Job-Mix Formula**:
  - The selection and blending of aggregates to meet the limits of the specification
  - The determination of the optimum asphalt content in the mixture
Pavement Materials

Bitumen-bound Pavement Materials (Cont’d):

- *Marshall method of mix design -- to determine the optimum binder content*
  - The test specimen 102 mm dia and 64 mm height is subjected to density and stability-flow test
  - Marshall stability is the maximum load resistance in units of Newtons.
  - The flow value is the total deformation of the specimen at the maximum load.
  - After completing the test, plots are prepared for bitumen content versus
    - (1) density,
    - (2) percentage of air voids in mix,
    - (3) percentages of voids in aggregate,
    - (4) stability, and
    - (5) flow
Pavement Materials

Bitumen-bound Pavement Materials (Cont’d):

*Marshall method of mix design to determine the optimum binder content*
**Pavement Materials**

- **Bitumen-bound Pavement Materials (Cont’d):**
  - **Surface Dressing (Treatment):** *is a wearing course construction by which a thin film of binder, generally bitumen or tar, is sprayed onto the road surface and then covered with a layer of stone chippings.*
    - A single surface dressing:
      - a wearing course on lightly trafficked roads, and
      - a maintenance measure on existing pavements.
    - Double surface dressing:
      - On roads expected to carry more than 100 vehicles per day and
      - where the chippings are particularly poor shaped or very weak.
  - **In this type of construction -- the thin film of binder acts as a waterproofing seal preventing the entry of surface water into the road structure. The stone chippings protect this film of binder from damage by vehicle tires, and form a durable, skid-resistant and dust-free wearing surface*
Pavement Materials

- Bitumen-bound Pavement Materials (Cont’d):

- Single
  - Existing road surface
  - Chippings
  - Binder

- Double
  - Existing road surface
  - Smaller chippings
  - Binder
  - Chippings
  - Binder

- Triple
  - Existing road surface
  - Smaller chippings
  - Binder
  - Smaller chippings
  - Binder
  - Chippings
  - Binder

Types of Surface Treatments
Pavement Materials

- Bitumen-bound Pavement Materials (Cont’d):
  - Materials for surface dressing:
    - Chippings
      - Single-sized, cubical, strong, durable, clean and dust-free
      - Aggregate crushing value (ACV) -- in the range of 20-35, and
      - In wet climates a minimum polished stone value (PSV) of 45-60 is required depending on traffic and site characteristic
      - The nominal size of chippings used for surface dressing is usually 6, 10, 14, or 20mm
      - For double surface dressings, the size of chippings for the second layer should be about half the size of the first layer to promote good interlock between layers
    - Binder: cutback and emulsified bitumen are normally used
      - The binder used must be sufficiently fluid at road temperature to the road surface and the chippings
      - At the same time the binder must be sufficiently viscous not to drain off from the road surface and strong enough to retain the chippings when the road is opened to traffic (Fig. 5-10)
Pavement Materials

- Bitumen-bound Pavement Materials (Cont’d):

  - Chippings/binder application rate – in surface dressing:

    - The rate of spread of chippings depends on the average thickness of the stone chippings when they have settled in their final position on the road termed as average least dimension (ALD).
    - The rate of application of binder also depends on the type of chippings, the level of traffic, the condition of the existing road surface, and the climate.
### Condition factors for the rate of binder application

#### Vehicles per day

<table>
<thead>
<tr>
<th>Vehicles per day</th>
<th>Existing surface</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–50</td>
<td>+3 Untreated base +6</td>
</tr>
<tr>
<td>50–250</td>
<td>+1 Very lean asphalt +4</td>
</tr>
<tr>
<td>250–500</td>
<td>0 Lean asphalt 0</td>
</tr>
<tr>
<td>500–1500</td>
<td>−1 Average asphalt −1</td>
</tr>
<tr>
<td>1500–3000</td>
<td>−3 Very rich asphalt −3</td>
</tr>
<tr>
<td>&gt;3000</td>
<td>−5</td>
</tr>
</tbody>
</table>

#### Climate

<table>
<thead>
<tr>
<th>Climate</th>
<th>Type of chippings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wet and cold</td>
<td>+2 Round/dusty +2</td>
</tr>
<tr>
<td>Wet and hot</td>
<td>+1 Cubical 0</td>
</tr>
<tr>
<td>Temperate</td>
<td>0 Flaky −2</td>
</tr>
<tr>
<td>Dry and hot</td>
<td>−1 Precoated −2</td>
</tr>
<tr>
<td>Very dry and hot</td>
<td>−2</td>
</tr>
</tbody>
</table>

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Pavement Materials

- **Bitumen-bound Pavement Materials (Cont’d):**
  - *Chippings application rate:*
    - The rate is read vertically at the top of the chart (Fig. 5-11) by the intercept between the ALD line and line AB, or
    - Chipping application rate (kg/m²) = 1.364*ALD
    - The chipping application rate should be regarded as a rough guide only. The precise application rate is determined by observing on site.
  - *Rate of spread of binder:* The rate of spread of cutback is determined by the intercept between the factor line and the appropriate ALD line (Fig. 5-11).
    - For penetration bitumen, the rate determined from the chart should be reduced by 10%.
    - For cutbacks with a viscosity greater than 2000 cSt, no modification is required, but when cutbacks with lower viscosity are used the rate of binder may need to be increased by 10%.
    - For emulsions the rate should be multiplied by (90/b) where b is the percentage of bitumen in the emulsion.
    - For slow traffic or steep climbing grades (>3%) the rate should be reduced by 10%.
    - For fast traffic or steep downgrades (>3%) the rate should be increased by 10 to 20%.